

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

**EP 1 559 802 A1**

(12)

**EUROPEAN PATENT APPLICATION**

(43) Date of publication:

**03.08.2005 Bulletin 2005/31**

(51) Int Cl.7: **C22C 9/04, C22F 1/08**

(21) Application number: **05075421.7**

(22) Date of filing: **16.11.1998**

(84) Designated Contracting States:

**BE DE FI FR GB IT SE**

(30) Priority: **12.10.1998 JP 28859098**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:

**98953071.2 / 1 045 041**

(71) Applicant: **Sambo Copper Alloy Co., Ltd**

**Osaka 590-0906 (JP)**

(72) Inventor: **Oishi, Keiichiro,**

**Sambo Copper Alloy Co., Ltd**

**Sakai-shi, Osaka 590-0906 (JP)**

(74) Representative:

**Brown, Fraser Gregory James et al**

**fJ Cleveland**

**40-43 Chancery Lane**

**London WC2A 1JQ (GB)**

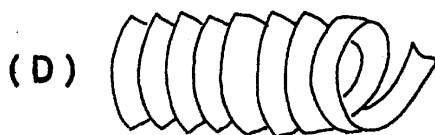
Remarks:

This application was filed on 21.02.2005 as a divisional application to the application mentioned under INID code 62.

(54) **Lead-free, free-cutting copper alloys**

(57) Lead-free copper alloys with industrially satisfactory machinability comprising 69 to 79 percent, by weight, of copper, 2.0 to 4.0 percent, by weight, of silicon, and the remaining percent, by weight, of zinc.

FIGURE 1



**EP 1 559 802 A1**

**Description**

## Field of The Invention

**[0001]** The present invention relates to lead-free, free-cutting copper alloys.

## Prior Art

**[0002]** Among the copper alloys with a good machinability are bronze alloys such as the one under JIS designation H5111 BC6 and brass alloys such as the ones under JIS designations H3250-C3604 and C3771. Those alloys are enhanced in machinability by the addition of 1.0 to 6.0 wt% of lead and provide an industrially satisfactory machinability. Because of their excellent machinability, those lead-contained copper alloys have been an important basic material for a variety of articles such as city water faucets, water supply/drainage metal fittings and valves.

**[0003]** However, the application of those lead-mixed alloys has been greatly limited in recent years, because lead contained therein is an environment pollutant harmful to humans. That is, the lead-containing alloys pose a threat to human health and environmental hygiene because lead is contained in metallic vapor that is generated in the steps of processing those alloys at high temperatures such as melting and casting and there is also concern that lead contained in the water system metal fittings, valves and others made of those alloys will dissolve out into drinking water.

**[0004]** On that ground, the United States and other advanced countries have been moving to tighten the standards for lead-contained copper alloys to drastically limit the permissible level of lead in copper alloys in recent years. In Japan, too, the use of lead-contained alloys has been increasingly restricted, and there has been a growing call for development of free-cutting copper alloys with a low lead content.

## Summary of the Invention

**[0005]** It is an object of the present invention to provide a lead-free copper alloy which does not contain the machinability-improving element lead yet is quite excellent in machinability and can be used as safe substitute for the conventional free cutting copper alloy with a large content of lead presenting environmental hygienic problems and which permits recycling of chips without problems, thus a timely answer to the mounting call for restriction of lead-contained products.

**[0006]** It is another object of the present invention to provide a lead-free copper alloy which has a high corrosion resistance as well as an excellent machinability and is suitable as basic material for cutting works, forgings, castings and others, thus having a very high practical value. The cutting works, forgings, castings and others include city water faucets, water supply/drainage metal fittings, valves, stems, hot water supply pipe fittings, shaft and heat exchanger parts.

**[0007]** It is yet another object of the present invention to provide a lead-free copper alloy with a high strength and wear resistance as well as machinability which is suitable as basic material for the manufacture of cutting works, forgings, castings and other uses requiring a high strength and wear resistance such as, for example, bearings, bolts, nuts, bushes, gears, sewing machine parts and hydraulic system parts, hence has a very high practical value.

**[0008]** It is a further object of the present invention to provide a lead-free copper alloy with an excellent high-temperature oxidation resistance as well as machinability which is suitable as basic material for the manufacture of cutting works, forgings, castings and other uses where a high thermal oxidation resistance is essential, e.g. nozzles for kerosene oil and gas heaters, burner heads and gas nozzles for hot-water dispensers, hence has a very high practical value.

**[0009]** According to an aspect of this invention, there is provided the use of silicon in an amount of 2.0 to 4.0 percent, as an additive to a lead-free copper alloy composition which comprises 69 to 79 wt% copper and the remaining wt% zinc, to improve the machinability of the alloy by producing in the metal structure at least one phase selected from the  $\gamma$  (gamma) and the  $\kappa$  (kappa) phases, as set out in claim 1 hereinafter. According to further aspects of the invention, there are provided uses as set out in claim 2 hereinafter. The uses of the invention are carried out in the manufacture of the following alloys:

1. A lead-free, free-cutting copper alloy with excellent machinability is composed of 69 to 79 wt% of copper, 2.0 to 4.0 wt% of silicon, and the remaining wt% of zinc. For purpose of simplicity, this copper alloy will be hereinafter called the "first alloy."

Lead forms no solid solution in the matrix but disperses in a granular form to improve the machinability. Silicon raises the easy-to-cut property by producing a gamma phase (in some cases, a kappa phase) in the structure of metal. That way, both are common in that they are effective in improving the machinability, though they are quite different in contribution to the properties of the alloy. On the basis of that recognition, silicon is added to the first

alloy in place of lead so as to bring about a high level of machinability meeting the industrial requirements. That is, the first alloy is improved in machinability through formation of a gamma phase with the addition of silicon.

The addition of less than 2.0 percent, by weight, of silicon cannot form a gamma phase sufficient to secure an industrially satisfactory machinability. With the increase in the addition of silicon, the machinability improves. But with the addition of more than 4.0 wt% of silicon, the machinability will not go up in proportion. The problem is, however, that silicon has a high melting point and a low specific gravity and is also liable to oxidize. If silicon alone is fed in the form of a simple substance into a furnace in the alloy melting step, then silicon will float on the molten metal and is oxidized into oxides of silicon or silicon oxide, hampering production of a silicon-contained copper alloy. In making an ingot of silicon-containing copper alloy, therefore, silicon is usually added in the form of a Cu-Si alloy, which boosts the production cost. In the light of the cost of making the alloy, too, it is not desirable to add silicon in a quantity exceeding the saturation point where machinability improvement levels off - 4.0 wt%wt%. An experiment showed that when silicon is added in an amount of 2.0 to 4.0 wt%, it is desirable to hold the content of copper at 69 to 79 wt% in consideration of its relation to the content of zinc in order to maintain the intrinsic properties of the Cu-Zn alloy. For this reason, the first alloy is composed of 69 to 79 wt%, of copper and 2.0 to 4.0 wt% of silicon. The addition of silicon improves not only the machinability but also the flow of the molten metal in casting, strength, wear resistance, resistance to stress corrosion cracking, high-temperature oxidation resistance. Also, the ductility and dezincification resistance will be improved to some extent.

2. Another lead-free, free-cutting copper alloy also with an excellent machinability feature is composed of 69 to 79 wt% of copper; 2.0 to 4.0 wt% of silicon; at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium; and the remaining wt% of zinc. This second copper alloy will be hereinafter called the "second alloy."

That is, the second alloy is composed of the first alloy and at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium.

Bismuth, tellurium and selenium as well as lead do not form a solid solution in the matrix but disperse in granular form to enhance the machinability and that through a mechanism different from that of silicon. Hence, the addition of those elements along with silicon could further improve the machinability beyond the level obtained by the addition of silicon alone. From this finding, the second alloy is provided in which at least one element selected from bismuth, tellurium and selenium is mixed to improve further the machinability obtained by the first alloy. The addition of bismuth, tellurium or selenium in addition to silicon produces a high machinability such that complicated forms could be freely cut at a high speed. But no improvement in machinability can be realized from the addition of bismuth, tellurium or selenium in an amount less than 0.02 percent, by weight. Meanwhile, those elements are expensive as compared with copper. Even if the addition exceeds 0.4 wt%, the proportional improvement in machinability is so small that the addition beyond that does not pay economically. What is more, if the addition is more than 0.4 wt%, the alloy will deteriorate in hot workability such as forgeability and cold workability such as ductility. While it might be feared that heavy metals like bismuth would cause problems similar to those of lead, an addition in a very small amount of less than 0.4 wt% is negligible and would present no particular problems. From those considerations, the second alloy is prepared with the addition of bismuth, tellurium or selenium kept to 0.02 to 0.4 wt%. The addition of those elements, which work on the machinability of the copper alloy through a mechanism different from that of silicon as mentioned above, would not affect the proper contents of copper and silicon. On this ground, the contents of copper and silicon in the second alloy are set at the same level as those in the first alloy.

3. A lead-free, free-cutting copper alloy also with an excellent machinability is composed of 70 to 80 wt% of copper; 1.8 to 3.5 wt% of silicon; at least one element selected from among 0.3 to 3.5 wt% of tin, 1.0 to 3.5 wt% of aluminum, and 0.02 to 0.25 wt% of phosphorus; and the remaining wt% of zinc. This third copper alloy will be hereinafter called the "third alloy".

Tin works the same way as silicon. That is, if tin is added to a Cu-Zn alloy, a gamma phase will be formed and the machinability of the Cu-Zn alloy will be improved. For example, the addition of tin in an amount of 1.8 to 4.0 wt% would bring about a high machinability in the Cu-Zn alloy containing 58 to 70 wt% of copper, even if silicon is not added. Therefore, the addition of tin to the Cu-Si-Zn alloy could facilitate the formation of a gamma phase and further improve the machinability of the Cu-Si-Zn alloy. The gamma phase is formed with the addition of tin in an amount of 1.0 or more wt% and the formation reaches the saturation point at 3.5 wt% of tin. If tin exceeds 3.5 wt%, the ductility will drop instead. With the addition of tin in less than 1.0 wt%, on the other hand, no gamma phase will be formed. If the addition is 0.3 percent or more by weight, then tin will be effective in uniformly dispersing the gamma phase formed by silicon. Through that effect of dispersing the gamma phase, too, the machinability is improved. In other words, the addition of tin in not smaller than 0.3 wt% improves the machinability.

Aluminum is, too, effective in promoting the formation of the gamma phase. The addition of aluminum together with tin or in place of tin could further improve the machinability of the Cu-Si-Zn. Aluminum is also effective in

improving the strength, wear resistance and high temperature oxidation resistance as well as the machinability and also in keeping down the specific gravity. If the machinability is to be improved at all, aluminum will have to be added in at least 1.0 wt%. But the addition of more than 3.5 wt% could not produce the proportional results. Instead, that could affect the ductility as is the case with aluminum.

As to phosphorus, it has no property of forming the gamma phase as tin and aluminum. But phosphorus works to uniformly disperse and distribute the gamma phase formed as a result of the addition of silicon alone or with tin or aluminum or both of them. That way, the machinability improvement through the formation of gamma phase is further enhanced. In addition to dispersing the gamma phase, phosphorus helps refine the crystal grains in the alpha phase in the matrix, improving hot workability and also strength and resistance to stress corrosion cracking. Furthermore, phosphorus substantially increases the flow of molten metal in casting. To produce such results, phosphorus will have to be added in an amount not smaller than 0.02 wt%. But if the addition exceeds 0.25 wt%, no proportional effect can be obtained. Instead, there would be a fall in hot forging property and extrudability.

In consideration of those observations, the third alloy is improved in machinability by adding to the Cu-Si-Zn alloy at least one element selected from among 0.3 to 3.5 wt% of tin, 1.0 to 3.5 wt% of aluminum, and 0.02 to 0.25 wt% of phosphorus.

Meanwhile, tin, aluminum and phosphorus are to improve the machinability by forming a gamma phase or dispersing that phase, and work closely with silicon in promoting the improvement in machinability through the gamma phase. In the third alloy mixed with silicon along with tin, aluminum or phosphorus, therefore, machinability is improved by not only silicon, but by tin, aluminum or phosphorus and thus the required addition of silicon is smaller than that in the second alloy in which the machinability is enhanced by adding bismuth, tellurium or selenium. That is, those elements bismuth, tellurium and selenium contribute to improving the machinability, not acting on the gamma phase but dispersing in the form of grains in the matrix. Even if the addition of silicon is less than 2.0 wt%, silicon along with tin, aluminum or phosphorus will be able to enhance the machinability to an industrially satisfactory level as long as the percentage of silicon is 1.8 or more wt%. But even if the addition of silicon is not larger than 4.0 wt%, the addition of tin, aluminum or phosphorus will saturate the effect of silicon in improving the machinability, when the silicon content exceeds 3.5 wt%. On this ground, the addition of silicon is set at 1.8 to 3.5 wt% in the third alloy. Also, in consideration of the added amount of silicon and also the addition of tin, aluminum or phosphorus, the content range of copper in this third alloy is slightly raised from the level in the second alloy and is set at 70 to 80 wt% as preferred content of copper.

4. An additional lead-free, free-cutting copper alloy also with an excellent easy-to-cut feature is composed of 70 to 80 wt% of copper; 1.8 to 3.5 wt% of silicon; at least one element selected from among 0.3 to 3.5 wt% of tin, 1.0 to 3.5 wt% of aluminum, and 0.02 to 0.25 wt% of phosphorus; at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium; and the remaining wt% of zinc. This fourth copper alloy will be hereinafter called the "fourth alloy".

The fourth alloy thus contains at least one element selected from among 0.02 to 0.4 percent; by weight, of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium in addition to the components in the third alloy. The grounds for adding those additional elements and setting the amounts to be added are the same as given for the second alloy.

5. A further lead-free, free-cutting copper alloy with an excellent machinability and with a high corrosion resistance which is composed of 69 to 79 wt% of copper; 2.0 to 4.0 wt% of silicon; at least one element selected from among 0.3 to 3.5 wt% of tin, 0.02 to 0.25 wt% of phosphorus, 0.02 to 0.15 wt% of antimony, and 0.02 to 0.15 wt% of arsenic, and the remaining wt% of zinc. This fifth copper alloy will be hereinafter called the "fifth alloy".

The fifth alloy thus contains at least one element selected from among 0.3 to 3.5 wt% of tin, 0.02 to 0.25 wt% of phosphorus, 0.02 to 0.15 wt% of antimony, and 0.02 to 0.15 wt% of arsenic in addition to the first alloy.

Tin is effective in improving not only the machinability but also corrosion resistance properties (dezincification resistance and erosion corrosion resistance) and forgeability. In other words, tin improves the corrosion resistance in the alpha phase matrix and, by dispersing the gamma phase, the corrosion resistance, forgeability and stress corrosion cracking resistance. The fifth alloy is thus improved in corrosion resistance by such property of tin and in machinability mainly by adding silicon. Therefore, the contents of silicon and copper in this alloy are set at the same as those in the first alloy. To raise the corrosion resistance and forgeability, on the other hand, tin would have to be added in an amount of at least 0.3 wt%. But even if the addition of tin exceeds 3.5 wt%, the corrosion resistance and forgeability will not improve in proportion to the added amount of tin. It is no good economy.

As described above, phosphorus disperses the gamma phase uniformly and at the same time refines the crystal grains in the alpha phase in the matrix, thereby improving the machinability and also the corrosion resistance properties (dezincification resistance and erosion corrosion resistance), forgeability, stress corrosion cracking resistance and mechanical strength. The fifth alloy is thus improved in corrosion resistance and others by such

properties of phosphorus and in machinability mainly by adding silicon. The addition of phosphorus in a very small quantity, that is, 0.02 or more wt% could produce results. But the addition in an amount of more than 0.25 wt% would not produce proportional results. Instead, that would reduce the hot forgeability and extrudability.

Just as with phosphorus, antimony and arsenic in a very small quantity - 0.02 or more wt% - are effective in improving the dezincification resistance and other properties. But the addition exceeding 0.15 wt% would not produce results in proportion to the quantity mixed. Instead, it would lower the hot forgeability and extrudability as phosphorus applied in excessive amounts.

Those observations indicate that the fifth alloy is improved in machinability and also corrosion resistance and other properties by adding at least one element selected from among tin, phosphorus, antimony and arsenic in quantities within the aforesaid limits in addition to the same quantities of copper and silicon as in the first invention copper alloy. In the fifth alloy, the additions of copper and silicon are set at 69 to 79 wt% and 2.0 to 4.0 wt% respectively - the same level as in the first alloy in which any other machinability improver than silicon is not added - because tin and phosphorus work mainly as corrosion resistance improver like antimony and arsenic.

6. A still further lead-free free-cutting copper alloy also with an excellent machinability and with a high corrosion resistance is composed of 69 to 79 wt% of copper; 2.0 to 4.0 wt% of silicon; at least one element selected from among 0.3 to 3.5 wt% of tin, 0.02 to 0.25 wt% of phosphorus, 0.02 to 0.15 percent, by weight, of antimony, and 0.02 to 0.15 percent, by weight, of arsenic; at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium; and the remaining wt% of zinc. This sixth copper alloy will be hereinafter called the "sixth alloy".

The sixth alloy thus contains at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium in addition to the components in the fifth alloy. The machinability is improved by adding silicon and at least one element selected from among bismuth, tellurium and selenium as in the second alloy and the corrosion resistance and other properties are raised by using at least one selected from among tin, phosphorus, antimony and arsenic as in the fifth alloy. Therefore, the additions of copper, silicon, bismuth, tellurium and selenium are set at the same levels as those in the second alloy, while the contents of tin, phosphorus, antimony and arsenic are adjusted to those in the fifth alloy.

7. Another lead-free free-cutting copper alloy also with an excellent machinability and with an excellent high strength feature and high corrosion resistance is composed of 62 to 78 wt% of copper; 2.5 to 4.5 wt% of silicon; at least one element selected from among 0.3 to 3.0 wt% of tin, 0.2 to 2.5 wt% of aluminum, and 0.02 to 0.25 wt% of phosphorus; and at least one element selected from among 0.7 to 3.5 wt% of manganese and 0.7 to 3.5 wt% of nickel; and the remaining wt% of zinc. The seventh copper alloy will be hereinafter called the "seventh alloy". Manganese and nickel combine with silicon to form intermetallic compounds represented by  $Mn_xSi_y$  or  $Ni_xSi_y$  which are evenly precipitated in the matrix, thereby raising the wear resistance and strength. Therefore, the addition of manganese and/or nickel would improve the high strength feature and wear resistance. Such effects will be exhibited if manganese and nickel are added in an amount not smaller than 0.7 wt% respectively. But the saturation state is reached at 3.5 wt%, and even if the addition is increased beyond that, no proportional results will be obtained. The addition of silicon is set at 2.5 to 4.5 wt% to match the addition of manganese or nickel, taking into consideration the consumption to form intermetallic compounds with those elements.

It is also noted that tin, aluminum and phosphorus help to reinforce the alpha phase in the matrix, thereby improving strength, wear resistance, and also machinability. Tin and phosphorus disperse the alpha and gamma phases, by which the strength, wear resistance and also machinability are improved. Tin in an amount of 0.3 or more wt% is effective in improving the strength and machinability. But if the addition exceeds 3.0 wt%, the ductility will fall. For this reason, the addition of tin is set at 0.3 to 3.0 wt% to raise the high strength feature and wear resistance in the seventh alloy and also to enhance the machinability. Aluminum also contributes to improving the wear resistance and exhibits its effect of reinforcing the matrix when added in 0.2 or more wt%. But if the addition exceeds 2.5 wt%, there will be a fall in ductility. Therefore, the addition of aluminum is set at 0.2 to 2.5 in consideration of improvement of machinability. Also, the addition of phosphorus disperses the gamma phase and at the same time refines the crystal grains in the alpha phase in the matrix, thereby improving the hot workability and also the strength and wear resistance. Furthermore, it is very effective in improving the flow of molten metal in casting. Such results will be produced when phosphorus is added in the range of 0.02 to 0.25 wt%. The content of copper is set at 62 to 78 wt% in the light of the addition of silicon and bonding of silicon with manganese and nickel.

8. Another lead-free, free-cutting copper alloy also with an excellent machinability and with an excellent high strength feature and a high wear resistance comprises 62 to 78 wt% of copper; 2.5 to 4.5 wt% of silicon; at least one element selected from among 0.3 to 3.0 wt% of tin, 1.0 to 2.5 wt% of aluminum, and 0.02 to 0.25 wt% of phosphorus; and at least one element selected from among 0.7 to 3.5 percent, by weight, of manganese and 0.7

to 3.5 percent, by weight, of nickel; at least one selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 wt% of selenium; and the remaining wt% of zinc. The eighth copper alloy will be hereinafter called the "eighth alloy".

The eighth copper alloy contains at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 wt% of tellurium, and 0.02 to 0.4 wt% of selenium in addition to the components in the seventh alloy. While as high a high-strength feature and wear resistance as in the seventh invention alloy is secured, the eighth alloy is further improved in machinability by adding at least one element selected among bismuth and other elements which are effective in raising the machinability through a mechanism different from that exhibited by silicon. The reasons for adding machinability improvers such as bismuth and others and deciding on the quantities to be added are the same as given for the second, fourth and sixth alloys. The grounds for adding the other elements copper, zinc, tin, manganese and nickel and setting the contents are the same as given for the seventh alloy.

9. A yet further lead-free, free-cutting copper alloy also with excellent machinability coupled with a good high-temperature oxidation resistance is composed of 69 to 79 wt% of copper; 2.0 to 4.0 wt% of silicon; 0.1 to 1.5 wt% of aluminum; 0.02 to 0.25 wt% of phosphorus; and the remaining wt% of zinc. The ninth copper alloy will be hereinafter called the "ninth alloy".

Aluminum is an element which improves the strength, machinability, wear resistance and also high-temperature oxidation resistance. Silicon, too, has a property of enhancing the machinability, strength, wear resistance, resistance to stress corrosion cracking and also high-temperature oxidation resistance, as mentioned above. Aluminum works to raise the high-temperature oxidation resistance when aluminum is added in an amount not less than 0.1 wt% together with silicon. But even if the addition of aluminum increases beyond 1.5 wt%, no proportional results can be expected. For this reason, the addition of aluminum is set at 0.1 to 1.5 wt%.

Phosphorus is added to enhance the flow of molten metal in casting. Phosphorus also works for improvement of the aforesaid machinability, dezincification resistance and also high-temperature oxidation resistance in addition to the flow of molten metal. Those effects are exhibited when phosphorus is added in an amount not less than 0.02 wt%. But even if phosphorus is used in more than 0.25 wt%, it will not result in a proportional increase in effect. For this consideration, the addition of phosphorus settles down on 0.02 to 0.25 wt%.

While silicon is added to improve the machinability as mentioned above, it is also capable of increasing the flow of molten metal like phosphorus. The effect of silicon in raising the flow of molten metal is exhibited when it is added in an amount not less than 2.0 wt%. The range of the addition of silicon for improving the flow of molten metal overlaps that for improvement of the machinability. These taken into consideration, the addition of silicon is set to 2.0 to 4.0 wt%.

10. Another further lead-free, free-cutting copper alloy also with excellent machinability and a good high-temperature oxidation resistance is composed of 69 to 79 wt% of copper; 2.0 to 4.0 percent, by weight, of silicon; 0.1 to 1.5 wt% of aluminum; 0.02 to 0.25 wt% of phosphorus; at least one element selected from among 0.02 to 0.4 wt% of chromium and 0.02 to 0.4 wt% of titanium; and the remaining wt% of zinc. The tenth copper alloy will be hereinafter called the "tenth alloy".

Chromium and titanium are added for improving the high-temperature oxidation resistance. Good results can be expected especially when they are added together with aluminum to produce a synergistic effect. Those effects are exhibited when the addition is 0.02 percent or more by weight, whether they are used alone or in combination. The saturation point is 0.4 wt%. In consideration of such observations, the tenth alloy contains at least one element selected from among 0.02 to 0.4 wt% of chromium and 0.02 to 0.4 wt% of titanium in addition to the components of the ninth alloy and is an improvement over the ninth alloy with regard to the high-temperature oxidation resistance.

11. A yet still further lead-free, free-cutting copper alloy also with excellent machinability and a good high-temperature oxidation resistance is composed of 69 to 79 wt% of copper; 2.0 to 4.0 wt% of silicon; 0.1 to 1.5 wt% of aluminum; 0.02 to 0.25 wt% of phosphorus; at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium and 0.02 to 0.4 wt% of selenium; and the remaining wt% of zinc. The eleventh copper alloy will be hereinafter called the "eleventh alloy".

The eleventh alloy contains at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium and 0.02 to 0.4 wt% of selenium in addition to the components of the ninth alloy. While as high a high-temperature oxidation resistance as in the ninth alloy is secured, the eleventh alloy is further improved in machinability by adding at least one element selected from among bismuth and other elements which are effective in raising the machinability through a mechanism other than that exhibited by silicon.

12. In An additional further lead-free, free-cutting copper alloy also with excellent machinability and a good high-temperature oxidation resistance is composed of 69 to 79 wt% of copper; 2.0 to 4.0 wt% of silicon; 0.1 to 1.5 wt% of aluminum; 0.02 to 0.25 wt% of phosphorus; at least one element selected from among 0.02 to 0.4 wt% of chromium, and 0.02 to 0.4 wt% of titanium; at least one element selected from among 0.02 to 0.4 wt% of bismuth, 0.02 to 0.4 wt% of tellurium and 0.02 to 0.4 wt% of selenium; and the remaining wt% of zinc. The twelfth copper alloy will be hereinafter called the "twelfth alloy".

The twelfth alloy contains at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 wt% of tellurium and 0.02 to 0.4 wt% of selenium in addition to the components of the tenth alloy. While as high a high-temperature oxidation resistance as in the tenth alloy is secured, the twelfth alloy is further improved in machinability by adding at least one element selected from among bismuth and other elements which are effective in raising the machinability through a mechanism other than that exhibited by silicon.

13. Yet another further lead-free, free-cutting copper alloy also with further improved machinability is obtained by subjecting any one of the preceding alloys to a heat treatment for 30 minutes to 5 hours at 400°C to 600° C. The thirteenth copper alloy will be hereinafter called the "thirteenth alloy".

**[0010]** The first to twelfth alloys contain machinability improving elements such as silicon and have an excellent machinability because of the addition of such elements. Of those alloys, the alloys with a high copper content which have great amounts of other phases, mainly kappa phase, than alpha, beta, gamma and delta phases can further improve in machinability in a heat treatment. In the heat treatment, the kappa phase turns to a gamma phase. The gamma phase finely disperses and precipitates to further enhance the machinability. The alloys with a high content of copper are high in ductility of the matrix and low in absolute quantity of gamma phase, and therefore are excellent in cold workability. But in case cold working such as caulking and cutting are required, the aforesaid heat treatment is very useful. In other words, among the first to twelfth alloys, those which are high in copper content with gamma phase in small quantities and kappa phase in large quantities (hereinafter referred to as the "high copper content alloy") undergo a change in phase from the kappa phase to the gamma phase in a heat treatment. As a result, the gamma phase is finely dispersed and precipitated, and the machinability is improved. In the manufacturing process of castings, expanded metals and hot forgings in practice, the materials are often force-air-cooled or water cooled depending on the forging conditions, productivity after hot working (hot extrusion, hot forging etc.), working environment and other factors. In such cases, among the first to twelfth alloys, those with a low content of copper (hereinafter called the low copper content alloy") are rather low in the content of the gamma phase and contain beta phase. In a heat treatment, the beta phase changes into gamma phase, and the gamma phase is finely dispersed and precipitated, whereby the machinability is improved. Experiments showed that heat treatment is especially effective with high copper content alloys where mixing ratio of copper and silicon to other added elements (except for zinc) A is given as  $67 \leq \text{Cu} - 3\text{Si} + a\text{A}$  or low copper content alloys with such a composition with  $64 \geq \text{Cu} - 3\text{Si} + a\text{A}$ . It is noted that a is a coefficient. The coefficient is different depending on the added element A. For example, with tin a is - 0.5; aluminum, -2; phosphorus, -3; antimony, 0; arsenic, 0; manganese, +2.5; and nickel, +2.5.

**[0011]** But a heat treatment temperature at less than 400°C is not economical and practical, because the aforesaid phase change will proceed slowly and much time will be needed. At temperatures over 600°C, on the other hand, the kappa phase will grow or the beta phase will appear, bringing about no improvement in machinability. From the practical viewpoint, therefore, it is desired to perform the heat treatment for 30 minutes to 5 hours at 400 to 600°C.

#### BRIEF DESCRIPTION OF THE DRAWING

**[0012]** Fig. 1 shows perspective views of cuttings formed in cutting a round bar of copper alloy by lathe.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

##### Example 1

**[0013]** As the first series of examples of the present invention, cylindrical ingots with compositions given in Tables 1 to 35, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to produce the following test pieces: first alloys Nos. 1001 to 1008, second alloys Nos. 2001 to 2011, third alloys Nos. 3001 to 3012, fourth alloys Nos. 4001 to 4049, fifth alloys Nos. 5001 to 5020, sixth alloys Nos. 6001 to 6105, seventh alloys Nos. 7001 to 7030, eighth alloys Nos. 8001 to 8147, ninth alloys Nos. 9001 to 9005, tenth alloys Nos. 10001 to 10008, eleventh alloys Nos. 11001 to 11007, and twelfth alloys Nos. 12001 to 12021. Also, cylindrical ingots with the compositions given in Table 36, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to produce the following test pieces: thirteenth

alloys Nos. 13001 to 13006. That is, No. 13001 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as first alloy No. 1005 for 30 minutes at 580°C. No. 13002 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as No. 13001 for two hours at 450°C. No. 13003 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as first alloy No. 1007 under the same conditions as for No. 13001 - for 30 minutes at 580°C. No. 13004 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as No. 13007 under the same conditions as for 13002 - for two hours at 450°C. No. 13005 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as first alloy No. 1008 under the same conditions as for No. 13001 - for 30 minutes at 580°C. No. 13006 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as No. 1008 and heat-treated under the same conditions as for 13002 - for two hours at 450°C.

**[0014]** As comparative examples, cylindrical ingots with the compositions as shown in Table 37, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750 °C to obtain the following round extruded test pieces: Nos. 14001 to 14006 (hereinafter referred to as the "conventional alloys"). No. 14001 corresponds to the alloy "JIS C 3604," No. 14002 to the alloy "CDA C 36000," No. 14003 to the alloy "JIS C 3771" and No. 14004 to the alloy "CDA C 69800." No. 14005 corresponds to the alloy "JIS C 6191." This aluminum bronze is the most excellent of the expanded copper alloys under the JIS designations with regard to strength and wear resistance. No. 14006 corresponds to the naval brass alloy "JIS C 4622" and is the most excellent of the expanded copper alloys under the JIS designations with regard to corrosion resistance. To study the machinability of the first to thirteenth alloys in comparison with the conventional alloys, cutting tests were carried out. In the tests, evaluations were made on the basis of cutting force, condition of chips cut surface condition.

**[0015]** The tests were conducted this way: The extruded test pieces obtained, as mentioned above, were cut on the circumferential surface by a lathe mounted with a point nose straight tool at a rake angle of - 8 degrees and at a cutting rate of 50 meters/minute, a cutting depth of 1.5 mm, a feed of 0.11 mm/rev. Signals from a three-component dynamometer mounted on the tool were converted into electric voltage signals and recorded on a recorder. From the signals were then calculated the cutting resistance. It is noted that while, to be perfectly exact, an amount of the cutting resistance should be judged by three component forces - cutting force, feed force and thrust force, the judgement was made on the basis of the cutting force (N) of the three component forces in the present example. The results are shown in Table 38 to Table 66.

**[0016]** Furthermore, the chips from the cutting work were examined and classified into four forms (A) to (D) as shown in Fig. 1. The results are enumerated in Table 38 to Table 66. In this regard, the chips in the form of a spiral with three or more windings as (D) in Fig. 1 are difficult to process, that is, recover or recycle, and could cause trouble in cutting work as, for example, getting tangled with the tool and damaging the cut metal surface. Chips in the form of an arc with a half winding to a spiral with two about windings as shown in (C), Fig. 1 do not cause such serious trouble as the chips in the form of a spiral with three or more windings yet are not easy to remove and could get tangled with the tool or damage the cut metal surface. In contrast, chips in the form of a fine needle as (A) in Fig. 1 or in the form of an arc as (B) will not present such problems as mentioned above and are not bulky as the chips in (C) and (D) and easy to process. But fine chips as (A) still could creep into the sliding surfaces of a machine tool such as a lathe and cause mechanical trouble, or could be dangerous because they could stick into the worker's finger, eye or other body parts. Those taken into account, it is appropriate to consider that the chips in (B) are the best, and the second best are the chips in (A). Those in (C) and (D) are not good. In Table 38 to Table 66, the chips judged to be shown in (B), (A), (C) and (D) are indicated by the symbols "◎", "○", "—" and "x" respectively.

**[0017]** In addition, the surface condition of the cut metal surface was checked after cutting work. The results are shown in Table 38 to Table 66. In this regard, the commonly used basis for indication of the surface roughness is the maximum roughness (Rmax). While requirements are different depending on the application field of brass articles, the alloys with Rmax < 10 microns are generally considered excellent in machinability. The alloys with 10 microns ≤ Rmax < 15 microns are judged as industrially acceptable, while those with Rmax ≥ 15 microns are taken as poor in machinability. In Table 38 to Table 65, the alloys with Rmax < 10 microns are marked "o", those with 10 microns ≤ Rmax < 15 microns are indicated as "—" and those with Rmax ≥ 15 microns are represented by a symbol "x".

**[0018]** As is evident from the results of the cutting tests shown in Table 38 to Table 66, the following alloys are all equal to the conventional lead- contained alloys Nos. 14001 to 14003 in machinability: first alloys Nos. 1001 to 1008, second alloys Nos. 2001 to 2011, third alloys Nos. 3001 to 3012, fourth alloys Nos. 4001 to 4049, fifth alloys Nos. 5001 to 5020, sixth alloys Nos. 6001 to 6105, seventh alloys Nos. 7001 to 7030, eighth alloys Nos. 8001 to 8147, ninth alloys Nos. 9001 to 9005, tenth alloys Nos. 10001 to 10008, eleventh alloys Nos. 11001 to 11007, twelfth alloys Nos. 12001 to 12021. Especially with regard to formation of the chips, those alloys are favourably compared not only with the conventional alloys Nos. 14004 to 14006 with a lead content of not higher than 0.1 wt% but also Nos. 14001 to 14003 which contain large quantities of lead.

**[0019]** Also to be noted is that as is clear from Tables Nos. 38 to 65, thirteenth alloys Nos. 13001 to 13006 are improved over first alloy No. 1005, No. 1007 and No. 1008 with the same composition as the thirteenth alloys in machina-

bility. It is thus confirmed that a proper heat treatment could further enhance the machinability.

**[0020]** In another series of tests, the first to thirteenth alloys were examined in comparison with the conventional alloys in hot workability and mechanical properties. For the purpose, hot compression and tensile tests were conducted the following way.

**[0021]** First, two test pieces, first and second test pieces, in the same shape 15 mm in outside diameter and 25 mm in length were cut out of each extruded test piece obtained as described above. In the hot compression tests, the first test piece was held for 30 minutes at 700°C, and then compressed 70 percent in the direction of axis to reduce the length from 25 mm to 7.5 mm. The surface condition after the compression (700°C deformability) was visually evaluated. The results are given in Table 38 to Table 66. The evaluation of deformability was made by visually checking for cracks on the side of the test piece. In Table 38 to Table 66, the test pieces with no cracks found are marked "o", those with small cracks are indicated in "\_" and those with large cracks are represented by a symbol "x".

**[0022]** The second test pieces were put to a tensile test by the commonly practised test method to determine the tensile strength, N/mm<sup>2</sup> and elongation, %.

**[0023]** As the test results of the hot compression and tensile tests in Table 38 to Table 66 indicate, it was confirmed that the first to thirteenth alloys are equal to or superior to the conventional alloys Nos. 14001 to 14004 and No. 14006 in hot workability and mechanical properties and are suitable for industrial use. The seventh and eighth alloys in particular have the same level of mechanical properties as the conventional alloy No. 14005, the aluminum bronze which is the most excellent in strength of the expanded copper alloys under the JIS designations, and thus have understandably a prominent high strength feature.

**[0024]** Furthermore, the first to six and ninth to thirteenth alloys were put to dezincification and stress corrosion cracking tests in accordance with the test methods specified under "ISO 6509" and "JIS H 3250" respectively to examine the corrosion resistance and resistance to stress corrosion cracking in comparison with the conventional alloys.

**[0025]** In the dezincification test by the "ISO 6509" method, a sample taken from each extruded test piece was imbedded in a phenolic resin material in such a way that part of the side surface of the sample is exposed, the exposed surface perpendicular to the extrusion direction of the extruded test piece. The surface of the example was polished with emery paper No. 1200, and then ultrasonic-washed in pure water and dried. The sample thus prepared was dipped in a 12.7 g/l aqueous solution of cupric chloride dihydrate (CuCl<sub>2</sub>·2H<sub>2</sub>O) 1.0% and left standing for 24 hours at 75°C. The sample was taken out of the aqueous solution and the maximum depth of dezincification was determined. The measurements of the maximum dezincification depth are given in Table 38 to Table 50 and Table 61 to Table 66.

**[0026]** As is clear from the results of dezincification tests shown in Table 38 to Table 50 and Table 61 to Table 66, the first to fourth alloys and the ninth to thirteenth alloys are excellent in corrosion resistance and favourably comparable with the conventional alloys Nos. 14001 to 14003 containing great amounts of lead. And it was confirmed that especially the fifth and sixth alloys which seek improvement in both machinability and corrosion resistance are very high in corrosion resistance and superior in corrosion resistance to the conventional alloy No. 14006, a naval brass which is the most resistant to corrosion of all the expanded alloys under the JIS designations.

**[0027]** In the stress corrosion cracking tests in accordance with the test method described in "JIS H 3250," a 150-mm-long sample was cut out from each extruded test piece. The sample was bent with its centre placed on an arc-shaped tester with a radius of 40 mm in such a way that one end and the other end subtend an angle of 45 degrees. The test sample thus subjected to a tensile residual stress was degreased and dried, and then placed in an ammonia environment in the desiccator with a 2.5% aqueous ammonia (ammonia diluted in the equivalent of pure water). To be exact, the test sample was held some 80 mm above the surface of aqueous ammonia in the desiccator. After the test sample was left standing in the ammonia environment for two hours, 8 hours and 24 hours, the test sample was taken out from the desiccator, washed in sulfuric acid solution 10% and examined for cracks under a magnifier of 10 magnifications. The results are given in Table 38 to Table 50 and Table 61 to Table 66. In those tables, the alloys which have developed clear cracks when held in the ammonia environment for two hours are marked "xx." The test samples which had no cracks at passage of two hours but were found to have clear cracks at 8 hours are indicated by "x." The test samples which had no cracks at 8 hours, but were found to have clear cracks at 24 hours were indicated by "\_". The test samples which were found to have no cracks at all at 24 hours are given a symbol "o."

**[0028]** As is indicated by the results of the stress corrosion cracking test given in Table 38 to Table 50 and Table 61 to Table 66, it was confirmed that not only the fifth and sixth alloys which seek improvement in both machinability and corrosion resistance but also the first to fourth alloys and the ninth and thirteenth alloys in which nothing particular was done to improve corrosion resistance were both equal to the conventional alloy No. 14005, an aluminum bronze containing no zinc, in stress corrosion cracking resistance and were superior in stress corrosion cracking resistance to the conventional naval brass alloy No. 14006, the one which has a highest corrosion resistance of all the expanded copper alloys under the JIS designations.

**[0029]** In addition, oxidation tests were carried out to study the high-temperature oxidation resistance of the ninth to twelfth alloys in comparison with the conventional alloys.

**[0030]** A test piece in the shape of a round bar with the surface cut to a outside diameter of 14 mm and the length

cut to 30 mm was prepared from each of the following extruded test pieces: No. 9001 to No. 9005, No. 10001 to No. 10008, No. 11001 to No. 11007, No. 12001 to No. 12021 and No. 14001 to No. 14006. Each test piece was then weighed to measure the weight before oxidation. After that, the test piece was placed in a porcelain crucible and held in an electric furnace maintained at 500°C. At passage of 100 hours, the test piece was taken out of the electric furnace and weighed to measure the weight after oxidation. From the measurements before and after oxidation was calculated the increase in weight by oxidation. It is understood that the increase by oxidation is an amount, mg, of increase in weight by oxidation per 10cm<sup>2</sup> of the surface area of the test piece and is calculated by the equation: increase in weight by oxidation, mg/10cm<sup>2</sup> = (weight, mg, after oxidation - weight, mg, before oxidation) x (10cm<sup>2</sup> / surface area, cm<sup>2</sup>, of test piece). The weight of each test piece increased after oxidation. The increase was brought about by high-temperature oxidation. Subjected to a high temperature, oxygen combines with copper, zinc and silicon to form Cu<sub>2</sub>O, ZnO, SiO<sub>2</sub>. That is, oxygen increase contributes to the weight gain. It can be said, therefore, that the alloys which are the smaller in weight increase by oxidation are the more excellent in high-temperature oxidation resistance. The results obtained are shown in Table 61 to Table 64 and Table 66.

**[0031]** As is evident from the test results shown in Table 61 to Table 64 and Table 66, the ninth to twelfth alloys are equal to the conventional alloy No. 14005, an aluminum bronze ranking high in resistance to high-temperature oxidation among the expanded copper alloys under the JIS designations and are far smaller than any other conventional copper alloy. Thus, it was confirmed that the ninth to twelfth alloys are very excellent in machinability and resistance to high-temperature oxidation as well.

## Example 2

**[0032]** As the second series of examples of the present invention, cylindrical ingots with compositions given in Tables 14 to 31, each 100 mm in outside diameter and 200 mm in length, were hot extruded into a round bar 35 mm in outside diameter at 700 C to produce the following test pieces: seventh alloys Nos. 7001a to 7030a and eighth alloys Nos. 8001a to 8147a. In parallel, cylindrical ingots with compositions given in Table 37, each 100 mm in outside diameter and 200 mm in length, were hot extruded into a round bar 35 mm in outside diameter at 700 C to produce the following alloy test pieces: Nos. 14001a to 14006a as second comparative examples (hereinafter referred to as the "conventional alloys"). It is noted that the alloys Nos. 7001a to 7030a, Nos. 8001a to 8147a and Nos. 14001a to 14006a are identical in composition with the aforesaid copper alloys Nos. 7001 to 7030, Nos. 8001 to 8147 and Nos. 14001 to No. 14006 respectively.

**[0033]** Those seventh alloys Nos. 7001a to 7030a and eighth alloys Nos. 8001a to 8147a were put to wear resistance tests in comparison with the conventional alloys Nos. 14001a to 14006a.

**[0034]** The tests were carried out in this procedure. Each extruded test piece thus obtained was cut on the circumferential surface, holed and cut down into a ringshaped test piece 32 mm in outside diameter and 10 mm in thickness (that is, the length in the axial direction). The test piece was then fitted around a free-rotating shaft, and a roll 48 mm in outside diameter placed in parallel with the axis of the shaft was urged against the test piece under a load of 50 kg. The roll was made of stainless steel under the JIS designation SUS 304. Then, the SUS 304 roll and the test piece put in rotational sliding contact with the roll were rotated at the same rate of revolutions/minute - 209 r.p.m., with multipurpose gear oil being dropped onto the circumferential surface of the test piece. When the number of revolutions reached 100,000, the SUS 304 roll and the test piece were stopped, and the weight difference between the start and the end of rotation, that is, the loss of weight by wear, mg, was determined. It can be said that the alloys which are smaller in the loss of weight by wear are higher in wear resistance. The results are given in Tables 67 to 77.

**[0035]** As is clear from the wear resistance test results shown in Tables 67 to 77, the tests showed that those seventh alloys Nos. 7001a to 7030a and eighth alloys Nos. 8001a to 8147a were excellent in wear resistance as compared with not only the conventional alloys Nos. 14001a to 14004a and 14006a but also No. 14005a, which is an aluminium bronze having a highest wear resistance of the expanded copper alloys under the JIS designations. From comprehensive considerations of the test results including the tensile test results, it may safely be said that the seventh and eighth alloys are excellent in machinability and also possess a higher strength feature and wear resistance than the aluminum bronze which is the highest in wear resistance of all the expanded copper alloys under the JIS designations.

## Statements of alloys made according to the invention

**[0036]** The following paragraphs define lead-free, free cutting copper alloys according to the present invention, or made in accordance therewith:

1. A lead-free, free cutting copper alloy which comprises 69 to 79 wt% copper, 2.0 to 4.0 wt% silicon and the remaining wt% zinc.

## EP 1 559 802 A1

2. An alloy according to paragraph 1, further comprising at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium, and 0.02 to 0.4 wt% selenium.

3. An alloy according to paragraph 1, further comprising at least one element selected from among 0.3 to 3.5 wt% tin, 0.02 to 0.25 wt% phosphorus, 0.02 to 0.15 wt% antimony, and 0.02 to 0.15 wt% arsenic.

4. An alloy according to paragraph 1, further comprising at least one element selected from among 0.3 to 3.5 wt% tin, 0.02 to 0.25 wt% phosphorus, 0.02 to 0.15 wt% antimony, and 0.02 to 0.15 wt% arsenic; at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium, and 0.02 to 0.4 wt% selenium.

5. An alloy according to paragraph 1, further comprising 0.1 to 1.5 wt% aluminum; and 0.02 to 0.25 wt% phosphorus.

6. An alloy according to paragraph 1, further comprising 0.1 to 1.5 wt% aluminum; 0.02 to 0.25 wt% phosphorus; at least one element selected from among 0.02 to 0.4 wt% chromium and 0.02 to 0.4 wt% titanium.

7. An alloy according to paragraph 1, further comprising 0.1 to 1.5 wt% aluminum; 0.02 to 0.25 wt% phosphorus; at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium and 0.02 to 0.4 wt% selenium.

8. An alloy according to paragraph 1, further comprising 0.1 to 1.5 wt% aluminum; 0.02 to 0.25 wt% phosphorus; at least one element selected from among 0.02 to 0.4 wt% chromium, and 0.02 to 0.4 wt% of titanium; at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium and 0.02 to 0.4 wt% selenium.

9. A lead-free, free cutting copper alloy comprising 70 to 80 wt% copper; 1.8 to 3.5 wt% silicon; at least one element selected from among 0.3 to 3.5 wt% tin, 1.0 to 3.5 wt% aluminium and 0.02 to 0.25 wt% phosphorus and the balance in wt% of zinc.

10. A lead-free, free cutting copper alloy comprising 62 to 78 wt% copper; 2.5 to 4.5 wt% silicon; at least one element selected from among 0.3 to 3.0 wt% tin, 0.2 to 2.5 wt% aluminium and 0.02 to 0.25 wt% phosphorus; and at least one element selected from among 0.7 to 3.5 wt% manganese and 0.7 to 3.5 wt% nickel, and the balance in wt% of zinc.

11. An alloy according to either of paragraphs 9 or 10 above, further comprising at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium, and 0.02 to 0.4 wt% selenium.

**[0037]** These free-cutting copper alloys are preferably subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600 °C.

**[0038]** The scope of protection sought is set out in the claims below.

[Table 1]

| No.  | alloy composition (wt%) |     |           |
|------|-------------------------|-----|-----------|
|      | Cu                      | Si  | Zn        |
| 1001 | 70.2                    | 2.1 | remainder |
| 1002 | 74.1                    | 2.9 | remainder |
| 1003 | 74.8                    | 3.1 | remainder |
| 1004 | 77.6                    | 3.7 | remainder |
| 1005 | 78.5                    | 3.2 | remainder |
| 1006 | 73.3                    | 2.4 | remainder |
| 1007 | 77.0                    | 2.9 | remainder |
| 1008 | 69.9                    | 2.3 | remainder |

# EP 1 559 802 A1

[Table 2]

| No.  | alloy composition (wt%) |     |      |      |      |           |
|------|-------------------------|-----|------|------|------|-----------|
|      | Cu                      | Si  | Bi   | Te   | Se   | Zn        |
| 2001 | 74.5                    | 2.9 | 0.05 |      |      | remainder |
| 2002 | 74.8                    | 2.8 |      | 0.25 |      | remainder |
| 2003 | 75.0                    | 2.9 |      |      | 0.13 | remainder |
| 2004 | 69.9                    | 2.1 | 0.32 | 0.03 |      | remainder |
| 2005 | 72.4                    | 2.3 | 0.11 |      | 0.31 | remainder |
| 2006 | 78.2                    | 3.4 |      | 0.14 | 0.03 | remainder |
| 2007 | 76.2                    | 2.9 | 0.03 | 0.05 | 0.12 | remainder |
| 2008 | 78.2                    | 3.7 | 0.33 |      |      | remainder |
| 2009 | 73.0                    | 2.4 | 0.16 |      |      | remainder |
| 2010 | 74.7                    | 2.8 | 0.04 | 0.30 |      | remainder |
| 2011 | 76.3                    | 3.0 | 0.18 | 0.12 |      | remainder |

[Table 3]

| No.  | alloy composition (wt%) |     |     |     |      |           |
|------|-------------------------|-----|-----|-----|------|-----------|
|      | Cu                      | Si  | Sn  | Al  | P    | Zn        |
| 3001 | 71.8                    | 2.4 | 3.1 |     |      | remainder |
| 3002 | 78.2                    | 2.3 |     | 3.3 |      | remainder |
| 3003 | 75.0                    | 1.9 | 1.5 | 1.4 |      | remainder |
| 3004 | 74.9                    | 3.2 |     |     | 0.09 | remainder |
| 3005 | 71.6                    | 2.4 | 2.3 |     | 0.03 | remainder |
| 3006 | 76.5                    | 2.7 |     | 2.4 | 0.21 | remainder |
| 3007 | 76.5                    | 3.1 | 0.6 | 1.1 | 0.04 | remainder |
| 3008 | 77.5                    | 3.5 | 0.4 |     |      | remainder |
| 3009 | 75.4                    | 3.0 | 1.7 |     |      | remainder |
| 3010 | 76.5                    | 3.3 |     |     | 0.21 | remainder |
| 3011 | 73.8                    | 2.7 |     |     | 0.04 | remainder |
| 3012 | 75.0                    | 2.9 | 1.6 |     | 0.10 | remainder |

[Table 4]

| No.  | alloy composition (wt%) |     |     |   |      |      |      |           |
|------|-------------------------|-----|-----|---|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | A | Bi   | Te   | Se   | Zn        |
| 4001 | 70.8                    | 1.9 | 3.4 |   | 0.36 |      |      | remainder |
| 4002 | 76.3                    | 3.4 | 1.3 |   |      | 0.03 |      | remainder |
| 4003 | 73.2                    | 2.5 | 1.9 |   |      |      | 0.15 | remainder |
| 4004 | 72.3                    | 2.4 | 0.6 |   | 0.29 | 0.23 |      | remainder |
| 4005 | 74.2                    | 2.7 | 2.0 |   | 0.03 |      | 0.26 | remainder |

# EP 1 559 802 A1

[Table 4] (continued)

| No.  | alloy composition (wt%) |     |     |     |      |      |      |           |
|------|-------------------------|-----|-----|-----|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | A   | Bi   | Te   | Se   | Zn        |
| 4006 | 75.4                    | 2.9 | 0.4 |     |      | 0.31 | 0.03 | remainder |
| 4007 | 71.5                    | 2.1 | 2.6 |     | 0.11 | 0.05 | 0.23 | remainder |
| 4008 | 79.1                    | 1.9 |     | 3.3 | 0.28 |      |      | remainder |
| 4009 | 76.3                    | 2.7 |     | 1.2 |      | 0.13 |      | remainder |
| 4010 | 77.2                    | 2.5 |     | 2.0 |      |      | 0.07 | remainder |
| 4011 | 79.2                    | 3.1 |     | 1.1 | 0.04 | 0.06 |      | remainder |
| 4012 | 76.3                    | 2.3 |     | 1.3 | 0.13 |      | 0.04 | remainder |
| 4013 | 77.4                    | 2.6 |     | 2.6 |      | 0.22 | 0.03 | remainder |
| 4014 | 77.9                    | 2.2 |     | 2.3 | 0.09 | 0.05 | 0.11 | remainder |
| 4015 | 73.5                    | 2.0 | 2.9 | 1.2 | 0.23 |      |      | remainder |
| 4016 | 76.3                    | 2.5 | 0.7 | 3.2 |      | 0.04 |      | remainder |
| 4017 | 75.5                    | 2.3 | 1.2 | 2.0 |      |      | 0.12 | remainder |
| 4018 | 77.1                    | 2.1 | 0.9 | 3.4 | 0.03 | 0.03 |      | remainder |
| 4019 | 72.9                    | 3.2 | 3.3 | 1.7 | 0.11 |      | 0.04 | remainder |
| 4020 | 74.2                    | 2.8 | 2.7 | 1.1 |      | 0.33 | 0.03 | remainder |

[Table 5]

| No.  | alloy composition (wt%) |     |     |     |      |      |      |      |           |
|------|-------------------------|-----|-----|-----|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Zn        |
| 4021 | 74.2                    | 2.3 | 1.5 | 2.3 | 0.07 | 0.05 | 0.09 |      | remainder |
| 4022 | 70.9                    | 2.1 |     |     | 0.11 |      |      | 0.11 | remainder |
| 4023 | 74.8                    | 3.1 |     |     |      | 0.07 |      | 0.06 | remainder |
| 4024 | 76.3                    | 3.2 |     |     |      |      | 0.05 | 0.02 | remainder |
| 4025 | 78.1                    | 3.1 |     |     | 0.26 | 0.02 |      | 0.15 | remainder |
| 4026 | 71.1                    | 2.2 |     |     | 0.13 |      | 0.02 | 0.05 | remainder |
| 4027 | 74.1                    | 2.7 |     |     | 0.03 | 0.06 | 0.03 | 0.03 | remainder |
| 4028 | 70.6                    | 1.9 | 3.2 |     | 0.31 |      |      | 0.04 | remainder |
| 4029 | 73.6                    | 2.4 | 2.3 |     |      | 0.03 |      | 0.04 | remainder |
| 4030 | 73.4                    | 2.6 | 1.7 |     |      |      | 0.31 | 0.22 | remainder |
| 4031 | 74.8                    | 2.9 | 0.5 |     | 0.03 | 0.02 |      | 0.05 | remainder |
| 4032 | 73.0                    | 2.6 | 0.7 |     | 0.09 |      | 0.02 | 0.08 | remainder |
| 4033 | 74.5                    | 2.8 |     |     |      | 0.03 | 0.12 | 0.05 | remainder |
| 4034 | 77.2                    | 3.3 | 1.3 |     |      | 0.03 | 0.12 | 0.04 | remainder |
| 4035 | 74.9                    | 3.1 | 0.4 |     | 0.02 | 0.05 | 0.05 | 0.08 | remainder |
| 4036 | 79.2                    | 3.3 |     | 2.5 | 0.05 |      |      | 0.12 | remainder |
| 4037 | 74.2                    | 2.6 |     | 1.2 |      | 0.12 |      | 0.05 | remainder |
| 4038 | 77.0                    | 2.8 |     | 1.3 |      |      | 0.05 | 0.20 | remainder |

# EP 1 559 802 A1

[Table 5] (continued)

| No.  | alloy composition (wt%) |     |    |     |      |      |      |      |           |
|------|-------------------------|-----|----|-----|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn | Al  | Bi   | Te   | Se   | P    | Zn        |
| 4039 | 76.0                    | 2.4 |    | 3.2 | 0.10 | 0.04 |      | 0.05 | remainder |
| 4040 | 74.8                    | 2.4 |    | 1.1 | 0.07 |      | 0.04 | 0.03 | remainder |

[Table 6]

| No.  | alloy composition (wt%) |     |     |     |      |      |      |      |           |
|------|-------------------------|-----|-----|-----|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Zn        |
| 4041 | 77.2                    | 2.7 |     | 2.1 |      | 0.33 | 0.05 | 0.05 | remainder |
| 4042 | 78.0                    | 2.6 |     | 2.5 | 0.03 | 0.02 | 0.10 | 0.14 | remainder |
| 4043 | 72.5                    | 2.4 | 1.9 | 1.1 | 0.12 |      |      | 0.03 | remainder |
| 4044 | 76.0                    | 2.6 | 0.5 | 2.0 |      | 0.20 |      | 0.07 | remainder |
| 4045 | 77.5                    | 2.6 | 0.7 | 3.1 |      |      | 0.21 | 0.12 | remainder |
| 4046 | 75.0                    | 2.6 | 0.8 | 2.2 | 0.04 | 0.05 |      | 0.06 | remainder |
| 4047 | 71.0                    | 1.9 | 3.1 | 1.0 | 0.15 |      | 0.02 | 0.04 | remainder |
| 4048 | 73.3                    | 2.1 | 2.6 | 1.2 |      | 0.04 | 0.03 | 0.05 | remainder |
| 4049 | 74.8                    | 2.5 | 0.6 | 1.1 | 0.03 | 0.03 | 0.04 | 0.07 | remainder |

[Table 7]

| No.  | alloy composition (wt%) |     |     |      |      |      |           |
|------|-------------------------|-----|-----|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | P    | Sb   | As   | Zn        |
| 5001 | 69.9                    | 2.1 | 3.3 |      |      |      | remainder |
| 5002 | 74.1                    | 2.7 |     | 0.21 |      |      | remainder |
| 5003 | 75.8                    | 2.4 |     |      | 0.14 |      | remainder |
| 5004 | 77.3                    | 3.4 |     |      |      | 0.05 | remainder |
| 5005 | 73.4                    | 2.4 | 2.1 | 0.04 |      |      | remainder |
| 5006 | 75.3                    | 2.7 | 0.4 |      | 0.04 |      | remainder |
| 5007 | 70.9                    | 2.2 | 2.4 |      |      | 0.07 | remainder |
| 5008 | 71.2                    | 2.6 | 1.1 | 0.03 | 0.03 |      | remainder |
| 5009 | 77.3                    | 2.9 | 0.7 | 0.19 |      | 0.03 | remainder |
| 5010 | 78.2                    | 3.1 | 0.4 |      | 0.09 | 0.15 | remainder |
| 5011 | 72.5                    | 2.1 | 2.8 | 0.02 | 0.10 | 0.03 | remainder |
| 5012 | 79.0                    | 3.3 |     | 0.24 | 0.02 |      | remainder |
| 5013 | 75.6                    | 2.9 |     | 0.07 |      | 0.14 | remainder |
| 5014 | 74.8                    | 3.0 |     |      | 0.11 | 0.02 | remainder |
| 5015 | 74.3                    | 2.8 |     | 0.06 | 0.02 | 0.03 | remainder |
| 5016 | 72.9                    | 2.5 |     | 0.03 |      |      | remainder |
| 5017 | 77.0                    | 3.4 |     | 0.14 |      |      | remainder |
| 5018 | 76.8                    | 3.2 | 0.7 | 0.12 |      |      | remainder |

# EP 1 559 802 A1

[Table 7] (continued)

| No.  | alloy composition (wt%) |     |     |      |      |    |           |
|------|-------------------------|-----|-----|------|------|----|-----------|
|      | Cu                      | Si  | Sn  | P    | Sb   | As | Zn        |
| 5019 | 74.5                    | 2.8 | 1.8 |      |      |    | remainder |
| 5020 | 74.9                    | 3.0 |     | 0.20 | 0.05 |    | remainder |

[Table 8]

| No.  | alloy composition (wt%) |     |     |      |      |      |      |      |           |
|------|-------------------------|-----|-----|------|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Bi   | Te   | P    | Sb   | As   | Zn        |
| 6001 | 69.6                    | 2.1 | 3.2 | 0.15 |      |      |      |      | remainder |
| 6002 | 77.3                    | 3.7 | 0.5 | 0.02 |      | 0.23 |      |      | remainder |
| 6003 | 75.2                    | 2.4 | 1.1 | 0.33 |      |      | 0.12 |      | remainder |
| 6004 | 70.9                    | 2.3 | 3.1 | 0.11 |      |      |      | 0.03 | remainder |
| 6005 | 78.1                    | 2.7 | 0.6 | 0.14 |      | 0.02 | 0.07 |      | remainder |
| 6006 | 74.5                    | 2.6 | 1.5 | 0.21 |      | 0.10 |      | 0.04 | remainder |
| 6007 | 74.7                    | 3.2 | 2.1 | 0.05 |      |      | 0.02 | 0.12 | remainder |
| 6008 | 73.8                    | 2.5 | 0.7 | 0.31 |      | 0.03 | 0.02 | 0.10 | remainder |
| 6009 | 74.5                    | 2.9 |     | 0.05 |      | 0.19 |      |      | remainder |
| 6010 | 78.1                    | 3.1 |     | 0.11 |      |      | 0.15 |      | remainder |
| 6011 | 74.6                    | 3.3 |     | 0.02 |      |      |      | 0.22 | remainder |
| 6012 | 69.9                    | 2.3 |     | 0.35 |      | 0.08 | 0.02 |      | remainder |
| 6013 | 73.2                    | 2.6 |     | 0.21 |      | 0.03 |      | 0.07 | remainder |
| 6014 | 76.3                    | 2.9 |     | 0.07 |      |      | 0.09 | 0.02 | remainder |
| 6015 | 74.4                    | 2.8 |     | 0.19 |      | 0.13 | 0.03 | 0.02 | remainder |
| 6016 | 70.5                    | 2.3 | 2.9 | 0.10 | 0.02 |      |      |      | remainder |
| 6017 | 74.7                    | 2.4 | 0.9 | 0.31 | 0.04 | 0.05 |      |      | remainder |
| 6018 | 78.1                    | 3.8 | 0.6 | 0.02 | 0.33 |      | 0.07 |      | remainder |
| 6019 | 69.4                    | 2.0 | 3.4 | 0.11 | 0.03 |      |      | 0.03 | remainder |
| 6020 | 77.8                    | 2.8 | 0.5 | 0.06 | 0.11 | 0.21 | 0.02 |      | remainder |

[Table 9]

| No.  | alloy composition (wt%) |     |     |      |      |    |      |      |      |           |
|------|-------------------------|-----|-----|------|------|----|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Bi   | Te   | Se | P    | Sb   | As   | Zn        |
| 6021 | 74.2                    | 2.6 | 0.6 | 0.20 | 0.03 |    | 0.02 |      | 0.14 | remainder |
| 6022 | 75.8                    | 3.3 | 1.8 | 0.03 | 0.06 |    |      | 0.11 | 0.02 | remainder |
| 6023 | 74.4                    | 2.6 | 1.5 | 0.09 | 0.12 |    | 0.03 | 0.02 | 0.06 | remainder |
| 6024 | 77.3                    | 3.1 |     | 0.02 | 0.25 |    | 0.08 |      |      | remainder |
| 6025 | 70.5                    | 2.4 |     | 0.12 | 0.04 |    | 0.06 | 0.03 |      | remainder |
| 6026 | 74.3                    | 2.9 |     | 0.24 | 0.02 |    | 0.13 |      | 0.11 | remainder |
| 6027 | 69.8                    | 2.3 |     | 0.34 | 0.03 |    | 0.21 | 0.02 | 0.02 | remainder |

# EP 1 559 802 A1

[Table 9] (continued)

| No.  | alloy composition (wt%) |     |     |      |      |      |      |      |      |           |
|------|-------------------------|-----|-----|------|------|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Bi   | Te   | Se   | P    | Sb   | As   | Zn        |
| 6028 | 74.5                    | 2.9 |     | 0.03 | 0.11 |      |      | 0.13 |      | remainder |
| 6029 | 78.4                    | 3.2 |     | 0.02 | 0.08 |      |      | 0.04 | 0.05 | remainder |
| 6030 | 73.8                    | 3.0 |     | 0.08 | 0.31 |      |      |      | 0.23 | remainder |
| 6031 | 72.8                    | 2.5 | 1.6 | 0.11 |      | 0.36 |      |      |      | remainder |
| 6032 | 78.1                    | 3.7 | 0.5 | 0.03 |      | 0.02 | 0.05 |      |      | remainder |
| 6033 | 77.2                    | 2.8 | 0.6 | 0.09 |      | 0.04 |      | 0.07 |      | remainder |
| 6034 | 76.9                    | 3.8 | 0.4 | 0.03 |      | 0.06 |      |      | 0.07 | remainder |
| 6035 | 74.1                    | 2.3 | 3.3 | 0.06 |      | 0.03 | 0.02 | 0.05 |      | remainder |
| 6036 | 69.8                    | 2.0 | 2.5 | 0.31 |      | 0.12 | 0.03 |      | 0.06 | remainder |
| 6037 | 74.9                    | 3.0 | 1.1 | 0.07 |      | 0.21 |      | 0.12 | 0.02 | remainder |
| 6038 | 72.6                    | 2.8 | 0.6 | 0.20 |      | 0.05 | 0.21 | 0.07 | 0.03 | remainder |
| 6039 | 69.7                    | 2.3 |     | 0.23 |      | 0.06 | 0.10 |      |      | remainder |
| 6040 | 75.4                    | 3.0 |     | 0.02 |      | 0.09 | 0.11 | 0.03 |      | remainder |

[Table 10]

| No.  | alloy composition (wt%) |     |     |      |      |      |      |      |      |           |
|------|-------------------------|-----|-----|------|------|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Bi   | Te   | Se   | P    | Sb   | As   | Zn        |
| 6041 | 73.2                    | 2.5 |     | 0.11 |      | 0.36 | 0.05 |      | 0.02 | remainder |
| 6042 | 78.2                    | 3.7 |     | 0.03 |      | 0.04 | 0.03 | 0.04 | 0.10 | remainder |
| 6043 | 77.8                    | 2.8 |     | 0.09 |      | 0.02 |      | 0.04 |      | remainder |
| 6044 | 73.4                    | 2.6 |     | 0.16 |      | 0.06 |      | 0.03 | 0.02 | remainder |
| 6045 | 71.2                    | 2.4 |     | 0.35 |      | 0.14 |      |      | 0.08 | remainder |
| 6046 | 70.3                    | 2.5 | 1.9 | 0.09 | 0.05 | 0.03 |      |      |      | remainder |
| 6047 | 74.5                    | 3.6 | 2.2 | 0.02 | 0.20 | 0.04 | 0.04 |      |      | remainder |
| 6048 | 73.8                    | 2.9 | 1.2 | 0.03 | 0.10 | 0.05 |      | 0.12 |      | remainder |
| 6049 | 69.8                    | 2.1 | 3.1 | 0.32 | 0.03 | 0.05 |      |      | 0.13 | remainder |
| 6050 | 74.2                    | 2.2 | 0.6 | 0.19 | 0.11 | 0.02 | 0.02 | 0.03 |      | remainder |
| 6051 | 74.8                    | 3.2 | 0.5 | 0.03 | 0.07 | 0.03 | 0.05 |      | 0.02 | remainder |
| 6052 | 78.0                    | 2.8 | 0.6 | 0.06 | 0.04 | 0.11 |      | 0.11 | 0.03 | remainder |
| 6053 | 76.3                    | 2.4 | 0.8 | 0.05 | 0.03 | 0.22 | 0.03 | 0.04 | 0.03 | remainder |
| 6054 | 74.2                    | 2.6 |     | 0.21 | 0.02 | 0.04 | 0.05 |      |      | remainder |
| 6055 | 78.2                    | 2.9 |     | 0.16 | 0.08 | 0.03 | 0.21 | 0.03 |      | remainder |
| 6056 | 72.3                    | 2.5 |     | 0.08 | 0.36 | 0.02 | 0.10 |      | 0.04 | remainder |
| 6057 | 69.8                    | 2.4 |     | 0.36 | 0.04 | 0.04 | 0.06 | 0.07 | 0.02 | remainder |
| 6058 | 74.6                    | 3.1 |     | 0.05 | 0.09 | 0.04 |      | 0.14 |      | remainder |
| 6059 | 73.8                    | 2.5 |     | 0.08 | 0.05 | 0.03 |      | 0.02 | 0.04 | remainder |
| 6060 | 74.9                    | 2.7 |     | 0.03 | 0.16 | 0.02 |      |      | 0.03 | remainder |

# EP 1 559 802 A1

[Table 11]

| No.  | alloy composition (wt%) |     |     |      |      |      |      |      |           |
|------|-------------------------|-----|-----|------|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Te   | Se   | P    | Sb   | As   | Zn        |
| 6061 | 69.7                    | 2.6 | 3.1 | 0.26 |      |      |      |      | remainder |
| 6062 | 74.2                    | 3.2 | 0.6 | 0.03 |      | 0.04 |      |      | remainder |
| 6063 | 74.9                    | 2.6 | 0.7 | 0.14 |      |      | 0.14 |      | remainder |
| 6064 | 73.8                    | 3.0 | 0.4 | 0.07 |      |      |      | 0.13 | remainder |
| 6065 | 78.1                    | 3.3 | 0.8 | 0.02 |      | 0.12 | 0.02 |      | remainder |
| 6066 | 72.8                    | 2.4 | 1.2 | 0.32 |      | 0.03 |      | 0.05 | remainder |
| 6067 | 73.6                    | 2.7 | 2.1 | 0.03 |      |      | 0.07 | 0.02 | remainder |
| 6068 | 72.3                    | 2.6 | 0.5 | 0.16 |      | 0.02 | 0.04 | 0.03 | remainder |
| 6069 | 70.6                    | 2.3 |     | 0.33 |      | 0.09 |      |      | remainder |
| 6070 | 76.5                    | 3.2 |     | 0.14 |      | 0.21 | 0.03 |      | remainder |
| 6071 | 74.5                    | 3.1 |     | 0.05 |      | 0.03 |      | 0.03 | remainder |
| 6072 | 72.8                    | 2.7 |     | 0.08 |      |      | 0.13 |      | remainder |
| 6073 | 78.0                    | 3.8 |     | 0.04 |      |      | 0.02 | 0.12 | remainder |
| 6074 | 73.8                    | 2.9 |     | 0.20 |      |      |      | 0.10 | remainder |
| 6075 | 74.5                    | 2.9 |     | 0.07 |      | 0.04 | 0.10 | 0.02 | remainder |
| 6076 | 73.6                    | 3.2 | 2.1 | 0.04 | 0.07 |      |      |      | remainder |
| 6077 | 74.1                    | 2.5 | 0.8 | 0.21 | 0.18 | 0.05 |      |      | remainder |
| 6078 | 77.8                    | 2.9 | 0.6 | 0.11 | 0.05 |      | 0.07 |      | remainder |
| 6079 | 71.5                    | 2.1 | 1.1 | 0.06 | 0.03 |      |      | 0.06 | remainder |
| 6080 | 72.6                    | 2.3 | 0.5 | 0.15 | 0.23 | 0.11 | 0.02 |      | remainder |

[Table 12]

| No.  | alloy composition (wt%) |     |     |      |      |      |      |      |           |
|------|-------------------------|-----|-----|------|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Te   | Se   | P    | Sb   | As   | Zn        |
| 6081 | 74.2                    | 3.0 | 0.5 | 0.03 | 0.03 | 0.20 |      | 0.02 | remainder |
| 6082 | 70.6                    | 2.2 | 2.6 | 0.32 | 0.05 |      | 0.13 | 0.03 | remainder |
| 6083 | 73.7                    | 2.6 | 0.8 | 0.14 | 0.16 | 0.06 | 0.02 | 0.03 | remainder |
| 6084 | 74.5                    | 3.1 |     | 0.04 | 0.04 | 0.05 |      |      | remainder |
| 6085 | 72.8                    | 2.7 |     | 0.09 | 0.21 | 0.04 | 0.02 |      | remainder |
| 6086 | 76.2                    | 3.3 |     | 0.03 | 0.04 | 0.11 |      | 0.04 | remainder |
| 6087 | 73.8                    | 2.7 |     | 0.11 | 0.03 | 0.02 | 0.04 | 0.03 | remainder |
| 6088 | 74.9                    | 2.9 |     | 0.05 | 0.31 |      | 0.05 |      | remainder |
| 6089 | 75.8                    | 2.8 |     | 0.08 | 0.04 |      | 0.03 | 0.14 | remainder |
| 6090 | 73.6                    | 2.4 |     | 0.27 | 0.10 |      |      | 0.06 | remainder |
| 6091 | 72.4                    | 2.2 | 3.2 |      | 0.33 |      |      |      | remainder |
| 6092 | 75.0                    | 3.2 | 0.6 |      | 0.05 | 0.10 |      |      | remainder |

# EP 1 559 802 A1

[Table 12] (continued)

| No.  | alloy composition (wt%) |     |     |    |      |      |      |      |           |
|------|-------------------------|-----|-----|----|------|------|------|------|-----------|
|      | Cu                      | Si  | Sn  | Te | Se   | P    | Sb   | As   | Zn        |
| 6093 | 76.8                    | 3.1 | 0.5 |    | 0.04 |      | 0.11 |      | remainder |
| 6094 | 74.5                    | 2.9 | 0.7 |    | 0.08 |      |      | 0.15 | remainder |
| 6095 | 73.2                    | 2.7 | 1.2 |    | 0.12 | 0.06 | 0.03 |      | remainder |
| 6096 | 69.6                    | 2.4 | 2.3 |    | 0.14 | 0.04 |      | 0.02 | remainder |
| 6097 | 74.2                    | 2.8 | 0.8 |    | 0.07 |      | 0.02 | 0.03 | remainder |
| 6098 | 74.4                    | 2.9 | 0.8 |    | 0.06 | 0.03 | 0.03 | 0.03 | remainder |
| 6099 | 74.8                    | 3.1 |     |    | 0.09 | 0.04 |      |      | remainder |
| 6100 | 73.9                    | 2.8 |     |    | 0.05 | 0.10 | 0.04 |      | remainder |

[Table 13]

| No.  | alloy composition (wt%) |     |      |      |      |      |           |
|------|-------------------------|-----|------|------|------|------|-----------|
|      | Cu                      | Si  | Se   | P    | Sb   | As   | Zn        |
| 6101 | 76.1                    | 3.0 | 0.04 | 0.05 |      | 0.02 | remainder |
| 6102 | 74.5                    | 2.8 | 0.03 | 0.04 | 0.02 | 0.03 | remainder |
| 6103 | 74.3                    | 2.6 | 0.31 |      | 0.04 |      | remainder |
| 6104 | 75.0                    | 3.3 | 0.06 |      | 0.02 | 0.05 | remainder |
| 6105 | 73.9                    | 2.9 | 0.10 |      |      | 0.11 | remainder |

[Table 14]

| No.   | alloy composition (wt%) |     |     |     |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | P    | Mn  | Ni  | Zn        |
| 7001  | 62.9                    | 2.7 | 2.6 |     |      | 2.2 |     | remainder |
| 7001a |                         |     |     |     |      |     |     |           |
| 7002  | 64.8                    | 3.4 | 1.8 |     |      |     | 3.1 | remainder |
| 7002a |                         |     |     |     |      |     |     |           |
| 7003  | 68.2                    | 4.1 | 0.6 |     |      | 1.9 | 1.5 | remainder |
| 7003a |                         |     |     |     |      |     |     |           |
| 7004  | 66.5                    | 3.5 | 1.9 | 0.9 |      | 1.9 |     | remainder |
| 7004a |                         |     |     |     |      |     |     |           |
| 7005  | 71.3                    | 3.7 | 0.4 | 1.8 |      |     | 2.3 | remainder |
| 7005a |                         |     |     |     |      |     |     |           |
| 7006  | 73.6                    | 2.9 | 0.7 | 2.1 |      | 1.3 | 0.8 | remainder |
| 7006a |                         |     |     |     |      |     |     |           |
| 7007  | 70.1                    | 3.2 | 0.5 | 1.4 | 0.11 | 1.8 |     | remainder |
| 7007a |                         |     |     |     |      |     |     |           |
| 7008  | 77.1                    | 4.2 | 0.8 | 2.3 | 0.03 |     | 1.8 | remainder |
| 7008a |                         |     |     |     |      |     |     |           |

# EP 1 559 802 A1

[Table 14] (continued)

| No.   | alloy composition (wt%) |     |     |     |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | P    | Mn  | Ni  | Zn        |
| 7009  | 67.3                    | 3.7 | 2.6 | 0.2 | 0.08 | 0.9 | 1.8 | remainder |
| 7009a |                         |     |     |     |      |     |     |           |
| 7010  | 75.5                    | 3.9 |     | 2.3 |      | 0.8 |     | remainder |
| 7010a |                         |     |     |     |      |     |     |           |

[Table 15]

| No.   | alloy composition (wt%) |     |     |     |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | P    | Mn  | Ni  | Zn        |
| 7011  | 69.8                    | 3.4 |     | 0.3 |      |     | 1.3 | remainder |
| 7011a |                         |     |     |     |      |     |     |           |
| 7012  | 71.2                    | 4.0 |     | 1.4 |      | 2.1 | 1.2 | remainder |
| 7012a |                         |     |     |     |      |     |     |           |
| 7013  | 73.3                    | 3.9 |     | 2.0 | 0.03 | 3.2 |     | remainder |
| 7013a |                         |     |     |     |      |     |     |           |
| 7014  | 65.9                    | 2.9 |     | 0.3 | 0.21 |     | 1.3 | remainder |
| 7014a |                         |     |     |     |      |     |     |           |
| 7015  | 68.8                    | 3.9 |     | 1.1 | 0.05 | 0.9 | 2.0 | remainder |
| 7015a |                         |     |     |     |      |     |     |           |
| 7016  | 68.1                    | 4.0 | 0.4 |     | 0.04 | 2.8 |     | remainder |
| 7016a |                         |     |     |     |      |     |     |           |
| 7017  | 63.8                    | 2.6 | 2.7 |     | 0.19 |     | 0.9 | remainder |
| 7017a |                         |     |     |     |      |     |     |           |
| 7018  | 66.7                    | 3.4 | 1.3 |     | 0.07 | 1.2 | 0.8 | remainder |
| 7018a |                         |     |     |     |      |     |     |           |
| 7019  | 67.2                    | 3.6 |     |     | 0.21 | 1.9 |     | remainder |
| 7019a |                         |     |     |     |      |     |     |           |
| 7020  | 69.1                    | 3.8 |     |     | 0.06 |     | 2.2 | remainder |
| 7020a |                         |     |     |     |      |     |     |           |

[Table 16]

| No.   | alloy composition (wt%) |     |    |     |      |     |     |           |
|-------|-------------------------|-----|----|-----|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn | Al  | P    | Mn  | Ni  | Zn        |
| 7021  | 72.1                    | 4.3 |    |     | 0.07 | 2.0 | 0.8 | remainder |
| 7021a |                         |     |    |     |      |     |     |           |
| 7022  | 71.3                    | 3.9 |    | 1.1 |      | 3.1 |     | remainder |
| 7022a |                         |     |    |     |      |     |     |           |

# EP 1 559 802 A1

[Table 16] (continued)

| No.   | alloy composition (wt%) |     |     |     |   |     |     |           |
|-------|-------------------------|-----|-----|-----|---|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | P | Mn  | Ni  | Zn        |
| 7023  | 70.5                    | 3.5 |     | 1.6 |   | 2.3 |     | remainder |
| 7023a |                         |     |     |     |   |     |     |           |
| 7024  | 70.0                    | 3.6 |     | 1.5 |   |     | 3.2 | remainder |
| 7024a |                         |     |     |     |   |     |     |           |
| 7025  | 69.3                    | 2.7 |     | 2.1 |   | 0.9 |     | remainder |
| 7025a |                         |     |     |     |   |     |     |           |
| 7026  | 70.2                    | 3.5 |     | 1.4 |   |     | 2.1 | remainder |
| 7026a |                         |     |     |     |   |     |     |           |
| 7027  | 65.0                    | 2.8 | 2.6 | 2.3 |   | 0.8 |     | remainder |
| 7027a |                         |     |     |     |   |     |     |           |
| 7028  | 69.8                    | 3.6 | 1.5 | 1.7 |   | 2.4 |     | remainder |
| 7028a |                         |     |     |     |   |     |     |           |
| 7029  | 71.0                    | 3.6 | 0.4 | 0.3 |   | 2.2 |     | remainder |
| 7029a |                         |     |     |     |   |     |     |           |
| 7030  | 68.4                    | 4.2 | 2.6 |     |   | 3.3 |     | remainder |
| 7030a |                         |     |     |     |   |     |     |           |

[Table 17]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | Mn  | Zn        |
| 8001  | 62.6                    | 2.6 | 2.6 |     | 0.31 |      |      | 1.9 | remainder |
| 8001a |                         |     |     |     |      |      |      |     |           |
| 8002  | 65.3                    | 3.4 | 1.8 |     | 0.11 | 0.02 |      | 2.5 | remainder |
| 8002a |                         |     |     |     |      |      |      |     |           |
| 8003  | 66.4                    | 4.2 | 0.5 |     | 0.05 |      | 0.03 | 3.4 | remainder |
| 8003a |                         |     |     |     |      |      |      |     |           |
| 8004  | 72.1                    | 4.4 | 0.4 |     | 0.06 | 0.05 | 0.02 | 2.8 | remainder |
| 8004a |                         |     |     |     |      |      |      |     |           |
| 8005  | 67.4                    | 3.3 | 2.3 |     |      | 0.31 |      | 0.9 | remainder |
| 8005a |                         |     |     |     |      |      |      |     |           |
| 8006  | 63.8                    | 2.8 | 2.9 |     |      | 0.06 | 0.07 | 2.1 | remainder |
| 8006a |                         |     |     |     |      |      |      |     |           |
| 8007  | 71.5                    | 3.9 | 1.5 |     |      |      | 0.20 | 1.4 | remainder |
| 8007a |                         |     |     |     |      |      |      |     |           |
| 8008  | 64.2                    | 2.9 | 2.4 | 0.3 | 0.28 |      |      | 2.1 | remainder |
| 8008a |                         |     |     |     |      |      |      |     |           |

# EP 1 559 802 A1

[Table 17] (continued)

| No.   | alloy composition (wt%) |     |     |     |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | Mn  | Zn        |
| 8009  | 68.8                    | 3.4 | 1.0 | 1.5 | 0.07 | 0.20 |      | 1.7 | remainder |
| 8009a |                         |     |     |     |      |      |      |     |           |
| 8010  | 65.3                    | 3.6 | 2.8 | 0.2 | 0.05 |      | 0.13 | 2.2 | remainder |
| 8010a |                         |     |     |     |      |      |      |     |           |

[Table 18]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Mn  | Zn        |
| 8011  | 66.8                    | 3.3 | 1.9 | 2.1 | 0.04 | 0.05 | 0.05 |      | 2.3 | remainder |
| 8011a |                         |     |     |     |      |      |      |      |     |           |
| 8012  | 75.1                    | 4.1 | 0.4 | 2.4 |      | 0.03 |      |      | 1.8 | remainder |
| 8012a |                         |     |     |     |      |      |      |      |     |           |
| 8013  | 74.2                    | 3.9 | 0.5 | 1.8 |      | 0.10 | 0.04 |      | 1.7 | remainder |
| 8013a |                         |     |     |     |      |      |      |      |     |           |
| 8014  | 77.1                    | 4.2 | 0.4 | 2.1 |      |      | 0.32 |      | 2.0 | remainder |
| 8014a |                         |     |     |     |      |      |      |      |     |           |
| 8015  | 62.8                    | 2.6 | 2.9 |     | 0.12 |      |      | 0.03 | 1.2 | remainder |
| 8015a |                         |     |     |     |      |      |      |      |     |           |
| 8016  | 64.4                    | 2.9 | 2.7 |     | 0.23 | 0.09 |      | 0.13 | 1.8 | remainder |
| 8016a |                         |     |     |     |      |      |      |      |     |           |
| 8017  | 68.3                    | 3.6 | 0.4 |     | 0.05 |      | 0.05 | 0.04 | 2.2 | remainder |
| 8017a |                         |     |     |     |      |      |      |      |     |           |
| 8018  | 73.2                    | 4.3 | 0.5 |     | 0.06 | 0.02 | 0.11 | 0.02 | 3.1 | remainder |
| 8018a |                         |     |     |     |      |      |      |      |     |           |
| 8019  | 72.4                    | 4.1 | 0.7 |     |      | 0.14 |      | 0.21 | 2.1 | remainder |
| 8019a |                         |     |     |     |      |      |      |      |     |           |
| 8020  | 69.5                    | 3.7 | 0.7 |     |      | 0.06 | 0.04 | 0.05 | 1.9 | remainder |
| 8020a |                         |     |     |     |      |      |      |      |     |           |

[Table 19]

| No.   | alloy composition (wt%) |     |     |     |      |    |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|----|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te | Se   | P    | Mn  | Zn        |
| 8021  | 64.2                    | 3.4 | 2.5 |     |      |    | 0.31 | 0.03 | 1.9 | remainder |
| 8021a |                         |     |     |     |      |    |      |      |     |           |
| 8022  | 65.6                    | 3.7 | 2.3 | 0.2 | 0.06 |    |      | 0.03 | 1.4 | remainder |
| 8022a |                         |     |     |     |      |    |      |      |     |           |

# EP 1 559 802 A1

[Table 19] (continued)

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Mn  | Zn        |
| 8023  | 67.1                    | 3.6 | 0.4 | 0.5 | 0.04 | 0.05 |      | 0.05 | 2.0 | remainder |
| 8023a |                         |     |     |     |      |      |      |      |     |           |
| 8024  | 73.2                    | 4.0 | 0.5 | 2.1 | 0.03 |      | 0.05 | 0.12 | 2.4 | remainder |
| 8024a |                         |     |     |     |      |      |      |      |     |           |
| 8025  | 68.8                    | 3.5 | 0.4 | 1.8 | 0.12 | 0.03 | 0.03 | 0.04 | 1.8 | remainder |
| 8025a |                         |     |     |     |      |      |      |      |     |           |
| 8026  | 66.5                    | 3.4 | 1.2 | 0.3 |      | 0.24 |      | 0.21 | 1.7 | remainder |
| 8026a |                         |     |     |     |      |      |      |      |     |           |
| 8027  | 64.8                    | 3.0 | 1.3 | 1.2 |      | 0.16 | 0.10 | 0.06 | 1.5 | remainder |
| 8027a |                         |     |     |     |      |      |      |      |     |           |
| 8028  | 71.2                    | 3.9 | 0.4 | 1.0 |      |      | 0.14 | 0.03 | 2.6 | remainder |
| 8028a |                         |     |     |     |      |      |      |      |     |           |
| 8029  | 68.1                    | 3.6 |     | 0.2 | 0.05 |      |      |      | 2.0 | remainder |
| 8029a |                         |     |     |     |      |      |      |      |     |           |
| 8030  | 64.9                    | 2.9 |     | 0.3 | 0.28 | 0.08 |      |      | 1.0 | remainder |
| 8030a |                         |     |     |     |      |      |      |      |     |           |

[Table 20]

| No.   | alloy composition (wt%) |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Al  | Bi   | Te   | Se   | P    | Mn  | Zn        |
| 8031  | 75.3                    | 3.9 | 2.1 | 0.07 |      | 0.04 |      | 0.8 | remainder |
| 8031a |                         |     |     |      |      |      |      |     |           |
| 8032  | 77.2                    | 4.3 | 2.3 | 0.03 | 0.25 | 0.04 |      | 2.8 | remainder |
| 8032a |                         |     |     |      |      |      |      |     |           |
| 8033  | 64.7                    | 2.8 | 2.2 |      | 0.33 |      |      | 0.9 | remainder |
| 8033a |                         |     |     |      |      |      |      |     |           |
| 8034  | 69.3                    | 3.5 | 1.6 |      | 0.03 | 0.03 |      | 1.8 | remainder |
| 8034a |                         |     |     |      |      |      |      |     |           |
| 8035  | 71.2                    | 3.8 | 1.5 |      |      | 0.21 |      | 2.0 | remainder |
| 8035a |                         |     |     |      |      |      |      |     |           |
| 8036  | 70.6                    | 3.7 | 0.3 | 0.04 |      |      | 0.13 | 1.7 | remainder |
| 8036a |                         |     |     |      |      |      |      |     |           |
| 8037  | 69.7                    | 3.8 | 1.4 | 0.12 | 0.04 |      | 0.04 | 1.8 | remainder |
| 8037a |                         |     |     |      |      |      |      |     |           |
| 8038  | 70.7                    | 4.2 | 1.5 | 0.03 |      | 0.16 | 0.03 | 3.3 | remainder |
| 8038a |                         |     |     |      |      |      |      |     |           |

# EP 1 559 802 A1

[Table 20] (continued)

| No.   | alloy composition (wt%) |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Al  | Bi   | Te   | Se   | P    | Mn  | Zn        |
| 8039  | 70.4                    | 3.9 | 0.2 | 0.15 | 0.10 | 0.02 | 0.04 | 2.2 | remainder |
| 8039a |                         |     |     |      |      |      |      |     |           |
| 8040  | 68.8                    | 3.7 | 0.4 |      | 0.05 |      | 0.12 | 1.9 | remainder |
| 8040a |                         |     |     |      |      |      |      |     |           |

[Table 21]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Mn  | Ni  | Zn        |
| 8041  | 70.3                    | 3.9 |     | 0.2 |      | 0.20 | 0.03 | 0.22 | 2.1 |     | remainder |
| 8041a |                         |     |     |     |      |      |      |      |     |     |           |
| 8042  | 74.6                    | 4.3 |     | 2.1 |      |      | 0.12 | 0.03 | 2.4 |     | remainder |
| 8042a |                         |     |     |     |      |      |      |      |     |     |           |
| 8043  | 77.0                    | 4.5 |     |     | 0.03 |      |      | 0.12 | 1.7 |     | remainder |
| 8043a |                         |     |     |     |      |      |      |      |     |     |           |
| 8044  | 70.6                    | 3.9 |     |     | 0.10 | 0.06 |      | 0.04 | 2.6 |     | remainder |
| 8044a |                         |     |     |     |      |      |      |      |     |     |           |
| 8045  | 74.2                    | 4.3 |     |     | 0.11 |      | 0.21 | 0.16 | 2.8 |     | remainder |
| 8045a |                         |     |     |     |      |      |      |      |     |     |           |
| 8046  | 69.9                    | 3.8 |     |     | 0.06 | 0.11 | 0.03 | 0.08 | 1.2 |     | remainder |
| 8046a |                         |     |     |     |      |      |      |      |     |     |           |
| 8047  | 66.8                    | 3.4 |     |     |      | 0.09 |      | 0.06 | 2.2 |     | remainder |
| 8047a |                         |     |     |     |      |      |      |      |     |     |           |
| 8048  | 71.3                    | 4.2 |     |     |      | 0.04 | 0.05 | 0.05 | 1.4 |     | remainder |
| 8048a |                         |     |     |     |      |      |      |      |     |     |           |
| 8049  | 72.4                    | 4.1 |     |     |      |      | 0.12 | 0.09 | 2.7 |     | remainder |
| 8049a |                         |     |     |     |      |      |      |      |     |     |           |
| 8050  | 62.9                    | 2.8 | 2.8 |     | 0.12 |      |      |      |     | 1.5 | remainder |
| 8050a |                         |     |     |     |      |      |      |      |     |     |           |

[Table 22]

| No.   | alloy composition (wt%) |     |     |    |      |      |      |     |           |
|-------|-------------------------|-----|-----|----|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al | Bi   | Te   | Se   | Ni  | Zn        |
| 8051  | 64.8                    | 3.1 | 2.4 |    | 0.08 | 0.03 |      | 2.0 | remainder |
| 8051a |                         |     |     |    |      |      |      |     |           |
| 8052  | 68.9                    | 3.9 | 0.3 |    | 0.03 |      | 0.06 | 1.8 | remainder |
| 8052a |                         |     |     |    |      |      |      |     |           |

# EP 1 559 802 A1

[Table 22] (continued)

| No.   | alloy composition (wt%) |     |     |     |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | Ni  | Zn        |
| 8053  | 67.3                    | 3.7 | 0.7 |     | 0.05 | 0.04 | 0.04 | 2.1 | remainder |
| 8053a |                         |     |     |     |      |      |      |     |           |
| 8054  | 66.5                    | 3.8 | 0.9 |     |      | 0.31 |      | 2.2 | remainder |
| 8054a |                         |     |     |     |      |      |      |     |           |
| 8055  | 73.8                    | 4.3 | 2.1 |     |      | 0.03 | 0.05 | 3.3 | remainder |
| 8055a |                         |     |     |     |      |      |      |     |           |
| 8056  | 74.2                    | 4.4 | 1.3 |     |      |      | 0.03 | 2.7 | remainder |
| 8056a |                         |     |     |     |      |      |      |     |           |
| 8057  | 70.1                    | 3.8 | 1.5 | 1.9 | 0.06 |      |      | 1.8 | remainder |
| 8057a |                         |     |     |     |      |      |      |     |           |
| 8058  | 67.9                    | 2.9 | 0.8 | 2.3 | 0.16 | 0.06 |      | 0.9 | remainder |
| 8058a |                         |     |     |     |      |      |      |     |           |
| 8059  | 68.2                    | 3.6 | 2.0 | 0.6 | 0.04 |      | 0.09 | 1.7 | remainder |
| 8059a |                         |     |     |     |      |      |      |     |           |
| 8060  | 66.6                    | 3.5 | 1.8 | 0.2 | 0.10 | 0.05 | 0.05 | 1.2 | remainder |
| 8060a |                         |     |     |     |      |      |      |     |           |

[Table 23]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Ni  | Zn        |
| 8061  | 67.6                    | 3.6 | 0.4 | 0.6 |      | 0.30 |      |      | 1.8 | remainder |
| 8061a |                         |     |     |     |      |      |      |      |     |           |
| 8062  | 68.8                    | 3.0 | 0.6 | 2.1 |      | 0.08 | 0.03 |      | 1.1 | remainder |
| 8062a |                         |     |     |     |      |      |      |      |     |           |
| 8063  | 71.2                    | 4.1 | 2.4 | 0.8 |      |      | 0.31 |      | 2.2 | remainder |
| 8063a |                         |     |     |     |      |      |      |      |     |           |
| 8064  | 68.2                    | 3.6 | 2.6 |     | 0.04 |      |      | 0.05 | 1.5 | remainder |
| 8064a |                         |     |     |     |      |      |      |      |     |           |
| 8065  | 63.9                    | 2.9 | 2.3 |     | 0.32 | 0.02 |      | 0.08 | 0.8 | remainder |
| 8065a |                         |     |     |     |      |      |      |      |     |           |
| 8066  | 70.5                    | 3.9 | 1.1 |     | 0.05 |      | 0.05 | 0.05 | 2.2 | remainder |
| 8066a |                         |     |     |     |      |      |      |      |     |           |
| 8067  | 67.7                    | 3.7 | 1.2 |     | 0.09 | 0.03 | 0.02 | 0.04 | 2.0 | remainder |
| 8067a |                         |     |     |     |      |      |      |      |     |           |
| 8068  | 66.6                    | 3.5 | 1.4 |     |      | 0.06 |      | 0.04 | 2.6 | remainder |
| 8068a |                         |     |     |     |      |      |      |      |     |           |

# EP 1 559 802 A1

[Table 23] (continued)

| No.   | alloy composition (wt%) |     |     |    |    |      |      |      |     |           |
|-------|-------------------------|-----|-----|----|----|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al | Bi | Te   | Se   | P    | Ni  | Zn        |
| 8069  | 72.3                    | 4.1 | 0.6 |    |    | 0.05 | 0.04 | 0.10 | 3.0 | remainder |
| 8069a |                         |     |     |    |    |      |      |      |     |           |
| 8070  | 70.6                    | 4.0 | 0.4 |    |    |      | 0.16 | 0.05 | 3.2 | remainder |
| 8070a |                         |     |     |    |    |      |      |      |     |           |

[Table 24]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Ni  | Zn        |
| 8071  | 75.6                    | 3.9 | 0.5 | 2.2 | 0.21 |      |      | 0.21 | 1.4 | remainder |
| 8071a |                         |     |     |     |      |      |      |      |     |           |
| 8072  | 71.2                    | 3.4 | 0.7 | 1.5 | 0.18 | 0.10 |      | 0.14 | 1.3 | remainder |
| 8072a |                         |     |     |     |      |      |      |      |     |           |
| 8073  | 68.5                    | 3.7 | 0.7 | 1.2 | 0.03 |      | 0.08 | 0.03 | 1.9 | remainder |
| 8073a |                         |     |     |     |      |      |      |      |     |           |
| 8074  | 64.9                    | 3.2 | 0.8 | 0.4 | 0.12 | 0.03 | 0.04 | 0.04 | 1.8 | remainder |
| 8074a |                         |     |     |     |      |      |      |      |     |           |
| 8075  | 65.3                    | 3.3 | 2.8 | 0.2 |      | 0.06 |      | 0.05 | 1.5 | remainder |
| 8075a |                         |     |     |     |      |      |      |      |     |           |
| 8076  | 68.8                    | 4.0 | 2.5 | 0.6 |      | 0.05 | 0.13 | 0.03 | 2.7 | remainder |
| 8076a |                         |     |     |     |      |      |      |      |     |           |
| 8077  | 67.3                    | 3.4 | 1.6 | 0.5 |      |      | 0.06 | 0.12 | 2.4 | remainder |
| 8077a |                         |     |     |     |      |      |      |      |     |           |
| 8078  | 77.0                    | 4.1 |     | 2.2 | 0.13 |      |      |      | 2.1 | remainder |
| 8078a |                         |     |     |     |      |      |      |      |     |           |
| 8079  | 71.2                    | 3.8 |     | 1.4 | 0.05 | 0.20 |      |      | 2.0 | remainder |
| 8079a |                         |     |     |     |      |      |      |      |     |           |
| 8080  | 68.2                    | 3.6 |     | 1.3 | 0.04 |      | 0.05 |      | 2.6 | remainder |
| 8080a |                         |     |     |     |      |      |      |      |     |           |

[Table 25]

| No.   | alloy composition (wt%) |     |     |      |      |      |   |     |           |
|-------|-------------------------|-----|-----|------|------|------|---|-----|-----------|
|       | Cu                      | Si  | Al  | Bi   | Te   | Se   | P | Ni  | Zn        |
| 8081  | 67.3                    | 3.4 | 0.8 | 0.05 | 0.06 | 0.03 |   | 1.7 | remainder |
| 8081a |                         |     |     |      |      |      |   |     |           |
| 8082  | 70.4                    | 3.9 | 1.2 |      | 0.05 |      |   | 2.2 | remainder |
| 8082a |                         |     |     |      |      |      |   |     |           |

# EP 1 559 802 A1

[Table 25] (continued)

| No.   | alloy composition (wt%) |     |     |      |      |      |      |     |           |
|-------|-------------------------|-----|-----|------|------|------|------|-----|-----------|
|       | Cu                      | Si  | Al  | Bi   | Te   | Se   | P    | Ni  | Zn        |
| 8083  | 73.6                    | 3.9 | 1.3 |      | 0.21 | 0.06 |      | 3.1 | remainder |
| 8083a |                         |     |     |      |      |      |      |     |           |
| 8084  | 68.8                    | 3.8 | 1.2 |      |      | 0.18 |      | 2.6 | remainder |
| 8084a |                         |     |     |      |      |      |      |     |           |
| 8085  | 67.5                    | 3.5 | 1.2 | 0.04 |      |      | 0.16 | 1.8 | remainder |
| 8085a |                         |     |     |      |      |      |      |     |           |
| 8086  | 64.9                    | 2.9 | 1.6 | 0.08 | 0.04 |      | 0.05 | 1.5 | remainder |
| 8086a |                         |     |     |      |      |      |      |     |           |
| 8087  | 76.3                    | 4.3 | 1.5 | 0.29 |      | 0.05 | 0.10 | 2.8 | remainder |
| 8087a |                         |     |     |      |      |      |      |     |           |
| 8088  | 65.8                    | 2.8 | 2.3 | 0.16 | 0.06 | 0.03 | 0.05 | 1.3 | remainder |
| 8088a |                         |     |     |      |      |      |      |     |           |
| 8089  | 66.7                    | 3.3 | 2.1 |      | 0.32 |      | 0.03 | 1.8 | remainder |
| 8089a |                         |     |     |      |      |      |      |     |           |
| 8090  | 69.2                    | 4.0 | 1.2 |      | 0.11 | 0.02 | 0.10 | 2.5 | remainder |
| 8090a |                         |     |     |      |      |      |      |     |           |

[Table 26]

| No.   | alloy composition (wt%) |     |    |     |      |      |      |      |    |     |           |
|-------|-------------------------|-----|----|-----|------|------|------|------|----|-----|-----------|
|       | Cu                      | Si  | Sn | Al  | Bi   | Te   | Se   | P    | Mn | Ni  | Zn        |
| 8091  | 70.6                    | 3.8 |    | 1.3 |      |      | 0.14 | 0.05 |    | 1.7 | remainder |
| 8091a |                         |     |    |     |      |      |      |      |    |     |           |
| 8092  | 67.2                    | 3.4 |    |     | 0.05 |      |      | 0.04 |    | 2.0 | remainder |
| 8092a |                         |     |    |     |      |      |      |      |    |     |           |
| 8093  | 65.8                    | 3.2 |    |     | 0.15 | 0.03 |      | 0.06 |    | 1.2 | remainder |
| 8093a |                         |     |    |     |      |      |      |      |    |     |           |
| 8094  | 67.7                    | 3.7 |    |     | 0.06 |      | 0.10 | 0.08 |    | 2.1 | remainder |
| 8094a |                         |     |    |     |      |      |      |      |    |     |           |
| 8095  | 64.7                    | 2.9 |    |     | 0.31 | 0.04 | 0.05 | 0.09 |    | 1.5 | remainder |
| 8095a |                         |     |    |     |      |      |      |      |    |     |           |
| 8096  | 66.5                    | 3.6 |    |     |      | 0.18 |      | 0.21 |    | 2.3 | remainder |
| 8096a |                         |     |    |     |      |      |      |      |    |     |           |
| 8097  | 67.3                    | 3.8 |    |     |      | 0.08 | 0.05 | 0.12 |    | 2.2 | remainder |
| 8097a |                         |     |    |     |      |      |      |      |    |     |           |
| 8098  | 65.9                    | 3.6 |    |     |      |      | 0.21 | 0.20 |    | 2.5 | remainder |
| 8098a |                         |     |    |     |      |      |      |      |    |     |           |

# EP 1 559 802 A1

[Table 26] (continued)

| No.   | alloy composition (wt%) |     |     |    |      |      |    |   |     |     |           |
|-------|-------------------------|-----|-----|----|------|------|----|---|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al | Bi   | Te   | Se | P | Mn  | Ni  | Zn        |
| 8099  | 64.9                    | 3.6 | 0.4 |    | 0.18 |      |    |   | 0.8 | 2.6 | remainder |
| 8099a |                         |     |     |    |      |      |    |   |     |     |           |
| 8100  | 67.3                    | 3.8 | 1.8 |    | 0.03 | 0.06 |    |   | 1.9 | 1.0 | remainder |
| 8100a |                         |     |     |    |      |      |    |   |     |     |           |

[Table 27]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | Mn  | Ni  | Zn        |
| 8101  | 62.9                    | 2.9 | 2.4 |     | 0.20 |      | 0.16 | 1.3 | 0.9 | remainder |
| 8101a |                         |     |     |     |      |      |      |     |     |           |
| 8102  | 66.3                    | 3.4 | 0.5 |     | 0.04 | 0.04 | 0.05 | 1.5 | 0.8 | remainder |
| 8102a |                         |     |     |     |      |      |      |     |     |           |
| 8103  | 65.8                    | 3.8 | 2.6 |     |      | 0.03 |      | 1.4 | 1.2 | remainder |
| 8103a |                         |     |     |     |      |      |      |     |     |           |
| 8104  | 64.7                    | 3.6 | 2.7 |     |      | 0.25 | 0.03 | 1.3 | 1.6 | remainder |
| 8104a |                         |     |     |     |      |      |      |     |     |           |
| 8105  | 70.4                    | 3.9 | 1.8 |     |      |      | 0.07 | 1.0 | 2.0 | remainder |
| 8105a |                         |     |     |     |      |      |      |     |     |           |
| 8106  | 70.3                    | 3.8 | 0.4 | 1.8 | 0.05 |      |      | 2.3 | 0.7 | remainder |
| 8106a |                         |     |     |     |      |      |      |     |     |           |
| 8107  | 72.1                    | 3.7 | 0.4 | 2.1 | 0.03 | 0.05 |      | 1.3 | 1.2 | remainder |
| 8107a |                         |     |     |     |      |      |      |     |     |           |
| 8108  | 69.8                    | 3.8 | 0.6 | 1.5 | 0.05 |      | 0.05 | 1.5 | 2.1 | remainder |
| 8108a |                         |     |     |     |      |      |      |     |     |           |
| 8109  | 75.4                    | 4.2 | 0.6 | 1.8 | 0.05 | 0.04 | 0.04 | 2.3 | 1.1 | remainder |
| 8109a |                         |     |     |     |      |      |      |     |     |           |
| 8110  | 66.4                    | 3.5 | 2.5 | 0.2 |      | 0.12 |      | 1.6 | 0.9 | remainder |
| 8110a |                         |     |     |     |      |      |      |     |     |           |

[Table 28]

| No.   | alloy composition (wt%) |     |     |     |    |      |      |   |     |     |           |
|-------|-------------------------|-----|-----|-----|----|------|------|---|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi | Te   | Se   | P | Mn  | Ni  | Zn        |
| 8111  | 64.9                    | 3.3 | 2.5 | 0.3 |    | 0.08 | 0.05 |   | 1.2 | 1.3 | remainder |
| 8111a |                         |     |     |     |    |      |      |   |     |     |           |
| 8112  | 70.0                    | 3.8 | 1.2 | 0.5 |    |      | 0.03 |   | 1.5 | 0.8 | remainder |
| 8112a |                         |     |     |     |    |      |      |   |     |     |           |

# EP 1 559 802 A1

[Table 28] (continued)

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Mn  | Ni  | Zn        |
| 8113  | 72.0                    | 3.9 | 1.1 |     | 0.25 |      |      | 0.20 | 2.4 | 0.9 | remainder |
| 8113a |                         |     |     |     |      |      |      |      |     |     |           |
| 8114  | 66.5                    | 3.6 | 1.2 |     | 0.06 | 0.04 |      | 0.05 | 1.3 | 1.1 | remainder |
| 8114a |                         |     |     |     |      |      |      |      |     |     |           |
| 8115  | 67.0                    | 3.5 | 1.3 |     | 0.12 |      | 0.04 | 0.08 | 0.9 | 1.2 | remainder |
| 8115a |                         |     |     |     |      |      |      |      |     |     |           |
| 8116  | 64.0                    | 2.8 | 2.6 |     | 0.30 | 0.08 | 0.03 | 0.05 | 0.8 | 1.0 | remainder |
| 8116a |                         |     |     |     |      |      |      |      |     |     |           |
| 8117  | 67.3                    | 3.7 | 2.3 |     |      | 0.03 |      | 0.03 | 1.2 | 1.3 | remainder |
| 8117a |                         |     |     |     |      |      |      |      |     |     |           |
| 8118  | 66.4                    | 3.8 | 2.4 |     |      | 0.05 | 0.15 | 0.03 | 1.0 | 1.6 | remainder |
| 8118a |                         |     |     |     |      |      |      |      |     |     |           |
| 8119  | 70.2                    | 3.9 | 0.5 |     |      |      | 0.30 | 0.07 | 1.7 | 0.9 | remainder |
| 8119a |                         |     |     |     |      |      |      |      |     |     |           |
| 8120  | 73.1                    | 4.2 | 0.5 | 2.3 | 0.04 |      |      | 0.14 | 2.0 | 1.1 | remainder |
| 8120a |                         |     |     |     |      |      |      |      |     |     |           |

[Table 29]

| No.   | alloy composition (wt%) |     |     |     |      |      |      |      |     |     |           |
|-------|-------------------------|-----|-----|-----|------|------|------|------|-----|-----|-----------|
|       | Cu                      | Si  | Sn  | Al  | Bi   | Te   | Se   | P    | Mn  | Ni  | Zn        |
| 8121  | 71.0                    | 3.6 | 0.6 | 2.3 | 0.03 | 0.12 |      | 0.20 | 1.8 | 1.0 | remainder |
| 8121a |                         |     |     |     |      |      |      |      |     |     |           |
| 8122  | 70.0                    | 3.5 | 0.5 | 1.8 | 0.06 |      | 0.03 | 0.10 | 1.2 | 1.3 | remainder |
| 8122a |                         |     |     |     |      |      |      |      |     |     |           |
| 8123  | 66.5                    | 3.4 | 0.5 | 0.7 | 0.30 | 0.03 | 0.02 | 0.03 | 1.0 | 1.5 | remainder |
| 8123a |                         |     |     |     |      |      |      |      |     |     |           |
| 8124  | 68.8                    | 3.9 | 1.2 | 0.2 |      | 0.06 |      | 0.05 | 1.0 | 1.2 | remainder |
| 8124a |                         |     |     |     |      |      |      |      |     |     |           |
| 8125  | 64.9                    | 3.0 | 1.8 | 0.5 |      | 0.25 | 0.05 | 0.05 | 1.1 | 0.8 | remainder |
| 8125a |                         |     |     |     |      |      |      |      |     |     |           |
| 8126  | 63.7                    | 2.9 | 2.7 | 1.0 |      |      | 0.31 | 0.03 | 1.2 | 0.8 | remainder |
| 8126a |                         |     |     |     |      |      |      |      |     |     |           |
| 8127  | 70.4                    | 3.9 |     | 0.2 | 0.04 |      |      |      | 1.6 | 1.3 | remainder |
| 8127a |                         |     |     |     |      |      |      |      |     |     |           |
| 8128  | 66.5                    | 3.6 |     | 0.3 | 0.02 | 0.04 |      |      | 1.2 | 1.1 | remainder |
| 8128a |                         |     |     |     |      |      |      |      |     |     |           |

# EP 1 559 802 A1

[Table 29] (continued)

| No.   | alloy composition (wt%) |     |    |     |      |      |      |   |     |     |           |
|-------|-------------------------|-----|----|-----|------|------|------|---|-----|-----|-----------|
|       | Cu                      | Si  | Sn | Al  | Bi   | Te   | Se   | P | Mn  | Ni  | Zn        |
| 8129  | 67.3                    | 3.7 |    | 0.7 | 0.03 |      | 0.08 |   | 1.3 | 1.2 | remainder |
| 8129a |                         |     |    |     |      |      |      |   |     |     |           |
| 8130  | 66.0                    | 3.4 |    | 0.7 | 0.22 | 0.06 | 0.04 |   | 1.3 | 1.0 | remainder |
| 8130a |                         |     |    |     |      |      |      |   |     |     |           |

[Table 30]

| No.   | alloy composition (wt%) |     |     |      |      |      |      |     |     |           |
|-------|-------------------------|-----|-----|------|------|------|------|-----|-----|-----------|
|       | Cu                      | Si  | Al  | Bi   | Te   | Se   | P    | Mn  | Ni  | Zn        |
| 8131  | 68.0                    | 3.8 | 0.8 |      | 0.05 |      |      | 1.1 | 1.4 | remainder |
| 8131a |                         |     |     |      |      |      |      |     |     |           |
| 8132  | 70.0                    | 3.4 | 2.1 |      | 0.03 | 0.22 |      | 0.9 | 1.1 | remainder |
| 8132a |                         |     |     |      |      |      |      |     |     |           |
| 8133  | 75.5                    | 4.2 | 2.2 |      |      | 0.05 |      | 1.2 | 1.9 | remainder |
| 8133a |                         |     |     |      |      |      |      |     |     |           |
| 8134  | 68.5                    | 3.8 | 1.8 | 0.10 |      |      | 0.04 | 1.4 | 1.6 | remainder |
| 8134a |                         |     |     |      |      |      |      |     |     |           |
| 8135  | 76.5                    | 4.3 | 2.1 | 0.03 | 0.10 |      | 0.15 | 1.6 | 1.3 | remainder |
| 8135a |                         |     |     |      |      |      |      |     |     |           |
| 8136  | 66.5                    | 3.6 | 1.2 | 0.05 |      | 0.16 | 0.05 | 1.2 | 1.3 | remainder |
| 8136a |                         |     |     |      |      |      |      |     |     |           |
| 8137  | 72.0                    | 4.1 | 1.0 | 0.04 | 0.03 | 0.02 | 0.07 | 1.3 | 2.2 | remainder |
| 8137a |                         |     |     |      |      |      |      |     |     |           |
| 8138  | 70.2                    | 4.0 | 1.0 |      | 0.04 |      | 0.03 | 2.1 | 1.4 | remainder |
| 8138a |                         |     |     |      |      |      |      |     |     |           |
| 8139  | 66.8                    | 3.8 | 0.5 |      | 0.32 | 0.03 | 0.03 | 1.2 | 1.6 | remainder |
| 8139a |                         |     |     |      |      |      |      |     |     |           |
| 8140  | 67.3                    | 3.9 | 0.4 |      |      | 0.05 | 0.03 | 1.8 | 1.0 | remainder |
| 8140a |                         |     |     |      |      |      |      |     |     |           |

[Table 31]

| No.   | alloy composition (wt%) |     |      |      |    |      |     |     |           |
|-------|-------------------------|-----|------|------|----|------|-----|-----|-----------|
|       | Cu                      | Si  | Bi   | Te   | Se | P    | Mn  | Ni  | Zn        |
| 8141  | 66.5                    | 3.6 | 0.05 |      |    | 0.05 | 1.5 | 1.2 | remainder |
| 8141a |                         |     |      |      |    |      |     |     |           |
| 8142  | 63.9                    | 2.9 | 0.30 | 0.03 |    | 0.04 | 1.2 | 0.9 | remainder |
| 8142a |                         |     |      |      |    |      |     |     |           |

# EP 1 559 802 A1

[Table 31] (continued)

| No.   | alloy composition (wt%) |     |      |      |      |      |     |     |           |
|-------|-------------------------|-----|------|------|------|------|-----|-----|-----------|
|       | Cu                      | Si  | Bi   | Te   | Se   | P    | Mn  | Ni  | Zn        |
| 8143  | 68.4                    | 3.8 | 0.03 |      | 0.05 | 0.12 | 0.9 | 2.5 | remainder |
| 8143a |                         |     |      |      |      |      |     |     |           |
| 8144  | 65.8                    | 3.4 | 0.10 | 0.05 | 0.02 | 0.03 | 1.0 | 1.4 | remainder |
| 8144a |                         |     |      |      |      |      |     |     |           |
| 8145  | 70.5                    | 3.9 |      | 0.12 |      | 0.05 | 2.6 | 0.8 | remainder |
| 8145a |                         |     |      |      |      |      |     |     |           |
| 8146  | 72.0                    | 4.2 |      | 0.04 | 0.05 | 0.18 | 1.0 | 2.4 | remainder |
| 8146a |                         |     |      |      |      |      |     |     |           |
| 8147  | 68.0                    | 3.7 |      |      | 0.20 | 0.06 | 1.5 | 1.0 | remainder |
| 8147a |                         |     |      |      |      |      |     |     |           |

[Table 32]

| No.  | alloy composition (wt%) |     |     |      |           |
|------|-------------------------|-----|-----|------|-----------|
|      | Cu                      | Si  | Al  | P    | Zn        |
| 9001 | 72.6                    | 2.3 | 0.8 | 0.03 | remainder |
| 9002 | 74.8                    | 2.8 | 1.3 | 0.09 | remainder |
| 9003 | 77.2                    | 3.6 | 0.2 | 0.21 | remainder |
| 9004 | 75.7                    | 3.0 | 1.1 | 0.07 | remainder |
| 9005 | 78.0                    | 3.8 | 0.7 | 0.12 | remainder |

[Table 33]

| No.   | alloy composition (wt%) |     |     |      |      |      |           |
|-------|-------------------------|-----|-----|------|------|------|-----------|
|       | Cu                      | Si  | Al  | P    | Cr   | Ti   | Zn        |
| 10001 | 74.3                    | 2.9 | 0.6 | 0.05 |      | 0.03 | remainder |
| 10002 | 74.8                    | 3.0 | 0.2 | 0.12 |      | 0.32 | remainder |
| 10003 | 74.9                    | 2.8 | 0.9 | 0.08 | 0.33 |      | remainder |
| 10004 | 77.8                    | 3.6 | 1.2 | 0.22 | 0.08 |      | remainder |
| 10005 | 71.9                    | 2.3 | 1.4 | 0.07 | 0.02 | 0.24 | remainder |
| 10006 | 76.0                    | 2.8 | 1.2 | 0.03 |      | 0.15 | remainder |
| 10007 | 75.5                    | 3.0 | 0.3 | 0.06 | 0.20 |      | remainder |
| 10008 | 71.5                    | 2.2 | 0.7 | 0.12 | 0.14 | 0.05 | remainder |

[Table 34]

| No.   | alloy composition (wt%) |     |     |      |      |    |    |           |
|-------|-------------------------|-----|-----|------|------|----|----|-----------|
|       | Cu                      | Si  | Al  | P    | Bi   | Te | Se | Zn        |
| 11001 | 74.8                    | 2.8 | 1.4 | 0.10 | 0.03 |    |    | remainder |

# EP 1 559 802 A1

[Table 34] (continued)

| No.   | alloy composition (wt%) |     |     |      |      |      |      |           |
|-------|-------------------------|-----|-----|------|------|------|------|-----------|
|       | Cu                      | Si  | Al  | P    | Bi   | Te   | Se   | Zn        |
| 11002 | 76.1                    | 3.0 | 0.6 | 0.06 |      | 0.21 |      | remainder |
| 11003 | 78.3                    | 3.5 | 1.3 | 0.19 |      |      | 0.18 | remainder |
| 11004 | 71.7                    | 2.4 | 0.8 | 0.04 | 0.21 | 0.03 |      | remainder |
| 11005 | 73.9                    | 2.8 | 0.3 | 0.09 | 0.33 |      | 0.03 | remainder |
| 11006 | 74.8                    | 2.8 | 0.7 | 0.11 |      | 0.16 | 0.02 | remainder |
| 11007 | 78.3                    | 3.8 | 1.1 | 0.05 | 0.22 | 0.05 | 0.04 | remainder |

[Table 35]

| No.   | alloy composition (wt%) |     |     |      |      |      |      |      |      |           |
|-------|-------------------------|-----|-----|------|------|------|------|------|------|-----------|
|       | Cu                      | Si  | Al  | Bi   | Te   | Se   | P    | Cr   | Ti   | Zn        |
| 12001 | 73.8                    | 2.6 | 0.5 | 0.21 |      |      | 0.05 | 0.11 |      | remainder |
| 12002 | 76.5                    | 3.2 | 0.9 |      | 0.03 |      | 0.11 | 0.03 |      | remainder |
| 12003 | 78.1                    | 3.4 | 1.3 |      |      | 0.09 | 0.20 | 0.05 |      | remainder |
| 12004 | 70.8                    | 2.1 | 0.6 | 0.22 | 0.06 |      | 0.08 | 0.32 |      | remainder |
| 12005 | 77.8                    | 3.8 | 0.2 | 0.02 |      | 0.03 | 0.03 | 0.26 |      | remainder |
| 12006 | 74.6                    | 2.9 | 0.7 |      | 0.15 | 0.02 | 0.10 | 0.06 |      | remainder |
| 12007 | 73.9                    | 2.8 | 0.3 | 0.04 | 0.05 | 0.16 | 0.03 | 0.18 |      | remainder |
| 12008 | 75.7                    | 2.9 | 1.2 | 0.03 |      |      | 0.12 |      | 0.05 | remainder |
| 12009 | 72.9                    | 2.6 | 0.5 |      | 0.33 |      | 0.04 |      | 0.12 | remainder |
| 12010 | 76.5                    | 3.2 | 0.3 |      |      | 0.32 | 0.03 |      | 0.35 | remainder |
| 12011 | 71.9                    | 2.5 | 0.8 | 0.19 | 0.03 |      | 0.03 |      | 0.03 | remainder |
| 12012 | 74.7                    | 2.9 | 0.6 | 0.07 |      | 0.05 | 0.21 |      | 0.06 | remainder |
| 12013 | 74.8                    | 2.8 | 1.3 |      | 0.04 | 0.21 | 0.06 |      | 0.26 | remainder |
| 12014 | 78.2                    | 3.8 | 1.1 | 0.22 | 0.05 | 0.03 | 0.04 |      | 0.24 | remainder |
| 12015 | 74.6                    | 2.7 | 1.0 | 0.15 |      |      | 0.03 | 0.02 | 0.10 | remainder |
| 12016 | 75.5                    | 2.9 | 0.7 |      | 0.22 |      | 0.05 | 0.34 | 0.02 | remainder |
| 12017 | 76.2                    | 3.4 | 0.3 |      |      | 0.05 | 0.12 | 0.08 | 0.31 | remainder |
| 12018 | 77.0                    | 3.3 | 1.1 | 0.03 | 0.14 |      | 0.03 | 0.05 | 0.03 | remainder |
| 12019 | 73.7                    | 2.8 | 0.3 | 0.32 |      | 0.03 | 0.10 | 0.03 | 0.19 | remainder |
| 12020 | 74.8                    | 2.8 | 1.2 |      | 0.02 | 0.14 | 0.05 | 0.14 | 0.05 | remainder |
| 12021 | 74.0                    | 2.9 | 0.4 | 0.07 | 0.05 | 0.05 | 0.08 | 0.11 | 0.26 | remainder |

[Table 36]

| No.   | alloy composition (wt%) |     |           | heat treatment |        |
|-------|-------------------------|-----|-----------|----------------|--------|
|       | Cu                      | Si  | Z         | temperature    | time   |
| 13001 | 78.5                    | 3.2 | remainder | 580°C          | 30min. |
| 13002 | 78.5                    | 3.2 | remainder | 450°C          | 2hr.   |

# EP 1 559 802 A1

[Table 36] (continued)

| No.   | alloy composition (wt%) |     |           | heat treatment |        |
|-------|-------------------------|-----|-----------|----------------|--------|
|       | Cu                      | Si  | Z         | temperature    | time   |
| 13003 | 77.0                    | 2.9 | remainder | 580°C          | 30min. |
| 13004 | 77.0                    | 2.9 | remainder | 450°C          | 2hr.   |
| 13005 | 69.9                    | 2.3 | remainder | 580°C          | 30min. |
| 13006 | 69.9                    | 2.3 | remainder | 450°C          | 2hr.   |

[Table 37]

| No.    | alloy composition (wt%) |     |     |     |     |     |     |     |           |
|--------|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----------|
|        | Cu                      | Si  | Sn  | Al  | Mn  | Pb  | Fe  | Ni  | Zn        |
| 14001  | 58.8                    |     | 0.2 |     |     | 3.1 | 0.2 |     | remainder |
| 14001a |                         |     |     |     |     |     |     |     |           |
| 14002  | 61.4                    |     | 0.2 |     |     | 3.0 | 0.2 |     | remainder |
| 14002a |                         |     |     |     |     |     |     |     |           |
| 14003  | 59.1                    |     | 0.2 |     |     | 2.0 | 0.2 |     | remainder |
| 14003a |                         |     |     |     |     |     |     |     |           |
| 14004  | 69.2                    | 1.2 |     |     |     | 0.1 |     |     | remainder |
| 14004a |                         |     |     |     |     |     |     |     |           |
| 14005  | remainder               |     |     | 9.8 | 1.1 |     | 3.9 | 1.2 |           |
| 14005a |                         |     |     |     |     |     |     |     |           |
| 14006  | 61.8                    |     | 1.0 |     |     | 0.1 |     |     | remainder |
| 14006a |                         |     |     |     |     |     |     |     |           |

[Table 38]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 1001 | Δ                 | Δ                        | 146               | 290                             | ○                   | 470                                   | 32             | Δ                                                  |
| 1002 | ⊙                 | ○                        | 122               | 210                             | ○                   | 524                                   | 36             | ○                                                  |
| 1003 | ⊙                 | ○                        | 119               | 190                             | ○                   | 543                                   | 34             | ○                                                  |
| 1004 | ⊙                 | ○                        | 126               | 170                             | Δ                   | 590                                   | 37             | ○                                                  |
| 1005 | Δ                 | ○                        | 134               | 150                             | Δ                   | 532                                   | 42             | ○                                                  |
| 1006 | ⊙                 | Δ                        | 129               | 230                             | ○                   | 490                                   | 34             | ○                                                  |
| 1007 | Δ                 | ○                        | 132               | 170                             | Δ                   | 512                                   | 41             | ○                                                  |
| 1008 | Δ                 | Δ                        | 137               | 270                             | ○                   | 501                                   | 31             | Δ                                                  |

EP 1 559 802 A1

[Table 39]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 2001 | ○                 | ○                        | 116               | 190                             | ○                   | 523                                   | 34             | ○                                                  |
| 2002 | ⊙                 | ○                        | 117               | 190                             | ○                   | 508                                   | 36             | ○                                                  |
| 2003 | ⊙                 | ○                        | 118               | 180                             | ○                   | 525                                   | 36             | ○                                                  |
| 2004 | ⊙                 | ○                        | 119               | 280                             | Δ                   | 463                                   | 28             | Δ                                                  |
| 2005 | ⊙                 | ○                        | 119               | 240                             | Δ                   | 481                                   | 30             | ○                                                  |
| 2006 | ⊙                 | ○                        | 119               | 170                             | Δ                   | 552                                   | 36             | ○                                                  |
| 2007 | ⊙                 | ○                        | 116               | 180                             | ○                   | 520                                   | 41             | ○                                                  |
| 2008 | ⊙                 | ○                        | 115               | 140                             | Δ                   | 570                                   | 34             | ○                                                  |
| 2009 | ⊙                 | ○                        | 117               | 200                             | Δ                   | 485                                   | 31             | ○                                                  |
| 2010 | ⊙                 | ○                        | 114               | 180                             | ○                   | 507                                   | 34             | ○                                                  |
| 2011 | ⊙                 | ○                        | 115               | 170                             | Δ                   | 522                                   | 33             | ○                                                  |

[Table 40]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability      | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|----------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 3001 | ⊙                 | Δ                        | 128               | 40                              | ○                    | 553                                   | 26             | ○                                                  |
| 3002 | ⊙                 | ○                        | 126               | 130                             | Δ                    | 538                                   | 32             | ○                                                  |
| 3003 | ⊙                 | ○                        | 126               | 50                              | ○                    | 526                                   | 28             | ○                                                  |
| 3004 | ⊙                 | ○                        | 119               | <5                              | ○                    | 533                                   | 36             | ○                                                  |
| 3005 | ⊙                 | ○                        | 125               | 50                              | ○                    | 525                                   | 28             | ○                                                  |
| 3006 | ⊙                 | ○                        | 120               | < 5                             | ○                    | 546                                   | 38             | ○                                                  |
| 3007 | ⊙                 | ○                        | 121               | < 5                             | ○                    | 552                                   | 34             | ○                                                  |
| 3008 | ⊙                 | ○                        | 122               | 80                              | ○                    | 570                                   | 36             | ○                                                  |
| 3009 | ⊙                 | ○                        | 123               | 50                              | ○                    | 541                                   | 29             | ○                                                  |
| 3010 | ⊙                 | ○                        | 118               | < 5                             | ○                    | 560                                   | 35             | ○                                                  |
| 3011 | ⊙                 | ○                        | 119               | 20                              | ○                    | 502                                   | 34             | ○                                                  |
| 3012 | ⊙                 | ○                        | 120               | < 5                             | ○                    | 534                                   | 31             | ○                                                  |

EP 1 559 802 A1

[Table 41]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 4001 | ⊙                 | ○                        | 119               | 40                              | Δ                   | 512                                   | 24             | ○                                                  |
| 4002 | ⊙                 | ○                        | 122               | 50                              | ○                   | 543                                   | 30             | ○                                                  |
| 4003 | ⊙                 | ○                        | 123               | 50                              | ○                   | 533                                   | 30             | ○                                                  |
| 4004 | ⊙                 | ○                        | 117               | 80                              | Δ                   | 520                                   | 31             | ○                                                  |
| 4005 | ⊙                 | ○                        | 119               | 50                              | ○                   | 535                                   | 32             | ○                                                  |
| 4006 | ⊙                 | ○                        | 116               | 60                              | ○                   | 532                                   | 31             | ○                                                  |
| 4007 | ⊙                 | ○                        | 122               | 50                              | ○                   | 528                                   | 26             | ○                                                  |
| 4008 | ⊙                 | ○                        | 124               | 100                             | Δ                   | 554                                   | 30             | ○                                                  |
| 4009 | ⊙                 | ○                        | 119               | 130                             | ○                   | 542                                   | 34             | ○                                                  |
| 4010 | ⊙                 | ○                        | 119               | 120                             | ○                   | 562                                   | 35             | ○                                                  |
| 4011 | ⊙                 | ○                        | 122               | 100                             | Δ                   | 563                                   | 34             | ○                                                  |
| 4012 | ⊙                 | ○                        | 119               | 130                             | ○                   | 524                                   | 40             | ○                                                  |
| 4013 | ⊙                 | ○                        | 120               | 110                             | ○                   | 548                                   | 37             | ○                                                  |
| 4014 | ⊙                 | ○                        | 120               | 120                             | Δ                   | 539                                   | 36             | ○                                                  |
| 4015 | ⊙                 | ○                        | 121               | 40                              | ○                   | 528                                   | 28             | ○                                                  |
| 4016 | ⊙                 | ○                        | 122               | 60                              | ○                   | 597                                   | 32             | ○                                                  |
| 4017 | ⊙                 | ○                        | 120               | 50                              | ○                   | 520                                   | 33             | ○                                                  |
| 4018 | ⊙                 | ○                        | 123               | 60                              | ○                   | 553                                   | 31             | ○                                                  |
| 4019 | ⊙                 | ○                        | 118               | 40                              | ○                   | 606                                   | 24             | ○                                                  |
| 4020 | ⊙                 | ○                        | 120               | 40                              | ○                   | 561                                   | 26             | ○                                                  |

[Table 42]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 4021 | ⊙                 | ○                        | 120               | 50                              | ○                   | 540                                   | 29             | ○                                                  |
| 4022 | ⊙                 | ○                        | 123               | <5                              | ○                   | 487                                   | 32             | Δ                                                  |

# EP 1 559 802 A1

[Table 42] (continued)

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 4023 | ⊙                 | ○                        | 117               | <5                              | ○                   | 524                                   | 34             | ○                                                  |
| 4024 | ⊙                 | ○                        | 117               | 40                              | ○                   | 541                                   | 37             | ○                                                  |
| 4025 | ⊙                 | ○                        | 115               | <5                              | Δ                   | 526                                   | 43             | ○                                                  |
| 4026 | ⊙                 | ○                        | 122               | 30                              | ○                   | 498                                   | 30             | Δ                                                  |
| 4027 | ⊙                 | ○                        | 118               | 30                              | ○                   | 516                                   | 35             | ○                                                  |
| 4028 | ⊙                 | ○                        | 120               | <5                              | ○                   | 529                                   | 27             | ○                                                  |
| 4029 | ⊙                 | ○                        | 121               | < 5                             | ○                   | 544                                   | 28             | ○                                                  |
| 4030 | ⊙                 | ○                        | 118               | <5                              | ○                   | 536                                   | 30             | ○                                                  |
| 4031 | ⊙                 | ○                        | 116               | <5                              | ○                   | 524                                   | 31             | ○                                                  |
| 4032 | ⊙                 | ○                        | 114               | <5                              | ○                   | 515                                   | 32             | ○                                                  |
| 4033 | ⊙                 | ○                        | 118               | <5                              | ○                   | 519                                   | 37             | ○                                                  |
| 4034 | ⊙                 | ○                        | 118               | <5                              | ○                   | 582                                   | 31             | ○                                                  |
| 4035 | ⊙                 | ○                        | 117               | <5                              | ○                   | 538                                   | 32             | ○                                                  |
| 4036 | ⊙                 | ○                        | 118               | <5                              | Δ                   | 600                                   | 34             | ○                                                  |
| 4037 | ⊙                 | ○                        | 117               | 20                              | ○                   | 523                                   | 34             | ○                                                  |
| 4038 | ⊙                 | ○                        | 116               | <5                              | Δ                   | 539                                   | 38             | ○                                                  |
| 4039 | ⊙                 | ○                        | 118               | 20                              | ○                   | 544                                   | 34             | ○                                                  |
| 4040 | ⊙                 | ○                        | 117               | 40                              | ○                   | 522                                   | 31             | ○                                                  |

[Table 4 3]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 4041 | ⊙                 | ○                        | 120               | 20                              | ○                   | 565                                   | 31             | ○                                                  |
| 4042 | ⊙                 | ○                        | 119               | <5                              | ○                   | 567                                   | 34             | ○                                                  |
| 4043 | ⊙                 | ○                        | 121               | <5                              | ○                   | 530                                   | 29             | ○                                                  |
| 4044 | ⊙                 | ○                        | 120               | <5                              | ○                   | 548                                   | 31             | ○                                                  |
| 4045 | ⊙                 | ○                        | 121               | <5                              | ○                   | 572                                   | 32             | ○                                                  |

# EP 1 559 802 A1

[Table 4 3] (continued)

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 4046 | ⊙                 | ○                        | 119               | <5                              | ○                   | 579                                   | 29             | ○                                                  |
| 4047 | ⊙                 | ○                        | 123               | <5                              | ○                   | 542                                   | 26             | ○                                                  |
| 4048 | ⊙                 | ○                        | 123               | <5                              | ○                   | 540                                   | 28             | ○                                                  |
| 4049 | ⊙                 | ○                        | 120               | <5                              | ○                   | 539                                   | 33             | ○                                                  |

[Table 44]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 5001 | ⊙                 | Δ                        | 127               | 30                              | ○                   | 501                                   | 25             | ○                                                  |
| 5002 | ⊙                 | ○                        | 119               | <5                              | ○                   | 524                                   | 37             | ○                                                  |
| 5003 | ⊙                 | Δ                        | 135               | 10                              | ○                   | 488                                   | 41             | ○                                                  |
| 5004 | ⊙                 | ○                        | 126               | 20                              | Δ                   | 552                                   | 38             | ○                                                  |
| 5005 | ⊙                 | ○                        | 123               | <5                              | ○                   | 518                                   | 29             | ○                                                  |
| 5006 | ⊙                 | ○                        | 122               | <5                              | ○                   | 520                                   | 34             | ○                                                  |
| 5007 | ⊙                 | Δ                        | 125               | <5                              | ○                   | 507                                   | 23             | ○                                                  |
| 5008 | ⊙                 | ○                        | 122               | <5                              | ○                   | 515                                   | 30             | ○                                                  |
| 5009 | ⊙                 | ○                        | 124               | <5                              | ○                   | 544                                   | 35             | ○                                                  |
| 5010 | ⊙                 | ○                        | 123               | <5                              | Δ                   | 536                                   | 36             | ○                                                  |
| 5011 | ⊙                 | Δ                        | 126               | <5                              | ○                   | 511                                   | 27             | ○                                                  |
| 5012 | ⊙                 | ○                        | 124               | <5                              | ○                   | 596                                   | 36             | ○                                                  |
| 5013 | ⊙                 | ○                        | 119               | <5                              | ○                   | 519                                   | 39             | ○                                                  |
| 5014 | ⊙                 | ○                        | 122               | <5                              | ○                   | 523                                   | 37             | ○                                                  |
| 5015 | ⊙                 | ○                        | 123               | <5                              | ○                   | 510                                   | 40             | ○                                                  |
| 5016 | ⊙                 | ○                        | 120               | 20                              | ○                   | 490                                   | 35             | Δ                                                  |
| 5017 | ⊙                 | ○                        | 121               | <5                              | ○                   | 573                                   | 40             | ○                                                  |
| 5018 | ⊙                 | ○                        | 120               | <5                              | ○                   | 549                                   | 39             | ○                                                  |
| 5019 | ⊙                 | ○                        | 122               | 50                              | ○                   | 537                                   | 30             | ○                                                  |

# EP 1 559 802 A1

[Table 44] (continued)

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 5020 | ⊙                 | ○                        | 118               | <5                              | ○                   | 521                                   | 37             | ○                                                  |

[Table 45]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6001 | ⊙                 | ○                        | 121               | 30                              | ○                   | 512                                   | 24             | ○                                                  |
| 6002 | ⊙                 | ○                        | 122               | <5                              | ○                   | 574                                   | 31             | ○                                                  |
| 6003 | ⊙                 | ○                        | 117               | <5                              | Δ                   | 501                                   | 32             | ○                                                  |
| 6004 | ⊙                 | ○                        | 120               | <5                              | ○                   | 514                                   | 26             | ○                                                  |
| 6005 | ⊙                 | ○                        | 121               | <5                              | Δ                   | 525                                   | 42             | ○                                                  |
| 6006 | ○                 | ○                        | 115               | <5                              | ○                   | 514                                   | 32             | ○                                                  |
| 6007 | ⊙                 | ○                        | 120               | <5                              | ○                   | 548                                   | 27             | ○                                                  |
| 6008 | ⊙                 | ○                        | 119               | <5                              | ○                   | 503                                   | 30             | ○                                                  |
| 6009 | ⊙                 | ○                        | 117               | <5                              | ○                   | 522                                   | 38             | ○                                                  |
| 6010 | ⊙                 | ○                        | 122               | <5                              | Δ                   | 527                                   | 41             | ○                                                  |
| 6011 | ⊙                 | ○                        | 119               | <5                              | ○                   | 536                                   | 32             | ○                                                  |
| 6012 | ⊙                 | ○                        | 123               | 20                              | ○                   | 478                                   | 27             | Δ                                                  |
| 6013 | ⊙                 | ○                        | 118               | <5                              | ○                   | 506                                   | 30             | ○                                                  |
| 6014 | ⊙                 | ○                        | 118               | <5                              | ○                   | 525                                   | 39             | ○                                                  |
| 6015 | ○                 | ○                        | 114               | <5                              | ○                   | 503                                   | 35             | ○                                                  |
| 6016 | ⊙                 | ○                        | 122               | 40                              | ○                   | 526                                   | 27             | ○                                                  |
| 6017 | ⊙                 | ○                        | 119               | <5                              | Δ                   | 507                                   | 30             | ○                                                  |
| 6018 | ⊙                 | ○                        | 121               | <5                              | ○                   | 589                                   | 31             | ○                                                  |
| 6019 | ⊙                 | ○                        | 120               | <5                              | ○                   | 508                                   | 25             | ○                                                  |
| 6020 | ⊙                 | ○                        | 121               | <5                              | Δ                   | 504                                   | 43             | ○                                                  |

EP 1 559 802 A1

[Table 46]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability      | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|----------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6021 | ⊙                 | ○                        | 116               | <5                              | ○                    | 501                                   | 33             | ○                                                  |
| 6022 | ⊙                 | ○                        | 120               | <5                              | ○                    | 547                                   | 29             | ○                                                  |
| 6023 | ○                 | ○                        | 119               | <5                              | ○                    | 523                                   | 30             | ○                                                  |
| 6024 | ⊙                 | ○                        | 120               | <5                              | Δ                    | 525                                   | 40             | ○                                                  |
| 6025 | ⊙                 | ○                        | 120               | <5                              | ○                    | 496                                   | 30             | ○                                                  |
| 6026 | ○                 | ○                        | 114               | <5                              | ○                    | 518                                   | 34             | ○                                                  |
| 6027 | ⊙                 | ○                        | 119               | <5                              | ○                    | 487                                   | 28             | Δ                                                  |
| 6028 | ⊙                 | ○                        | 118               | <5                              | ○                    | 524                                   | 35             | ○                                                  |
| 6029 | ⊙                 | ○                        | 122               | <5                              | Δ                    | 540                                   | 41             | ○                                                  |
| 6030 | ⊙                 | ○                        | 118               | <5                              | ○                    | 511                                   | 29             | ○                                                  |
| 6031 | ⊙                 | ○                        | 119               | 40                              | ○                    | 519                                   | 28             | ○                                                  |
| 6032 | ⊙                 | ○                        | 120               | <5                              | ○                    | 572                                   | 32             | ○                                                  |
| 6033 | ⊙                 | ○                        | 123               | <5                              | Δ                    | 515                                   | 36             | ○                                                  |
| 6034 | ⊙                 | ○                        | 122               | <5                              | ○                    | 580                                   | 35             | ○                                                  |
| 6035 | ⊙                 | ○                        | 123               | <5                              | ○                    | 517                                   | 27             | ○                                                  |
| 6036 | ⊙                 | ○                        | 121               | < 5                             | ○                    | 503                                   | 26             | ○                                                  |
| 6037 | ○                 | ○                        | 117               | <5                              | ○                    | 536                                   | 30             | ○                                                  |
| 6038 | ⊙                 | ○                        | 116               | <5                              | ○                    | 506                                   | 30             | ○                                                  |
| 6039 | ⊙                 | ○                        | 120               | <5                              | ○                    | 485                                   | 28             | Δ                                                  |
| 6040 | ○                 | ○                        | 116               | <5                              | ○                    | 528                                   | 36             | ○                                                  |

[Table 47]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability      | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|----------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6041 | ⊙                 | ○                        | 117               | <5                              | ○                    | 496                                   | 30             | ○                                                  |
| 6042 | ⊙                 | ○                        | 120               | <5                              | Δ                    | 574                                   | 34             | ○                                                  |

# EP 1 559 802 A1

[Table 47] (continued)

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability      | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|----------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6043 | ⊙                 | ○                        | 123               | 10                              | Δ                    | 506                                   | 43             | ○                                                  |
| 6044 | ⊙                 | ○                        | 115               | 10                              | ○                    | 500                                   | 30             | ○                                                  |
| 6045 | ⊙                 | ○                        | 119               | 20                              | Δ                    | 485                                   | 27             | Δ                                                  |
| 6046 | ⊙                 | ○                        | 121               | 40                              | ○                    | 512                                   | 24             | ○                                                  |
| 6047 | ⊙                 | ○                        | 123               | <5                              | ○                    | 557                                   | 25             | ○                                                  |
| 6048 | ⊙                 | ○                        | 120               | <5                              | ○                    | 526                                   | 30             | ○                                                  |
| 6049 | ⊙                 | ○                        | 120               | <5                              | ○                    | 502                                   | 24             | ○                                                  |
| 6050 | ⊙                 | ○                        | 124               | <5                              | ○                    | 480                                   | 31             | ○                                                  |
| 6051 | ○                 | ○                        | 117               | <5                              | ○                    | 534                                   | 32             | ○                                                  |
| 6052 | ⊙                 | ○                        | 123               | <5                              | Δ                    | 523                                   | 38             | ○                                                  |
| 6053 | ⊙                 | ○                        | 123               | <5                              | ○                    | 506                                   | 39             | ○                                                  |
| 6054 | ⊙                 | ○                        | 115               | <5                              | ○                    | 485                                   | 31             | ○                                                  |
| 6055 | ⊙                 | ○                        | 122               | <5                              | Δ                    | 512                                   | 44             | ○                                                  |
| 6056 | ⊙                 | ○                        | 120               | <5                              | ○                    | 480                                   | 33             | Δ                                                  |
| 6057 | ⊙                 | ○                        | 121               | <5                              | ○                    | 479                                   | 25             | Δ                                                  |
| 6058 | ○                 | ○                        | 116               | <5                              | ○                    | 525                                   | 34             | ○                                                  |
| 6059 | ⊙                 | ○                        | 119               | 20                              | ○                    | 482                                   | 35             | ○                                                  |
| 6060 | ○                 | ○                        | 118               | 30                              | ○                    | 513                                   | 38             | ○                                                  |

[Table 48]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6061 | ⊙                 | ○                        | 123               | 30                              | ○                   | 530                                   | 22             | ○                                                  |
| 6062 | ⊙                 | ○                        | 119               | 10                              | ○                   | 538                                   | 33             | ○                                                  |
| 6063 | ⊙                 | ○                        | 118               | <5                              | ○                   | 504                                   | 37             | ○                                                  |
| 6064 | ⊙                 | ○                        | 121               | <5                              | ○                   | 526                                   | 30             | ○                                                  |
| 6065 | ⊙                 | ○                        | 123               | <5                              | ○                   | 565                                   | 35             | ○                                                  |

EP 1 559 802 A1

[Table 48] (continued)

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6066 | ⊙                 | ○                        | 120               | <5                              | ○                   | 501                                   | 25             | ○                                                  |
| 6067 | ⊙                 | ○                        | 119               | <5                              | ○                   | 526                                   | 26             | ○                                                  |
| 6068 | ⊙                 | ○                        | 122               | <5                              | ○                   | 502                                   | 30             | ○                                                  |
| 6069 | ⊙                 | ○                        | 124               | <5                              | ○                   | 484                                   | 28             | Δ                                                  |
| 6070 | ○                 | ○                        | 115               | <5                              | ○                   | 548                                   | 37             | ○                                                  |
| 6071 | ⊙                 | ○                        | 118               | <5                              | ○                   | 530                                   | 34             | ○                                                  |
| 6072 | ⊙                 | ○                        | 119               | <5                              | ○                   | 515                                   | 30             | ○                                                  |
| 6073 | ⊙                 | ○                        | 121               | <5                              | Δ                   | 579                                   | 35             | ○                                                  |
| 6074 | ⊙                 | ○                        | 117               | <5                              | ○                   | 517                                   | 32             | ○                                                  |
| 6075 | ⊙                 | ○                        | 117               | <5                              | ○                   | 513                                   | 38             | ○                                                  |
| 6076 | ⊙                 | ○                        | 122               | 40                              | ○                   | 535                                   | 28             | ○                                                  |
| 6077 | ○                 | ○                        | 119               | <5                              | ○                   | 490                                   | 30             | ○                                                  |
| 6078 | ⊙                 | ○                        | 122               | <5                              | Δ                   | 513                                   | 40             | ○                                                  |
| 6079 | ⊙                 | ○                        | 118               | <5                              | ○                   | 524                                   | 30             | ○                                                  |
| 6080 | ⊙                 | ○                        | 123               | <5                              | ○                   | 482                                   | 35             | ○                                                  |

[Table 49]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability      | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|----------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6081 | ⊙                 | ○                        | 118               | <5                              | ○                    | 536                                   | 34             | ○                                                  |
| 6082 | ⊙                 | ○                        | 123               | <5                              | ○                    | 510                                   | 25             | ○                                                  |
| 6083 | ⊙                 | ○                        | 119               | <5                              | ○                    | 504                                   | 32             | ○                                                  |
| 6084 | ⊙                 | ○                        | 117               | <5                              | ○                    | 533                                   | 34             | ○                                                  |
| 6085 | ⊙                 | ○                        | 118               | 10                              | ○                    | 501                                   | 30             | ○                                                  |
| 6086 | ⊙                 | ○                        | 117               | <5                              | ○                    | 545                                   | 37             | ○                                                  |
| 6087 | ⊙                 | ○                        | 119               | <5                              | ○                    | 503                                   | 34             | ○                                                  |
| 6088 | ○                 | ○                        | 115               | <5                              | ○                    | 526                                   | 36             | ○                                                  |

EP 1 559 802 A1

[Table 49] (continued)

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability      | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|----------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6089 | ⊙                 | ○                        | 119               | <5                              | ○                    | 514                                   | 39             | ○                                                  |
| 6090 | ⊙                 | ○                        | 121               | 20                              | Δ                    | 480                                   | 35             | ○                                                  |
| 6091 | ⊙                 | ○                        | 122               | 30                              | ○                    | 516                                   | 24             | ○                                                  |
| 6092 | ⊙                 | ○                        | 118               | <5                              | ○                    | 532                                   | 30             | ○                                                  |
| 6093 | ⊙                 | ○                        | 119               | <5                              | ○                    | 539                                   | 34             | ○                                                  |
| 6094 | ○                 | ○                        | 117               | <5                              | ○                    | 528                                   | 32             | ○                                                  |
| 6095 | ⊙                 | ○                        | 119               | <5                              | ○                    | 507                                   | 30             | ○                                                  |
| 6096 | ⊙                 | ○                        | 122               | <5                              | ○                    | 508                                   | 22             | ○                                                  |
| 6097 | ⊙                 | ○                        | 117               | <5                              | ○                    | 510                                   | 31             | ○                                                  |
| 6098 | ⊙                 | ○                        | 117               | <5                              | ○                    | 527                                   | 32             | ○                                                  |
| 6099 | ⊙                 | ○                        | 116               | <5                              | ○                    | 529                                   | 34             | ○                                                  |
| 6100 | ⊙                 | ○                        | 119               | <5                              | ○                    | 515                                   | 32             | ○                                                  |

[Table 50]

| No.  | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 6101 | ○                 | ○                        | 115               | <5                              | ○                   | 530                                   | 38             | ○                                                  |
| 6102 | ⊙                 | ○                        | 118               | <5                              | ○                   | 512                                   | 36             | ○                                                  |
| 6103 | ⊙                 | ○                        | 119               | <5                              | ○                   | 501                                   | 35             | ○                                                  |
| 6104 | ⊙                 | ○                        | 117               | <5                              | ○                   | 535                                   | 32             | ○                                                  |
| 6105 | ⊙                 | ○                        | 117               | <5                              | ○                   | 517                                   | 37             | ○                                                  |

EP 1 559 802 A1

[Table 51]

| 5  | No.  | machinability        |                             |                      | hot workability        | mechanical properties                        |                |
|----|------|----------------------|-----------------------------|----------------------|------------------------|----------------------------------------------|----------------|
|    |      | form of<br>chippings | condition of cut<br>surface | cutting force<br>(N) | 700°C<br>deformability | tensile<br>strength (N/<br>mm <sup>2</sup> ) | elongation (%) |
| 10 | 7001 | ⊙                    | Δ                           | 138                  | ○                      | 670                                          | 18             |
|    | 7002 | ⊙                    | Δ                           | 136                  | ○                      | 712                                          | 20             |
|    | 7003 | ⊙                    | ○                           | 132                  | ○                      | 783                                          | 23             |
|    | 7004 | ⊙                    | ○                           | 138                  | ○                      | 736                                          | 21             |
|    | 7005 | ⊙                    | ○                           | 136                  | ○                      | 785                                          | 23             |
| 15 | 7006 | ⊙                    | Δ                           | 139                  | ○                      | 700                                          | 24             |
|    | 7007 | Δ                    | ○                           | 138                  | ○                      | 707                                          | 23             |
|    | 7008 | ⊙                    | ○                           | 131                  | ○                      | 805                                          | 22             |
|    | 7009 | ⊙                    | ○                           | 136                  | ○                      | 768                                          | 19             |
| 20 | 7010 | ⊙                    | ○                           | 135                  | ○                      | 778                                          | 23             |
|    | 7011 | Δ                    | ○                           | 137                  | ○                      | 677                                          | 23             |
|    | 7012 | ⊙                    | ○                           | 134                  | ○                      | 800                                          | 21             |
| 25 | 7013 | ⊙                    | ○                           | 133                  | ○                      | 819                                          | 22             |
|    | 7014 | Δ                    | ○                           | 138                  | ○                      | 641                                          | 21             |
|    | 7015 | ⊙                    | ○                           | 134                  | ○                      | 764                                          | 23             |
| 30 | 7016 | ⊙                    | ○                           | 129                  | ○                      | 759                                          | 20             |
|    | 7017 | Δ                    | ○                           | 139                  | ○                      | 638                                          | 18             |
|    | 7018 | ⊙                    | ○                           | 135                  | ○                      | 717                                          | 20             |
|    | 7019 | ⊙                    | ○                           | 136                  | ○                      | 694                                          | 24             |
| 35 | 7020 | Δ                    | ○                           | 138                  | ○                      | 712                                          | 25             |

[Table 52]

| 40 | No.  | machinability        |                             |                      | hot workability        | mechanical properties                        |                |
|----|------|----------------------|-----------------------------|----------------------|------------------------|----------------------------------------------|----------------|
|    |      | form of<br>chippings | condition of cut<br>surface | cutting force<br>(N) | 700°C<br>deformability | tensile<br>strength (N/<br>mm <sup>2</sup> ) | elongation (%) |
| 45 | 7021 | ⊙                    | ○                           | 130                  | ○                      | 754                                          | 24             |
|    | 7022 | ⊙                    | Δ                           | 134                  | ○                      | 780                                          | 23             |
|    | 7023 | ⊙                    | ○                           | 133                  | ○                      | 765                                          | 22             |
|    | 7024 | ⊙                    | ○                           | 135                  | ○                      | 772                                          | 23             |
| 50 | 7025 | Δ                    | ○                           | 138                  | ○                      | 687                                          | 24             |
|    | 7026 | ⊙                    | ○                           | 135                  | ○                      | 718                                          | 24             |
|    | 7027 | ⊙                    | Δ                           | 136                  | ○                      | 742                                          | 18             |
| 55 | 7028 | Δ                    | ○                           | 138                  | ○                      | 785                                          | 20             |
|    | 7029 | ⊙                    | ○                           | 134                  | ○                      | 703                                          | 23             |
|    | 7030 | ⊙                    | ○                           | 135                  | ○                      | 820                                          | 18             |

# EP 1 559 802 A1

[Table 53]

| No.  | machinability     |                          |                   | hot workability      | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|----------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8001 | ⊙                 | ○                        | 132               | ○                    | 655                                   | 15             |
| 8002 | ⊙                 | ○                        | 129               | ○                    | 708                                   | 17             |
| 8003 | ⊙                 | ○                        | 127               | ○                    | 768                                   | 20             |
| 8004 | ⊙                 | ○                        | 128               | ○                    | 785                                   | 18             |
| 8005 | ⊙                 | ○                        | 131               | ○                    | 714                                   | 16             |
| 8006 | ⊙                 | ○                        | 134               | ○                    | 680                                   | 16             |
| 8007 | ⊙                 | ○                        | 132               | ○                    | 764                                   | 17             |
| 8008 | ⊙                 | ○                        | 130               | ○                    | 673                                   | 16             |
| 8009 | ⊙                 | ○                        | 132               | ○                    | 759                                   | 18             |
| 8010 | ⊙                 | ○                        | 132               | ○                    | 751                                   | 15             |
| 8011 | ⊙                 | ○                        | 134               | ○                    | 767                                   | 17             |
| 8012 | ⊙                 | ○                        | 128               | ○                    | 796                                   | 18             |
| 8013 | ⊙                 | ○                        | 129               | ○                    | 784                                   | 18             |
| 8014 | ⊙                 | ○                        | 129               | ○                    | 802                                   | 17             |
| 8015 | ⊙                 | ○                        | 133               | ○                    | 679                                   | 15             |
| 8016 | ⊙                 | ○                        | 130               | ○                    | 706                                   | 16             |
| 8017 | ⊙                 | ○                        | 129               | ○                    | 707                                   | 18             |
| 8018 | ⊙                 | ○                        | 131               | ○                    | 780                                   | 16             |
| 8019 | ⊙                 | ○                        | 128               | ○                    | 768                                   | 16             |
| 8020 | ⊙                 | ○                        | 132               | ○                    | 723                                   | 19             |

[Table 54]

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8021 | ⊙                 | ○                        | 134               | ○                   | 765                                   | 16             |
| 8022 | ⊙                 | ○                        | 132               | ○                   | 770                                   | 16             |
| 8023 | ⊙                 | ○                        | 131               | ○                   | 746                                   | 18             |
| 8024 | ⊙                 | ○                        | 132               | ○                   | 816                                   | 19             |
| 8025 | ⊙                 | ○                        | 129               | ○                   | 759                                   | 18             |
| 8026 | ⊙                 | ○                        | 130               | ○                   | 726                                   | 17             |
| 8027 | ⊙                 | ○                        | 133               | ○                   | 703                                   | 17             |
| 8028 | ⊙                 | ○                        | 132               | ○                   | 737                                   | 18             |
| 8029 | ⊙                 | ○                        | 129               | ○                   | 719                                   | 20             |

# EP 1 559 802 A1

[Table 54] (continued)

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8030 | ⊙                 | ○                        | 133               | ○                   | 645                                   | 23             |
| 8031 | ⊙                 | ○                        | 129               | ○                   | 764                                   | 22             |
| 8032 | ⊙                 | ○                        | 131               | ○                   | 790                                   | 19             |
| 8033 | ⊙                 | ○                        | 133               | ○                   | 674                                   | 20             |
| 8034 | ⊙                 | ○                        | 131               | ○                   | 748                                   | 23             |
| 8035 | ⊙                 | ○                        | 129               | ○                   | 777                                   | 22             |
| 8036 | ⊙                 | ○                        | 131               | ○                   | 725                                   | 23             |
| 8037 | ⊙                 | ○                        | 128               | ○                   | 770                                   | 21             |
| 8038 | ⊙                 | ○                        | 131               | ○                   | 815                                   | 18             |
| 8039 | ⊙                 | ○                        | 127               | ○                   | 739                                   | 24             |
| 8040 | ⊙                 | ○                        | 130               | ○                   | 721                                   | 22             |

[Table 55]

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8041 | ⊙                 | ○                        | 128               | ○                   | 735                                   | 23             |
| 8042 | ⊙                 | ○                        | 127               | ○                   | 822                                   | 18             |
| 8043 | ⊙                 | ○                        | 131               | ○                   | 780                                   | 18             |
| 8044 | ⊙                 | ○                        | 126               | ○                   | 726                                   | 21             |
| 8045 | ⊙                 | ○                        | 128               | ○                   | 766                                   | 22             |
| 8046 | ⊙                 | ○                        | 127               | ○                   | 712                                   | 23             |
| 8047 | ⊙                 | ○                        | 128               | ○                   | 674                                   | 21             |
| 8048 | ⊙                 | ○                        | 129               | ○                   | 753                                   | 24             |
| 8049 | ⊙                 | ○                        | 127               | ○                   | 768                                   | 22             |
| 8050 | ⊙                 | ○                        | 132               | ○                   | 691                                   | 17             |
| 8051 | ⊙                 | ○                        | 131               | ○                   | 717                                   | 17             |
| 8052 | ⊙                 | ○                        | 128               | ○                   | 739                                   | 21             |
| 8053 | ⊙                 | ○                        | 128               | ○                   | 730                                   | 22             |
| 8054 | ⊙                 | ○                        | 127               | ○                   | 735                                   | 20             |
| 8055 | ⊙                 | ○                        | 134               | ○                   | 818                                   | 15             |
| 8056 | ⊙                 | ○                        | 132               | ○                   | 812                                   | 16             |
| 8057 | ⊙                 | ○                        | 131               | ○                   | 755                                   | 18             |
| 8058 | ⊙                 | ○                        | 133               | ○                   | 659                                   | 20             |
| 8059 | ⊙                 | ○                        | 132               | ○                   | 740                                   | 17             |

# EP 1 559 802 A1

[Table 55] (continued)

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8060 | ⊙                 | ○                        | 130               | ○                   | 714                                   | 19             |

[Table 56]

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8061 | ⊙                 | ○                        | 129               | ○                   | 705                                   | 21             |
| 8062 | ⊙                 | ○                        | 131               | ○                   | 690                                   | 22             |
| 8063 | ⊙                 | ○                        | 133               | ○                   | 811                                   | 18             |
| 8064 | ⊙                 | ○                        | 131               | ○                   | 746                                   | 17             |
| 8065 | ⊙                 | ○                        | 133               | ○                   | 652                                   | 19             |
| 8066 | ⊙                 | ○                        | 130               | ○                   | 758                                   | 19             |
| 8067 | ⊙                 | ○                        | 129               | ○                   | 734                                   | 19             |
| 8068 | ⊙                 | ○                        | 131               | ○                   | 710                                   | 17             |
| 8069 | ⊙                 | ○                        | 131               | ○                   | 767                                   | 20             |
| 8070 | ⊙                 | ○                        | 131               | ○                   | 753                                   | 18             |
| 8071 | ⊙                 | ○                        | 129               | ○                   | 792                                   | 19             |
| 8072 | ⊙                 | ○                        | 131               | ○                   | 736                                   | 21             |
| 8073 | ⊙                 | ○                        | 130               | ○                   | 767                                   | 22             |
| 8074 | ⊙                 | ○                        | 132               | ○                   | 679                                   | 19             |
| 8075 | ⊙                 | ○                        | 134               | ○                   | 728                                   | 17             |
| 8076 | ⊙                 | ○                        | 133               | ○                   | 795                                   | 16             |
| 8077 | ⊙                 | ○                        | 133               | ○                   | 716                                   | 18             |
| 8078 | ⊙                 | ○                        | 132               | ○                   | 809                                   | 18             |
| 8079 | ⊙                 | ○                        | 129               | ○                   | 758                                   | 22             |
| 8080 | ⊙                 | ○                        | 130               | ○                   | 724                                   | 21             |

[Table 57]

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8081 | ⊙                 | ○                        | 132               | ○                   | 706                                   | 23             |
| 8082 | ⊙                 | ○                        | 130               | ○                   | 768                                   | 23             |
| 8083 | ⊙                 | ○                        | 128               | ○                   | 774                                   | 25             |

# EP 1 559 802 A1

[Table 57] (continued)

| 5  | No.  | machinability        |                             |                      | hot workability        | mechanical properties                        |                |
|----|------|----------------------|-----------------------------|----------------------|------------------------|----------------------------------------------|----------------|
|    |      | form of<br>chippings | condition of cut<br>surface | cutting force<br>(N) | 700°C<br>deformability | tensile<br>strength (N/<br>mm <sup>2</sup> ) | elongation (%) |
| 10 | 8084 | ⊙                    | ○                           | 129                  | ○                      | 765                                          | 22             |
|    | 8085 | ⊙                    | ○                           | 130                  | ○                      | 729                                          | 23             |
|    | 8086 | ⊙                    | ○                           | 133                  | ○                      | 687                                          | 24             |
|    | 8087 | ⊙                    | ○                           | 131                  | ○                      | 798                                          | 20             |
|    | 8088 | ⊙                    | ○                           | 132                  | ○                      | 699                                          | 23             |
| 15 | 8089 | ⊙                    | ○                           | 130                  | ○                      | 740                                          | 21             |
|    | 8090 | ⊙                    | ○                           | 132                  | ○                      | 782                                          | 18             |
|    | 8091 | ⊙                    | ○                           | 129                  | ○                      | 763                                          | 22             |
|    | 8092 | ⊙                    | ○                           | 130                  | ○                      | 680                                          | 22             |
|    | 8093 | ⊙                    | ○                           | 131                  | ○                      | 655                                          | 23             |
| 20 | 8094 | ⊙                    | ○                           | 128                  | ○                      | 714                                          | 21             |
|    | 8095 | ⊙                    | ○                           | 132                  | ○                      | 638                                          | 24             |
|    | 8096 | ⊙                    | ○                           | 128                  | ○                      | 689                                          | 22             |
|    | 8097 | ⊙                    | ○                           | 129                  | ○                      | 711                                          | 21             |
|    | 8098 | ⊙                    | ○                           | 130                  | ○                      | 693                                          | 20             |
| 25 | 8099 | ⊙                    | ○                           | 127                  | ○                      | 702                                          | 21             |
|    | 8100 | ⊙                    | ○                           | 129                  | ○                      | 724                                          | 18             |

[Table 58]

|    |      |                      |                             |                      |                        |                                              |                |
|----|------|----------------------|-----------------------------|----------------------|------------------------|----------------------------------------------|----------------|
| 35 | No.  | machinability        |                             |                      | hot workability        | mechanical properties                        |                |
|    |      | form of<br>chippings | condition of cut<br>surface | cutting force<br>(N) | 700°C<br>deformability | tensile<br>strength (N/<br>mm <sup>2</sup> ) | elongation (%) |
| 40 | 8101 | ⊙                    | ○                           | 131                  | ○                      | 685                                          | 18             |
|    | 8102 | ⊙                    | ○                           | 132                  | ○                      | 690                                          | 21             |
|    | 8103 | ⊙                    | ○                           | 133                  | ○                      | 744                                          | 17             |
| 45 | 8104 | ⊙                    | ○                           | 130                  | ○                      | 726                                          | 17             |
|    | 8105 | ⊙                    | ○                           | 133                  | ○                      | 751                                          | 19             |
|    | 8106 | ⊙                    | ○                           | 130                  | ○                      | 752                                          | 21             |
|    | 8107 | ⊙                    | ○                           | 131                  | ○                      | 760                                          | 21             |
| 50 | 8108 | ⊙                    | ○                           | 132                  | ○                      | 748                                          | 22             |
|    | 8109 | ⊙                    | ○                           | 130                  | ○                      | 807                                          | 18             |
|    | 8110 | ⊙                    | ○                           | 133                  | ○                      | 739                                          | 16             |
| 55 | 8111 | ⊙                    | ○                           | 132                  | ○                      | 717                                          | 17             |
|    | 8112 | ⊙                    | ○                           | 134                  | ○                      | 763                                          | 20             |
|    | 8113 | ⊙                    | ○                           | 129                  | ○                      | 745                                          | 22             |

# EP 1 559 802 A1

[Table 58] (continued)

| No.  | machinability     |                          |                   | hot workability     | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|---------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8114 | ⊙                 | ○                        | 132               | ○                   | 722                                   | 20             |
| 8115 | ⊙                 | ○                        | 130               | ○                   | 706                                   | 17             |
| 8116 | ⊙                 | ○                        | 133               | ○                   | 684                                   | 19             |
| 8117 | ⊙                 | ○                        | 132               | ○                   | 740                                   | 18             |
| 8118 | ⊙                 | ○                        | 133               | ○                   | 765                                   | 16             |
| 8119 | ⊙                 | ○                        | 128               | ○                   | 733                                   | 22             |
| 8120 | ⊙                 | ○                        | 131               | ○                   | 819                                   | 19             |

[Table 59]

| No.  | machinability     |                          |                   | hot workability      | mechanical properties                 |                |
|------|-------------------|--------------------------|-------------------|----------------------|---------------------------------------|----------------|
|      | form of chippings | condition of cut surface | cutting force (N) | 700 °C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |
| 8121 | ⊙                 | ○                        | 130               | ○                    | 788                                   | 20             |
| 8122 | ⊙                 | ○                        | 131               | ○                    | 755                                   | 22             |
| 8123 | ⊙                 | ○                        | 127               | ○                    | 711                                   | 21             |
| 8124 | ⊙                 | ○                        | 130               | ○                    | 763                                   | 20             |
| 8125 | ⊙                 | ○                        | 131               | ○                    | 687                                   | 18             |
| 8126 | ⊙                 | ○                        | 134               | ○                    | 706                                   | 17             |
| 8127 | ⊙                 | ○                        | 128               | ○                    | 730                                   | 22             |
| 8128 | ⊙                 | ○                        | 130               | ○                    | 702                                   | 23             |
| 8129 | ⊙                 | ○                        | 132               | ○                    | 727                                   | 21             |
| 8130 | ⊙                 | ○                        | 130               | ○                    | 701                                   | 24             |
| 8131 | ⊙                 | ○                        | 129               | ○                    | 745                                   | 22             |
| 8132 | ⊙                 | ○                        | 132               | ○                    | 749                                   | 21             |
| 8133 | ⊙                 | ○                        | 130               | ○                    | 826                                   | 18             |
| 8134 | ⊙                 | ○                        | 128               | ○                    | 770                                   | 20             |
| 8135 | ⊙                 | ○                        | 129               | ○                    | 828                                   | 17             |
| 8136 | ⊙                 | ○                        | 129               | ○                    | 746                                   | 20             |
| 8137 | ⊙                 | ○                        | 130               | ○                    | 784                                   | 23             |
| 8138 | ⊙                 | ○                        | 131               | ○                    | 779                                   | 21             |
| 8139 | ⊙                 | ○                        | 128               | ○                    | 710                                   | 22             |
| 8140 | ⊙                 | ○                        | 131               | ○                    | 717                                   | 22             |

[Table 60]

| No.  | machinability        |                             |                      | hot workability        | mechanical properties                        |                |
|------|----------------------|-----------------------------|----------------------|------------------------|----------------------------------------------|----------------|
|      | form of<br>chippings | condition of cut<br>surface | cutting force<br>(N) | 700°C<br>deformability | tensile<br>strength (N/<br>mm <sup>2</sup> ) | elongation (%) |
| 8141 | ⊙                    | ○                           | 131                  | ○                      | 687                                          | 22             |
| 8142 | ⊙                    | ○                           | 130                  | ○                      | 635                                          | 20             |
| 8143 | ⊙                    | ○                           | 129                  | ○                      | 710                                          | 23             |
| 8144 | ⊙                    | ○                           | 130                  | ○                      | 662                                          | 24             |
| 8145 | ⊙                    | ○                           | 128                  | ○                      | 728                                          | 23             |
| 8146 | ⊙                    | ○                           | 129                  | ○                      | 753                                          | 21             |
| 8147 | ⊙                    | ○                           | 130                  | ○                      | 709                                          | 24             |

【 Table 6 1 】

| N o. | machinability     |                          |                   | corrosion resistance | hot work-ability | mechanical properties                 |                | stress resistance | high-temperature oxidation |
|------|-------------------|--------------------------|-------------------|----------------------|------------------|---------------------------------------|----------------|-------------------|----------------------------|
|      | form of chippings | condition of cut surface | cutting force (N) |                      |                  | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                   |                            |
| 9001 | ◎                 | △                        | 1 3 2             | 2 0                  | ○                | 5 0 0                                 | 3 7            | ○                 | 0. 3                       |
| 9002 | ◎                 | ○                        | 1 2 2             | <5                   | ○                | 5 6 4                                 | 3 5            | ○                 | 0. 2                       |
| 9003 | ◎                 | ○                        | 1 2 3             | <5                   | ○                | 5 8 5                                 | 3 9            | ○                 | 0. 5                       |
| 9004 | ◎                 | ○                        | 1 1 8             | <5                   | ○                | 5 5 8                                 | 3 4            | ○                 | 0. 2                       |
| 9005 | △                 | ○                        | 1 3 2             | <5                   | △                | 5 9 3                                 | 3 7            | ○                 | 0. 3                       |

【 Table 6 2 】

| N o.  | machinability     |                          |                   | corrosion resistance | hot work-ability | mechanical properties                 |                | stress resistance | high-temperature oxidation |
|-------|-------------------|--------------------------|-------------------|----------------------|------------------|---------------------------------------|----------------|-------------------|----------------------------|
|       | form of chippings | condition of cut surface | cutting force (N) |                      |                  | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                   |                            |
| 10001 | ◎                 | ○                        | 1 2 4             | <5                   | ○                | 5 3 4                                 | 3 5            | ○                 | 0. 3                       |
| 10002 | ◎                 | ○                        | 1 2 0             | <5                   | ○                | 5 4 0                                 | 3 3            | ○                 | 0. 2                       |
| 10003 | ◎                 | ○                        | 1 2 2             | <5                   | ○                | 5 3 9                                 | 3 8            | ○                 | 0. 2                       |
| 10004 | ◎                 | ○                        | 1 2 4             | <5                   | ○                | 5 7 5                                 | 4 0            | ○                 | 0. 1                       |
| 10005 | ◎                 | △                        | 1 2 8             | <5                   | ○                | 5 1 2                                 | 3 3            | ○                 | 0. 1                       |
| 10006 | ◎                 | ○                        | 1 2 0             | 2 0                  | ○                | 5 6 0                                 | 3 5            | ○                 | 0. 1                       |
| 10007 | ◎                 | ○                        | 1 1 9             | <5                   | ○                | 5 3 6                                 | 3 6            | ○                 | 0. 3                       |
| 10008 | △                 | ○                        | 1 3 2             | <5                   | ○                | 5 0 1                                 | 3 1            | △                 | 0. 1                       |

【 Table 6 3 】

| N o.  | machinability                |                                     |                              | corrosion<br>resistance<br>maximum<br>depth of<br>corrosion<br>( $\mu$ m) | hot work-<br>ability<br>7 0 0 °C<br>deformabi-<br>lity | mechanical<br>properties                      |                        | stress<br>resistance<br>corrosion<br>cracking<br>resistance | high-temperature<br>oxidation<br>increase in weight<br>by oxidation<br>(m g / 10 c m <sup>2</sup> ) |
|-------|------------------------------|-------------------------------------|------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------|------------------------|-------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
|       | form<br>of<br>chipp-<br>ings | conditi-<br>on of<br>cut<br>surface | cutti-<br>ng<br>force<br>(N) |                                                                           |                                                        | tensile<br>strength<br>(N / mm <sup>2</sup> ) | elongat-<br>ion<br>(%) |                                                             |                                                                                                     |
| 11001 | ◎                            | ○                                   | 1 1 7                        | <5                                                                        | ○                                                      | 5 4 0                                         | 3 6                    | ○                                                           | 0. 2                                                                                                |
| 11002 | ◎                            | ○                                   | 1 1 7                        | <5                                                                        | ○                                                      | 5 3 7                                         | 3 4                    | ○                                                           | 0. 3                                                                                                |
| 11003 | ◎                            | ○                                   | 1 2 1                        | <5                                                                        | △                                                      | 5 7 3                                         | 3 8                    | ○                                                           | 0. 2                                                                                                |
| 11004 | ◎                            | ○                                   | 1 1 9                        | 3 0                                                                       | ○                                                      | 5 1 2                                         | 3 0                    | ○                                                           | 0. 3                                                                                                |
| 11005 | ○                            | ○                                   | 1 1 4                        | <5                                                                        | △                                                      | 5 1 8                                         | 3 0                    | ○                                                           | 0. 4                                                                                                |
| 11006 | ◎                            | ○                                   | 1 1 8                        | <5                                                                        | ○                                                      | 5 3 5                                         | 3 2                    | ○                                                           | 0. 3                                                                                                |
| 11007 | ◎                            | ○                                   | 1 1 9                        | <5                                                                        | △                                                      | 5 8 6                                         | 3 7                    | ○                                                           | 0. 2                                                                                                |

【 Table 6 4 】

| N o.  | machinability                |                                     |                              | corrosion<br>resistance | hot work-<br>ability | mechanical<br>properties                    |                        | stress<br>resistance | high-temperature<br>oxidation |
|-------|------------------------------|-------------------------------------|------------------------------|-------------------------|----------------------|---------------------------------------------|------------------------|----------------------|-------------------------------|
|       | form<br>of<br>chipp-<br>ings | conditi-<br>on of<br>cut<br>surface | cutti-<br>ng<br>force<br>(N) |                         |                      | tensile<br>strength<br>(N/mm <sup>2</sup> ) | elongat-<br>ion<br>(%) |                      |                               |
| 12001 | ◎                            | ○                                   | 1 2 1                        | <5                      | ○                    | 5 1 2                                       | 3 2                    | ○                    | 0. 2                          |
| 12002 | ◎                            | ○                                   | 1 1 9                        | <5                      | ○                    | 5 4 4                                       | 3 6                    | ○                    | 0. 2                          |
| 12003 | ◎                            | ○                                   | 1 2 3                        | <5                      | ○                    | 5 7 0                                       | 3 8                    | ○                    | 0. 1                          |
| 12004 | ◎                            | ○                                   | 1 2 4                        | <5                      | △                    | 4 9 5                                       | 3 1                    | △                    | 0. 2                          |
| 12005 | ◎                            | ○                                   | 1 2 3                        | 3 0                     | △                    | 5 8 3                                       | 3 2                    | ○                    | 0. 3                          |
| 12006 | ◎                            | ○                                   | 1 1 8                        | <5                      | ○                    | 5 3 7                                       | 3 3                    | ○                    | 0. 2                          |
| 12007 | ◎                            | ○                                   | 1 1 8                        | 2 0                     | ○                    | 5 1 6                                       | 3 0                    | ○                    | 0. 2                          |
| 12008 | ◎                            | ○                                   | 1 1 7                        | <5                      | ○                    | 5 4 3                                       | 3 8                    | ○                    | 0. 1                          |
| 12009 | ◎                            | ○                                   | 1 2 2                        | 2 0                     | ○                    | 5 0 1                                       | 3 2                    | ○                    | 0. 2                          |
| 12010 | ◎                            | ○                                   | 1 1 9                        | 3 0                     | ○                    | 5 4 6                                       | 3 5                    | ○                    | 0. 2                          |
| 12011 | ◎                            | ○                                   | 1 2 1                        | 2 0                     | ○                    | 5 1 6                                       | 3 1                    | ○                    | 0. 1                          |
| 12012 | ◎                            | ○                                   | 1 1 7                        | <5                      | ○                    | 5 3 9                                       | 3 3                    | ○                    | 0. 2                          |
| 12012 | ◎                            | ○                                   | 1 2 1                        | <5                      | ○                    | 5 4 4                                       | 3 3                    | ○                    | <0. 1                         |
| 12014 | ◎                            | ○                                   | 1 2 1                        | <5                      | △                    | 5 9 0                                       | 3 7                    | ○                    | <0. 1                         |
| 12015 | ◎                            | ○                                   | 1 2 0                        | 2 0                     | ○                    | 5 2 8                                       | 3 2                    | ○                    | 0. 1                          |
| 12016 | ◎                            | ○                                   | 1 1 7                        | <5                      | ○                    | 5 3 5                                       | 3 3                    | ○                    | 0. 1                          |
| 12017 | ◎                            | ○                                   | 1 2 1                        | <5                      | ○                    | 5 7 7                                       | 3 5                    | ○                    | 0. 2                          |
| 12018 | ◎                            | ○                                   | 1 2 0                        | <5                      | △                    | 5 8 6                                       | 3 7                    | ○                    | 0. 1                          |
| 12019 | ◎                            | ○                                   | 1 1 5                        | <5                      | ○                    | 5 2 0                                       | 3 1                    | ○                    | 0. 2                          |
| 12020 | ◎                            | ○                                   | 1 1 8                        | <5                      | ○                    | 5 4 9                                       | 3 4                    | ○                    | 0. 1                          |
| 12021 | ◎                            | ○                                   | 1 1 6                        | <5                      | ○                    | 5 3 3                                       | 3 4                    | ○                    | 0. 1                          |

# EP 1 559 802 A1

[Table 65]

| No.   | machinability     |                          |                   | corrosion resistance            | hot workability     | mechanical properties                 |                | stress resistance<br>corrosion cracking resistance |
|-------|-------------------|--------------------------|-------------------|---------------------------------|---------------------|---------------------------------------|----------------|----------------------------------------------------|
|       | form of chippings | condition of cut surface | cutting force (N) | maximum depth of corrosion (μm) | 700°C deformability | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                                                    |
| 13001 | ⊙                 | ○                        | 128               | 140                             | Δ                   | 521                                   | 39             | ○                                                  |
| 13002 | ⊙                 | ○                        | 126               | 130                             | Δ                   | 524                                   | 41             | ○                                                  |
| 13003 | ⊙                 | ○                        | 127               | 150                             | Δ                   | 500                                   | 38             | ○                                                  |
| 13004 | ⊙                 | ○                        | 127               | 160                             | Δ                   | 508                                   | 38             | ○                                                  |
| 13005 | ⊙                 | ○                        | 128               | 180                             | ○                   | 483                                   | 35             | ○                                                  |
| 13006 | ⊙                 | ○                        | 129               | 170                             | ○                   | 488                                   | 37             | ○                                                  |

【 Table 6 6 】

| N o.  | machinability      |                          |                   | corrosion resistance | hot work-ability | mechanical properties                 |                | stress resistance | high-temperature oxidation |
|-------|--------------------|--------------------------|-------------------|----------------------|------------------|---------------------------------------|----------------|-------------------|----------------------------|
|       | form of chip-tings | condition of cut surface | cutting force (N) |                      |                  | tensile strength (N/mm <sup>2</sup> ) | elongation (%) |                   |                            |
| 14001 | ○                  | ○                        | 103               | 1100                 | △                | 408                                   | 37             | ××                | 1.8                        |
| 14002 | ○                  | ○                        | 101               | 1000                 | ×                | 387                                   | 39             | ××                | 1.7                        |
| 14003 | ○                  | △                        | 112               | 1050                 | ○                | 414                                   | 38             | ××                | 1.7                        |
| 14004 | ×                  | ○                        | 223               | 900                  | ○                | 438                                   | 38             | ×                 | 1.2                        |
| 14005 | ×                  | ○                        | 178               | 350                  | △                | 735                                   | 28             | ○                 | 0.2                        |
| 14006 | ×                  | ○                        | 217               | 600                  | ○                | 425                                   | 39             | ×                 | 1.8                        |

[Table 67]

| No.   | wear resistance                        |
|-------|----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot.) |
| 7001a | 1. 3                                   |
| 7002a | 0. 8                                   |
| 7003a | 0. 9                                   |
| 7004a | 1. 4                                   |
| 7005a | 1. 3                                   |
| 7006a | 1. 7                                   |
| 7007a | 1. 8                                   |
| 7008a | 1. 2                                   |
| 7009a | 0. 8                                   |
| 7010a | 2. 4                                   |
| 7011a | 1. 9                                   |
| 7012a | 1. 2                                   |
| 7013a | 1. 1                                   |
| 7014a | 2. 7                                   |
| 7015a | 1. 4                                   |
| 7016a | 1. 3                                   |
| 7017a | 1. 6                                   |
| 7018a | 1. 4                                   |
| 7019a | 1. 9                                   |
| 7020a | 1. 5                                   |

[Table 68]

| No.   | wear resistance                         |
|-------|-----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot. ) |
| 7021a | 1. 3                                    |
| 7022a | 0. 9                                    |
| 7023a | 1. 2                                    |
| 7024a | 1. 0                                    |
| 7025a | 2. 3                                    |
| 7026a | 1. 7                                    |
| 7027a | 1. 8                                    |
| 7028a | 1. 1                                    |
| 7029a | 1. 5                                    |
| 7030a | 1. 4                                    |

[Table 69]

| No.   | wear resistance                        |
|-------|----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot.) |
| 8001a | 1. 4                                   |
| 8002a | 1. 1                                   |
| 8003a | 0. 9                                   |
| 8004a | 1. 2                                   |
| 8005a | 1. 8                                   |
| 8006a | 1. 3                                   |
| 8007a | 1. 5                                   |
| 8008a | 1. 0                                   |
| 8009a | 1. 2                                   |
| 8010a | 0. 7                                   |
| 8011a | 1. 0                                   |
| 8012a | 1. 3                                   |
| 8013a | 1. 4                                   |
| 8014a | 1. 3                                   |
| 8015a | 1. 5                                   |
| 8016a | 0. 9                                   |
| 8017a | 1. 4                                   |
| 8018a | 0. 9                                   |
| 8019a | 1. 0                                   |
| 8020a | 1. 5                                   |

[Table 70]

| No.   | wear resistance                         |
|-------|-----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot. ) |
| 8021a | 1. 0                                    |
| 8022a | 1. 4                                    |
| 8023a | 1. 4                                    |
| 8024a | 0. 8                                    |
| 8025a | 1. 2                                    |
| 8026a | 1. 4                                    |
| 8027a | 1. 9                                    |
| 8028a | 0. 9                                    |
| 8029a | 1. 4                                    |
| 8130a | 2. 2                                    |
| 8131a | 2. 1                                    |

# EP 1 559 802 A1

[Table 70] (continued)

| No.   | wear resistance                         |
|-------|-----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot. ) |
| 8132a | 1. 0                                    |
| 8133a | 2. 4                                    |
| 8134a | 1. 4                                    |
| 8135a | 1. 2                                    |
| 8136a | 1. 5                                    |
| 8137a | 1. 3                                    |
| 8138a | 0. 8                                    |
| 8139a | 1. 4                                    |
| 8140a | 1. 5                                    |

[Table 71]

| No.   | wear resistance                         |
|-------|-----------------------------------------|
|       | weight loss by wear<br>(mg/1.00000rot.) |
| 8041a | 1. 5                                    |
| 8042a | 1. 3                                    |
| 8043a | 1. 6                                    |
| 8044a | 1. 2                                    |
| 8045a | 1. 0                                    |
| 8046a | 2. 0                                    |
| 8047a | 1. 6                                    |
| 8048a | 1. 7                                    |
| 8049a | 1. 3                                    |
| 8050a | 1. 5                                    |
| 8051a | 1. 0                                    |
| 8052a | 1. 5                                    |
| 8053a | 1. 3                                    |
| 8054a | 1. 2                                    |
| 8055a | 0. 7                                    |
| 8056a | 0. 9                                    |
| 8057a | 1. 6                                    |
| 8058a | 2. 4                                    |
| 8059a | 1. 6                                    |
| 8060a | 1. 9                                    |

[Table 72]

| No.   | wear resistance                         |
|-------|-----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot. ) |
| 8061a | 1. 6                                    |
| 8062a | 1. 9                                    |
| 8063a | 1. 2                                    |
| 8064a | 1. 7                                    |
| 8065a | 2. 0                                    |
| 8066a | 1. 4                                    |
| 8067a | 1. 5                                    |
| 8068a | 1. 2                                    |
| 8069a | 0. 9                                    |
| 8070a | 1. 0                                    |
| 8071a | 1. 7                                    |
| 8072a | 1. 9                                    |
| 8073a | 1. 6                                    |
| 8074a | 1. 6                                    |
| 8075a | 1. 8                                    |
| 8076a | 0. 8                                    |
| 8077a | 1. 3                                    |
| 8078a | 1. 2                                    |
| 8079a | 1. 4                                    |
| 8080a | 1. 3                                    |

[Table 73]

| No.   | wear resistance                        |
|-------|----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot.) |
| 8081a | 1. 6                                   |
| 8082a | 1. 3                                   |
| 8083a | 1. 0                                   |
| 8084a | 1. 2                                   |
| 8085a | 1. 5                                   |
| 8086a | 1. 6                                   |
| 8087a | 1. 1                                   |
| 8088a | 2. 0                                   |
| 8089a | 1. 4                                   |
| 8090a | 1. 2                                   |
| 8091a | 1. 5                                   |

# EP 1 559 802 A1

[Table 73] (continued)

| No.   | wear resistance                        |
|-------|----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot.) |
| 8092a | 1. 6                                   |
| 8093a | 2. 1                                   |
| 8094a | 1. 5                                   |
| 8095a | 1. 9                                   |
| 8096a | 1. 5                                   |
| 8097a | 1. 5                                   |
| 8098a | 1. 4                                   |
| 8099a | 1. 1                                   |
| 8100a | 0. 9                                   |

[Table 74]

| No.  | wear resistance                        |
|------|----------------------------------------|
|      | weight loss by wear<br>(mg/100000rot.) |
| 8101 | 1. 4                                   |
| 8102 | 1. 3                                   |
| 8103 | 0. 8                                   |
| 8104 | 0. 8                                   |
| 8105 | 0. 7                                   |
| 8106 | 0. 9                                   |
| 8107 | 1. 2                                   |
| 8108 | 1. 1                                   |
| 8109 | 1. 0                                   |
| 8110 | 0. 7                                   |
| 8111 | 0. 8                                   |
| 8112 | 1. 2                                   |
| 8113 | 0. 9                                   |
| 8114 | 1. 2                                   |
| 8115 | 1. 1                                   |
| 8116 | 1. 4                                   |
| 8117 | 1. 1                                   |
| 8118 | 0. 9                                   |
| 8119 | 1. 1                                   |
| 8120 | 0. 9                                   |

[Table 75]

| No.   | wear resistance                        |
|-------|----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot.) |
| 8121a | 1. 0                                   |
| 8122a | 1. 0                                   |
| 8123a | 1. 2                                   |
| 8124a | 0. 8                                   |
| 8125a | 1. 1                                   |
| 8126a | 0. 9                                   |
| 8127a | 1. 3                                   |
| 8128a | 1. 4                                   |
| 8129a | 1. 3                                   |
| 8130a | 1. 5                                   |
| 8131a | 1. 2                                   |
| 8132a | 1. 3                                   |
| 8133a | 0. 8                                   |
| 8134a | 1. 0                                   |
| 8135a | 0. 8                                   |
| 8136a | 1. 3                                   |
| 8137a | 1. 1                                   |
| 8138a | 0. 9                                   |
| 8139a | 1. 2                                   |
| 8140a | 1. 0                                   |

[Table 76]

| No.   | wear resistance                         |
|-------|-----------------------------------------|
|       | weight loss by wear<br>(mg/100000rot. ) |
| 8141a | 1. 4                                    |
| 8142a | 1. 8                                    |
| 8143a | 1. 6                                    |
| 8144a | 1. 9                                    |
| 8145a | 1. 1                                    |
| 8146a | 1. 2                                    |
| 8147a | 1. 4                                    |

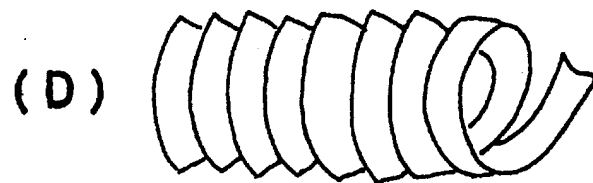
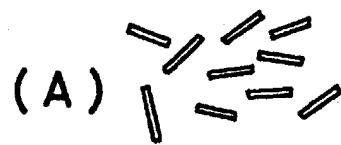
[Table 77]

| No.    | wear resistance                        |
|--------|----------------------------------------|
|        | weight loss by wear<br>(mg/100000rot.) |
| 14001a | 500                                    |
| 14002a | 620                                    |
| 14003a | 520                                    |
| 14004a | 450                                    |
| 14005a | 25                                     |
| 14006a | 600                                    |

### Claims

1. Use of silicon in an amount of 2.0 to 4.0 percent, as an additive to a lead-free copper alloy composition which comprises 69 to 79 wt% copper and the remaining wt% zinc, to improve the machinability of the alloy by producing in the metal structure at least one phase selected from the  $\gamma$  (gamma) and the  $\kappa$  (kappa) phases.
2. The use as claimed in claim 1 wherein the lead-free copper alloy composition further includes one of:
  - a) at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium, and 0.02 to 0.4 wt% selenium; or
  - b) at least one element selected from among 0.3 to 3.5 wt% tin, 0.02 to 0.25 wt% phosphorus, 0.02 to 0.15 wt% antimony, and 0.02 to 0.15 wt% arsenic; or
  - c) at least one element selected from among 0.3 to 3.5 wt% tin, 0.02 to 0.25 wt% phosphorus, 0.02 to 0.15 wt% antimony, and 0.02 to 0.15 wt% arsenic; at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium, and 0.02 to 0.4 wt% selenium; or
  - d) 0.1 to 1.5 wt% aluminum; and 0.02 to 0.25 wt% phosphorus; or
  - e) 0.1 to 1.5 wt% aluminum; 0.02 to 0.25 wt% phosphorus; at least one element selected from among 0.02 to 0.4 wt% chromium and 0.02 to 0.4 wt% titanium; or
  - f) 0.1 to 1.5 wt% aluminum; 0.02 to 0.25 wt% phosphorus; at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium and 0.02 to 0.4 wt% selenium; or
  - g) 0.1 to 1.5 wt% aluminum; 0.02 to 0.25 wt% phosphorus; at least one element selected from among 0.02 to 0.4 wt% chromium, and 0.02 to 0.4 wt% of titanium; at least one element selected from among 0.02 to 0.4 wt% bismuth, 0.02 to 0.4 wt% tellurium and 0.02 to 0.4 wt% selenium.
3. A lead-free free-cutting copper alloy as defined in claim 1 or claim 2, which is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.

FIGURE 1





European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 05 07 5421

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                          |                                  |                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|----------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                                                            | Relevant to claim                | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | CH 148 824 A (HIRSCH KUPFER UND MESSINGWERKE) 16 October 1931 (1931-10-16)<br>* claims 2,5 *                                                                                             | 1-3                              | C22C9/04<br>C22F1/08                         |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | GB 1 443 090 A (ANACONDA CO) 21 July 1976 (1976-07-21)<br>* page 3; table II *<br>* page 4; table III *<br>* claims *                                                                    | 1-3                              |                                              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | GB 359 570 A (HIRSCH KUPFER UND MESSINGWERKE) 19 October 1931 (1931-10-19)<br>* page 1, line 42 - line 66 *<br>* claims *                                                                | 1-3                              |                                              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 1 954 003 A (EUGEN VADERS) 10 April 1934 (1934-04-10)<br>* page 1, line 67 - line 80 *<br>* claim 1 *                                                                                 | 1,3                              |                                              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | DE 15 58 470 A (DIES DR ING KURT) 19 March 1970 (1970-03-19)<br>* page 4; example 10 *<br>* claim 1 *                                                                                    | 1,3                              | TECHNICAL FIELDS<br>SEARCHED (Int.Cl.7)      |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | GB 354 966 A (HIRSCH KUPFER UND MESSINGWERKE) 20 August 1931 (1931-08-20)<br>* page 1, line 30 - line 57 *<br>* claims *                                                                 | 1-3                              | C22C<br>C22F                                 |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 3 900 349 A (COSTAS LOUIS P) 19 August 1975 (1975-08-19)<br>* column 4, line 50 - line 60; examples; table II *<br>* column 5, line 10 - line 24; examples; table III *<br>* claims * | 1-3                              |                                              |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                          |                                  |                                              |
| Place of search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                          | Date of completion of the search | Examiner                                     |
| Munich                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                          | 13 May 2005                      | Patton, G                                    |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                          |                                  |                                              |

1  
EPO FORM 1503 03 82 (P04C01)



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 05 07 5421

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                     |                                                        |                                              |                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------|-----------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                       | Relevant to claim                                      | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | US 2 237 774 A (WOOD MAURICE L)<br>8 April 1941 (1941-04-08)<br>* page 1, line 1 - line 31 *                                                                                                                        | 1-3                                                    |                                              |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | FR 1 031 211 A (DEMEL KARL)<br>22 June 1953 (1953-06-22)<br>* claim 2 *                                                                                                                                             | 1-3                                                    |                                              |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | PATENT ABSTRACTS OF JAPAN<br>vol. 015, no. 227 (C-0839),<br>10 June 1991 (1991-06-10)<br>-& JP 03 068731 A (NIPPON MINING CO LTD),<br>25 March 1991 (1991-03-25)<br>* abstract *<br>* page 3; example 12; table 1 * | 1-3                                                    |                                              |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | PATENT ABSTRACTS OF JAPAN<br>vol. 1998, no. 04,<br>31 March 1998 (1998-03-31)<br>-& JP 09 316570 A (CHUETSU GOKIN CHUKO KK), 9 December 1997 (1997-12-09)<br>* abstract *<br>* page 4; examples; table 1 *          | 1-3                                                    |                                              | TECHNICAL FIELDS<br>SEARCHED (Int.Cl.7) |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | PATENT ABSTRACTS OF JAPAN<br>vol. 1997, no. 10,<br>31 October 1997 (1997-10-31)<br>-& JP 09 143598 A (CHUETSU GOKIN CHUKO KK), 3 June 1997 (1997-06-03)<br>* abstract *<br>* page 3; example 2; table 1 *           | 1-3                                                    |                                              |                                         |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                     |                                                        |                                              |                                         |
| Place of search<br><b>Munich</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                     | Date of completion of the search<br><b>13 May 2005</b> | Examiner<br><b>Patton, G</b>                 |                                         |
| <p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone<br/>Y : particularly relevant if combined with another document of the same category<br/>A : technological background<br/>O : non-written disclosure<br/>P : intermediate document</p> <p>T : theory or principle underlying the invention<br/>E : earlier patent document, but published on, or after the filing date<br/>D : document cited in the application<br/>L : document cited for other reasons<br/>&amp; : member of the same patent family, corresponding document</p> |                                                                                                                                                                                                                     |                                                        |                                              |                                         |

1  
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 05 07 5421

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-05-2005

| Patent document<br>cited in search report |   | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---|---------------------|----------------------------|---------------------|
| CH 148824                                 | A | 15-08-1931          | NONE                       |                     |
| GB 1443090                                | A | 21-07-1976          | NONE                       |                     |
| GB 359570                                 | A | 19-10-1931          | CH 148194 A                | 15-07-1931          |
|                                           |   |                     | CH 148199 A                | 15-07-1931          |
|                                           |   |                     | FR 698776 A                | 05-02-1931          |
|                                           |   |                     | FR 698778 A                | 05-02-1931          |
|                                           |   |                     | GB 352639 A                | 16-07-1931          |
| US 1954003                                | A | 10-04-1934          | NONE                       |                     |
| DE 1558470                                | A | 19-03-1970          | DE 1558470 A1              | 19-03-1970          |
| GB 354966                                 | A | 20-08-1931          | NONE                       |                     |
| US 3900349                                | A | 19-08-1975          | NONE                       |                     |
| US 2237774                                | A | 08-04-1941          | NONE                       |                     |
| FR 1031211                                | A | 22-06-1953          | NONE                       |                     |
| JP 03068731                               | A | 25-03-1991          | NONE                       |                     |
| JP 09316570                               | A | 09-12-1997          | NONE                       |                     |
| JP 09143598                               | A | 03-06-1997          | NONE                       |                     |