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(71) Applicant: **Sambo Copper Alloy Co., Ltd**
Osaka 590-0906 (JP)

(72) Inventor: **Oishi, Keiichiro**
Sakai-shi Osaka 590-0906 (JP)

(74) Representative:
Brown, Fraser Gregory James et al
fJ Cleveland
40-43 Chancery Lane
London WC2A 1JQ (GB)

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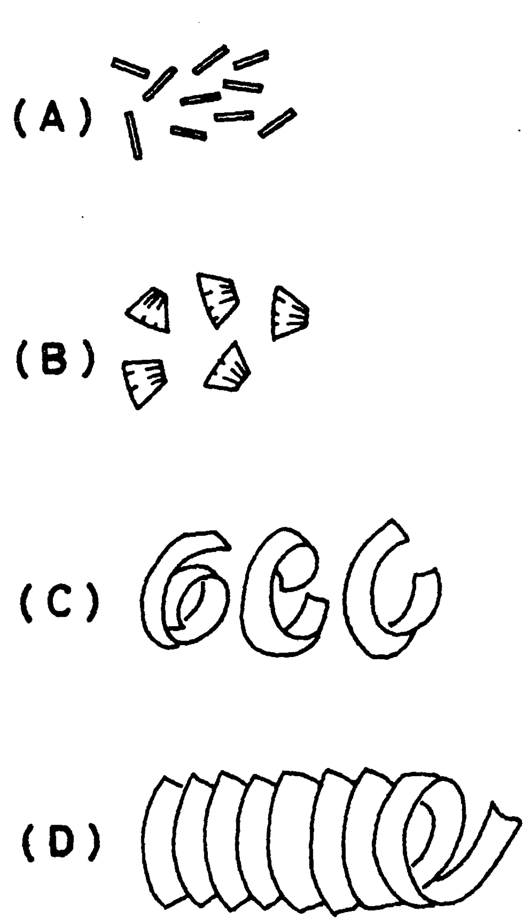
(54) Lead-free, free-cutting copper alloys

(57) The present invention relates to lead free, free cutting copper alloys and methods of their manufacture. In particular, the present invention is directed to a lead-free, free-cutting copper alloy which comprises 70 to 80 percent, by weight, of copper; 1.8 to 3.5 percent, by weight, of silicon; and at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, 1.0 to 3.5 percent, by weight, of aluminium, and 0.02 to 0.25 percent, by weight, of phosphorous; and the remaining percent, by weight, of zinc and wherein the metal structure of the free cutting copper alloy has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.

FIGURE 1



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Description

BACKGROUND OF THE INVENTION

1. Field of The Invention

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

2. 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 percent, by weight, 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 an 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] The objects of the present inventions are achieved by provision of the following copper alloys:

1. A lead-free, free-cutting copper alloy with excellent machinability which is composed of 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. For purpose of simplicity, this copper alloy will be hereinafter called the "first invention 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 invention alloy in place of lead so as to bring about a high level of machinability meeting the industrial requirements. That is, the first invention 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 percent, by weight, 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 percent by weight. An experiment showed that when silicon is added in an amount of 2.0 to 4.0 percent, by weight, it is desirable to hold the content of copper at 69 to 79 percent, by weight, 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 invention alloy is composed of 69 to 79 percent by weight, of copper and 2.0 to 4.0 percent, by weight, 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. A lead-free, free-cutting copper alloy also with an excellent machinability feature which is composed of 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; at least one element 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 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. This second copper alloy will be hereinafter called the "second invention alloy."

That is, the second invention alloy is composed of the first invention alloy and at least one element 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 percent, by weight, 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 invention 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 invention 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 percent by weight, 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 percent by weight, 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 percent by weight is negligible and would present no particular problems. From those considerations, the second invention alloy is prepared with the addition of bismuth, tellurium or selenium kept to 0.02 to 0.4 percent by weight. The addition of those elements, which work on the machinability of the copper alloy though 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 invention alloy are set at the same level as those in the first invention alloy.

3. A lead-free, free-cutting copper alloy also with an excellent machinability which is composed of 70 to 80 percent, by weight, of copper; 1.8 to 3.5 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, 1.0 to 3.5 percent, by weight, of aluminum, and 0.02 to 0.25 percent, by weight, of phosphorus; and the remaining percent, by weight, of zinc. This third copper alloy will be hereinafter called the "third invention 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 percent by weight would bring about a high machinability in the Cu-Zn alloy containing 58 to 70 percent, by weight, 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 percent by weight and the formation reaches the saturation point at 3.5 percent, by weight, of tin. If tin exceeds 3.5 percent by weight, the ductility will drop instead. With the addition of tin in less than 1.0 percent by weight, 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 percent by weight 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 percent by weight. But the addition of more than 3.5 percent by weight 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 percent by weight. But if the addition exceeds 0.25 percent by weight, 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 invention 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 percent, by weight, of tin, 1.0 to 3.5 percent, by weight, of aluminum, and 0.02 to 0.25 percent, by weight, 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 invention alloy mixed with silicon along with tin, aluminum or phosphorus, therefore, machinability is improved by not only silicon, but by tin, aluminium or phosphorus and thus the required addition of silicon is smaller than that in the second invention 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 percent by weight, 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 percent by weight. But even if the addition of silicon is not larger than 4.0 percent by weight, the addition of tin, aluminum or phosphorus will saturate the effect of silicon in improving the machinability, when the silicon content exceeds 3.5 percent by weight. On this ground, the addition of silicon is set at 1.8 to 3.5 percent by weight in the third invention 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 invention alloy is slightly raised from the level in the second invention alloy and is set at 70 to 80 percent by weight as preferred content of copper.

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

The fourth invention 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 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium in addition to the components in the third invention alloy. The grounds for adding those additional elements and setting the amounts to be added are the same as given for the second invention alloy.

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

The fifth invention alloy thus contains at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, 0.02 to 0.25 percent, by weight, of phosphorus, 0.02 to 0.15 percent, by weight, of antimony, and 0.02 to 0.15 percent, by weight, of arsenic in addition to the first invention 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 invention 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 invention 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 percent by weight. But even if the addition of tin exceeds 3.5 percent by weight, 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 invention 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 percent by weight could produce results. But the addition in an amount of more than 0.25 percent by weight would not produce proportional results. Instead, that would reduce the hot forgeability and extrudability.

Just as phosphorus, antimony and arsenic in a very small quantity - 0.02 or more percent by weight - are effective in improving the dezincification resistance and other properties. But the addition exceeding 0.15 percent by weight 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 invention 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 invention alloy, the additions of copper and silicon are set at 69 to 79 percent by weight and 2.0 to 4.0 percent by weight respectively - the same level as in the first invention 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 lead-free free-cutting copper alloy also with an excellent machinability and with a high corrosion resistance which is composed of 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, 0.02 to 0.25 percent, by weight, 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 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. This sixth copper alloy will be hereinafter called the "sixth invention alloy".

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

7. A lead-free free-cutting copper alloy also with an excellent machinability and with an excellent high strength feature and high corrosion resistance which is composed of 62 to 78 percent, by weight, of copper; 2.5 to 4.5 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.0 percent, by weight, of tin, 0.2 to 2.5 percent, by weight, of aluminum, and 0.02 to 0.25 percent, by weight, 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; and the remaining percent, by weight, of zinc. The seventh copper alloy will be hereinafter called the "seventh invention alloy".

Manganese and nickel combine with silicon to form intermetallic compounds represented by MnxSiy or NixSiy 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 percent by weight respectively. But the saturation state is reached at 3.5 percent by weight, 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 percent by weight 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 percent by weight is effective in improving the strength and machinability. But if the addition exceeds 3.0 percent by weight, the ductility will fall. For this reason, the addition of tin is set at 0.3 to 3.0 percent by weight to raise the high strength feature and wear resistance in the seventh invention 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 percent by weight. But if the addition exceeds 2.5 percent by weight, 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 percent by weight. The content of copper is set at 62 to 78 percent by weight in the light of the addition of silicon and bonding of silicon with manganese and nickel.

8. A lead-free, free-cutting copper alloy also with an excellent machinability and with an excellent high strength feature and a high wear resistance which comprises 62 to 78 percent, by weight, of copper; 2.5 to 4.5 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.0 percent, by weight, of tin, 1.0 to 2.5 percent, by weight, of aluminum, and 0.02 to 0.25 percent, by weight, 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 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. The eighth copper alloy will be hereinafter called the "eighth invention 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 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium in addition to the components in the seventh invention alloy. While as high a high-strength feature and wear resistance as in the seventh invention alloy is secured, the eighth invention 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 invention 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 lead-free, free-cutting copper alloy also with excellent machinability coupled with a good high-temperature oxidation resistance which is composed of 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; 0.1 to 1.5 percent, by weight, of aluminum; 0.02 to 0.25 percent, by weight, of phosphorus; and the remaining percent, by weight, of zinc. The ninth copper alloy will be hereinafter called the "ninth invention 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 aluminium is added in an amount not less than 0.1 percent by weight together with silicon. But even if the addition of aluminum increases beyond 1.5 percent by weight, no proportional results can be expected. For this reason, the addition of aluminum is set at 0.1 to 1.5 percent by weight.

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 percent by weight. But even if phosphorus is used in more than 0.25 percent by weight, 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 percent by weight.

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 percent by weight. 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 percent by weight.

10. A lead-free, free-cutting copper alloy also with excellent machinability and a good high-temperature oxidation resistance which is composed of 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; 0.1 to 1.5 percent, by weight, of aluminum; 0.02 to 0.25 percent, by weight, of phosphorus; at least one element selected from among 0.02 to 0.4 percent, by weight, of chromium and 0.02 to 0.4 percent, by weight, of titanium; and the remaining percent, by weight, of zinc. The tenth copper alloy will be hereinafter called the "tenth invention 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 percent by weight. In consideration of such observations, the tenth invention alloy contains at least one element selected from among 0.02 to 0.4 percent by weight of chromium and 0.02 to 0.4 percent by weight of titanium in addition to the components of the ninth invention alloy and is an improvement over the ninth invention alloy with regard to the high-temperature oxidation resistance.

11. A lead-free, free-cutting copper alloy also with excellent machinability and a good high-temperature oxidation resistance which is composed of 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; 0.1 to 1.5 percent, by weight, of aluminum; 0.02 to 0.25 percent, by weight, of phosphorus; at least one element 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 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. The eleventh copper alloy will be hereinafter called the "eleventh invention alloy".

The eleventh invention alloy contains at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium an 0.02 to 0.4 percent, by weight, of selenium in addition to the components of the ninth invention alloy. While as high a high-temperature oxidation resistance as in the ninth invention alloy is secured, the eleventh invention 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. A lead-free, free-cutting copper alloy also with excellent machinability and a good high-temperature oxidation resistance which is composed of 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; 0.1 to 1.5 percent, by weight, of aluminum; 0.02 to 0.25 percent, by weight, of phosphorus; at least one element selected from among 0.02 to 0.4 percent, by weight, of chromium, and 0.02 to 0.4 percent by weight of titanium; at least one element 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 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. The twelfth copper alloy will be hereinafter called the "twelfth invention alloy".

The twelfth invention alloy contains at least one element 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 percent, by weight, of selenium in addition to the components of the tenth invention alloy. While as high a high-temperature oxidation resistance as in the tenth invention alloy is secured, the twelfth invention 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. A lead-free, free-cutting copper alloy also with further improved machinability obtained by subjecting any one of the preceding invention 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 invention alloy".

[0010] The first to twelfth invention alloys contain machinability improving elements such as silicon and have an excellent machinability because of the addition of such elements. Of those invention 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 invention 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 invention 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 $67 \leq Cu - 3Si + aA$ or low copper content alloys with such a composition with $64 \geq Cu - 3Si + aA$. 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 invention alloys Nos. 1001 to 1008, second invention alloys Nos. 2001 to 2011, third invention alloys Nos. 3001 to 3012, fourth invention alloys Nos. 4001 to 4049, fifth invention alloys Nos. 5001 to 5020, sixth invention alloys Nos. 6001 to 6105, seventh invention alloys Nos. 7001 to 7030, eighth invention alloys Nos. 8001 to 8147, ninth invention alloys Nos. 9001 to 9005, tenth invention alloys Nos. 10001 to 10008, eleventh invention alloys Nos. 11001 to 11007, and twelfth invention 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 invention 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 invention 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 invention 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 invention 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.

[0015] To study the machinability of the first to thirteenth invention 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.

[0016] 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 noise 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.

[0017] 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 serous 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 "◎ ", "○", "Δ" and "x" respectively.

[0018] 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 s 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 "○", those with 10 microns ≤ Rmax < 15 microns are indicated as "Δ" and those with Rmax ≥ 15 microns are represented by a symbol "x".

[0019] As is evident from the results of the cutting tests shown in Table 38 to Table 66, the following invention alloys are all equal to the conventional lead- contained alloys Nos. 14001 to 14003 in machinability: first invention alloys Nos. 1001 to 1008, second invention alloys Nos. 2001 to 2011, third invention alloys Nos. 3001 to 3012, fourth invention alloys Nos. 4001 to 4049, fifth invention alloys Nos. 5001 to 5020, sixth invention alloys Nos. 6001 to 6105, seventh invention alloys Nos. 7001 to 7030, eighth invention alloys Nos. 8001 to 8147, ninth invention alloys Nos. 9001 to 9005, tenth invention alloys Nos. 10001 to 10008, eleventh invention alloys Nos. 11001 to 11007, twelfth invention alloys Nos. 12001 to 12021. Especially with regard to formation of the chips, those invention alloys are favourably compared not only with the conventional alloys Nos. 14004 to 14006 with a lead content of not higher than 0.1 percent by weight but also Nos. 14001 to 14003 which contain large quantities of lead.

[0020] Also to be noted is that as is clear from Tables Nos. 38 to 65, thirteenth invention alloys Nos. 13001 to 13006 are improved over first invention alloy No. 1005, No. 1007 and No. 1008 with the same composition as the thirteenth invention alloys in machinability. It is thus confirmed that a proper heat treatment could further enhance the machinability.

[0021] In another series of tests, the first to thirteenth invention 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.

[0022] 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 "Δ" and those with large cracks are represented by a symbol "x".

[0023] The second test pieces were put to a tensile test by the commonly practised test method to determine the tensile strength, N/mm^2 and elongation, %.

[0024] 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 invention 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 invention 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.

[0025] Furthermore, the first to six and ninth to thirteenth invention 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.

[0026] 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 ($CuCl_2.2H_2O$) 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.

[0027] 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 invention alloys and the ninth to thirteenth invention 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 invention 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.

[0028] 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 12.5% 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 "Δ". The test samples which were found to have no cracks at all at 24 hours are given a symbol "o."

[0029] 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 invention alloys which seek improvement in both machinability and corrosion resistance but also the first to fourth invention 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. In addition, oxidation tests were carried out to study the high-temperature oxidation resistance of the ninth to twelfth invention 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 $10cm^2$ of the surface area of the test piece and is calculated by the equation: increase in weight by oxidation, $mg/10cm^2$ = (weight, mg, after oxidation - weight, mg, before oxidation) x ($10cm^2$ / surface area, cm^2, 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_2O, ZnO, SiO_2. 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 invention 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 invention 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 invention alloys Nos. 7001a to 7030a and eighth invention 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 invention alloys Nos. 7001a to 7030a and eighth invention 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 invention alloys Nos. 7001a to 7030a and eighth invention 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 invention 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.

[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

[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

[Table 3] (continued)

No.	alloy composition (wt%)					
	Cu	Si	Sn	Al	P	Zn
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	Al	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
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
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
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

[Table 8] (continued)

No.	alloy composition (wt%)								
	Cu	Si	Sn	Bi	Te	P	Sb	As	Zn
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
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	4.03		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

[Table 10] (continued)

No.	alloy composition (wt%)									
	Cu	Si	Sn	Bi	Te	Se	P	Sb	As	Zn
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

[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

[Table 11] (continued)

No.	alloy composition (wt%)								
	Cu	Si	Sn	Te	Se	P	Sb	As	Zn
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
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

[Table 13] (continued)

No.	alloy composition (wt%)						
	Cu	Si	Se	P	Sb	As	Zn
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	S i	Sn	A l	P	Mn	N i	Zn
7001 7001a	62.9	2.7	2.6			2.2		remainder
7002 7002a	64.8	3.4	1.8				3.1	remainder
7003 7003a	68.2	4.1	0.6			1.9	1.5	remainder
7004 7004a	66.5	3.5	1.9	0.9		1.9		remainder
7005 7005a	71.3	3.7	0.4	1.8			2.3	remainder
7006 7006a	73.6	2.9	0.7	2.1		1.3	0.8	remainder
7007 7007a	70.1	3.2	0.5	1.4	0.11	1.8		remainder
7008 7008a	77.1	4.2	0.8	2.3	0.03		1.8	remainder
7009 7009a	67.3	3.7	2.6	0.2	0.08	0.9	1.8	remainder
7010 7010a	75.5	3.9		2.3		0.8		remainder

[Table 15]

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
7011 7011a	69.8	3.4		0.3			1.3	remainder
7012 7012a	71.2	4.0		1.4		2.1	1.2	remainder
7013 7013a	73.3	3.9		2.0	0.03	3.2		remainder

[Table 15] (continued)

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
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								
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								

[Table 16] (continued)

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
7030 7030a	68.4	4.2	2.6			3.3		remainder

[Table 17]

No.	alloy composition (wt%)								
	Cu	S i	Sn	Al	Bi	Te	Se	Mn	Zn
8001 8001a	62.6	2.6	2.6		0.31			1. 9	remainder
8002 8002a	65.3	3.4	1.8		0.11	0.02		2.5	remainder
8003 8003a	66.4	4.2	0.5		0.05		0.03	3.4	remainder
8004 8004a	72.1	4.4	0.4		0.06	0.05	0.02	2.8	remainder
8005 8005a	67.4	3.3	2.3			0.31		0.9	remainder
8006 8006a	63.8	2.8	2.9			0.06	0.07	2.1	remainder
8007 8007a	71.5	3.9	1.5				0.20	1.4	remainder
8008 8008a	64.2	2.9	2.4	0.3	0.28			2.1	remainder
8009 8009a	68.8	3.4	1.0	1.5	0.07	0.20		1.7	remainder
8010 8010a	65.3	3.6	2.8	0.2	0.05		0.13	2.2	remainder

[Table 18]

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Zn
8011 8011a	66.8	3.3	1.9	2.1	0.04	0.05	0.05		2.3	remainder
8012 8012a	75.1	4.1	0.4	2.4		0.03			1.8	remainder
8013 8013a	74.2	3.9	0.5	1.8		0.10	0.04		1.7	remainder

[Table 18] (continued)

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Zn
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	S i	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										
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
8029 a										

[Table 19] (continued)

No.	alloy composition (wt%)									
	Cu	S i	Sn	Al	Bi	Te	Se	P	Mn	Zn
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									
8032a	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									
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	S i	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											

[Table 21] (continued)

No.	alloy composition (wt%)										
	Cu	S i	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
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									
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		1.9	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	remainer
8059a									

[Table 22] (continued)

No.	alloy composition (wt%)								
	Cu	Si	Sn	Al	Bi	Te	Se	Ni	Zn
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	68.6	3.5	1.4			0.06		0.04	2.6	remainder
8068a										
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										

[Table 24] (continued)

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Ni	Zn
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	Z 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									
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									

[Table 25] (continued)

No.	alloy composition (wt%)								
	Cu	Si	Al	Bi	Te	Se	P	Ni	Zn
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											
8099	64.9	3.6	0.9		0.18				0.8	2.6	remainder
8099a											
8100	67.3	18	1.8		0.03	0.06			1.9	1.0	remainder
8100a											

[Table 27]

No.	alloy composition (wt%)									
	Cu	S i	Sn	A l	Bi	Te	Se	Mn	N i	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										

[Table 27] (continued)

No.	alloy composition (wt%)									
	Cu	S i	Sn	A l	Bi	Te	Se	Mn	N i	Zn
8104 8104a	64.7	3.6	2.7			0.25	0.03	1.3	1.6	remainder
8105 8105a	70.4	3.9	1.8				0.07	1.0	2.0	remainder
8106 8106a	70.3	3.8	0.4	1.8	0.05			2.3	0.7	remainder
8107 8107a	72.1	3.7	0.4	2.1	0.03	0.05		1.3	1.2	remainder
8108 8108a	69.8	3.8	0.6	1.5	0.05		0.05	1.5	2.1	remainder
8109 8109a	75.4	4.2	0.6	1.8	0.05	0.04	0.04	2.3	1.1	remainder
8110 8110a	66.4	3.5	2.5	0.2		0.12		1.6	0.9	remainder

[Table 28]

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8111 8111a	64.9	3.3	2.5	0.3		0.08	0.05		1.2	1.3	remainder
8112 8112a	70.0	3.8	1.2	0.5			0.03		1.5	0.8	remainder
8113 8113a	72.0	3.9	1.1		0.25			0.20	2.4	0.9	remainder
8114 8114a	66.5	3.6	1.2		0.06	0.04		0.05	1.3	1.1	remainder
8115 8115a	67.0	3.5	1.3		0.12		0.04	0.08	0.9	1.2	remainder
8116 8116a	64.0	2.8	2.6		0.30	0.08	0.03	0.05	0.8	1.0	remainder
8117 8117a	67.3	3.7	2.3			0.03		0.03	1.2	1.3	remainder
8118 8118a	66.4	3.8	2.4			0.05	0.15	0.03	1.0	1.6	remainder
8119 8119a	70.2	3.9	0.5				0.30	0.07	1.7	0.9	remainder

[Table 28] (continued)

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
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											
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										

[Table 30] (continued)

No.	alloy composition (wt%)									
	Cu	Si	Al	Bi	Te	Se	P	Mn	Ni	Zn
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	L 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									
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

[Table 32] (continued)

No	alloy composition (wt%)				
.	Cu	Si	Al	P	Zn
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
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

[Table 35] (continued)

No.	alloy composition (wt%)									
	Cu	Si	Al	Bi	Te	Se	P	Cr	Ti	Zn
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	Zn	temperature	time
13001	78.5	3.2	remainder	580°C	30min.
13002	78.5	3.2	remainder	450°C	2hr.
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									

[Table 37] (continued)

No.	alloy composition (wt%)								
	Cu	Si	Sn	Al	Mn	Pb	Fe	Ni	Zn
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 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^2)	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

[Table 39]

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance 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^2)	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	○

[Table 39] (continued)

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm²)	elongation (%)	
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 corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm²)	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	2 0	○	502	34	○
3012	◎	○	120	< 5	○	534	31	○

[Table 41]

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μ m)	700°C deformability	tensile strength (N/mm²)	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 corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	7 0 0°C deformability	tensile strength (N/mm²)	elongation (%)	
4021	◎	○	120	50	○	540	29	○
4022	◎	○	123	<5	○	487	32	Δ

[Table 42] (continued)

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	7 0 0°C deformability	tensile strength (N/mm^2)	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	3 1	○
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 43]

No.	machinability			corrosion resistance	hot work-ability	mechanical properties		stress resistance 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^2)	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	○

[Table 43] (continued)

No.	machinability			corrosion resistance	hot work-ability	mechanical properties		stress resistance 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^2)	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 work-ability	mechanical properties		stress resistance 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^2)	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	O	507	23	○
5008	◎	○	122	< 5	○	515	30	○
5009	◎	○	124	< 5	○	544	35	○
5010	◎	○	123	< 5	Δ	536	36	○
5011	◎	Δ	126	< 5	O	511	27	○
5012	◎	○	124	< 5	○	596	36	○
5013	◎	○	119	< 5	○	519	39	○
5014	◎	○	122	< 5	○	523	37	○
5015	◎	○	123	< 5	○	510	40	○
5016	◎	○	120	2 0	○	490	35	Δ
5017	◎	○	121	< 5	○	573	40	○
5018	◎	○	120	< 5	○	549	39	○
5019	◎	○	122	50	○	537	30	○

[Table 44] (continued)

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (µm)	700°C deformability	tensile strength (N/mm²)	elongation (%)	
5020	◎	○	118	< 5	○	521	37	○

[Table 45]

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (µm)	700°C deformability	tensile strength (N/mm²)	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	○

[Table 46]

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance 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^2)	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 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^2)	elongation (%)	
6041	◎	○	117	<5	○	496	3 0	○
6042	◎	○	120	<5	Δ	574	34	○

[Table 47] (continued)

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm²)	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 corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm²)	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	○

[Table 48] (continued)

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm²)	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 corrosion cracking resistance
.	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm²)	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	○

[Table 49] (continued)

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance 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^2)	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 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^2)	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	○

[Table 51]

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

[Table 52]

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

[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^2)	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^2)	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

[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^2)	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^2)	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

[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^2)	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^2)	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	◎	○	13	○	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^2)	elongation (%)
8081	◎	○	132	○	706	23
8082	◎	○	130	○	768	23
8083	◎	○	128	○	774	25

[Table 57] (continued)

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

[Table 58]

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

[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^2)	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^2)	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 chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm^2)	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 61】

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance	high-temperature oxidation
	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700℃ deformability	tensile strength (N/mm²)	elongation (%)	corrosion cracking resistance	increase in weight by oxidation (mg/10cm²)
9001	◎	△	132	20	○	500	37	○	0.3
9002	◎	○	122	<5	○	564	35	○	0.2
9003	◎	○	123	<5	○	585	39	○	0.5
9004	◎	○	118	<5	○	558	34	○	0.2
9005	△	○	132	<5	△	593	37	○	0.3

【Table 62】

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance	high-temperature oxidation
	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700℃ deformability	tensile strength (N/mm²)	elongation (%)	corrosion cracking resistance	increase in weight by oxidation (mg/10cm²)
10001	◎	○	124	<5	○	534	35	○	0.3
10002	◎	○	120	<5	○	540	33	○	0.2
10003	◎	○	122	<5	○	539	38	○	0.2
10004	◎	○	124	<5	○	575	40	○	0.1
10005	◎	△	128	<5	○	512	33	○	0.1
10006	◎	○	120	20	○	560	35	○	0.1
10007	◎	○	119	<5	○	536	36	○	0.3
10008	△	○	132	<5	○	501	31	△	0.1

【Table 6 3】

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance	high-temperature oxidation
	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700℃ deformability	tensile strength (N/mm²)	elongation (%)	corrosion cracking resistance	increase in weight by oxidation (mg/10cm²)
11001	◎	○	117	<5	○	540	36	○	0.2
11002	◎	○	117	<5	○	537	34	○	0.3
11003	◎	○	121	<5	△	573	38	○	0.2
11004	◎	○	119	30	○	512	30	○	0.3
11005	○	○	114	<5	△	518	30	○	0.4
11006	◎	○	118	<5	○	535	32	○	0.3
11007	◎	○	119	<5	△	586	37	○	0.2

【Table 6 4】

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance	high-temperature oxidation
	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700℃ deformability	tensile strength (N/mm²)	elongation (%)	corrosion cracking resistance	increase in weight by oxidation (mg/10cm²)
12001	◎	○	121	<5	○	512	32	○	0.2
12002	◎	○	119	<5	○	544	36	○	0.2
12003	◎	○	123	<5	○	570	38	○	0.1
12004	◎	○	124	<5	△	495	31	△	0.2
12005	◎	○	123	30	△	583	32	○	0.3
12006	◎	○	118	<5	○	537	33	○	0.2
12007	◎	○	118	20	○	516	30	○	0.2
12008	◎	○	117	<5	○	543	38	○	0.1
12009	◎	○	122	20	○	501	32	○	0.2
12010	◎	○	119	30	○	546	35	○	0.2
12011	◎	○	121	20	○	516	31	○	0.1
12012	◎	○	117	<5	○	539	33	○	0.2
12012	◎	○	121	<5	○	544	33	○	<0.1
12014	◎	○	121	<5	△	590	37	○	<0.1
12015	◎	○	120	20	○	528	32	○	0.1
12016	◎	○	117	<5	○	535	33	○	0.1
12017	◎	○	121	<5	○	577	35	○	0.2
12018	◎	○	120	<5	△	586	37	○	0.1
12019	◎	○	115	<5	○	520	31	○	0.2
12020	◎	○	118	<5	○	549	34	○	0.1
12021	◎	○	116	<5	○	533	34	○	0.1

[Table 65]

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance 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^2)	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 66】

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance	high-temperature oxidation
	form of chippings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700℃ deformability	tensile strength (N/mm²)	elongation (%)	corrosion cracking resistance	increase in weight by oxidation (mg/10cm²)
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 (mg/100000rot.)
7001a	1.3

[Table 67] (continued)

No.	wear resistance
	weight loss by wear (mg/100000rot.)
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 (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 (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 (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
8132a	1.0

[Table 70] (continued)

No.	wear resistance
	weight loss by wear (mg/100000rot.)
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 (mg/100000rot.)
8041a	1.5
8042a	1.3
8043a	1.6
8044a	1.2
8045a	1.0
8046a	2.0
8097a	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 (mg/100000rot.)
8061a	1.6

[Table 72] (continued)

No.	wear resistance
	weight loss by wear (mg/100000rot.)
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 (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
8092a	1.6
8093a	2.1
8094a	1.5

[Table 73] (continued)

No.	wear resistance
	weight loss by wear (mg/100000rot.)
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 (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 (mg/100000rot.)
8121a	1.0
8122a	1.0
8123a	1.2

[Table 75] (continued)

No.	wear resistance
	weight loss by wear (mg/100000rot.)
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 (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 (mg/100000rot.)
14001a	500
14002a	620
14003a	520
14004a	450
14005a	25

[Table 77] (continued)

No.	wear resistance
	weight loss by wear (mg/100000rot.)
14006a	600

Claims

1. A lead-free, free-cutting copper alloy which comprises 70 to 80 percent, by weight, of copper; 1.8 to 3.5 percent, by weight, of silicon; and at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, 1.0 to 3.5 percent, by weight, of aluminium, and 0.02 to 0.25 percent, by weight, of phosphorous; and the remaining percent, by weight, of zinc and wherein the metal structure of the free cutting copper alloy has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.

2. A lead-free, free cutting copper alloy which comprises 70 to 80 percent, by weight, of copper; 1.8 to 3.5 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, 1.0 to 3.5 percent, by weight, aluminium, and 0.02 to 0.25 percent, by weight, of phosphorous; at least one element selected from among 0.02 to 0.4 percent, by weight, bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium; and the remaining percent, by weight, of zinc and wherein the metal structure of the free cutting copper alloy has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.

3. A lead-free cutting copper alloy according to claim 1 or 2 wherein when cut on a circumferential surface by a lathe provided with a point noise straight tool at a rake angle of -8 (minus 8) and at a cutting rate of 50 m/min, a cutting depth of 1.5 mm, a feed rate of 0.11 mm/rev yields chips having one or more shapes selected from the group consisting of an arch shape and a fine needle shape.

4. A lead free, free-cutting copper alloy according to any one of the preceding claims which is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.

5. A method of forming a lead-fee, free cutting alloy having a metal structure which has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase which comprises alloying copper, silicon and zinc in an amount of 70 to 80 percent, by weight, of copper, 1.8 to 3.5 percent, by weight, of silicon; and at least one element selected from tin, aluminium and phosphorous in an amount of 0.3 to 3.5 percent, by weight, of tin, 1.0 to 3.5 percent, by weight, of aluminium and 0.02 to 0.25 percent, by weight, of phosphorous and the remaining percent by weight of zinc.

6. The method of claim 5 wherein said silicon is provided as a Cu-Si alloy.

7. The method of claim 5 or 6 further comprising alloying at least one element selected from bismuth, tellurium and selenium in an amount of 0.02 to 0.4 percent, by weight, bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium, the remaining percent, by weight, of zinc.

8. The method of any one of claims 5 to 7 wherein said lead-free, free cutting alloy is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.

FIGURE 1