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

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Alliage de cuivre de décolletage sans plomb

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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.

[0005] CH 148824 provides a method of producing particles of coquille and die casting through the use of a silicon containing alloy. The alloy comprises copper and silicon and from 0.2 to 28% zinc.

[0006] GB 1443090 discloses a silicon-brass alloy which is resistant to parting corrosion consisting of 3-21% by weight of zinc, and an amount of silicon being sufficient to produce a structure consisting of alpha plus zeta phases in the brass and the remainder of the alloy comprising copper. The alloy may also comprise 0.030% by weight of solid solubility of one or more elements of the group consisting of arsenic, antimony and phosphorus. US 359570 discloses a bearing metal comprising a copper-silicon-zinc alloy having a content of 65-80% of copper and 2-6% of silicon. The alloy may further comprise 0.1 to 3% of tin.

[0007] US 1954003 discloses a copper alloy for chill and die casting having 65-94 wt% copper, 6-2 wt% silicon and 28-3 wt% zinc. The alloy may also comprise up to 2% of lead, antimony, bismuth, cadmium, tin, nickel, cobalt, manganese, iron, chromium, aluminium, titanium, tungsten, molybdenum or zircon.

[0008] DE 1558470 provides the use of a copper alloy of 0.5-2.5% silicon, 29-35% zinc and the remainder of copper and up to 30% of a Beta joining portion for the production of an extruded valve guide for burning power engines. The alloy may further comprise lead, iron, manganese with traces of aluminium.

[0009] US 354966 discloses a bell manufactured from a copper-silicon alloy having up to 6% silicon and up to 20% zinc.

[0010] US 3900349 discloses a silicon brass alloy which is resistant to parting corrosion comprising 3-20% zinc, 2.5-6% silicon, and from 0.03% up to the percentage of solid solubility of one or more elements of the group consisting of arsenic, antimony and phosphorous and the remainder copper. The alloy includes substantial quantities of alpha and zeta phases.

SUMMARY OF THE INVENTION

[0011] 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.

[0012] 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.

[0013] 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.

[0014] 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.

[0015] The objects of the present inventions are achieved by provision of the following copper alloys:

A lead-free, free-cutting copper alloy which comprises 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 0.25 percent, by weight, of phosphorous and/or 0.02 to 0.15 percent, by weight, of antimony; optionally at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, and 0.02 to 0.15 percent, by weight, of arsenic, and/or; optionally 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 and wherein the metal structure of the free cutting copper alloy at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.

[0016] The present invention also provides the method of forming a lead-free, free cutting alloy having metal structure which has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase which comprises 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 0.25 percent, by weight, of phosphorous and/or 0.02 to 0.15 percent, by weight, of antimony; optionally at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, and 0.02 to 0.15 percent, by weight, of arsenic, and/or; optionally 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 and wherein the metal structure of the free cutting copper alloy at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.

[0017] 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 alloy of the present invention 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.

[0018] The alloy of the present invention comprises 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.

[0019] 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 alloy of the present invention 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 alloy of the present invention 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 through a mechanism different from that of silicon as mentioned above, would not affect the proper contents of copper and silicon.

[0020] The alloy of the present invention comprises 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.

[0021] 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 alloy of the present invention is thus improved in corrosion resistance by such property of tin and in machinability mainly by adding silicon.

[0022] 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.

[0023] 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 alloy of the present invention 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.

[0024] 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.

[0025] Those observations indicate that the alloy of the present invention 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 as described above.

[0026] In the alloy of the present invention, 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 because tin and phosphorus work mainly as corrosion resistance improver like antimony and arsenic.

[0027] The present invention also provides lead-free, free-cutting copper alloy 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 4000C to 600° C.

[0028] The alloys of the present invention 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 alloys of the present invention 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 alloys of the present invention, those with a low content of copper (hereinafter called the low copper content alloy") are rather low in the content of the gamma phase and contain beta phase. In a heat treatment, the beta phase changes into gamma phase, and the gamma phase is finely dispersed and precipitated, whereby the machinability is improved. Experiments showed that heat treatment is especially effective with high copper content alloys where mixing ratio of copper and silicon to other added elements (except for zinc) A is given as $67 \leq \text{Cu} - 3\text{Si} + a\text{A}$ or low copper content alloys with such a composition with $64 \geq \text{Cu} - 3\text{Si} + a\text{A}$. It is noted that a is a coefficient. The coefficient is different depending on the added element A. For example, with tin a is - 0.5; aluminum, -2; phosphorus, -3; antimony, 0; arsenic, 0; manganese, +2.5; and nickel, +2.5.

[0029] But a heat treatment temperature at less than 4000C 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

[0030]

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

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Example 1

[0031] As the first series of examples of the present invention, cylindrical ingots with compositions given in Tables 1-2, 4-10, 13-17, 19-26, 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: invention alloys Nos. 3004 to 3005 and 3010 to 3012, 4022 to 4035, 5002 to 5003 and 5005 to 5006 and 5008 to 5018 and 5020, 6002, 6003, 6005 to 6010, 6012 to 6015, 6017 to 6018, 6020 to 6029, 6032, 6033, 6035 to 6044, 6047, 6048, 6050 to 6059, 6062, 6063, 6065 to 6073, 6075, 6077, 6078, 6080 to 6089, 6092, 6093, 6095 to 6104.

[0032] As comparative examples, cylindrical ingots with the compositions as shown in Table 13, 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.

[0033] To study the machinability of the 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.

[0034] The tests were conducted this way: The extruded test pieces obtained, as mentioned above, were cut on the circumferential surface by a lathe mounted with a point nose straight tool at a rake angle of - 8 degrees and at a cutting rate of 50 meters/minute, a cutting depth of 1.5 mm, a feed of 0.11 mm/rev. Signals from a three-component dynamometer mounted on the tool were converted into electric voltage signals and recorded on a recorder. From the signals were then calculated the cutting resistance. It is noted that while, to be perfectly exact, an amount of the cutting resistance should be judged by three component forces - cutting force, feed force and thrust force, the judgement was made on the basis of the cutting force (N) of the three component forces in the present example. The results are shown in Tables 14-17, 19-28, 29.

[0035] 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 Tables 14-17, 19-26, 29. In this regard, the chips in the form of a spiral with three or more windings as (D) in Fig. 1 are difficult to process, that is, recover or recycle, and could cause trouble in cutting work as, for example, getting tangled with the tool and damaging the cut metal surface. Chips in the form of an arc with a half winding to a spiral with two about windings as shown in (C), Fig. 1 do not cause such serious trouble as the chips in the form of a spiral with three or more windings yet are not easy to remove and could get tangled with the tool or damage the cut metal surface. In contrast, chips in the form of a fine needle as (A) in Fig. 1 or in the form of an arc as (B) will not present such problems as mentioned above and are not bulky as the chips in (C) and (D) and easy to process. But fine chips as (A) still could creep into the sliding surfaces of a machine tool such as a lathe and cause mechanical trouble, or could be dangerous because they could stick into the worker's finger, eye or other body parts. Those taken into account, it is appropriate to consider that the chips in (B) are the best, and the second best are the chips in (A). Those in (C) and (D) are not good. Tables 14-17, 19-26, 29, the chips judged to be shown in (B), (A), (C) and (D) are indicated by the symbols "O", "o", "Δ" and "χ" respectively.

[0036] In addition, the surface condition of the cut metal surface was checked after cutting work. The results are shown in Tables 14-17, 19-26, 29. In this regard, the commonly used basis for indication of the surface roughness is the maximum roughness (Rmax). While requirements are different depending on the application field of brass articles, the alloys with Rmax < 10 microns are generally considered excellent in machinability. The alloys with 10 microns ≤ Rmax < 15 microns are judged as industrially acceptable, while those with Rmax ≥ 15 microns are taken as poor in machinability. In Tables 14-17, 19-26, the alloys with Rmax < 10 microns are marked "o", those with 10 microns < Rmax < 15 microns are indicated as "Δ" and those with Rmax ≥ 15 microns are represented by a symbol "χ".

[0037] As is evident from the results of the cutting tests shown in Tables 14-17, 19-26, 29; the following invention

alloys are all equal to the conventional lead-contained alloys Nos. 14001 to 14003 in machinability: third invention alloys Nos. 3004 to 3005 and 3010 to 3012, 4022 to 4035, 5002, 5003, 5005, 5006, 5008 to 5018, 5020, 6002, 6003, 6005, 6010, 6012 to 6015, 6017, 6018, 6020 to 6029, 6032, 6033, 6035 to 6044, 6047, 6048, 6050 to 6059, 6062, 6063, 6065 to 6073, 6075, 6077, 6078, 6080 to 6089, 6092, 6093, 6095 to 6104.

[0038] 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.

[0039] In another series of tests, the 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.

[0040] 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 Tables 14-17, 19-26. The evaluation of deformability was made by visually checking for cracks on the side of the test piece. In Tables 14-17, 19-26 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 "χ".

[0041] The second test pieces were put to a tensile test by the commonly practised test method to determine the tensile strength, N/mm² and elongation, %.

[0042] As the test results of the hot compression and tensile tests in Tables 14-17, 19-26 indicate, it was confirmed that the alloys of the present invention 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.

[0043] Furthermore, the 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.

[0044] 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 sample 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 (CuCl₂·2H₂O) 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 Tables 14-17, 19-25.

[0045] As is clear from the results of dezincification tests shown in Tables 14-17, 19-25, the 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 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.

[0046] 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 Tables 14-17, 19-25.

[0047] 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".

[0048] As is indicated by the results of the stress corrosion cracking test given in Tables 14-17, 19-25, 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.

[Table 1]

No	alloy composition (wt%)					
	Cu	Si	Sn	Al	P	Zn
3004	74.9	3.2			0.09	remainder
3005	71.6	2.4	2.3		0.03	remainder
3010	76.5	3.3			0.21	remainder
3011	73.8	2.7			0.04	remainder
3012	73.0	2.9	1.8		0.10	remainder

[Table 2]

No	alloy composition (wt%)								
	Cu	Si	Sn	Al	Bi	Te	Se	P	Zn
4022	70.9	2.1			0.11			0.11	remainder
4023	74.8	3.1				0.07		0.08	remainder
4024	76.3	3.2					0.05	0.02	remainder
4025	78.1	3.1			0.28	0.02		0.15	remainder
4026	71.1	2.2			0.13		0.02	0.05	remainder
4027	74.1	2.7			0.08	0.08	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		0.03		0.02	0.03	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

[Table 4.]

No	alloy composition (wt%)						
	Cu	Si	Sn	P	Sb	As	Zn
5002	74.1	2.7		0.21			remainder
5003	73.8	2.4			0.14		remainder
5005	73.4	2.4	2.1	0.04			remainder
5006	73.3	2.7	0.4		0.04		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	73.6	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
5020	74.9	3.0		0.20	0.05		remainder

[Table 5]

No	alloy composition (wt%)								
	Cu	Si	Sn	Bi	Te	P	Sb	As	Zn
6002	77.3	3.7	0.5	0.02		0.23			remainder
6003	73.2	2.4	1.1	0.33			0.12		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		0.18			remainder
6010	78.1	3.1		0.11			0.15		remainder
6012	69.9	2.3		0.35		0.08	0.02		remainder
6013	73.2	2.6		0.21		0.03		0.07	remainder
6014	76.3	2.9		0.07			0.09	0.02	remainder
6015	74.4	2.8		0.19		0.13	0.03	0.02	remainder
6017	74.7	2.4	0.9	0.31	0.04	0.05			remainder
6018	78.1	3.8	0.6	0.02	0.38		0.07		remainder
6020	77.8	2.8	0.5	0.06	0.11	0.21	0.02		remainder

[Table 6] --

N a	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	73.8	3.3	1.8	0.03	0.06			0.11	0.03	remainder
6023	74.4	2.6	1.5	0.09	0.12		0.03	0.02	0.06	remainder
6024	77.3	3.1		0.03	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
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
6035	74.1	2.3	3.3	0.08		0.03	0.02	0.05		remainder
6036	69.8	2.0	2.5	0.31		0.12	0.03		0.06	remainder
6037	74.9	3.0	1.1	0.07		0.21		0.12	0.02	remainder
6038	72.6	2.8	0.6	0.20		0.05	0.21	0.07	0.03	remainder
6039	69.7	2.3		0.23		0.06	0.10			remainder
6040	75.4	3.0		0.02		0.09	0.11	0.03		remainder

[Table 7]

N a	alloy composition (wt%)									
	Cu	Si	Sn	Bi	Te	Se	P	Sb	As	Zn
6041	73.2	2.5		0.11		0.36	0.05		0.02	remainder
6042	78.2	3.7		0.03		0.04	0.03	0.04	0.10	remainder
6043	77.8	2.8		0.09		0.02		0.04		remainder
6044	73.4	2.6		0.16		0.06		0.03	0.02	remainder
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
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

[Table 8]

No	alloy composition (wt%)								
	Cu	Si	Sn	Te	Se	P	Sb	As	Zn
6062	74.2	3.2	0.6	0.03		0.04			remainder
6063	74.9	2.6	0.7	0.14			0.14		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	0.18		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	3.9		0.04			0.02	0.12	remainder
6075	74.5	2.9		0.07		0.04	0.10	0.02	remainder
6077	74.1	2.9	0.8	0.21	0.18	0.05			remainder
6078	77.8	2.9	0.6	0.11	0.05		0.07		remainder
6080	72.6	2.3	0.5	0.15	0.23	0.11	0.02		remainder

[Table 9]

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	2.8	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	78.2	3.3		0.03	0.04	0.11		0.04	remainder
6087	73.6	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
6092	75.0	3.2	0.6		0.05	0.10			remainder
6093	76.8	3.1	0.5		0.04		0.11		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 10]

No.	alloy composition (wt%)						
	Cu	Si	Se	P	Sb	As	Zn
6101	78.1	3.0	0.04	0.05		0.02	remainder
6102	74.5	2.8	0.03	0.04	0.02	0.03	remainder
6103	74.3	2.6	0.31		0.04		remainder
6104	73.0	3.3	0.06		0.02	0.05	remainder

[Table 13]

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

[Table 14]

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
1001	Δ	Δ	148	290	$\bigcirc$	470	32	Δ
1002	$\odot$	$\bigcirc$	122	210	$\bigcirc$	524	36	$\bigcirc$
1003	$\odot$	$\bigcirc$	119	190	$\bigcirc$	543	34	$\bigcirc$
1004	$\odot$	$\bigcirc$	126	170	Δ	590	37	$\bigcirc$
1005	Δ	$\bigcirc$	134	150	Δ	532	42	$\bigcirc$
1006	$\odot$	Δ	129	230	$\bigcirc$	490	34	$\bigcirc$
1007	Δ	$\bigcirc$	132	170	Δ	512	41	$\bigcirc$
1008	Δ	Δ	137	270	$\bigcirc$	501	31	Δ

【 Table 5】

N o.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance
	form of chip-ings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm^2)	elongation (%)	corrosion cracking resistance
2001	○	○	116	190	○	523	34	○
2002	◎	○	117	190	○	508	36	○
2003	◎	○	118	180	○	525	36	○
2004	◎	○	119	280	△	463	28	△
2005	◎	○	119	240	△	481	30	○
2006	◎	○	119	170	△	552	36	○
2007	◎	○	118	180	○	520	41	○
2008	◎	○	115	140	△	570	34	○
2009	◎	○	117	200	△	485	31	○
2010	◎	○	114	180	○	507	34	○
2011	◎	○	115	170	△	522	33	○

【 Table 6】

N o.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance
	form of chip-ings	condition of cut surface	cutting force (N)	maximum depth of corrosion (μm)	700°C deformability	tensile strength (N/mm^2)	elongation (%)	corrosion cracking resistance
3004	◎	○	119	<5	○	533	36	○
3005	◎	○	123	50	○	525	28	○
3010	◎	○	118	<5	○	560	35	○
3011	◎	○	119	20	○	502	34	○
3012	◎	○	120	<5	○	534	31	○

[Table 7]

N o	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
4022	⊙	○	123	<5	○	487	32	△
4023	⊙	○	117	<5	○	524	34	○
4024	⊙	○	117	40	○	541	37	○
4025	⊙	○	115	<5	△	526	43	○
4026	⊙	○	122	30	○	498	30	△
4027	⊙	○	118	30	○	516	35	○
4028	⊙	○	120	<5	○	529	27	○
4029	⊙	○	121	<5	○	544	28	○
4030	⊙	○	118	<5	○	536	30	○
4031	⊙	○	116	<5	○	524	31	○
4032	⊙	○	114	<5	○	515	32	○
4033	⊙	○	118	<5	○	519	37	○
4034	⊙	○	118	<5	○	582	31	○
4035	⊙	○	117	<5	○	538	32	○

[Table 9]

N o	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
5002	⊙	○	119	<5	○	524	37	○
5003	⊙	△	135	10	○	488	41	○
5005	⊙	○	123	<5	○	518	29	○
5006	⊙	○	122	<5	○	520	34	○
5008	⊙	○	122	<5	○	515	30	○
5009	⊙	○	124	<5	○	544	35	○
5010	⊙	○	123	<5	△	536	36	○
5011	⊙	△	126	<5	○	511	27	○
5012	⊙	○	124	<5	○	596	36	○
5013	⊙	○	119	<5	○	519	39	○
5014	⊙	○	122	<5	○	523	37	○
5015	⊙	○	123	<5	○	510	40	○
5016	⊙	○	120	20	○	490	35	△
5017	⊙	○	121	<5	○	573	40	○
5018	⊙	○	120	<5	○	549	39	○
5020	⊙	○	118	<5	○	521	37	○

[Table 2]

N o	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
6002	◎	○	122	<5	○	574	31	○
6003	◎	○	117	<5	△	501	32	○
6005	◎	○	121	<5	△	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	△	527	41	○
6012	◎	○	123	20	○	478	27	△
6013	◎	○	118	<5	○	506	30	○
6014	◎	○	118	<5	○	525	39	○
6015	○	○	114	<5	○	503	35	○
6017	◎	○	119	<5	△	507	30	○
6018	◎	○	121	<5	○	589	31	○
6020	◎	○	121	<5	△	504	43	○

[Table 2]

N o.	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
6021	⊙	○	118	<5	○	501	33	○
6022	⊙	○	120	<5	○	547	29	○
6023	○	○	119	<5	○	523	30	○
6024	⊙	○	120	<5	△	525	40	○
6025	⊙	○	120	<5	○	498	30	○
6026	○	○	114	<5	○	518	34	○
6027	⊙	○	119	<5	○	487	28	△
6028	⊙	○	118	<5	○	524	35	○
6029	⊙	○	122	<5	△	540	41	○
6032	⊙	○	120	<5	○	512	32	○
6033	⊙	○	123	<5	△	515	36	○
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	△
6040	○	○	116	<5	○	528	36	○

[Table 22]

N o	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
6041	◎	○	117	<5	○	496	30	○
6042	◎	○	120	<5	△	574	34	○
6043	◎	○	123	10	△	508	43	○
6044	◎	○	115	10	○	500	30	○
6047	◎	○	123	<5	○	557	25	○
6048	◎	○	120	<5	○	526	30	○
6050	◎	○	124	<5	○	480	31	○
6051	○	○	117	<5	○	534	32	○
6052	◎	○	123	<5	△	523	38	○
6053	◎	○	123	<5	○	508	39	○
6054	◎	○	115	<5	○	485	31	○
6055	◎	○	122	<5	△	512	44	○
6056	◎	○	120	<5	○	480	33	△
6057	◎	○	121	<5	○	479	25	△
6058	○	○	116	<5	○	525	34	○
6059	◎	○	119	20	○	482	35	○

[Table 23]

N o.	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
6062	◎	○	119	10	○	538	33	○
6063	◎	○	118	<5	○	504	37	○
6065	◎	○	123	<5	○	585	35	○
6066	◎	○	120	<5	○	501	25	○
6067	◎	○	119	<5	○	528	28	○
6068	◎	○	122	<5	○	502	30	○
6069	◎	○	124	<5	○	484	28	△
6070	○	○	115	<5	○	548	37	○
6071	◎	○	118	<5	○	530	34	○
6072	◎	○	119	<5	○	515	30	○
6073	◎	○	121	<5	△	579	35	○
6075	◎	○	117	<5	○	513	38	○
6077	○	○	119	<5	○	490	30	○
6078	◎	○	122	<5	△	513	40	○
6080	◎	○	123	<5	○	482	35	○

[Table 24]

N o.	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
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	○
6089	⊙	○	119	<5	○	514	39	○
6092	⊙	○	118	<5	○	532	30	○
6093	⊙	○	119	<5	○	539	34	○
6095	⊙	○	119	<5	○	507	30	○
6096	⊙	○	122	<5	○	508	22	○
6097	⊙	○	117	<5	○	510	31	○
6098	⊙	○	117	<5	○	527	32	○
6099	⊙	○	118	<5	○	529	34	○
6100	⊙	○	119	<5	○	515	32	○

[Table 25]

N o.	machinability			corrosion resistance	hot workability	mechanical properties		stress 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 (%)	corrosion cracking resistance
6101	○	○	115	<5	○	530	38	○
6102	⊙	○	118	<5	○	512	36	○
6103	⊙	○	119	<5	○	501	35	○
6104	⊙	○	117	<5	○	535	32	○

[Table 26]

N o	machinability			hot work- ability	mechanical properties	
	form of chipp- ings	conditi- on of cut surface	cutti- ng force (N)	700°C deformabi- lity	tensile strength (N/mm ²)	elongat- ion (%)
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	⊙	○	138	○	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 24]

N o	wear resistance weight loss by wear (mg/10000rot.)
14001a	500
14002a	620
14003a	520
14004a	450
14005a	25
14006a	600

Claims

1. A lead-free, free-cutting copper alloy which comprises 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 0.25 percent, by weight, of phosphorous and/or 0.02 to 0.15 percent, by weight, of antimony; optionally at least one element selected from among 0.3 to 3.5 percent, by weight, of tin, and 0.02 to 0.15 percent, by weight, of arsenic, and/or; optionally 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 and wherein the metal structure of the free cutting copper alloy at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.
2. A lead-free, free cutting copper alloy according to claim 1 wherein when cut on a circumferential surface by a lathe

provided with a point nose straight tool at a rake angle of -8 (minus 8) and at a cutting rate of 50m/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.

- 5 3. 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.
- 10 4. A method of forming a lead-free, 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 69 to 79 percent, by weight, of copper, 2.0 to 4.0 percent, by weight of silicon and 0.02 to 0.25 percent, by weight, of phosphorous and/or 0.02 to 0.15 percent, by weight, of antimony; optionally alloying least one element selected from tin and arsenic in an amount of 0.3 to 3.5 percent, by weight, of tin, and 0.02 to 0.15 percent, by weight, of arsenic and/or; optionally alloying at least one element selected from bismuth, tellurium and selenium in an amount of 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, 0.02 to 0.4 percent, by weight, of selenium and the remaining percent, by weight of zinc.
- 15 5. The method according to claim 4, wherein said silicon is provided as a Cu-Si alloy.
- 20 6. The method according to claim 4 or 5 wherein said lead-free, free cutting alloy is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.

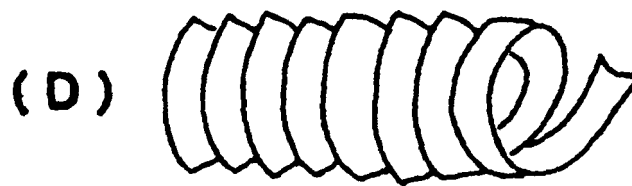
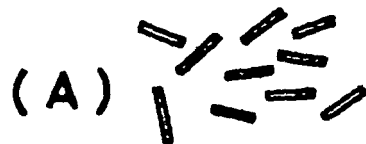
Patentansprüche

- 25 1. Bleifreie Automatenkupferlegierung, umfassend 69 bis 79 Gew.-% Kupfer; 2,0 bis 4,0 Gew.-% Silicium; wenigstens ein Element, das ausgewählt ist unter 0,02 bis 0,25 Gew.-% Phosphor und/oder 0,02 bis 0,15 Gew.-% Antimon; wahlweise wenigstens ein Element, das ausgewählt ist unter 0,3 bis 3,5 Ges.-% Zinn und 0,02 bis 0,15 Gew.-% Arsen; und/oder wahlweise wenigstens ein Element, das ausgewählt ist unter 0,02 bis 0,4 Gew.-% Wismut, 0,02 bis 0,4 Gew.-% Tellur und 0,02 bis 0,4 Gew.-% Selen, wobei die restlichen Gew.-% Zink sind, und wobei die
30 Metallstruktur der Automatenkupferlegierung mindestens eine Phase umfasst, die ausgewählt ist aus der χ -(Gamma) Phase und der κ -(Kappa)Phase.
- 35 2. Bleifreie Automatenkupferlegierung nach Anspruch 1, wobei beim Spanen auf einer umlaufenden Fläche mit einer Drehmaschine, die mit einem geraden Drehspitzmeißel mit einem Spanwinkel von -8 (minus 8) und einer Spanungsgeschwindigkeit von 50m/min, einer Spannungstiefe von 1,5mm und einer Vorschubgeschwindigkeit von 0,11mm/U versehen ist, Späne mit einer oder mehreren Formen entstehen, die ausgewählt sind aus der Gruppe bestehend aus einer Bogenform und einer feinen Nadelform.
- 40 3. Bleifreie Automatenkupferlegierung nach einem der vorhergehenden Ansprüche, die 30 Minuten bis 5 Stunden lang einer Wärmebehandlung bei 400 bis 600°C unterworfen wird.
- 45 4. Verfahren zur Herstellung einer bleifreien Automatenkupferlegierung mit einer metallischen Struktur, die wenigstens eine Phase aufweist, die ausgewählt ist aus der χ -(Gamma)Phase und der κ -(Kappa)Phase, umfassend das Legieren von Kupfer, Silicium und Zink in einer Menge von 69 bis 79 Gew.-% Kupfer; 2,0 bis 4,0 Gew.-% Silicium und 0,02 bis 0,25 Gew.-% Phosphor und/oder 0,02 bis 0,15 Gew.-% Antimon; wahlweise das Legieren wenigstens eines Elementes, das ausgewählt ist aus Zinn und Arsen in einer Menge von 0,3 bis 3,5 Gew.-% Zinn und 0,02 bis 0,15 Gew.-% Arsen; und/oder wahlweise das Legieren wenigstens eines Elementes, das ausgewählt ist aus Wismut, Tellur und Selen in einer Menge von 0,02 bis 0,4 Gew.-% Wismut, 0,02 bis 0,4 Gew.-% Tellur und 0,02 bis 0,4 Gew.-% Selen, wobei die restlichen Gew.-% Zink sind.
- 50 5. Verfahren nach Anspruch 4, wobei das Silicium als eine Cu-Si-Legierung bereitgestellt ist.
- 55 6. Verfahren nach Anspruch 4 oder 5, wobei die bleifreie Automatenkupferlegierung 30 Minuten bis 5 Stunden lang einer Wärmebehandlung bei 400 bis 600°C unterworfen wird.

Revendications

1. Alliage de cuivre de décolletage, sans plomb, qui comprend 69 à 79% en poids de cuivre ; 2,0 à 4,0% en poids de silicium ; au moins un élément sélectionné parmi 0,02 à 0,25% en poids de phosphore et/ou 0,02 à 0,15% en poids d'antimoine ; en option au moins un élément sélectionné parmi 0,3 à 3,5% en poids d'étain et 0,02 à 0,15% en poids d'arsenic et/ou en option au moins un élément sélectionné parmi 0,02 à 0,4% en poids de bismuth, 0,02 à 0,4% en poids de tellure et 0,02 à 0,4% en poids de sélénium, et le pour cent en poids restant de zinc, et où la structure métallique de l'alliage de cuivre de décolletage possède au moins une phase sélectionnée parmi la phase γ (gamma) et la phase κ (kappa).
2. Alliage de cuivre de décolletage sans plomb selon la revendication 1, où lors de la coupe sur une surface circonférentielle par un tour muni d'un outil rectiligne à nez pointé selon un angle de coupe de -8 (moins 8) et une vitesse de coupe de 50m/min, une profondeur de coupe de 1,5 mm, un débit d'amenée de 0,11 mm/tr produit des copeaux ayant une ou plusieurs formes sélectionnées dans le groupe consistant en une forme d'arc et une forme d'aiguille fine.
3. Alliage de cuivre de décolletage sans plomb selon l'une quelconque des revendications précédentes, qui est soumis à un traitement thermique pendant 30 minutes à 5 heures à 400 jusqu'à 600°C.
4. Procédé pour former un alliage de décolletage sans plomb ayant une structure métallique qui présente au moins une phase sélectionnée parmi la phase γ (gamma) et la phase κ (kappa) qui comprend l'alliage de cuivre, de silicium et de zinc en une quantité de 69 à 79% en poids de cuivre, 2,0 à 4,0% en poids de silicium et 0,02 à 0,25% en poids de phosphore et/ou 0,02 à 0,15% en poids d'antimoine ; allier en option au moins un élément sélectionné parmi l'étain et l'arsenic en une quantité de 0,3 à 3,5% en poids d'étain et de 0,02 à 0,15% en poids d'arsenic et/ou ; en option allier au moins un élément sélectionné parmi le bismuth, tellure et sélénium en une quantité de 0,02 à 0,4% en poids de bismuth, 0,02 à 0,4% en poids de tellure, 0,02 à 0,4% en poids de sélénium et le pour cent en poids restant de zinc.
5. Procédé selon la revendication 4, où ledit silicium est réalisé comme un alliage Cu-Si.
6. Procédé selon la revendication 4 ou 5, où ledit alliage de décolletage sans plomb est soumis à un traitement thermique pendant 30 minutes à 5 heures à 400 jusqu'à 600°C.

FIGURE 1



REFERENCES CITED IN THE DESCRIPTION

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