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Description

BACKGROUND OF THE INVENTION

1. Field of The Invention

[0001] The present invention relates to 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 so enhanced in machinability with the addition of 1.0 to 6.0 percent, by weight, of lead as to give industrially satisfactory results as easy-to-work copper alloy. 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] In those conventional free-cutting copper alloys, lead does not form a solid solution in the matrix but disperses in granular form, thereby improving the machinability of those alloys. To produce the desired results, lead has to be added in as much as 2.0 or more percent by weight. If the addition of lead is less than 1.0 percent by weight, chippings will be spiral in form as (D) in Fig. 1. Spiral chippings cause various troubles such as, for example, tangling with the tool. If, on the other hand, the content of lead is 1.0 or more percent by weight and not larger than 2.0 percent by weight, the cut surface will be rough, though that will produce some results such as reduction of the cutting resistance. It is usual, therefore, that lead is added in not smaller than 2.0 percent by weight. Some expanded copper alloys in which a high degree of cutting property is required are mixed with some 3.0 or more percent, by weight, of lead. Further, some bronze castings have a lead content of as much as some 5.0 percent, by weight. The alloy under the JIS H 5111 BC6, for example, contains some 5.0 percent, by weight, of lead.

[0004] However, the application of those lead-mixed alloys has been greatly limited in recent years, because lead contained therein is harmful to humans as an environment pollutant. That is, the lead-contained alloys pose a threat to human health and environmental hygiene because lead finds its way in metallic vapor that generates in the steps of processing those alloys at high temperatures such as melting and casting and there is also danger that lead contained in the water system metal fittings, valves and others made of those alloys will dissolve out into drinking water.

[0005] On that ground, the United States and other advanced nations 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

[0006] It is an object of the present invention to provide a free-cutting copper alloy which contains an extremely small amount (0.02 to 0.4 percent by weight) of lead as a machinability improving element, yet is quite excellent in machinability, can be used as safe substitute for the conventional easy-to-cut copper alloy with a large content of lead, and presents no environmental hygienic problems while permitting the recycling of chippings, thus providing a timely answer to the mounting call for restriction of lead-contained products.

[0007] It is an another object of the present invention to provide a free-cutting copper alloy which has a high corrosion resistance coupled with 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.

[0008] It is yet another object of the present invention to provide a free-cutting copper alloy with a high strength and wear resistance coupled with an easy-to-cut property 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.

[0009] It is a further object of the present invention to provide a free-cutting copper alloy with an excellent high-temperature oxidation resistance combined with an easy-to-cut property 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.

[0010] The objects of the present inventions are achieved by provision of the following copper alloy;

[0011] A 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; 0.02 to 0.4 percent, by weight, of lead; at least one 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; and optionally 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 wherein the metal structure comprises at least one phase selected from the γ (gamma) phase and the κ (Kappa) phase.

[0012] 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 the same 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 so as to bring about a high level of machinalbility meeting the industrial requirements, while making it possible to reduce greatly the lead content. That is, the alloy of the present invention is improved in machinability through formation of a gamma phase with the addition of silicon.

[0013] The addition of less that 1.8 percent, by weight, of silicon can not form a gamma phase sufficient enough 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 is high in melting point and low in specific gravity and also liable to oxidize. If silicon in a single form is fed into the furnace in the melting step, silicon will float on the molten metal and is oxidized into oxides of silicon or silicon oxide, hampering the production a silicon-contained copper alloy. In producing the ingot of silicon-contained 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 or plateau of machinability improvement - 4.0 percent by weight. 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 dezincing corrosion resistance will be improved to some extent.

[0014] The addition of lead is set at 0.02 to 0.4 percent by weight on this ground. In the alloy of the present invention, a sufficient level of machinability is obtained by adding silicon that has the aforesaid effect even if the addition of lead is reduced. Yet, lead has to be added in the amount not smaller than 0.02 percent by weight if the alloy is to be superior to the conventional free-cutting copper alloy in machinability, while the addition of lead exceeding 0.4 percent would have adverse effects, resulting in a rough surface condition, poor hot workability such as poor forging behaviour and low cold ductility. Meanwhile, it is expected that such a small content of not higher than 0.4 percent by weight will be able to clear the lead-related regulations however strictly they are to be stipulated in the advanced nations including Japan in the future. On that ground, the addition range of lead is set at 0.02 to 0.4 percent by weight in the alloy of the present invention.

[0015] Tin works the same way as silicon. That is, if tin is added, a gamma phase will be formed and the machinability of the Cu-Zn alloy will be improved. For example, the addition of tin in the 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 present. 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 the 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 the amount less than 1.0 percent by weight, on the other hand, an insufficient gamma phase will be formed. If the addition is 0.3 or more percent 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 the amount not smaller than 0.3 percent by weight improves the machinability.

[0016] Aluminum is, too, effective in facilitating the formation of the gamma phase. The addition of aluminum together with or in place of tin could further improve the machinability of the Cu-Si-Zn alloy. 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 the amount of 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 lower the ductility as is the case with tin.

[0017] 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 the 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.

[0018] In consideration of those observations, the alloy of the present invention is improved in machinability by adding to a Cu-Si-Pb-Zn alloy at least one 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 phosphorus.

[0019] 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.

[0020] The 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, adding of tin, aluminum or phosphorus together will silicon 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 alloy of the present invention. Also, in consideration of the addition amount of silicon and also the addition of tin, aluminum or phosphorus, the content range of copper in the alloy of the present invention is properly set out at 70 to 80 percent by weight.

[0021] Bismuth, tellurium and selenium as well as lead do not form a solid solution with the matrix but disperse in granular form to enhance the machinability. That makes up for the reduction of the lead content. The addition of any one of those elements along with silicon and lead could further improve the machinability beyond the level hoped from the addition of silicon and lead. From this finding, the alloy of the present invention is worked out in which one element selected from among bismuth, tellurium and selenium is mixed. The addition of bismuth, tellurium or selenium as well as silicon and lead could make the copper alloy so machinable that complicated forms could be freely cut out at a high speed. But no improvement in machinability can be realized from the addition of bismuth, tellurium or selenium in the 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 off 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 a problem similar to that of lead, a very small addition 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. In this regard, it is desired to keep the combined content of lead and bismuth, tellurium or selenium to not higher than 0.4 percent by weight. That is because if the combined content exceeds 0.4 percent by weight, if slightly, then there will begin a deterioration in hot workability and cold ductility and also there is fear that the form of chippings will change from (B) to (A) in Fig. 1. But the addition of bismuth, tellurium or selenium, which improves 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.

[0022] Tin is effective in improving not only the machinability but also corrosion resistance properties (dezincification 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.

[0023] To raise the corrosion resistance and forgeability, on the other hand, tin would have to be added in the 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 amount added of tin. It is no good economy.

[0024] 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 corrosion), forgeability, stress corrosion cracking resistance and mechanical strength.

[0025] 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 more than 0.25 percent by weight would not be so effective as hoped from the quantity added. Rather, that would reduce the hot forgeability and extrudability.

[0026] A free-cutting copper alloy also with further improved easy-to-cut feature obtained by subjecting any alloy of the present invention to a heat treatment for 30 minutes to 5 hours at 400 to 600˚C.

[0027] The alloy of the present invention contains machinability improving elements such as silicon and have an excellent machinability because of the addition of such elements. The effect of those machinability improving elements could be further enhanced by heat treatment. For example, the alloy of the present invention which is high in copper content with gamma phase in small quantities and kappa phase in large quantities 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.

[0028] Alloys with a low content of copper in particular 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.

[0029] But a heat treatment temperature at less than 400˚C is not economical and practical in any case, 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 EMBODIMENTS

Example 1

[0031] As the first series of examples of the present invention, cylindrical ingots with compositions given in Table 1, 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 test pieces of the alloy of the present invention Nos. 4001 to 4021.

[0032] As comparative examples, cylindrical ingots with the compositions as shown in Table 2, 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. 13001 to 13006 (hereinafter referred to as the "conventional alloys"). No. 13001 corresponds to the alloy "JIS C 3604", No. 13002 to the alloy "CDA C 36000", No. 13003 to the alloy "JIS C 3771" and No. 13004 to the alloy "CDA C 69800". No. 13005 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. 13006 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 alloys of the present invention 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 chippings, and cut surface condition. The tests were conducted this way: The extruded test pieces thus obtained were cut on the circumferential surface by a lathe provided 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. The signals were then converted into the cutting resistance. It is noted that while, to be perfectly exact, the 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 3 and 4.

[0034] 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 3 and 4. In this regard, the chippings 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. Chippings in the form of a spiral arc from one with a half winding to one with two windings as shown in (C), Fig. 1 do not cause such serous trouble as the chippings 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, chippings in the form of a fine needle as (A) in Fig. 1 or in the form of arc shaped pieces as (B) will not present such problems as mentioned above and are not bulky as the chippings in (C) and (D) and easy to process. But fine chippings as (A) still could creep in on the slide table 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, when judging machinability, the alloy with the chippings in (B) is the best, and the second best is the one with the chippings in (A). Those with the chippings in (C) and (D) are not good. In Tables 3 and 4, the alloys with the chippings shown in (B), (A), (C) and (D) are indicated by the symbols "●", "○", "Δ" and "x" respectively.

[0035] In addition, the surface condition of the cut metal surface was checked after cutting work. The results are shown in Tables 3 and 4. 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

3 and 4, the alloys with Rmax < 10 microns are marked "o"; those with 10 microns ≤ Rmax < 15 microns are indicated in "Δ" and those with Rmax ≥ 15 microns are represented by a symbol "x".

[0036] As is evident from the results of the cutting tests shown in Tables 3 and 4, the alloys of the present invention are all equal to the conventional lead-contained alloys Nos. 13001 to 13003 in machinability

[0037] Especially with regard to the form of chippings, alloys of the present invention are favorably compared not only with the conventional alloys Nos. 13004 to 13006 with a lead content of not higher than 0.1 percent by weight but also Nos. 13001 to 13003 which contain large quantities of lead.

[0038] It is understood that a proper heat treatment could further enhance the machinability of the alloys of the present invention .

[0039] In another series of tests, the alloys of the present invention 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 7000C, and then compressed at the compression rate of 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 were given in Tables 3 and 4. The evaluation of deformability was made by visually checking for cracks on the side of the test piece. In Tables 3 and 4, the test pieces with no cracks found are marked "o"; those with small cracks are indicated by "▲" and those with large cracks are represented by a symbol "x".

[0041] 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, %.

[0042] As the test results of the hot compression and tensile tests in Tables 3 and 4 indicate, it was confirmed that the alloys of the present invention are equal to or superior to the conventional alloys Nos. 13001 to 13004 and No. 13006 in hot workability and mechanical properties and are suitable for industrial use.

[0043] Furthermore, the alloy of the present invention as put to dezincification corrosion 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 dezincing corrosion test by the "ISO 6509" method, the test piece taken from each extruded test piece was imbedded laid in a phenolic resin material in such a way that the exposed test piece surface is perpendicular to the extrusion direction of the extruded test piece. The surface of the test piece was polished with emery paper No. 1200, and then ultrasonic-washed in pure water and dried. The test piece thus prepared was dipped in a 12.7 g/l aqueous solution of cupric chloride dihydrate ($CuCl_2.2N_2O$) 1.0% and left standing for 24 hours at 75˚C. The test piece was taken out of the aqueous solution and the maximum depth of dezincing corrosion was determined. The measurements of the maximum dezincification corrosion depth are given in Tables 3, and 4.

[0045] As is clear from the results of dezincification corrosion tests shown in Tables 3 and 4 the alloy of the present invention is excellent in corrosion resistance in comparison with the conventional alloys Nos. 13001 to 13003 which contain great amount of lead.

[0046] In the stress corrosion cracking tests in accordance with the test method described in "JIS H 3250", a 150-mm-long test piece was cut out from each extruded material. The test piece was bent with the center placed on an arc-shaped tester with a radius of 40 mm in such a way that one end forms an angle of 45 degrees with respect the other end. The test piece 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 piece was held some 80 mm above the surface of aqueous ammonia in the desiccator. After the test piece was left standing in the ammonia environment for 2 hours, 8 hours and 24 hours, the test piece 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 3 and 4. In those tables, the alloys which developed clear cracks when held in the ammonia environment for two hours are marked "xx." The test pieces which had no cracks at two hours but were found clearly cracked in 8 hours are indicated in "x." The test pieces which had no cracks in 8 hours, but were found clearly to have cracks in 28 hours are identified by the symbol "Δ". The test pieces which were found to have no cracks at all in 24 hours are given a symbol "o".

[0047] As is indicated by the results of the stress corrosion cracking test given in Tables 3 and 4 the alloy of the present invention is both equal to the conventional alloy No. 13005, an aluminum bronze containing no zinc, in stress corrosion cracking resistance. The alloy of the present invention was superior in stress corrosion cracking resistance to the conventional naval brass alloy No. 13006, the best in corrosion resistance of all the expanded copper alloys under the JIS designations.

Table 1

No.	alloy composition (wt%)									
	Cu	Si	Pb	Sn	Al	P	Bi	Te	Se	Zn
4001	73.8	2.8	0.04	0.5			0.10			remainder
4002	74.5	2.6	0.11		1.5		0.04			remainder
4003	73.7	2.1	0.21	1.2	2.2		0.03			remainder
4004	76.8	3.2	0.05			0.03	0.31			remainder
4005	74.1	2.6	0.07	1.4		0.04	0.09			remainder
4006	75.5	L9	0.32		3.2	0.15	0.16			remainder
4007	74.8	2.8	0.10	0.7	1.2	0.05	0.05			remainder
4008	70.5	L9	0.22	3.4				0.03		remainder
4009	79.1	2.7	0.15		3.4			0.05		remainder
4010	74.5	2.8	0.10			0.05		0.05		remainder
4011	77.3	3.3	0.07	0.4		0.21		0.31		remainder
4012	76.8	2.8	0.05		2.0	0.03		0.13		remainder
4013	74.5	2.6	0.18	1.4	2.1			0.21		remainder
4014	74.0	2.5	0.20	2.1	L1	0.10		0.07		remainder
4015	72.5	2.4	0.11	1.0					0.05	remainder
4016	76.1	2.5	0.07		2.3				0.10	remainder
4017	76.4	2.7	0.05	0.6	3.1				0.22	remainder
4018	74.0	2.5	0.23			0.22			0.03	remainder
4019	71.2	2.2	0.11	2.8		0.05			0.30	remainder
4020	75.3	2.7	0.22		1.4	0.03			0.05	remainder
4021	74.1	2.5	0.05	2.4	1.2	0.07			0.07	remainder

Table 2

No.	alloy composition (wt%)								
	Cu	Si	Pb	Sn	Al	Mn	Ni	Fe	Zn
13001 13001a	58.8		3.1	0.2				0.2	remainder
13002 13002a	61.4		3.0	0.2				0.2	remainder
13003 13003a	59.1		2.0	0.2				0.2	remainder
13004 13004a	69.2	1.2	0.1						remainder
13005 13005a	remainder				9.8	1.1	1.2	3.9	
13006 13006a	61.8		0.1	1.0					remainder

Table 3

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
4001	◎	○	119	70	○	535	30	○
4002	◎	○	116	120	○	547	33	○
4003	◎	○	118	60	Δ	539	26	○
4004	○	○	113	30	Δ	550	31	○
4005	◎	○	117	<5	○	534	27	○
4006	◎	○	118	<5	Δ	542	30	○
4007	○	○	116	<5	○	563	32	○
4008	◎	○	120	40	Δ	507	25	○
4009	◎	○	117	110	Δ	572	36	○
4010	◎	○	115	10	○	524	33	○
4011	◎	○	116	<5	Δ	580	31	○
4012	◎	○	114	20	○	515	34	○
4013	○	○	115	50	Δ	588	28	○
4014	◎	○	117	<5	○	543	26	○
4015	◎	○	117	60	○	501	27	○
4016	◎	○	116	130	Δ	539	32	○
4017	◎	○	118	50	○	574	34	○
4018	◎	○	115	<5	○	506	30	○
4019	◎	○	118	<5	○	523	28	○
4020	◎	○	115	20	Δ	548	32	○
4021	◎	○	118	<5	O	553	27	○

Table 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°C deformability	tensile strength (N/mm^2)	elongation (%)	corrosion cracking resistance	increase in weight by oxidation ($mg/10cm^3$)
13001	○	○	103	1100	Δ	408	37	××	1.8
13002	○	○	101	1000	×	387	39	××	1.7
13003	○	Δ	112	1050	○	414	38	××	1.7
13004	×	○	223	900	○	438	38	×	1.2
13005	×	○	178	350	Δ	735	28	○	0.2
13006	×	○	217	600	○	425	39	×	1.8

Claims

1. A free-cutting copper alloy which comprises 70 to 80 percent, by weight, of copper; 1.8 to 3.5 percent, by weight, of silicon; 0.02 to 0.4 percent, by weight, of lead; 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, the remaining percent, by weight, of zinc;
and optionally 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 wherein the metal structure comprises at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.

2. A free-cutting copper alloy as defined in claim 1; wherein when cut on the 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 1.5mm, 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 fine needle shape.

3. A free-cutting copper alloy as defined in claim 1 or 2 which is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600˚C.

Patentansprüche

1. Automatenlegierung auf Kupferbasis, die folgendes umfasst: 70 bis 80 Gewichtsprozent Kupfer; 1,8 bis 3,5 Gewichtsprozent Silizium; 0,02 bis 0,4 Gewichtsprozent Blei; mindestens ein Element, das gewählt wird unter 0,3 bis 3,5 Gewichtsprozent Zinn, 1,0 bis 3,5 Gewichtsprozent Aluminium und 0,02 bis 0,25 Gewichtsprozent Phosphor, die restlichen Gewichtsprozente als Zink;
sowie wahlweise ein Element, das gewählt wird unter 0,02 bis 0,4 Gewichtsprozent Wismut, 0,02 bis 0,4 Gewichtsprozent Tellur, und 0,02 bis 0,4 Gewichtsprozent Selen und wobei die Metallstruktur mindestens eine Phase umfasst, die unter der γ (Gamma)-Phase und der K (Kappa)-Phase gewählt ist.

2. Automatenlegierung auf Kupferbasis wie in Anspruch 1 definiert, die, wenn sie an Ihrer Umfangsfläche auf einer Drehbank, die einen geraden Drehstahl mit punktförmigem Arbeitsende aufweist, mit einem Spanwinkel von -8 (Minus 8) und bei einer Bearbeitungsgeschwindigkeit von 50 m/min, einer Bearbeitungstiefe von 1,5 mm, einer Zuführungsgeschwindigkeit von 0,11 mm/Umdrehung bearbeitet wird, Späne ergibt, die eine oder mehrere Formen haben, die gewählt sind aus der Gruppe, die aus einer Bogenform und einer feinen Nadelform besteht.

3. Automatenlegierung auf Kupferbasis wie in Anspruch 1 oder 2 definiert, die einer Wärmebehandlung von 30 Minuten bis 5 Stunden bei 400 bis 600 ˚C unterzogen wird.

Revendications

1. Alliage de décolletage à base de cuivre comprenant 70 à 80 pour cent, en poids, de cuivre; 1,8 à 3,5 pour cent, en poids, de silicium; 0,02 à 0,4 pour cent, en poids, de plomb; au moins un élément sélectionné parmi entre 0,3 et 3,5 pour cent, en poids, d'étain, 1,0 et 3,5 pour cent, en poids, d'aluminium, et 0,02 et 0,25 pour cent, en poids, de phosphore, le pourcentage en poids restant étant constitué de zinc;
et optionnellement un élément sélectionné parmi entre 0,02 et 0,4 pour cent, en poids, de bismuth, 0,02 et 0,4 pour cent, en poids, de tellure, et 0,02 et 0,4 pour cent, en poids, de sélénium, et dans lequel la structure métallique comprend au moins une phase sélectionnée parmi la phase γ (gamma) et la phase κ (kappa).

2. Alliage de décolletage à base de cuivre selon la revendication 1, dans lequel, lorsqu'il est coupé sur la surface circonférentielle par un tour pourvu d'un outil droit à nez pointu à un angle de coupe de -8 (moins 8) et une vitesse de coupe de 50 mètres par minute, une profondeur de coupe de 1,5 mm, une vitesse d'avance de 0,11 mm par tour, il donne des copeaux présentant une ou plusieurs forme(s) sélectionnée(s) dans le groupe comprenant une forme arquée et une forme d'aiguille fine.

3. Alliage de décolletage à base de cuivre selon la revendication 1 ou 2 soumis à un traitement thermique pendant une durée de 30 minutes à 5 heures à une température de 400˚C à 600˚C.

FIGURE 1

