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(54) **Free-cutting copper alloys**

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- **MANNHEIM R ET AL: "Silicon brass: an alternative for lead-free faucets and fittings" CAPLUS, 1997, XP002223301 & CONGRESSO ANUAL - ASSOCIACAO BRASILEIRA DE METALURGIA E MATERIAIS (1998), VOLUME DATE 1997, 52ND(II CONGRESSO INTERNACIONAL DE TECNOLOGIA METALURGICA E DE MATERIAIS), 5012-5032, 1997,**
- **PATENT ABSTRACTS OF JAPAN vol. 010, no. 321 (C-382), 31 October 1986 (1986-10-31) & JP 61 133357 A (SHOWA ALUM IND KK), 20 June 1986 (1986-06-20)**
- **"ASM Speciality Handbook: Copper and Copper Alloys" 2001, ASM INTERNATIONAL , OHIO, USA , XP002223300 * page 545; example C87800 ***

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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

[0006] The use of a modified form of the low-lead silicon-brass alloy C87800 for faucets and fittings is known from "Silicon-Brass : An alternative for lead-free faucets and fittings" - Wannheim et al. Annual Congress-Associaco Brasilia de Metalurgia & Materials (1997), 52nd (II congresso) 5012-5032.

SUMMARY OF THE INVENTION

[0007] 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 a 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.

[0008] It is 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.

[0009] 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.

[0010] 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.

[0011] The objects of the present inventions are achieved by provision of the following copper alloy:

1. A free-cutting copper alloy with an excellent easy-to-cut feature 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; 0.02 to 0.4 percent, by weight, of lead; 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 and wherein the metal structure of the free cutting copper alloy has at least one phase selected from the γ (gamma) and the κ (kappa) phase.

[0012] Manganese and nickel combine with silicon to form intermetallic compounds represented by Mn_xSi_y or Ni_xSi_y which are evenly precipitated in the matrix, thereby raising the wear resistance and strength. Therefore, the addition of manganese and nickel or either of the two would improve the high strength feature and wear resistance. Such effects will be exhibited if manganese and nickel are added in the amount of not less 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.

[0013] It is also noted that tin, aluminum and phosphorus help to reinforce the alpha phase in the matrix, thereby improving the machinability. Tin and phosphorus disperse the alpha and gamma phases, by which the strength, wear resistance and also machinability are improved. Tin in the 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 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 the amount of 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 pulverizes 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 amount 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 the property of manganese and nickel of combining with silicon.

[0014] 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 alloy of the present invention so as to bring about a high level of machinability 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.

[0015] The addition of less than 2.0 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 4.5 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.

[0016] 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 which will be described later.

[0017] 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. 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 35 percent, by weight, of tin. If tin exceeds 3.5 percent by weight, the ductility will drop instead. 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.

[0018] 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.

[0019] 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. The alloy of the present invention is thus improved in corrosion resistance by the property of tin and in machinability mainly by adding silicon. 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 35 percent by weight, the corrosion resistance and forgeability will not improve in proportion to the amount added of tin. It is no good economy.

[0020] While silicon is added to improve the machinability as mentioned above, it is also capable of improving the flow of molten metal like phosphorus. The effect of silicon in improving the flow of molten metal is exhibited when it is added in the amount of not smaller than 2.0 percent by weight. The range of the addition for the flow improvement overlaps that for improvement of the machinability.

[0021] A free-cutting copper alloy also with further improved easy-to-cut feature obtained by subjecting the alloy of the present invention to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.

[0022] The alloy of the present invention contain 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 are 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. The alloy of the present invention with a low content of copper in particular is 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.

[0023] 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

[0024]

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

[0025] As the first series of examples of the present invention, cylindrical ingots with compositions given in Tables 1

to 3, 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 piece alloys Nos. 7001 to 7029.

[0026] As comparative examples, cylindrical ingots with the compositions as shown in Table 4, 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.

[0027] 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 5 and 6.

[0028] 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 5 and 6. 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 serious 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 5 and 6, the alloys with the chippings shown in (B), (A), (C) and (D) are indicated by the symbols "◎", "○", "△" and "x" respectively.

[0029] In addition, the surface condition of the cut metal surface was checked after cutting work. The results are shown in Tables 5 and 6. In this regard, the commonly used basis for indication of the surface roughness is the maximum roughness (R_{max}). While requirements are different depending on the application field of brass articles, the alloys with R_{max} < 10 microns are generally considered excellent in machinability. The alloys with 10 microns ≤ R_{max} < 15 microns are judged as industrially acceptable while those with R_{max} ≥ 15 microns are taken as poor in machinability. In Tables 5 and 6, the alloys with R_{max} < 10 microns are marked "o"; those with 10 microns ≤ R_{max} < 15 microns are indicated in "△" and those with R_{max} ≥ 15 microns are represented by a symbol "x".

[0030] As is evident from the results of the cutting tests shown in Tables 5 and 6, the alloys of the present invention are all equal to the conventional lead-contained alloys Nos. 13001 to 13003 in machinability. It is understood that a proper heat treatment could further enhance the machinability of the alloys of the present invention.

[0031] In another series of tests, 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.

[0032] 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 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 5 and 6. The evaluation of deformability was made by visually checking for cracks on the side of the test piece. In Tables 5 and 6, 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".

[0033] 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, %.

[0034] As the test results of the hot compression and tensile tests in Tables 5 and 6 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. The alloy of the present invention in particular has the same level of mechanical properties as the conventional alloy No. 13005, i.e. 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.

Example 2

[0035] As the second series of examples of the present invention, circular cylindrical ingots with compositions given in Tables 1 to 3, 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 alloy Nos. 7001a to 7029a. In parallel, circular cylindrical ingots with compositions given in Table 4, 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. 13001a to 13006a as second comparative examples (hereinafter referred to as the "conventional alloys"). It is noted that the alloys Nos. 7001a to 7029a and Nos. 13001a to 13006a are identical in composition with the aforesaid copper alloys Nos. 7001 to 7029 and Nos. 13001 to No. 13006 respectively.

[0036] Alloy Nos. 7001a to 7029a were put to wear resistance tests in comparison with the conventional alloys Nos. 13001a to 13006a.

[0037] 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 ring-shaped 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 and clamped on a rotatable shaft, and a roll 48 mm in diameter placed in parallel with the axis of the shaft was thrust 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 against the roll were rotated at the same number of revolutions/minute -209 r.p.m., with multipurpose gear oil being dropping on 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 before and after 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 8 to 10.

[0038] As is clear from the wear resistance test results shown in Tables 8 to 10, the tests showed that those alloys Nos. 7001a to 7029a were excellent in wear resistance as compared with not only the conventional alloy Nos. 13001a to 13004a and 13006a but also No. 13005a, which is an aluminium bronze most excellent in wear resistance among expanded copper designated in JIS. From comprehensive considerations of the test results including the tensile test results, it may safely be said that the alloy of the present invention is excellent in machinability and also possess a high strength feature and wear resistance equal to or superior to 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	Pb	Sn	Al	P	Mn	Ni	Zn
7001	67.0	3.8	0.04	1.8			3.2		remainder
7001a									
7002	69.3	4.2	0.15	0.4				2.2	remainder
7002a									
7003	63.8	2.6	0.33	2.8			0.9		remainder
7003a									
7004	88.5	3.4	0.07	1.5			2.0		remainder
7004a									
7005	67.2	3.6	0.10	0.9			1.8	0.9	remainder
7005a									
7006	68.0	2.7	0.27	2.7	1.2		2.1		remainder
7006a									

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Table continued

No.	alloy composition (wt%)								
	Cu	Si	Pb	Sn	Al	P	Mn	Ni	Zn
7007	68.7	3.4	0.05	1.4	1.3		0.9		remainder
7007a									
7008	70.6	4.1	0.03	0.5	1.6		3.4		remainder
7008a									
7009	67.8	3.6	0.12	2.6	2.1			3.8	remainder
7009a									
7010	68.4	3.5	0.06	0.4	0.3			1.8	remainder
7010a									

[Table 2]

No.	alloy composition (wt%)								
	Cu	Si	Pb	Sn	Al	P	Mn	Ni	Zn
7011	73.9	4.4	0.17	1.2	11.7		0.8	1.5	remainder
7011a									
7012	65.5	2.9	0.20	1.5	1.0	0.12	2.3		remainder
7012a									
7013	65.1	3.3	0.08	1.8	1.1	0.03		2.6	remainder
7013a									
7014	70.3	3.9	0.15	1.0	1.4	0.21	1.8	1.2	remainder
7014a									
7015	66.8	3.7	0.20	2.6		0.14	2.7		remainder
7015a									
7016	69.0	4.0	0.07	0.5		0.20		3.2	remainder
7016a									
7017	64.5	2.9	0.19	1.8		0.05	1.5	0.8	remainder
7017a									
7018	72.4	3.5	0.08		1.5		1.1		remainder
7018a									
7019	69.2	3.9	0.03		0.4		3.1		remainder
7019a									
7020	76.6	4.3	0.14		2.3		1.9		remainder
7020a									

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[Table 3]

No.	alloy composition (wt%)								
	Cu	Si	Pb	Sn	Al	P	Mn	Ni	Zn
7021	75.0	4.2	019		1.7			2.1	remainder
7021a									
7022	72.3	3.7	005		1.4		1.1	0.8	remainder
7022a									
7023	64.5	3.8	035		0.3		2.0	2.3	remainder
7023a									
7024	75.8	3.9	005		2.7	004	1.0		remainder
7024a									
7025	70.1	3.5	0.06 0.06		1.2	0.23 0.23		3.0	remainder
7025a									
7026	67.2	2.8	022		1.8	014	2.2	0.9	remainder
7026a									
7027	70.2	3.8	011			003	3.2		remainder
7027a									
7028	75.9	4.4	003			020		1.1	remainder
7028a									
7029	66.0	3.0	018			012	1.0	2.1	remainder
7029a									

[Table 4]

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

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[Table 5]

No.	machinability			hot workability	mechanical properties	
	form of chipping	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ³)	elongation (%)
7001	⊙	○	132	○	755	17
7002	⊙	○	127	○	776	19
7003	⊙	△	135	○	620	15
7004	⊙	○	130	○	714	18
7005	⊙	○	128	○	708	19
7006	⊙	○	130	○	685	16
7007	⊙	○	132	○	717	18
7008	⊙	○	130	○	811	18
7009	⊙	○	130	○	790	15
7010	⊙	○	131	○	708	18
7011	⊙	○	128	○	810	17
7012	⊙	○	128	○	694	17
7013	⊙	○	132	○	742	16
7014	⊙	○	128	○	809	17
7015	⊙	○	129	○	725	15
7016	⊙	○	128	○	785	18
7017	⊙	○	130	○	684	16
7018	⊙	○	128	○	710	21
7019	⊙	○	128	○	746	20
7020	⊙	○	126	○	802	19

[Table 6]

No.	machinability			hot workability	mechanical properties	
	form condition of of chippings cut surface		cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
7021	⊙	○	126	○	792	19
7022	⊙	○	128	○	762	20
7023	⊙	○	129	○	725	17
7024	⊙	○	128	○	744	21
7025	⊙	○	130	○	750	20
7028	△	○	132	○	671	28
7027	⊙	○	128	○	740	23
7028	⊙	○	133	○	763	22
7029	△	○	129	○	647	24

【 Table 7 】

No.	machinability			corrosion resistance	hot workability	mechanical properties		stress resistance	high-temperature oxidation
	form of chip- lings	condition of cut surface	cutting force (N)			tensile strength (N/mm ²)	elongat- ion (%)		
13001	○	○	108	1100	△	408	37	××	1.8
13002	○	○	101	1000	×	387	39	××	1.7
13003	○	△	112	1050	○	414	38	××	1.7
13004	×	○	223	900	○	488	38	×	1.2
13005	×	○	178	350	△	785	28	○	0.2
13006	×	○	217	600	○	425	39	×	1.8

[Table 8]

No.	wear resistance
	weight loss by wear (mg/100000rot.)
7001a	0.7
7002a	1.4

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Table continued

No.	wear resistance
	weight loss by wear (mg/100000rot.)
7003a	2.0
7004a	1.4
7005a	1.2
7006a	1.8
7007a	2.3
7008a	0.7
7009a	0.6
7010a	1.3
7011a	0.8
7012a	1.7
7013a	1.1
7014a	0.8
7015a	1.1
7016a	1.0
7017a	1.6
7018a	1.9
7019a	1.1
7020a	1.4

[Table 9]

No.	wear resistance
	weight loss by wear (mg/100000rot.)
7021a	1.5
7022a	1.4
7023a	0.9
7024a	2.0
7025a	1.2
7026a	1.2
7027a	1.1
7028a	2.1
7029a	1.5

[Table 10]

No.	wear resistance
	weight loss by wear (mg/100000rot.)
13001a	500

Table continued

No.	wear resistance
	weight loss by wear (mg/100000rot.)
13002a	620
13003a	520
13004a	450
13005a	25
13006a	600

Claims

1. A free-cutting copper alloy which comprises 62 to 78 percent, by weight, of copper; 2.5 to 4.5 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 3.0 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 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 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 50 m/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 3 minutes to 5 hours at 400 to 600°C.

Patentansprüche

1. Automatenkupferlegierung, umfassend 62 bis 78 Gewichtsprozent Kupfer; 2,5 bis 4,5 Gewichtsprozent Silicium; 0,02 bis 0,4 Gewichtsprozent Blei; mindestens ein Element ausgewählt aus 0,3 bis 3,0 Gewichtsprozent Zinn, 0,2 bis 2,5 Gewichtsprozent Aluminium und 0,02 bis 0,25 Gewichtsprozent Phosphor; sowie mindestens ein Element ausgewählt aus 0,7 bis 3,5 Gewichtsprozent Mangan und 0,7 bis 3,5 Gewichtsprozent Nickel; und die übrigen Gewichtsprozent Zink, und wobei die Metallstruktur der Automatenkupferlegierung mindestens eine Phase ausgewählt aus der γ (Gamma-)Phase und der κ (Kappa-)Phase hat.
2. Automatenkupferlegierung nach Anspruch 1, die, wenn sie in einer Drehbank mit spitz zulaufendem, geradem Drehmeißel an der Umfangsfläche mit einem Spanwinkel von -8 (minus 8) und einer Schneidgeschwindigkeit von 50 m/min, einer Schneidetiefe von 1,5 mm und einer Vorschubgeschwindigkeit von 0,11 mm/rev. geschnitten wird, Späne abgibt, welche eine oder mehrere Formen aufweisen ausgewählt aus einer Gruppe bestehend aus einer Bogenform und einer feinen Nadelform.
3. Automatenkupferlegierung nach Anspruch 1 oder 2, die 30 Minuten bis 5 Stunden lang einer Hitzebehandlung bei 400 bis 600 °C unterzogen wird.

Revendications

1. Alliage de décolletage à base de cuivre qui comprend 62 à 78 pour cent, en poids, de cuivre ; 2,5 à 4,5 pour cent, en poids, de silicium ; 0,02 à 0,4 pour cent, en poids, de plomb ; au moins un élément choisi parmi 0,3 à 3,0 pour cent, en poids, d'étain, 0,2 à 2,5 pour cent, en poids, d'aluminium, et 0,02 à 0,25 pour cent, en poids, de phosphore ; et au moins un élément choisi parmi 0,7 à 3,5 pour cent, en poids, de manganèse, et 0,7 à 3,5 pour cent, en poids, de nickel ; et le pourcentage restant, en poids, de zinc et dans lequel la structure métallique de l'alliage de décolletage

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à base de cuivre a au moins une phase choisie 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 circonferentielle avec un tour équipé d'un outil droit à pointe à un angle de coupe de -8 (moins 8) et à une vitesse de coupe de 50 mètres par minute, une profondeur de coupe de 1,5 mm, une avancée de 0,11 mm/tour donne des copeaux ayant une ou plusieurs formes choisies parmi le groupe consistant en une forme en arc et une forme en aiguille fine.
3. Alliage de décolletage à base de cuivre selon la revendication 1 ou 2, qui est soumis à un traitement thermique pendant 30 minutes à 5 heures à 400 à 600°C.

FIGURE 1

