

- [54] **COPPER BASE ALLOY**
[75] Inventors: **Kunio Kitazawa, Takada; Tatsuichi Fukusako**, Tokyo, both of Japan
[73] Assignee: **Toyo Valve Co., Ltd.**, Tokyo, Japan
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Primary Examiner—C. Lovell
Attorney, Agent, or Firm—Toren, McGeady and Stanger

[57] **ABSTRACT**

In essence, this invention relates to a copper base alloy comprising 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 2.5 – 10 percent by weight of Al, the balance being copper and ordinary impurities. According to this invention, there are provided a high strength copper base alloy excellent in corrosion resistance and machinability, an iron-containing, high strength copper base alloy excellent in corrosion resistance and machinability, an aluminum-containing copper base alloy excellent in corrosion resistance and machinability, and a tough copper base alloy excellent in impact resistance and machinability, by changing the aluminum content in said basic alloy, adding Fe in an amount ranging from 0.1 to 5 percent by weight to said basic alloy, or adding up to 5 percent by weight of Ni, up to 3 percent by weight of Mn and up to 0.1 percent by weight of Be to said basic alloy.

8 Claims, No Drawings

COPPER BASE ALLOY

This is a continuation of application Ser. No. 277,750, filed Aug. 3, 1972 now abandoned.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to a high strength copper base alloy excellent in corrosion resistance and machinability, which comprises as the main ingredients copper and aluminum, and contained therein, tin, zinc, nickel, manganese, beryllium and iron, and to a process for the manufacture of the same.

Cast products of conventional copper base alloys are generally superior to cast products of other metals and alloys, especially ferrous cast products, in respect of electric conductivity, thermal conductivity, dimagnetic property, freedom from cold brittleness, corrosion resistance, color and luster, abrasion resistance, machinability, etc. Especially, a bronze cast product exhibits high abrasion resistance, high corrosion resistance and excellent machinability, and therefore, this alloy is the most suitable for bearings, bushes, sleeves, pump trunks, blade wheels, injectors, attachments for railway uses, parts for meters, valves and cocks for low and medium pressure uses.

However, such alloys cannot be used as valves and cocks for high pressure uses because their mechanical properties, such as, tensile strength, are not good and they are inferior in proof stress, hardness, heat resistance, etc.

On the other hand, an aluminum bronze which is excellent in corrosion resistance, tensile strength, proof stress and hardness is the toughest alloy among casting copper alloys, but this alloy is defective in that it is difficult to produce a cast product of a complicated configuration therefrom and its machinability is especially bad.

A primary object of this invention is to provide a copper base alloy highly improved in tensile strength, proof stress, impact resistance, hardness, corrosion resistance, machinability, abrasion resistance and heat resistance by alloying aluminum into a conventional bronze.

It has heretofore been considered that in bronzes, aluminum is an impurity and the presence of aluminum damages the soundness of such bronze. In particular, the tensile strength of about 23 Kg/mm² observed with the addition of 0.005 percent by weight of aluminum is reduced to about 18.5 Kg/mm² when the aluminum content is increased to 0.1 percent by weight. Further, the elongation of about 25 percent by weight observed with the addition of 0.005 percent of aluminum is reduced to about 15 percent when the aluminum content is increased to 0.1 percent by weight. Moreover, the pressure loss of 0.7 ml/sec observed with the addition of 0.005 percent by weight of aluminum is increased to 21 ml/sec when the aluminum content is increased to 0.1 percent by weight.

With increase of the aluminum content, these properties are degraded, and the pressure tightness severely deteriorates. Therefore, in practice, the aluminum content is reduced to below 0.005 percent by weight in such alloys.

In this invention, the above-mentioned defects of conventional copper base alloys are overcome by using

Further, an aluminum-containing copper base alloy improved especially in tensile strength is provided by

addition of aluminum in an amount of 8 to 10 percent by weight.

Still further, as a result of various tests made on copper base alloys comprising aluminum in an amount varying from 5 to 8 percent by weight, it has been found that there can be provided a copper base alloy having a very high impact resistance by containing 1 to 5 percent by weight of aluminum.

A secondary object of this invention is to provide a corrosion-resistant copper base alloy having excellent color and luster.

The alloy of this invention, when cast, exhibits a beautiful casting skin composed of a tough oxide film of a copper-brown color which is due to the presence of aluminum, and when subjected to the post-treatment, the color of the oxide film is changed into a dark red color or other various colors.

Further, the alloy of this invention is characterized in that the cut surface is highly resistant against atmospheric corrosion as compared with brass, bronze, cupro-nickel and cupro-aluminum.

A third object of this invention is to provide a copper base alloy which is readily ductile by hot working, warm working and cold working. Namely, this invention provides a copper base alloy excellent in not only ductility but also castability.

A fourth object of this invention is to provide a copper base alloy which is highly improved in tensile strength and hardness by containing 2 to 5 percent by weight of Fe.

Other objects and advantages of this invention will be apparent from the description given hereinbelow.

Reasons for limitations of contents of ingredients given in this invention will now be explained.

0.1 TO 5 PERCENT BY WEIGHT OF Sn

One of characteristic features of the alloy of this invention resides in the Sn content. At Sn contents below 0.1 percent, the elongation is high, but the proof stress is low. When the Sn content exceeds 2 percent by weight, especially 5 percent by weight, the reduction of elongation is extreme and the resulting alloy is hard and brittle. On the other hand, tin exhibits effects of improving the corrosion resistance and preventing dezincification and dealuminification. Thus, tin is added in an amount ranging from 0.1 to 5 percent by weight. It is especially preferred that the Sn content is adjusted to 0.1 - 1 percent by weight when high tensile strength, high elongation and high impact resistance are desired and that the Sn content is adjusted to 1 - 5 percent by weight when high hardness is required.

0.1 TO 5 PERCENT BY WEIGHT OF Zn

Mechanical properties, castability, machinability and other processing properties can be improved by addition of a suitable amount of zinc. However, when zinc is contained in an amount not exceeding 0.1 percent by weight, castability is insufficient, and when zinc is contained in too great an amount, the corrosion resistance is reduced and dezincification tends to occur. Therefore, it is desired that the zinc content is controlled to up to 5 percent by weight, especially within a range of from 0.1 to 2.5 percent by weight. Further it is preferred that the Zn content is adjusted to 0.1 - 1.5 percent by weight when high tensile strength, high elongation are desired, and that the Zn content is adjusted to 1.5 - 4 percent by weight when high hardness is demanded.

0.1 TO 5 PERCENT BY WEIGHT OF Pb

When Pb is contained in suitable amounts, lead improves the machinability and pressure tightness. At Pb contents below 0.1 percent by weight, sufficient machinability and pressure tightness cannot be obtained, and at Pb contents exceeding 5 percent by weight, reduction of tensile strength, elongation and impact resistance is observed. When the alloy is used as a ductile metal, it is preferred that the Pb content is within a range of from 0.1 to 2 percent by weight.

2.5 TO 5 PERCENT BY WEIGHT, 5 TO 8 PERCENT BY WEIGHT AND 8 TO 10 PERCENT BY WEIGHT OF Al

One of characteristic features of the alloy of this invention resides in the aluminum content as well as the tin content. Aluminum has the effect of improving the ductility at high temperatures, tensile strength, elastic limit and corrosion resistance. At Al contents below 5 percent by weight, effects of improving mechanical properties such as tensile strength, proof stress are not so remarkable, but elongation and impact resistance are improved, and at Al contents exceeding 8 percent by weight, the tensile strength and proof stress are improved. Therefore, if improvements in the tensile strength, impact resistance, proof stress and hardness are especially desired, aluminum contents exceeding 8 percent by weight exhibit greater improvements than with aluminum contents 5 - 8 percent. If aluminum is present in an amount exceeding 10 percent by weight, the improving effects are not as significant.

UP TO 5 PERCENT BY WEIGHT OF Ni

Nickel improves mechanical properties. More specifically, in case nickel is contained in an amount of up to 5 percent by weight the tensile strength is heightened and at the same time, elongation, toughness and corrosion resistance are improved. When nickel is contained in an amount exceeding 5 percent by weight, increase of these effects is not so great and the cost of the alloy is made high. Thus, it is preferred that nickel is contained in an amount of up to 5 percent by weight. In case room temperature rolling is conducted, it is preferred that nickel is contained in an amount of up to 3 percent by weight.

UP TO 3 PERCENT BY WEIGHT OF Mn

Manganese acts as a deoxidant and gives a cast product of a minute and elaborate structure. When Mn is contained in an amount of 3 percent by weight, tensile strength, impact resistance and abrasion resistance are heightened. At Mn contents exceeding 3 percent by weight, however, no improvement of the toughness is observed and the dross is readily formed during casting step. Therefore, it is preferred that the Mn content is adjusted to up to 3 percent by weight.

0.1 TO 5 PERCENT BY WEIGHT OF Fe

Iron exhibits the effect of improving castability and grain refining, but at Fe contents below 0.1 percent by weight, these improving effects are very low. In case iron is contained in an amount greater than 2 percent by weight, especially the tensile strength and hardness are highly improved as compared with the case where iron is contained in an amount of up to 2 percent by weight. At Fe contents exceeding 5 percent by weight, reduction of the tensile strength and ductility is ob-

served, and hard spots are sometimes formed as a result of the combination of Fe with Al or Sn, thus causing an undesired reduction of machinability. Furthermore, Fe contents 2.5 - 5 percent are preferable to improve effects of refining grains.

UP TO 0.1 BY WEIGHT OF Be

Beryllium is an effective deoxidant and is included for stabilizing each ingredient of the alloy and making the structure of the alloy homogeneous. Further, the amount of aluminum oxide is reduced by addition of Be, and as a result, the fluidity property of the alloy in the molten state is improved. However, too high a Be content is economically disadvantageous because the increase in such improvements is not as great. Thus, it is preferred that beryllium is added in an amount of up to 0.1 percent by weight.

The alloy of this invention can be attained by combining copper with the above-mentioned elements suitably within the above ranges, and as a result, there can be obtained an alloy possessions excellent tensile strength, impact resistance, hardness, corrosion resistance, machinability, abrasion resistance and heat resistance.

Another important feature of this invention resides in a process for the production of such alloy. More specifically, this invention provides a process for the production of copper base alloys comprising adding the above-mentioned ingredient elements and melting them to form a molten metal composition comprising the ingredients within the above-mentioned ranges, blowing an inert gas such as N₂ gas and Ar gas into the molten metal and thus effecting the degassing treatment and the alloy grain-refining treatment. During this process, readily oxidizing metals such as Al, Zn and Mn are prevented from being converted into oxides by the selective oxidation of Be, and the formation of such oxides are inhibited and stabilization of the ingredients can be accomplished.

The conditions for the degassing treatment should be selected so that removal of dissolved hydrogen gas, floating and removal of suspended oxides, and dispersion and refining of alloy grains can be sufficiently accomplished. In view of the foregoing, the temperature of the molten metal, the treatment time, the blowing method and other conditions are suitably chosen. This treatment may be conducted once or repeated several times during the melting step.

As impurities that may be contained in the alloy of this invention, there may be mentioned phosphorus, sulfur, chromium, magnesium, etc. The alloy of this invention may further comprise silicon, silver, arsenic, indium, etc. as minor alloying elements which do not alter the characteristics of the alloy. However, in the alloy of this invention, the total content of these impurities and minor alloying elements is maintained at a level not exceeding 1 percent by weight.

Uses of the alloy of this invention are summarized below.

1. Articles, machines and parts, of which pressure tightness, abrasion resistance, corrosion resistance, erosion resistance, mechanical strength and machinability are required, and those, of which strength, corrosion resistance, erosion resistance, acid resistance and abrasion resistance are required, such as bearings (for bridge parts, machine tools, electrical instruments, pump propeller shafts, ships, transportation facilities, etc.), pump bodies, bushes, sleeves, blade wheels,

valves (high temperature valves, high pressure valves, heat-resistant valves, low temperature valves, erosion-resistant valves, sea water-resistant valves, acid-resistant valves, water steam-resistant valves and moisture-resistant valves), valve parts (bodies, bonnets, stems, discs, body rings and sheets rings), cocks, railway parts, ship parts, flanges, liners, pistons, machine parts, engine parts, carburetor, oil rings, meter parts, joints, parts for the ocean development, parts of machines for preventing public pollution, parts of water-supply facilities, draining facilities and sanitary equipments, parts of freezers and air-conditioning machines, vessels for high pressure gas, parts for atomic power plants, condensing tubes for heat exchangers, water cooling parts of heat exchangers, automobile parts, gears, valve seats, worm gears, machine parts for the chemical industries where acid resistance and sea water resistance are required, bearing cages and friction parts of thrusts, etc.

2. Articles, machines and parts, of which castability, processability, machinability and resistance against atmospheric corrosion are required, such as general tools, construction tools, parts of water-supply facilities, draining facilities and sanitary equipments, decoration parts, name plates, and parts of machines for preventing public pollution, etc.

3. Ductile metal such as rods, plates, pipes and ordinary decoration materials, etc.

4. Materials for forging (including the melt forging).

Functions and effects of the alloy of this invention will now be explained more specifically by reference to examples.

Alloys shown in examples are prepared, for instance, by the following method. After a melting furnace and a melting vessel have been heated sufficiently, preheated return scrap and ingot of copper are charged. After the charge has been made completely molten, zinc (brass scrap), copper-tin alloy ingot and lead ingot are added to the melt. The heating is continued to attain the melt temperature of 1,250°C. Then, nickel ingot (nickel-copper alloy ingot), manganese ingot (manganese-copper alloy), aluminum ingot (aluminum-copper alloy) and berylliumcopper alloy ingot are added to the melt, and the melt is stirred gently. Immediately, dried inert gas is blown into the melt for 3 – 10 minutes to such an extent that the surface of the melt is not so disturbed, thereby to effect the degassing treatment. This treatment is carried out as deliberately and sufficiently as possible. Immediately after completion of the degassing treatment, the molten metal is cast into the chill block test piece for quality control, and the spontaneously solidified surface and the fracture surface are examined. When the draw is observed in the spontaneously solidified surface and the fracture surface has a minute and fine structure, the melt is regarded as having good quality and is cast into a prepared mold.

Nextly, examples are shown, but example 1 – example 9 are corresponding to the following copper base alloy (1) – (5), especially (6) (7) (8).

1. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 2.5 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

2. A high strength, iron-containing, copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 –

5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb, 2.5 – 10 percent by weight of Al and 0.1 – 5 percent by weight of Fe, the balance being Cu and ordinary impurities.

3. An alloy set forth in (1), which further comprises at least one of Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of by weight, with or without addition of 0.1 – 5 percent by weight of Fe.

4. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 3 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

5. An alloy set forth in (4), which further comprises at least one of Fe in an amount of 0.1 – 5 percent by weight, Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight.

6. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 4 percent weight of Sn, 0.1 – 4 percent by weight of Zn, 0.1 – 4 percent by weight of Pb and 5 – 8 percent by weight of Al, the balance being Cu and ordinary impurities.

7. A high strength, iron-containing, copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 4 percent by weight of Sn, 0.1 – 4 percent by weight of Zn, 0.1 – 4 percent by weight of Pb, 5 – 8 percent by weight of Al and 0.1 – 5 percent by weight of Fe, the balance being Cu and ordinary impurities.

8. An alloy set forth in (6), which further comprises at least one of Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight, with or without addition of 0.1 – 5 percent by weight of Fe.

EXAMPLE 1

Table 1 illustrates data of the chemical composition, tensile strength, elongation and hardness of examples of the alloy of this invention.

In each sample, the casting was effected at 1,150° – 1,200°C. and JIS (Japanese Industrial Standard) A test specimens (Y block) were formed (in the case of samples Nos. 18 – 20 JIS B test specimens were formed), JIS No. 4 tension test pieces were processed from such cast specimens and their properties were examined.

In samples Nos. 1, 2, 3, 4 and 5, the influence by change in the Sn content was examined. In sample No. 1 the Sn content is lower (almost trace) than in the alloy of this invention. Samples Nos. 2, 3 and 4 are those of alloys according to Example 1. In sample No. 5, the Pb content is higher than in the alloy of Example 1.

The Sn content (percent by weight) is one of great factors determining the tensile strength and elongation in the alloy of this invention.

In samples Nos. 6, 7 and 8 the change in the Zn content was examined, and in samples Nos. 9, 10 and 11 the change in the Pb content was examined.

In each of the above samples, a great difference of the tensile strength is not observed, but it is seen that when either the Zn content or the Pb content is outside the range specified in Example 1, the elongation is reduced.

Table 1

Sample No.	Chemical Composition (% by weight)									Tensile strength (Kg/mm ²)	Mechanical Properties		Remarks
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	impurities		Elongation (%)	Hardness (HB)	
1	88.0	0	2.0	4.0	5.6	0	0	0	0.40	28.3	44	90	Comparison
2	88.0	0.1	2.0	4.0	5.6	0	0	0	0.30	29.5	40	90	Example
3	87.0	1.5	2.0	3.9	5.5	0	0	0	0.10	29.5	20	110	Example
4	86.1	2.0	1.6	3.9	6.2	0	0	0	0.20	31.0	12	104	Example
5	81.7	3.9	4.0	4.4	5.5	0	0	0	0.50	29.5	4	121	Comparison
6	86.8	2.1	0.1	4.4	6.3	0	0	0	0.10	31.3	13	110	Comparison
7	86.6	1.7	2.0	3.5	6.0	0	0	0	0.20	33.2	21	—	Example
8	82.1	2.0	4.1	4.2	7.3	0	0	0	0.30	30.0	8	114	Comparison
9	85.8	2.2	4.3	1.6	6.1	0	0	0	0.30	30.5	8	110	Comparison
10	86.5	1.7	2.0	3.5	6.1	0	0	0	0.20	36.5	23	110	Example
11	85.5	1.7	1.6	4.2	6.9	0	0	0	0.10	31.0	14	110	Comparison
12	83.3	3.9	4.5	4.8	2.6	0	0	0	0.90	15.3	3	—	Comparison
13	85.9	1.8	1.8	3.8	6.4	0	0	0	0.30	34.3	20	114	Example
14	84.2	1.8	1.8	3.6	8.5	0	0	0	0.10	32.5	3	138	Comparison
15	84.9	1.7	1.5	3.9	6.6	1.3	0	0	0.10	31.3	26	104	Example
16	85.3	1.5	1.9	3.9	6.3	0	0.9	0	0.20	31.8	24	104	Example
17	82.0	1.6	1.6	3.5	7.9	2.4	0.8	0	0.20	34.0	26	110	Example
18	86.0	1.7	1.7	3.7	6.4	0	0	0	0.50	33.8	18	125	Example
19	85.1	1.7	1.7	3.6	6.0	0.7	0.8	0.3	0.10	41.6	30	117	Example
20	83.8	1.6	1.6	3.5	6.5	1.5	0.9	0.5	0.10	38.3	30	110	Example

In samples Nos. 12, 13 and 14 the influence by change in the aluminum content was examined. In sample No.12, the aluminum content is lower than the range specified in Example 1 (the Zn and Pb contents are higher); therefore, the tensile strength and elongation are low. In sample No.14, the tensile strength is high, but the elongation is low. The aluminum content (percent by weight) is one of the important factors determining the tensile strength and elongation of the alloy of this invention.

Effects attained by addition of Ni and Mn were examined in samples Nos. 15, 16 and 17. In each sample, high tensile strength and high elongation are obtained. Especially with respect to the elongation, good results are obtained constantly.

Results of samples Nos. 18, 19 and 20 are those of JIS-B test specimens. From these results, it is seen that in JIS-B test specimens higher tensile strength and higher elongation can be more consistently obtained than in JIS-A test specimens.

EXAMPLE 2A

JIS A test specimens were cast at about 1,150°C. from alloys according to Example 2 and alloys according to JIS BC 6, and JIS No.4 tension test pieces were prepared therefrom. Mechanical properties of these pieces are shown in Table 2.

From the results, it is seen that alloys of Example 2 have higher tensile strength and higher hardness than comparative alloys. More specifically, the tensile strength of the alloys of this invention is higher by about 30 percent than that of the comparative

alloys and the hardness of the alloys of this invention is higher by about 40 percent than that of the comparative alloys. Further, the proof stress of the alloys of this invention is higher by about 75 percent than that of the comparative alloys.

EXAMPLE 2B

Table 3

Temperature	Charpy Impact Value Alloy of Example 2	Alloy according to JIS BC 6
-75°C.	2.8 - 3.2	2.3 - 2.5
20°C.	3.0 - 3.5	2.4 - 2.7
100°C.	3.2 - 3.5	2.4 - 2.7
200°C.	3.2 - 3.5	2.0 - 2.2
300°C.	2.8 - 3.2	1.0 - 1.3

Table 3 shows results of Charpy impact tests made on JIS No.3 impact test pieces with U-notches from the alloy of Example 2 and the alloy according to JIS BC 6.

As compared with the alloy corresponding to JIS BC 6 in which the impact value is greatly lowered at temperatures exceeding 200°C., the alloy of Example 2 is excellent in that a reduction in the impact value is not observed at temperatures of up to 300°C. At temperatures exceeding 200°C., the impact value of the alloy of Example 2 is higher by about 60 percent than that of the alloy according to JIS BC 6, and at 300°C. the impact value of the alloy of this invention is higher by about 150 percent than that of the JIS BC 6 alloy. Thus, it is seen that the alloy of this invention exhibits high and stable mechanical properties at high temperatures.

EXAMPLE 3

Table 2

Sample	Chemical Composition (% by weight)									Mechanical Properties			
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	impurities	Tensile strength (Kg/mm ²)	Elongation (%)	Hardness (HB)	Proof Stress (Kg/mm ²)
Alloys of Example 2	86.5	1.7	2.0	3.5	6.1	0	0	0	0.20	36.5	23	110	21.1
	82.0	1.6	1.6	3.5	7.9	2.4	0.8	0	0.20	34.0	26	110	20.9
Alloys according to JIS BC 6	84.3	4.4	5.2	5.6	—	0.4	—	0	0.10	26.5	28	74	12.2
	84.0	4.7	5.1	5.7	—	0	—	0	0.50	25.8	22	75	11.5

Table 4

		Chemical Composition (% by weight)							Relative value of Machinability
		Cu	Sn	Zn	Pb	Ni	Al	Others	
1st group	leaded bronze	85	5	5	5				90
		81	3	9	7				90
		81	3	15	6				90
	leaded bronze	70	5		25				90
		80	10		10				80
		78	7		15				80
	brass	71	1	25	3				80
		67	1	29	3				80
	free cutting brass rod	61.5		35.5	3				100
	tin	88	6	4	2				60
2nd group	bronze	88	10	2					50
		88	8	4					50
	brass	61	0.75	35.5	0.75				60
3rd group	high strength brass	64		balance			7.5	3(Fe)	20
	aluminum	89					10	1(Fe)	35
	bronze	85					11	4(Fe)	20
4th group	alloy of Example 3	85.5	1.5	1.5	3.5	1	7		90

Table 4 illustrates relative values of machinability of casting and ductile metal of various copper alloys, each relative value being calculated based on the value of free-cutting brass rod as 100.

Higher contents of lead give a better machinability, and aluminum bronze and high strength brass, each of which contains aluminum are inferior in machinability. In contrast, even if the alloy of Example 3 contains aluminum, since it also contains lead, it exhibits an excellent machinability comparable to that of the JIS BC 6 alloy.

EXAMPLE 4

Table 5

pH value	Weight decrease by corrosion (mg/cm ² /month)		
	Alloy of Example 4	JIS BC 6 alloy	BSBF2 alloy
2	8.19	15.07	6.98*
4	0.96	0.98	0.93
6	0.16	0.13	0.07
9	0.08	0.07	0.07
11	8.49	14.12	12.22
12	11.12	21.94	12.57

*dezincification was observed

The chemical composition (%) of the alloy according to Example 4 is following:

Cu 85.9%, Sn 1.8%, Pb 3.8%, Al 6.4%, impurities 0.30%.

The alloy of Example 4 and the JIS BC 6 alloy were cast into JIS B test specimens, and test specimens having a size of 35 mm × 20 mm × 3 mm were prepared therefrom. These test specimens were dipped in a corrosive liquid to examine the weight decrease by corrosion.

The pH of the corrosive liquid was adjusted as indicated in Table 5, and the test was carried out at room temperature. The value of the weight decrease by corrosion is converted to the value of the unit of mg/cm²/month. Results are shown in Table 5.

The alloy of Example 4 exhibits a low weight decrease especially at either low or high pH values (good resistance especially against contaminated water or contaminated sea water), and has a very good corrosion resistance.

EXAMPLE 5

Table 6 illustrates data of the chemical composition, tensile strength, elongation and hardness of examples of the alloy of this invention.

In each case, JIS-B specimens were cast at 1,150°C. – 1,200°C. and JIS No. 4 tension test pieces were prepared from them to determine the properties.

In samples Nos. 1, 2, 3 and 4, the influence by change in the Sn content was examined. Sample No. 1 has the Sn content lower than the range specified in this invention, the Sn content of each of samples Nos. 2 and 3 is within the range specified in Example 5, and the Sn content of sample No. 4 is above the upper limit of the preferable Sn content specified in Example 5.

Table 6

Sample No.	Chemical Composition (% by weight)										Mechanical Properties		Remarks
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	impurities	Tensile strength (Kg/mm ²)	Elongation (%)	Hardness (HB)	
1	88.0	0	2.0	4.0	5.6	0	0	0	0.40	28.3	44	90	Comparison
2	85.4	0.1	2.2	3.5	6.3	0	0	2.3	0.20	35.5	20	100	Example
3	84.2	2.0	1.8	3.1	5.8	0	0	2.8	0.30	37.6	10	120	"
4	82.1	4.5	1.5	3.7	5.5	0	0	2.3	0.40	35.4	4	110	Comparison
5	85.3	2.0	0.1	3.6	6.1	0	0	2.5	0.40	33.7	20	120	Example
6	82.1	1.8	2.5	3.8	6.8	0	0	2.6	0.40	33.0	18	120	"
7	81.6	2.2	4.3	3.2	5.9	0	0	2.6	0.20	30.2	8	113	Comparison
8	85.0	1.6	2.0	1.2	7.0	0	0	2.9	0.30	41.3	14	128	Example
9	83.3	2.0	1.8	3.4	6.5	0	0	2.7	0.30	39.3	20	107	"
10	83.0	1.8	1.8	4.3	6.6	0	0	2.1	0.40	30.4	15	110	Comparison

Table 6—Continued

Sample No.	Chemical Composition (% by weight)									Mechanical Properties			Remarks
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	impurities	Tensile strength (Kg/mm ²)	Elongation (%)	Hardness (HB)	
11	86.5	1.5	1.9	3.9	3.1	0	0	2.8	0.30	20.2	3	—	"
12	81.7	3.1	2.2	3.6	6.5	0	0	2.5	0.40	38.5	18	115	Example
13	80.9	1.8	2.0	3.9	8.7	0	0	2.5	0.20	44.8	10	130	Comparison
14	86.5	1.7	2.0	3.5	6.1	0	0	0	0.20	36.5	23	110	Example
15	84.9	1.6	1.5	3.7	6.0	0.01	0	1.7	0.30	32.0	31	93.6	"
16	83.5	1.6	0.9	3.7	6.6	0.02	0	3.5	0.20	45.7	15	130	Example
17	82.7	1.5	1.4	3.5	6.1	0	0	4.6	0.20	45.2	12	135	"
18	81.6	1.6	1.5	3.7	6.0	0	0	5.3	0.30	50.9	5	135	Comparison
19	85.1	1.7	1.7	3.6	6.0	0.7	0.8	0.3	0.10	41.6	30	117	Example
20	81.9	1.7	1.5	3.3	6.5	0.9	1.0	3.1	0.10	52.5	21	140	"

The Sn content (percent by weight) is one of great factors determining the tensile strength and elongation of the alloy of this invention.

In samples Nos. 5, 6 and 7, the influence by change in the Zn content was examined. Samples Nos. 5 and 6 are samples of the alloy of Example 5, and the Zn content of Sample No. 7 is above the upper limit specified in Example 5. Samples Nos. 8, 9 and 10 were given to examine the influence by change in the Pb content. Samples Nos. 8 and 9 are of the alloy of Example 5, and the Pb content of Sample No. 10 is above the upper limit spec-

5. The Fe content of Sample No. 18 is higher than the upper limit of the preferable Fe content range specified in this invention. It is seen that the elongation is reduced when the Fe content is higher than 5 percent by weight. Samples Nos. 10 and 20 were given to examine effects attained by addition of Ni and Mn. From the data it is seen that good results are consistently obtained with respect to the tensile strength by addition of these elements.

EXAMPLE 6

Table 7

Alloy	Chemical Composition (% by weight)								Impurities
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn	
Alloys of	85.3	1.7	2.1	3.2	7.4	3.3	0	0	0.3
Example 6-1	83.6	1.5	1.8	3.0	7.2	2.6	0	0	0.3
Alloys of	85.1	1.8	2.0	3.2	7.4	0	0	0	0.5
Example 6-2	86.5	1.8	1.5	3.0	6.5	0.3	0	0	0.4
Alloys	83.4	4.5	6.0	5.6	—	—	0.3	0	0.2
corresponding to JIS BC 6	83.4	4.3	6.5	5.5	—	—	0	0	0.3

Alloy	Mechanical Properties			
	Tensile strength (Kg/mm ²)	Elongation (%)	Proof stress (Kg/mm ²)	Hardness (HB)
Alloys of	42.2	20	22.8	135
Example 6-1	41.6	22	21.0	130
Alloys of	36.4	23	20.5	110
Example 6-2	34.0	25	19.7	110
Alloys	27.5	27	12.5	75
corresponding to JIS BC 6	28.3	25	12.0	73

ified in Example 5. In each of these samples, a substantial difference of the tensile strength is not observed, but from the data of these samples, it is seen that the elongation is reduced if either the Zn or Pb content is outside the range specified in Example 5. Samples Nos. 11, 12 and 13 were given to examine the influence by change in the Al content. In Sample No. 11, the Al content is below the lower limit specified in Example 5, the Al content of Sample No. 12 is within the range specified in Example 5, and the Al content of Sample No. 13 is above the upper limit specified in one embodiment of Example 5. The aluminum content (percent by weight) is one of great factors determining the tensile strength and elongation of the alloy of this invention.

Samples Nos. 14, 15, 16, 17 and 18 were given to examine the influence by change in the Fe content. Samples Nos. 14, 15, 16 and 17 are of the alloy of Example

JIS-B test specimens were cast at about 1,150°C. from the alloy of Example 6-1, the alloy of Example 6-2 and the JIS BC 6 alloy, and JIS No. 4 tension test pieces were processed therefrom. Results of determination of properties of these pieces are shown in Table 7.

From the results it is seen that the alloy of Example 6-1 is superior to the alloy of Example 6-2 and the JIS BC 6 alloy with respect to the tensile strength and hardness. More specifically, the tensile strength of the alloy of Example 6-1 is higher by about 19 percent and by about 50 percent than those of the alloy of Example 6-2 and the JIS BC 6 alloy, respectively. Further, the hardness of the alloy of Example 6-1 is higher than by about 20 percent and by about 79 percent than those of the alloy of Example 6-2 and the JIS BC 6 alloy, respectively.

Table 8

Alloy	Impact Value (Kg-m/cm ²) Temperature				
	-75°C.	20°C.	100°C.	200°C.	300°C.
alloy of	2.6~3.0	2.7~3.2	3.0~3.2	3.0~3.2	2.6~3.0
Example 7-2	2.5~3.0	2.8~3.5	3.0~3.5	3.1~3.5	2.8~3.2
JIS BC 6 alloy	2.2~2.6	2.5~2.8	2.5~2.8	2.1~2.3	1.0~1.5

Table 9

Alloy	Chemical Composition (% by weight)								
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn	impurities
alloy of Example 7-1	83.5	1.3	2.0	3.1	6.9	2.8	0	0	0.40
alloy of Example 7-2	85.04	1.6	2.2	3.3	7.5	0.06	0	0	0.30
JIS BC 6 alloy	83.73	4.5	6.1	5.2	—	0.1	0.32	0	0.05

Table 8 illustrates results of the Charpy impact test at different temperatures made on U-notched test pieces prepared from alloys of Example 7-1, 7-2 and the JIS BV 6 alloy.

Table 9 illustrates the data of chemical compositions of these samples.

In contract to the JIS BC 6 alloy in which the impact value is greatly decreased at temperatures exceeding 200°C., either the alloy of Example 7-1 or the alloy of Example 7-2 does not show the reduction of the impact value at temperatures up to 300°C. The impact value of the alloy of Example 7-1 is higher by about 39 percent at 200°C. and by about 100 percent at 300°C. than the impact value of the JIS BC 6 alloy. The alloy of Example 7-1 exhibits an impact value equivalent to that of the alloy of Example 7-2 at each temperature stage.

EXAMPLE 8

Table 10

Alloy	Chemical Composition (% by weight)							Relative value of Machina- bility
	Cu	Sn	Zn	Pb	Ni	Al	Others	
alloy of Example 8-1	83.7	1.6	1.5	3.7	0	6	3.5(Fe)	75
alloy of Example 8-2	85.3	1.5	1.5	3.5	1	7	0.2 (impurities)	90
JIS BC6 alloy	83.7	4.3	6.0	5.5	0.3	—	0.2 (impurities)	90
JIS AlBC 1 alloy	86.3	—	—	—	0.3	9.1	3.2(Fe)	22
free-cutting brass rod	59.5	0.2	balance	3	—	—	0.2(Fe)	100

Table 10 illustrates the relative values of machinability of casting and ductile metal of various copper alloys, each relative value being calculated based on the value of a free-cutting brass rod as 100.

The machinability was compared with respect to a reciprocal number of the time required for boring a

Kg by means of a twist drill (SKH9) of a diameter of 7.0 mm rotated at 1100 rpm on a bench drilling machine.

As is seen from the results shown in the Table, the aluminum-containing JIS AlBC 1 alloy is inferior in machinability. In contrast, the alloy of Example 8-1 containing aluminum is excellent in machinability, because it also contains lead.

However, the machinability of the alloy of Example 8-1 is a little lower than that of the alloy of Example 8-2.

EXAMPLE 9

Table 11

pH value	Weight Decrease by Corrosion (mg/cm ² /month)		
	alloy of Example 9-1	Casting alloy according to JIS BC 6	Alloy of Example 9-2

2	11.43	15.07	8.19
4	0.98	0.98	0.96
6	0.15	0.13	0.16
9	0.08	0.07	0.08
11	8.92	14.12	8.49
12	12.25	21.94	11.12

Table 12

Alloy	Chemical Composition (% by weight)								
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	impurities
Alloy of Example 9-1	83.6	1.7	1.5	3.4	6.4	0	0	3.1	0.3
JIS BC 6 alloy	83.7	4.3	6.0	5.5	—	0.3	0	—	0.2

Table 12-continued

Alloy	Chemical Composition (% by weight)								impurities
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	
Alloy of Example 9-2	85.5	1.5	2.1	3.5	7.2	0	0	—	0.2

The alloy of Example 9-1, the JIS BC 6 alloy and the alloy of Example 9-2 were cast to form JIS B test specimens, from which test pieces having a size of 35mm × 20 mm × 3 mm were prepared. The test pieces were dipped in a corrosive liquid having a pH value shown in Table 11. The corrosion test was conducted at room temperature and the weight decrease by corrosion was determined and converted to the value of the unit of mg/cm²/month. The results are shown in Table 11.

Table 12 illustrates chemical compositions of these samples.

As is seen from the results shown in Table 11, the alloy of Example 9-1 exhibits a lower weight decrease by corrosion especially at lower pH values and higher pH values than the JIS BC 6 alloy. Thus, it will readily be understood that the alloy of Example 9-1 is excellent in corrosion resistance.

The following examples 10 – 14 correspond to the following copper base alloys (1) – (5), especially (9) (10) and (11).

1. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 2.5 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

2. A high strength, iron-containing, copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 14.5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb, 2.5 – 10 percent by weight of Al and 0.1 – 5 percent by weight of Fe, the balance being Cu and ordinary impurities.

3. An alloy set forth in (1), which further comprises at least one of Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight, with or without addition of 0.1 – 5 percent by weight of Fe.

4. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 3 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

5. An alloy set forth in (4), which further comprises at least one of Fe in an amount of 0.1 – 5 percent by weight, Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight.

9. At high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 4 percent by weight of Sn, 0.1 – 4 percent by weight of Zn, 0.1 – 4 percent by weight of Pb and 8 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

10. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 4 percent by weight of Sn, 0.1 – 4 percent by weight of Zn, 0.1 – 4 percent by weight of Pb, 8 – 10 percent by weight of Al and 0.1 – 5 percent by weight of Fe, the balance being Cu and ordinary impurities.

11. An alloy set forth in (9), which further comprises at least one of Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight, with or without addition of 0.1 – 5 percent by weight of Fe.

EXAMPLE 10

Table 13 illustrates data of the chemical composition, tensile strength, elongation and hardness of examples of the alloy of this invention.

Each sample was cast at 1,150°–1,200°C. To form a JIS B test specimen (in sample No. 17, a JIS A test specimen was formed), and the specimen was processed into a JIS No. 4 tension test pieces and its properties were determined.

Samples Nos. 1, 2, 3 and 4 were given to examine the influence by change in the Sn content. The Sn content of sample No. 1 is lower than the lower limit specified in this invention, the Sn contents of samples Nos. 2, 3, and 4 are within the range specified in Example 10.

The Sn content (percent by weight) is one of great factors having influence on the tensile strength and elongation of the alloy of this invention.

Samples Nos. 5, 6, 7 and 8 were given to examine the influence by change in the Zn content. In samples Nos. 5, 6 and 7 and Zn content is within the range specified in Example 10, but in sample No. 8 the Zn content is above the upper limit specified in this invention. From the results shown in the Table, it is seen that the elongation is reduced when the Zn content is outside the range specified in this invention. Samples Nos. 9, 10 and 11 were given to examine the influence by change in the Pb content. In samples Nos. 9 and 10 the Pb content is within the range specified in Example 10, but the Pb content of sample No. 11 is outside the range specified in this invention, i.e., higher than

Table 13

Sample No.	Chemical Composition (% by weight)									Mechanical Properties			Remarks
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn	impurities	Tensile strength (Kg/mm ²)	Elongation (%)	Hardness (HB 10/1000)	
1	89.22	0.05	0.60	0.60	8.89	0.34	0	0	0.30	40.9	42	89.8	Comparison
2	88.95	0.50	0.62	0.10	8.67	0.80	0	0	0.35	44.2	46	95	Example
3	86.01	1.95	0.70	1.20	8.70	1.03	0	0	0.41	36.7	12	107	"
4	86.64	2.40	0.54	1.27	7.85	1.10	0	0	0.20	36.1	8	104	"
5	89.00	0.50	0.10	0.82	8.40	0.93	0	0	0.25	38.0	32	87.2	"

Table 13-continued

Sample No.	Chemical Composition (% by weight)									Mechanical Properties			Remarks
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn	impurities	Tensile strength (Kg/mm ²)	Elongation (%)	Hardness (HB 10/1000)	
6	87.37	0.55	1.05	1.22	8.40	1.10	0	0	0.31	36.7	27	95	"
7	85.33	0.64	3.20	0.93	8.65	1.00	0	0	0.25	33.5	10	110	"
8	83.35	0.65	5.10	1.00	8.80	0.80	0	0	0.30	39.6	5	125	Comparison
9	88.22	0.50	0.81	1.10	8.95	0.20	0	0	0.22	43.9	31	101	Example
10	86.38	0.61	0.78	2.70	8.95	0.20	0	0	0.38	43.2	23	104	"
11	84.58	0.55	0.50	5.30	8.60	0.16	0	0	0.31	32.8	8	101	Comparison
12	88.96	0.68	0.53	1.10	8.50	0.03	0	0	0.20	44.2	37	97.8	Example
13	87.66	0.50	0.56	1.22	8.80	0.90	0	0	0.36	48.4	28	110	"
14	86.53	0.50	0.66	1.18	8.55	2.41	0	0	0.17	55.2	27	121	"
15	84.28	0.63	0.55	1.20	8.80	4.05	0	0	0.49	57.5	25	128	"
16	83.62	0.50	0.50	1.18	8.65	5.30	0	0	0.25	56.8	23	130	Comparison
17	85.90	1.80	1.80	3.80	6.40	0	0	0	0.30	34.3	20	114	"
18	83.80	1.60	1.60	3.50	6.50	0.50	1.50	0.90	0.10	38.3	30	110	"
19	87.92	0.70	0.63	1.30	8.10	1.10	0	0	0.25	42.5	30	113	Example
20	87.60	0.53	0.60	0.94	8.90	1.12	0	0	0.31	49.4	34	117	"
21	86.42	0.50	0.60	1.03	8.90	2.15	0	0	0.40	52.0	26	121	"
22	83.40	1.60	1.40	3.60	10.35	0.21	0.01	0	0.20	40.5	15	171	Comparison
23	85.72	1.60	1.20	1.75	6.80	0.23	2.50	0.03	0.17	36.7	30	82.6	"
24	87.72	0.60	1.05	1.70	8.20	0.11	0.10	0.08	0.44	48.3	35	128	Example
25	86.81	0.60	1.05	1.65	9.30	0.11	0.18	0.08	0.40	55.4	30	135	"

the upper limit specified in this invention. From the results shown in Table 13, it is seen that such Pb content brings about degradation of the elongation. Samples Nos. 12, 13, 14, 15 and 16 were given to examine the influence by change in the Fe content. The Fe content in samples Nos. 12, 13, 14 and 15 within the preferable Fe content range specified in Example 10, while the Fe content of sample No. 16 is higher than the upper limit of the preferable Fe content range specified in this invention. Samples Nos. 17, 18, 19, 20, 21 and 22 were given to examine the influence by change in the Al content. Samples Nos. 17 and 18 are of the alloy in the range of Examples 1 - 9, samples Nos. 19, 20 and 21 are of the alloy of Example 10 and sample No. 22 is of an alloy in which the Al content is above the upper limit of the Al content specified in this invention. As is

23 is of the alloy in the range of Examples 1 - 9. The samples Nos. 24 and 25 are the alloy of this Example 10. From the results shown in Table 13, it is seen that higher tensile strength, higher elongation and higher hardness can be attained stably by addition of Ni and Mn.

EXAMPLE 11

Alloys of Examples 11-1, 11-2 and the JIS BC 6 alloy were cast at about 1,150°C. to form JIS B test specimens, and they were processed into JIS NO. 4 tension test pieces. The mechanical properties of these pieces were determined to obtain results shown in Table 14. In the case of the sample of the alloy of Example 11-2, the JIS A test specimen was formed by casting and it was processed into a JIS No. 4 tension test pieces.

Table 14

Alloy	Chemical Composition (% by Weight)								
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn	Impuri- ties
alloy of	86.53	0.50	0.66	1.18	8.55	2.41	0	0	0.17
Example 11-1	86.81	0.60	1.05	1.65	9.30	0.11	0.18	0.08	0.40
JIS BC 6	84.30	4.40	5.20	5.60	—	—	0.40	0	0.10
alloy	84.00	4.70	5.10	5.70	—	—	0	0	0.50
alloy of	86.50	1.70	2.00	3.50	6.10	0	0	0	0.20
Example 11-2	82.00	1.60	1.60	3.50	7.90	0	2.40	0.80	0.20

alloy	Tensile test		Hardness (HB 10/1000)	Proof stress (Kg/mm ²)
	Tensile strength (Kg/mm ²)	Elong- ation (%)		
alloy of	55.2	27	121	22.3
Example 11-1	55.4	30	135	23.0
JIS BC 6	26.5	28	74	12.2
alloy	25.8	22	75	11.5
alloy of	36.5	23	110	21.1
Example 11-2	34.0	26	110	20.9

Note: the mark "—" indicates the trace

seen from the data shown in Table 13, samples of this Example 10 are superior to samples of the alloy of Example 1 - 9 (samples Nos. 17 and 18) with respect to the tensile strength, hardness, impact value and proof stress. Thus, the aluminum content (percent by weight) is one of great factors determining the mechanical properties of the alloy of this invention.

Samples Nos. 23, 24 and 25 were given to examine effects attained by addition of Ni and Mn. Sample No.

From the results shown in Table 14, it will readily be understood that the alloy of this Example 11-1 is superior to the other alloys with respect to the tensile strength, hardness and proof stress. More specifically, the tensile strength of the alloy of this Example is higher by about 111 percent and by about 56 percent than those of the JIS BC 6 alloy and the alloy of Example 11-2, respectively. The hardness of the alloy of this example is higher by about 71 percent and by about 16

percent than those of the JIS BC 6 alloy and the alloy of Example 11-1, respectively. Futhermore, the proof stress of the alloy of this Example is higher by about 90% and by about 8% than the JIS BC 6 alloy and the alloy of Example 11-2, respectively.

EXAMPLE 12

Table 15

Alloy	Impact Value (Kg-m/cm ²) Temperature				
	-75°C.	20°C.	100°C.	200°C.	300°C.
alloy of Example 12-1	4.5~4.8	4.7~5.0	4.8~5.2	4.6~5.0	4.5~4.8
JIS BC 6 alloy	2.2~2.6	2.5~2.8	2.5~2.8	2.1~2.3	1.0~1.5
alloy of Example 12-2	2.7~3.1	3.0~3.6	3.3~3.6	3.3~3.6	2.8~3.4
JIS AIBC 1 alloy	5.1~5.4	5.3~5.6	5.3~5.6	5.2~5.4	4.5~4.9

Table 16

Alloy	Chemical Composition (% by weight)							
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn
alloy of Example 12-1*	87.69	0.81	0.56	1.10	9.05	0.47	0	0
JIS BC 6 alloy	83.92	4.30	6.00	5.50	—	—	0.28	0
alloy of Example 12-2**	85.46	1.5	2.1	3.5	7.2	0.04	0	0
JIS AIBC 1 alloy	86.60	0.05	—	—	9.10	3.23	0.29	0.73

Notes:
1) *:impurities content = 0.32%
**: impurities content = 0.20%
2) the mark "—" means the trace.

Table 15 illustrates results of the Charpy impact test made on U-notched JIS No. 3 impact test pieces of the alloy of this Example 12-1, the JIS BC 6 alloy, the alloy of Example 12-2 and the JIS AIBC 1 alloy at different temperatures shown in Table 15. The chemical compositions of these sample alloys are shown in Table 16.

In contrast to the JIS BC 6 alloy in which the impact

ture stage. The alloy of Example 12-1 is excellent in high temperature mechanical properties and is stable at high temperatures.

The impact value at 200°C. of the alloy of Example 12-1 is higher by about 127 percent and by about 39 percent than those of the JIS BC 6 alloy and the alloy of Example 12-2, and is comparable to that of the JIS

AIBC 1 alloy. Further, the impact value at 300°C. of the alloy of Example 12-1 is higher than by about 220 percent and by about 41 percent than those of the JIS BC 6 alloy and the alloy of Example 12-2, respectively, and is comparable to that of the JIS AIBC 1 alloy.

EXAMPLE 13

Table 17

Alloy	Chemical Composition (% by weight)								Relative Value of Machina- bility
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn	
JIS BC 6	84.96	4.30	4.95	5.50	—	—	0.28	0	445
JIS BSBME 2 alloy	58.50	0.40	37.30	3.45	0	0.23	0.21	—	325
JIS ABBF 2 alloy	84.40	0.03	0	0	10.90	2.60	1.08	0.99	90
JIS AIBC 1 alloy	86.60	0.05	—	—	9.10	3.23	0.29	0.73	100
alloy of Example 13-2*	84.65	1.60	1.50	3.70	7.10	0.13	0.67	0.50	400
alloy of Example 13-1**	86.38	0.61	0.78	2.70	8.95	0.20	0	0	250
alloy of Example 13-1***	87.30	0.50	0.50	1.08	8.20	2.11	0	0	201

Notes:
1) *: impurities content = 0.22%
**: impurities content = 0.38%
***: impurities content = 0.30%
2) the mark "—" indicates the trace.

value is greatly decreased at temperatures exceeding 200°C., the alloy of Example 12-1 does not show such decrease of the impact value at temperatures of up to 300°C. As is seen from the results shown in Table 15, the impact value of the alloy of Example 12-1 is better than that of the alloy of Example 12-2 at each tempera-

Table 17 illustrates relative values of machinability of casting and ductile metals of various copper alloys, each value being calculated based on the value of JIS AIBC 1 as 100.

Each value was derived from a reciprocal number of the time required for boring a specimen of a certain

thickness under a load of about 10 Kg by means of a twist drill of a diameter of 7.0 mm (SKH 9) rotated at 1100 rpm on a bench drilling machine.

As is seen from the results shown in the Table, aluminium-containing alloys such as aluminum bronze casting and special aluminum bronze rod are inferior in machinability. In contrast, although the alloy of Example 13-1 contains aluminum, it exhibits an excellent machinability, because it also comprises lead.

EXAMPLE 14

Table 18

	Weight Decrease by Corrosion (mg/cm ² /month)			
	alloy of Example 14-1	JIS BC 6 alloy casting	alloy of Example 14-2	JIS AIBC 1 alloy casting
10% HCl	10.02	27.12	13.68	17.10
pH of 13	15.72	17.70	16.84	15.72

Table 19

Alloy	Chemical Composition (% by weight)							
	Cu	Sn	Zn	Pb	Al	Fe	Ni	Mn
alloy of Example 14-1*	87.82	0.55	0.50	1.08	9.10	0.54	0	0
alloy according to JIS BC 6	83.92	4.30	6.00	5.50	—	—	0.28	—
alloy of Example 14-2**	85.46	1.50	2.10	3.50	7.20	0.04	0	0
alloy according to JIS AIBC 1	86.60	0.05	—	—	9.10	3.23	0.29	0.73

Notes:

1) *: impurities content = 0.41%

** : impurities content = 0.20%

2) the mark "—" indicates the trace.

The alloys of this Example 14-1 and Example 14-2, the JIS BC 6 alloy and the JIS AIBC 1 alloy were cast to obtain JIS B test specimens, from which test pieces having a size of 10 mm × 10 mm × 8 mm were prepared. These test pieces were dipped in a corrosive liquid.

As the corrosive liquid were used 10 percent HCl and a liquid whose pH was adjusted to 13. The test was conducted at room temperature while keeping the liquid in the tranquil state. The value of the weight decrease by corrosion was converted to the value of the unit of mg/cm²/month. Results of the test are shown in Table 18.

Chemical compositions of sample alloys are shown in Table 19.

The alloy of Example 14-1 exhibits a smaller weight decrease in 10 percent HCl and high pH value (especially resistant against contaminated sea water and contaminated water) than the JIS BC 6 alloy, the alloy of Example 14-2 and the JIS AIBC 1 alloy. Thus, it is seen that the alloy of Example 14-1 has a very excellent corrosion resistance. In view of the fact that the results of the alloy of Example 14-1 are superior to those of the alloy of Example 14-2, it is presumed that at a low pH value corrosion test, the alloy of this Example will show a smaller weight decrease by corrosion than any of other sample alloys and it will exhibit an excellent corrosion resistance against a low pH liquid.

The following Examples 15 – 17 correspond to the following copper base alloys (1) – (5), especially (12) (13).

1 A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5% by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 2.5 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

2. A high strength, iron-containing, copper base alloy excellent in corrosion resistance and machinability which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb, 2.5 – 10% by weight of Al and 0.1 – 5 percent by weight of Fe, the balance being Cu and ordinary impurities.

3. An alloy set forth in (1), which further comprises at least one of Ni in an amount of up to 5% by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight, with or without addition of 0.1 – 5 percent by weight of Fe.

4. A high strength copper base alloy excellent in corrosion resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 5 percent by weight of Pb and 3 – 10 percent by weight of Al, the balance being Cu and ordinary impurities.

5. An alloy set forth in (4), which further comprises at least one of Fe in an amount of 0.1 – 5 percent by weight, Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight.

12. A high strength copper base alloy excellent in impact resistance and machinability, which comprises 0.1 – 5 percent by weight of Sn, 0.1 – 5 percent by weight of Zn, 0.1 – 2 percent by weight of Pb and 1 – 5 percent by weight, preferably 2.5 – 5 percent by weight, of Al, the balance being Cu and ordinary impurities.

13 An alloy set forth in (12), which further comprises at least one of Fe in an amount of 0.1 – 4 percent by weight, Ni in an amount of up to 5 percent by weight, Mn in an amount of up to 3 percent by weight and Be in an amount of up to 0.1 percent by weight.

EXAMPLE 15

Table 20 illustrates data of the chemical composition, tensile strength, elongation and hardness of examples of the alloy of this invention. In each case, a JIS B test specimen was formed by casting at 1,150°–1200°C. and it was formed into a JIS No. 4 tension test

pieces for the tensile test and a JIS No. 3 impact test pieces for the impact test.

influence by change in the Pb content. As the Pb content (percent by weight) increases, each of the tensile

Table 20

Chemical Composition (% by weight)									
Sample No.	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	im-purities
1	96.1	0.03	0	0	3.9	0	0	0.01	0.20
2	95.3	0.1	0.5	0.2	3.8	0	0	0	0.10
3	93.2	0.5	0.6	0.6	3.9	0	0	0.9	0.30
4	91.2	1.0	2.2	0.7	3.8	0	0	0.8	0.30
5	92.2	3.2	0.4	0.4	3.5	0	0	0.1	0.20
6	94.8	1.1	0	0.1	3.8	0	0	0	0.20
7	92.9	1.1	2.0	0.1	3.8	0	0	0	0.10
8	91.3	1.1	3.3	0.4	3.5	0	0	0.1	0.30
9	92.5	1.1	2.0	0.4	3.8	0	0	0	0.20
10	91.9	1.1	2.0	0.8	3.8	0	0	0	0.40
11	90.3	0.1	0	5.5	3.8	0	0	0.1	0.20
12	95.2	0.07	0	0	3.8	0	0	0.6	0.30
13	90.4	0.9	2.1	0.8	3.9	0	0	1.7	0.20
14	88.0	0.9	2.0	0.8	3.7	0	0	4.2	0.40
15	91.6	1.0	2.3	1.4	1.0	0	0	2.5	0.20
16	89.8	1.0	2.3	1.4	2.9	0	0	2.5	0.10
17	88.0	1.0	2.3	1.4	4.7	0	0	2.5	0.10
18	88.2	0.6	1.2	3.7	6.0	0	0	0.1	0.20
19	90.4	1.1	2.2	0.5	3.8	0.9	0.8	0	0.30
20	83.8	1.6	1.6	3.5	6.5	1.5	0.9	0.5	0.10

Mechanical Properties					Remarks
Sample No.	Tensile strength (Kg/mm ²)	elongation (%)	hardness (HB)	impact value (Kg-m/cm ²)	
1	21.8	72	65.6	15.0	Comparison
2	23.7	70	58.2	15.3	Example
3	28.5	49	76.2	11.9	"
4	30.2	48	80.4	13.0	"
5	26.6	30	74.2	8.0	"
6	26.6	67	65.6	15.6	Comparison
	25.5	57	65.6	14.3	Example
7					
8	28.6	68	68.6	14.9	"
9	26.1	65	65.6	13.4	"
10	18.0	24	54.2	9.8	"
11	9.2	10	48.6	1.5	Comparison
12	28.1	62	65.6	12.0	"
13	35.4	30	95.0	7.9	Example
14	40.9	27	11.0	2.7	Comparison
15	30.5	22	87.2	9.5	Example
16	32.0	18	10.1	7.5	"
17	34.1	14	11.0	5.2	"
18	21.4	46	61.0	3.5	Comparison
19	32.6	43	—	13.4	Example
20	38.3	30	11.0	3.1	Comparison

Samples Nos. 1, 2, 3, 4 and 5 were given to examine the influence by change in the Sn content. In sample No. 1 the Sn content is lower than the lower limit specified in this invention (almost trace), and in samples Nos. 2, 3, 4 and 5, the Sn content is within the range specified in Example 15.

The Sn content (percent by weight) is one of great factors determining the tensile strength and elongation of the alloy of this invention. At the Sn contents below 0.1 percent by weight, although the elongation is high, the proof stress is reduced. At the Sn contents exceeding 5 percent by weight, each of the tensile strength, elongation and impact value is lowered.

Samples Nos. 6, 7 and 8 were given to examine the influence by change in the Zn content. No substantial difference in the tensile strength, elongation or impact value was brought about by the change in the Zn content. However, in view of the castability and corrosion resistance, it is preferable that the Zn content is limited to 0.1 to 5 percent by weight.

Samples Nos. 9, 10 and 11 were given to examine the

strength, elongation and impact value is reduced. In view of the machinability and pressure tightness, it is preferable that the Pb content is limited to 0.1 to 2 percent by weight.

Samples Nos. 12, 13 and 14 were given to examine the influence by change in the Fe content. In general, as the Fe content (percent by weight) increases, the tensile strength is heightened but both the elongation and impact value are reduced.

Samples Nos. 15, 16, 17 and 18 were given to examine the influence by change in the Al content. The increase in the aluminum content (percent by weight) results in heightening of the tensile strength but in lowering of the elongation and impact value. The Al content is one of great factors determining the tensile strength and elongation of the alloy of this invention.

Samples Nos. 19 and 20 were given to examine the effects attained by addition of Mn and Ni. From the results shown in Table 20, it is seen that addition of these elements heightens the tensile strength and elongation stably.

Table 21

Alloy	Chemical Composition (% by weight)								
	Cu	Sn	Zn	Pb	Al	Ni	Mn	Fe	Impuri- ties
alloy of	92.5	1.1	2.0	0.4	3.8	0	0	0	0.20
Example 16-1	91.2	1.0	2.2	0.7	3.8	0	0	0.8	0.30
alloy of	90.4	1.1	2.2	0.5	3.8	0.9	0.8	0	0.30
Example 16-2	86.5	1.7	2.0	3.5	6.1	0	0	0	0.20
	82.0	1.6	1.6	3.5	7.9	2.4	0.8	0	0.20
Alloy	Mechanical Properties								
	Tensile strength (Kg/mm ²)	Elong- gation (%)	Hardness (HB)	Proof stress (Kg/mm ²)					
alloy of	26.1	65	65.6	10.3					
Example 16-1	30.2	48	80.4	14.1					
alloy of	32.6	43	75.0	17.8					
Example 16-2	36.5	23	11.0	21.1					
	34.0	26	11.0	20.9					

Table 21 illustrates the mechanical properties of the alloy of Example 16-1 and the alloy of Example 16-2 for comparison.

From the data shown in the Table, it is seen that the tensile strength of the alloy of Example 16-1 has the value of about 80 percent of the alloy of Example 16-2, the hardness of the alloy of Example 16-1 has the value of about 70 percent of the alloy of Example 16-2, the proof-stress of the alloy of Example 16-1 has the value of about 75% of the of Example 16-2, but the elonga-
tion of the alloy of Example 16-1 has the value of about 200 percent of the alloy of Example 16-2.

EXAMPLE 16 B

Table 22

Alloy	Impact Value (Kg-m/cm ²)				
	-75°C.	20°C.	100°C.	200°C.	300°C.
alloy of Example 16-1	10.2~13.4	12.1~14.2	12.1~14.2	12.1~14.2	9.2~11.0
alloy of Example 16-2	2.8~ 3.2	3.0~ 3.5	3.2~ 3.5	3.2~ 3.5	2.8~ 3.2
alloy of JIS AIBC 1	5.1~ 5.4	5.3~ 5.6	5.3~ 5.6	5.3~ 5.4	4.5~ 4.9

Note: the chemical composition of the alloy of Example 16-1 is 90.9% by weight of Cu, 0.9% by weight of Sn, 2.1% by weight of Zn, 0.8% by weight of Pb, 3.9% by weight of Al, 1.1% by weight of Fe and 0.3% by weight of impurities.

Table 22 illustrates the result of the charpy impact test made on U-notched test pieces of the alloy of Example 16-1.

The alloy of Example 16- exhibits a high impact value at each temperature stage. More specifically, the impact value of Example 16-1 is about 300 percent of those of the alloy of Example 16-2, and is about 200 percent of the JIS AIBC 1 alloy, respectively.

EXAMPLE 17

Table 23

Alloy	Chemical Composition (% by weight)							Relative Value of Machina- bility
	Cu	Sn	Zn	Pb	Ni	Al	Others	
alloy of Example 17-1	91.5	1	2	0.5	0	4	1(Fe)	60
alloy of Example 17-2	85.5	1.5	1.5	3.5	1	7		90
JIS AIBC 1 alloy	86.3				0.3	9.1	3.5(Fe)	22
free-cutting brass rod	61.5		35.5	3				100

ity of the alloy of Example 17-1, the alloy of Example 17-2 and the alloy according to JIS AIBC 1, each value being calculated based on the value of a free cutting brass rod as 100. From the results shown in Table 23, it is seen that the machinability of the alloy of Example 17-1 has the value of about 300 percent of the JIS AIBC 1 alloy.

What we claim is:

1. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1 – 4 percent by weight Sn, 0.1–4 percent by weight Zn, 0.1–4 percent by weight Pb, and 5.0 to 10 percent by weight Al, the balance being essen-

tially copper.

2. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1–4 percent by weight Sn, 0.1 – 4 percent by weight Zn, 0.1–4 percent by weight Pb, and 8.0 to 10 percent by weight Al, the balance being essentially copper.

3. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1 – 4 percent by weight Sn, 0.1–4 per-

cent by weight Zn, 0.1–4 percent by weight Pb, 5.0 to 10 percent by weight Al and from 0.1 to 5.0 percent by weight Fe, the balance being essentially copper.

4. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1 – 4 percent by weight Sn, 0.1 – 4 percent by weight Zn, 0.1 – 4 percent by weight Pb, 5.0 to 10 percent by weight Al, and at least one element selected from the group consisting of Ni in an amount up to 5 percent by weight, Mn in an amount up to 3 percent by weight, and Be in an amount up to 0.1 percent by weight, the balance being essentially copper.

5. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1 – 4 percent by weight Sn, 0.1 – 4 percent by weight Zn, 0.1–4 percent by weight pb, 5.0 to 10 percent by weight Al, 0.1 to 5.0 percent by weight Fe, and at least one element selected from the group consisting of Ni in an amount up to 5 percent by weight, Mn in an amount of to 3 percent by weight, and Be in an amount up to 0.1 percent by weight, the balance being essentially copper.

6. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting

essentially of 0.1 – 4 percent by weight Sn, 0.1 – 4 percent by weight Zn, 0.1 – 4 percent by weight Pb, 8.0 to 10 percent by weight Al, and 0.1 to 5.0 percent by weight Fe, the balance being essentially copper.

7. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1 – 4 percent by weight Sn, 0.1 – 4 percent by weight Zn, 0.1 – 4 percent by weight Pb, 8.0 to 10 percent by weight Al, and at least one element selected from the group consisting of Ni in an amount up to 5 percent by weight, Mn in an amount up to 3 percent by weight, and Be in an amount up to 0.1 percent by weight, the balance being essentially copper.

8. A high strength copper base alloy possessing excellent corrosion resistance and machinability, consisting essentially of 0.1 – 4 percent by weight Sn, 0.1 – 4 percent by weight Zn, 0.1 – 4 percent by weight Pb, 8.0 to 10 percent by weight Al, 0.1 to 5.0 percent by weight Fe, and at least one element selected from the group consisting of Ni in an amount up to 5 percent by weight, Mn in an amount up to 3 percent by weight, and Be in an amount up to 0.1 percent by weight, the balance being essentially copper.

* * * * *

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