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(71) Applicant : HITACHI ALLOY, LTD.
3-11-7 Uchikanda
Chiyoda-ku, Tokyo (JP)

(72) Inventor : Yamaji, Kenkichi, c/o Hitachi Alloy, Ltd.
3-11-7 Uchikanda, Chiyoda-ku
Tokyo (JP)
Inventor : Kawanishi, Rokuro, c/o Hitachi Alloy, Ltd.
3-11-7 Uchikanda, Chiyoda-ku
Tokyo (JP)

(74) Representative : Jackson, Peter Arthur
GILL JENNINGS & EVERY, Broadgate House,
7 Eldon Street
London EC2M 7LH (GB)

(54) Free cutting brass.

(57) Free cutting brass containing no lead or the minimum amount of lead is provided. In place of lead in conventional free cutting brass, bismuth in contained therein. In addition, misch metal is added thereto as a third metal, such that intermetallic compounds are formed by bismuth and misch metal, and lead and misch metal.

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The invention relates to free cutting brass, and more particularly to, brass with free cutting property having no harmful effect to the quality of water and containing no lead or the minimum amount of lead.

Copper alloy containing lead is used in a variety of fields as an industrial material having free cutting property. The increase of machinability by adding lead to a metal is not only used for nonferrous alloy, but also in the field of steel.

Copper-Zinc system alloy containing lead is used in the large quantity for parts of life-related machines or devices. In the field of water-contact metal fittings (metallic parts), especially, this tendency is remarkable. On the other hand, the contamination of water in quality which is caused by the change of our living environment, and the use of hot water which is resulted from the popularization of hot water heaters are generalized.

Under the circumstance, the elution of lead has been a problem these days. Recently, attention has been paid to the poisonous character of lead from the point of health and environment, and a law is enacted in countries in the world to severely regulate a level of lead which is tolerated for drinking water.

For this tendency, the development of alloys which are gentle for the quality of water has been sought in the world.

Accordingly, it is an object of the invention to provide free cutting brass which meets the above described requirements and has properties equivalent to conventional free cutting brass.

It is a further object of the invention to provide free cutting brass containing no lead or the minimum amount of lead.

It is a still further object of the invention to provide free cutting brass from which no elution of lead is resulted.

According to the invention, free cutting brass, comprises :

57 to 61 weight % of copper ;
0.5 to 4 weight % of bismuth ;
0.05 to 0.9 weight % of misch metal ; and
a remaining amount of zinc.

According to another aspect of the invention, free cutting brass, comprises :

57 to 61 weight % of copper ;
0.5 to 4 weight % in total of bismuth and lead ;
0.05 to 0.5 weight % of misch metal ; and
a remaining amount of zinc.

In one aspect of the invention, the content of lead is zero, and a metal element which is gentle for the environment and the quality of water is contained to improve machinability in place of lead.

In another aspect of the invention, the content of lead is as low as possible, and a selected metal element is contained in the co-existence with a third added metal to provide intermetallic compound therebetween, thereby improving machinability and increasing the elution resistance of lead.

The selection of a metal element used in place of lead will be explained below.

Lead in brass (Cu-Zn) does not form solid solution with copper and zinc, and precipitates at grain boundaries at the time of solidification. Consequently, cutting property is effectively improved.

For this reason, the conditions of selecting a metal element in place of lead are ;

(1) the metal element does not form solid solution with copper and zinc ; and

(2) the metal element does not form intermetallic compound with copper and zinc.

As candidates of added elements, bismuth, calcium, antimony, tellurium, selenium, and lanthanum have been evaluated.

Table 1 explains the formation and the non-formation of intermetallic compounds with copper and zinc by the above described candidate elements, and the state of solid solution thereof.

TABLE 1

ELEMENT	Cu		Zn	
	I.C.	S.S.	I.C.	S.S.
Bi	○	○	○	○
Ca	□	○	□	○
Ce	□	○	□	○
La	□	○	□	○
Pb	○	○	○	○
Sb	□	□	□	○
Te	□	○	□	○

Table 1 explains the reaction of each element with copper and zinc, where □ indicates the formation of intermetallic compound I.C. and solid solution S.S., and ○ indicates the non-formation thereof.

In accordance with the results in Table 1, and the poisonous aspect of the candidate elements, bismuth has been selected as a metal element replacing lead.

Next, the selection of a third added metal will be explained below.

Lead and bismuth are of low melting points (Pb : 327°C and Bi : 271°C). The density of lead is 10.5 g/cm³ at 800°C and 9.81 g/cm³ at 1000°C, and that of bismuth is 9.4 g/cm³ at 800 °C and 9.2 g/cm³ at 1000°C. These values are considerably high as compared to the density of 7.32 g/cm³ at 1000°C for a mother material of 60/40 brass .

These high densities of lead and bismuth cause gravity segregration at the time of casting the molten metals.

For this reason, the conditions of selecting a third added metal are :

(1) the third added metal forms intermetallic compounds with lead and bismuth ; and

(2) the third added metal does not form intermetallic compound with copper and zinc.

These conditions are considered for the reason why intermetallic compound formed between the third added metal and lead or bismuth is uniformly precipitated in the form of minute organization.

Table 2 shows properties of reacting products between Misch Metal (defined "M.M." hereinafter, and mixture of rare earth elements consisting mainly of cerium and lanthanum) and each of elements composing a mother material.

TABLE 2

Cu-M.Metal	Ce (%)	MELTING POINT (°C)
$CeCu_6$	26.89	940
$CeCu_4$	35.44	780
$CeCu_2$	52.44	820
CeCu	68.80	515
Zn-M.Metal	Ce (%)	MELTING POINT (°C)
$CeZn_{11}$	16.31	785
$CeZn_7$	19.23	972
$CeZn_5$	30.00	870
Pb-M.Metal	Ce (%)	MELTING POINT (°C)
$CePb_3$	18.40	1170
CePb	57.49	1380
Pb-M.Metal	Ce (%)	MELTING POINT (°C)
$CeBi_2$	25.19	883
CeBi	40.14	1525
$CeBi_3$	47.20	~1630
Ce_3 Bi	66.79	1400
Table 2 explains compositions and melting points of intermetallic compounds.		

As understood in Table 2, intermetallic compounds of M.M. formed in accordance with the reaction with lead and bismuth are thermodynamically more stable than intermetallic compounds with copper and zinc.

In accordance with these results, M.M. is selected as a third added metal.

The invention will be explained in more detail in conjunction with the drawings, wherein :

Figs. 1A to 1D are pictures for showing X-MA analysis images of dispersion phase of a test material A-8 for Cu-Zn-Bi-M.M. system alloy ;

Figs. 2A and 2B are pictures for showing X-MA analysis images of dispersion phase of a test material C-2 for Cu-Zn-Bi-Pb-M.M. system alloy ;

Figs. 3A to 3C are explanatory views for showing a configuration of bits blade tip, and Figs. 3D and 3E are tables for explaining the configuration thereof ;

Fig. 4 is an explanatory view for showing a bore formation test ;

Fig. 5A to 5E are pictures for showing chips in a cutting test for Cu-Zn-Bi-M.M. system alloy ;

Fig. 6A and 6B are pictures for showing chips in the cutting test for Cu-Zn-Bi-Pb-M.M. system alloy ; and

Fig. 7 is a graph for explaining a relation between a bore formation time and a content of M.M. for Cu-Zn-Bi-M.M. system alloy.

The preferred embodiments according to the invention are divided into two cases, wherein elution of lead is discussed to be important in free cutting brass in one preferred embodiment, and machinability is discussed to be important in free cutting brass in another preferred embodiment. The free cutting brass in the former preferred embodiment is Cu-Zn-Bi-M.M system alloy, and the free cutting brass in the latter preferred embodiment is Cu-Zn-Bi-Pb-M.M. system alloy in which lead and bismuth are co-existed.

Test materials are prepared as set out below.

Table 3 explains chemical compositions of Cu-Zn-Bi-M.M. system alloy, and Table 4 explains those of Cu-Zn-Bi-Pb-M.M. system alloy.

TABLE 3

TEST MATERIAL	CHEMICAL COMPOSITION (%)					REMARK
	Cu	Bi	Pb	M.Metal	Zn	
A-1	59.6	0	0	0	Res	CASTING MATERIAL
A-2	59.7	0	3.22	0	Res	same as above
A-3	59.4	2.48	0	0	Res	same as above
A-4	59.4	0.51	0	0.14	Res	same as above
A-5	59.5	1.04	0	0.28	Res	same as above
A-6	59.6	1.30	0	0.47	Res	same as above
A-7	59.4	2.38	0	0.30	Res	same as above
A-8	59.7	2.22	0	0.50	Res	same as above
B-1	60.2	0	2.96	0	Res	WORKING MATERIAL
B-2	60.3	0.99	0	0	Res	same as above
B-3	60.1	1.99	0	0	Res	same as above
B-4	60.3	1.01	0	0.06	Res	same as above
B-5	60.4	1.06	0	0.30	Res	same as above
B-6	60.2	1.10	0	0.36	Res	same as above
B-7	60.2	2.10	0	0.28	Res	same as above
B-8	60.3	1.81	0	0.42	Res	same as above
B-9	60.4	1.71	0	0.40	Res	same as above
Table 3 explains chemical compositions of test materials for Cu-Zn-Bi-M.M. system alloy.						

TABLE 4

TEST MATERIAL	CHEMICAL COMPOSITION (%)					REMARK
	Cu	Bi	Pb	M.Metal	Zn	
C-1	59.4	1.52	1.48	0.10	Res	CASTING MATERIAL
C-2	59.6	1.51	1.52	0.27	Res	same as above
D-1	60.4	1.49	1.48	0	Res	WORKING MATERIAL
D-2	60.3	1.55	0.45	0.16	Res	same as above
D-3	60.5	1.47	0.91	0.08	Res	same as above
D-4	60.5	1.43	1.41	0.08	Res	same as above
Table 4 explains chemical compositions of test materials for Cu-Zn-Bi-Pb-M.M. system alloy.						

The property-research of these system alloys is mainly carried out by metallurgical investigation and machinability investigation.

For this purpose, test materials for the former alloy are prepared in accordance with the steps of casting by using a carbon mold having a diameter of 30 mm, and machining to be a diameter of 25mm, and those for the latter alloy are prepared in accordance with the steps of casting by using a water cooling mold having a diameter of 45 mm, machining to be a diameter of 40mm, extruding at a temperature of 720 °C to be a diameter of 18.5 mm, and cold-drawing with a drawing degree of 10.5 % to be a diameter of 17.5 mm.

The property research will be explained below.

(a) metallurgical investigation

Dispersion phase is observed by an optical microscope, and is analyzed in distribution state in accordance with the treatment by an image analysis system, intermetallic compounds formed by adding M.M. are observed by an electronic microscope, and is analyzed by an X ray microanalyzer (X-MA), and the behavior of dispersion phase is observed at a high temperature by heating.

(1) analysis of intermetallic compounds

Figs. 1A to 1D and 2A and 2B show X-MA analysis images of typical intermetallic compounds observed in the test material A-8 (59.7 Cu-37.32 Zn-2.22 Bi-0.5 M.M.) and the test material C-2 (59.6 Cu-37Zn-1.51Bi-1.52Pb-0.27 M.M.). The intermetallic compounds of the test material A-8 have nucleus formed by Bi-M.M. and covered in periphery with bismuth. On the other hand, the intermetallic compounds of the test material C-2 are observed to have main bodies of Bi-M.M. covered with lead.

(2) behavior of dispersion phase by heating

The present system alloys are generally processed to be products by hot working (extruding, forging, etc.), cold working, annealing, etc. Due to thermal load at the time of the process, bismuth and lead contained therein as dispersion phase are cohered to be coarse, because they are of low melting points, so that this will be a cause for a problem to occur in the alloys. In order to make this point clear, test materials are prepared from a forging material and an extruding material (extruding temperature less than 720°C) to investigate the state of dispersion phase.

Table 5 shows the behavior of dispersion phase prior to thermal load and thereafter observed in accordance with the treatment by an image analysis system.

TABLE 5

TEST MATERIAL	CASTING MATERIAL			EXTRUDING MATERIAL*		
	NUMBER OF PARTICLE (N/0.04mm^2)	PARTICLE SIZE (Mm^2) MAXIMUM VALUE	PARTICLE SIZE (Mm^2) MEAN VALUE	NUMBER OF PARTICLE (N/0.04mm^2)	PARTICLE SIZE (Mm^2) MAXIMUM VALUE	PARTICLE SIZE (Mm^2) MEAN VALUE
B-1	380	24.06	3.19	193	113.50	15.40
B-3	239	16.63	2.68	177	85.60	11.51
B-9	268	13.78	2.33	205	49.14	10.68
D-1	279	28.13	4.59	224	170.62	14.93
D-4	241	27.01	4.73	195	88.75	11.74

(*) EXTRUDING TEMPERATURE : 720 °C

Table 5 explains behavior of dispersion phase by heating.

The conventional free cutting brass (test material B-1) is observed to be remarkable in thermal effect. In accordance with the result, it is understood that lead of dispersion phase is cohered to be coarse. Comparing the test materials B-3 and B-9, thermal effect of dispersion phase for the latter test material is considerably suppressed. Considering the composition of the test material B-9, the alloy is Cu-Zn-Bi-M.M system alloy having the added M.M., although the Bi-content is constant. As discussed in the metallurgical investigation, it is considered that this is because Bi-M.M. compounds which are high in thermal stability are formed by the addition of M.M. Comparing the test materials D-1 and D-4, the influence of thermal load to dispersion phase for the latter test material is considerably suppressed. This phenomenon is for the same reason as discussed above.

(b) workability

The workability is studied mainly in regard to cutting property (machinability) and ductility.

(1) ductility (marginal compressibility factor)

The marginal compressibility factor is obtained by measuring a deformation amount of a test piece having a size of 10mm diameter and 10mm length immediately prior to the occurrence of crack under the condition that a load is applied to the test piece, which is prepared by machining a cold drawing material having a diameter of 17.5mm, by a compression test machine.

The marginal compressibility factor MCF is defined by the below equation.

$$MCF = \frac{He - H}{He} \times 100$$

where He is a height of the test piece prior to the test, and H is that of the test piece after the test.

Table 6 explains one example of the test results.

As clear from the results, the Cu-Zn-Bi-M.M. system alloy and the Cu-Zn-Bi-Pb-M.M. system alloy provide better compression workability than the conventional free cutting brass, and, especially, the Cu-Zn-Bi-Pb-M.M. system alloy represents excellent property.

TABLE 6

TEST MATERIAL	MARGINAL COMPRESSIBILITY FACTOR (%)
B-1	49.06
B-3	62.10
B-7	62.22
B-9	63.54
D-1	56.19
D-4	56.04
Table 6 explains marginal compressibility factors.	

(2) cutting property (machinability)

A test method is explained below.

The cutting property is investigated by a cutting test and a bore formation test, and the comparison between the preferred free cutting brass and the conventional free cutting brass is carried out in these tests. Test materials for the cutting test are mainly casting materials, and test materials for the bore formation test are mainly cold drawing materials.

Figs. 3A to 3E show cutting conditions and the configuration of a bits (cutting tool), and the evaluation of the cutting property is made dependent on the size and the configuration of chips.

Table 7 explains bore formation test conditions. In the test, a time required to form a bore having a depth of 5mm is measured to evaluate the bore formation property.

TABLE 7

ITEM		DATA
DRILL	MATERIAL	W. C
	DIAMETER (mm)	3.5
	TORSION ANGLE (°)	27
	TIP END ANGLE (°)	118
REVOLUTION NUMBER (r.p.m)		1935
WEIGHT (kg)		8
BORE DEPTH (mm)		5
Table 7 explains conditions for bore formation test.		

The bore formation is carried out as shown in Fig. 4.

The test results will be explained below.

First, the results of the cutting test will be explained.

Cu-Zn-Bi-M.M. system alloy

Figs. 5A to 5E are pictures showing the appearance of the chips of each test material, wherein the test material A-1 is 60/40 brass, the test material A-2 is the conventional free cutting brass, and the test materials A-4, A-5 and A-6 are the free cutting brasses in the preferred embodiment. The curling diameter of the chips for the test materials A-4, A-5 and A-6 is slightly larger than those for the test material A-2, and the length thereof is similar to each other for those test materials. This means that the free cutting brass of the invention provides a stable cutting property.

Cu-Zn-Bi-Pb-M.M. system alloy

Figs. 6A and 6B are for pictures showing the appearance of the chips of each test material.

The configuration (curling diameter and chip length) of the chips for the test materials in the preferred embodiment represents cutting property equivalent to that of the conventioned free cutting brass.

Second, the results of the bore formation test will be explained

Cu-Zn-Bi-M.M. system alloy

TABLE 8

TEST MATERIAL	BORE FORMATION TIME (s)				
	1	2	3	4	MEAN VALUE
B-1	3.43	3.52	3.44	3.29	3.44
B-2	14.20	11.85	13.52	14.27	13.46
B-3	6.76	6.48	6.56	6.52	6.58
B-4	11.32	10.58	11.08	10.66	10.91
B-5	11.55	12.41	11.75	11.01	11.68
B-6	10.14	11.35	11.08	11.49	11.02
B-7	4.79	5.46	5.12	5.47	5.21
B-8	6.45	6.28	6.24	6.15	6.38
B-9	5.97	6.21	6.08	6.18	6.11
Table 8 explains bore formation time for Cu-Zn-Bi-M.M. system alloy.					

Table 8 explains the measurement results of the bore formation test. In accordance with the results, it is understood that the bore formation property is improved in proportion to the content amount of bismuth. Especially, when the content amount of bismuth is greater than 2%, a considerably good property is obtained. In this test, it is considered that a good property is obtained in the present system alloy containing bismuth and M.M. as compared to an alloy containing no M.M., but bismuth, because compound formed by bismuth and M.M. is uniformly dispersed.

Fig. 7 shows the state of bore formation property for alloys in which a bismuth content is constant, but a M.M. content is changed. In accordance with the results, the aforementioned tendency is confirmed.

Cu-Zn-Bi-Pb-M.M. system alloy

TABLE 9

TEST MATERIAL	BORE FORMATION TIME (s)				
	1	2	3	4	MEAN VALUE
D-1	3.88	4.31	3.81	3.75	3.93
D-2	4.58	5.22	4.81	4.93	4.89
D-3	4.12	4.75	3.86	3.79	4.13
D-4	3.48	3.85	3.14	3.65	3.53
Table 9 explains bore formation time for Cu-Zn-Bi-Pb-M.M. system alloy.					

Table 9 explains the measurement results of the alloy. In accordance with the results, it is confirmed in the present system alloys that a good bore formation property is obtained as confirmed in the aforementioned cutting property. Even in a composition having a considerably less content of dispersion phase, the bore formation property approximately equivalent to the conventional free cutting brass is obtained. This is because bismuth and lead are co-existed, so that eutectic of a low melting point is formed, and dispersion phase is uniformly depersed in accordance with the formation of intermetallic compounds by the addition of M.M.

As described above, a first type of free cutting alloy containing no lead according to the invention results in no effect or influence to the quality of water, and a second type of free cutting alloy containing the minimum amount of lead results in no decrease of free cutting property.

Although the invention has been described with respect to specific embodiment for complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modification and alternative constructions that may occur to one skilled in the art which fairly fall within the basic teaching herein set forth.

Claims

1. Free cutting brass, comprising :
   57 to 61 weight % of copper ;
   0.5 to 4 weight % of bismuth ;
   0.05 to 0.9 weight % of misch metal ; and
   a remaining amount of zinc.

2. Free cutting brass, according to claim 1, wherein :
   said bismuth and said misch metal form intermetallic compound to be uniformly dispersed.

3. Free cutting brass, comprising :
   57 to 61 weight % of copper ;
   0.5 to 4 weight % in total of bismuth and lead ;
   0.05 to 0.5 weight % of misch metal ; and
   a remaining amount of zinc.

4. Free cutting brass, according to claim 3 wherein :
   said bismuth and said misch metal, and said lead and said misch metal form intermetallic compounds, respectively, to be uniformly dispersed.

FIG. 1A

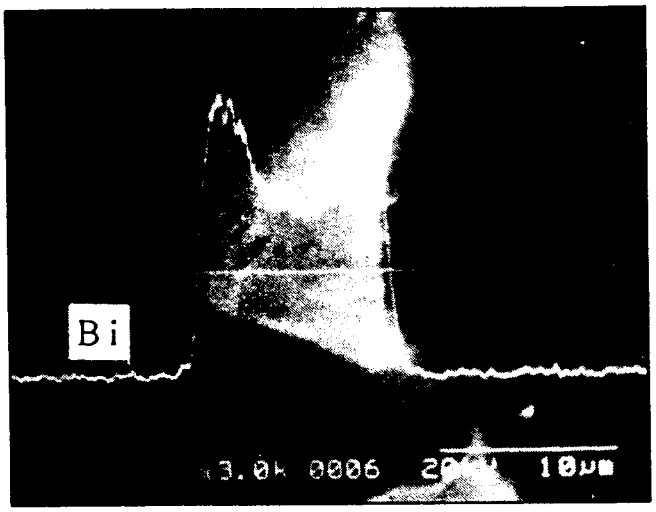
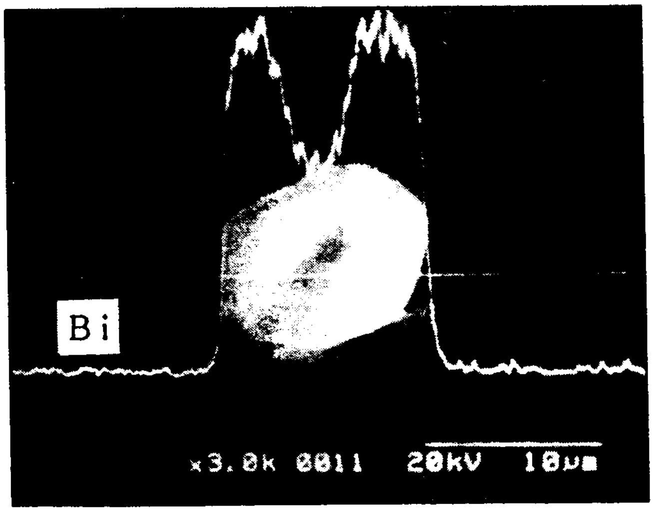


FIG. 1B



X–MA ANALYSIS IMAGE OF DISPERSION PHASE OF TEST MATERIAL A–8 FOR Cu–Zn–Bi–M.M. SYSTEM ALLOY

FIG. 1C

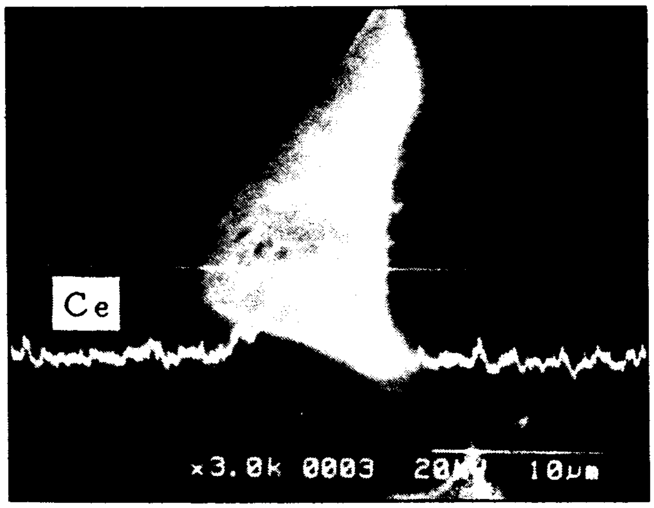
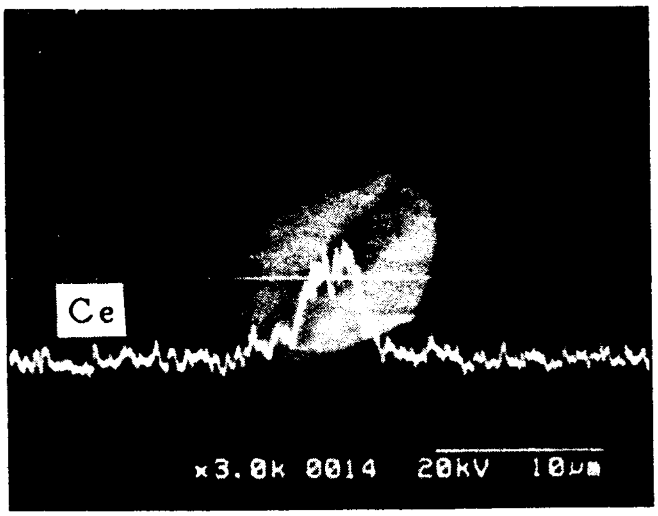


FIG. 1D



X–MA ANALYSIS IMAGE OF DISPERSION PHASE OF TEST MATERIAL A–8 FOR Cu–Zn–Bi–M.M. SYSTEM ALLOY

FIG. 2A

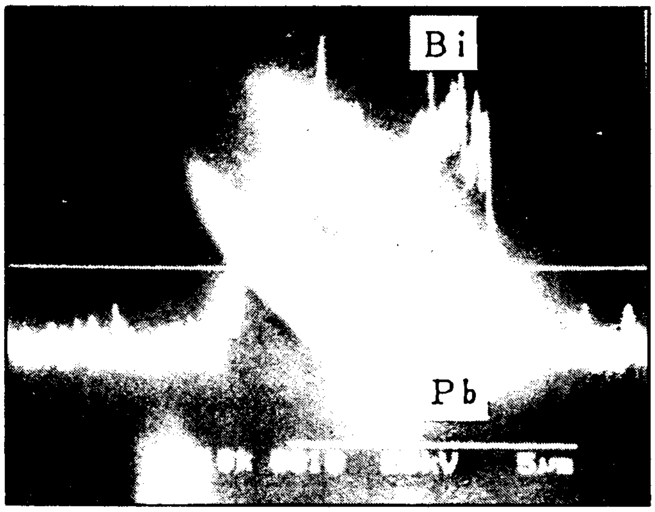
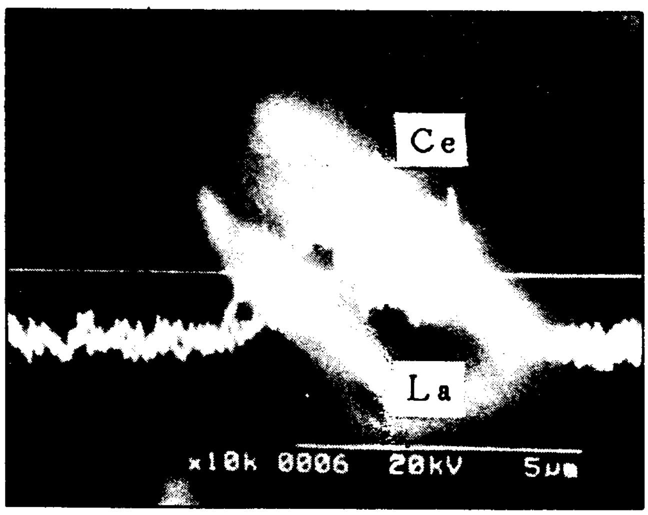


FIG. 2B



X–MA ANALYSIS IMAGE OF DISPERSION PHASE OF TEST MATERIAL C–2 FOR Cu–Zn–Bi-Pb–M.M. SYSTEM ALLOY

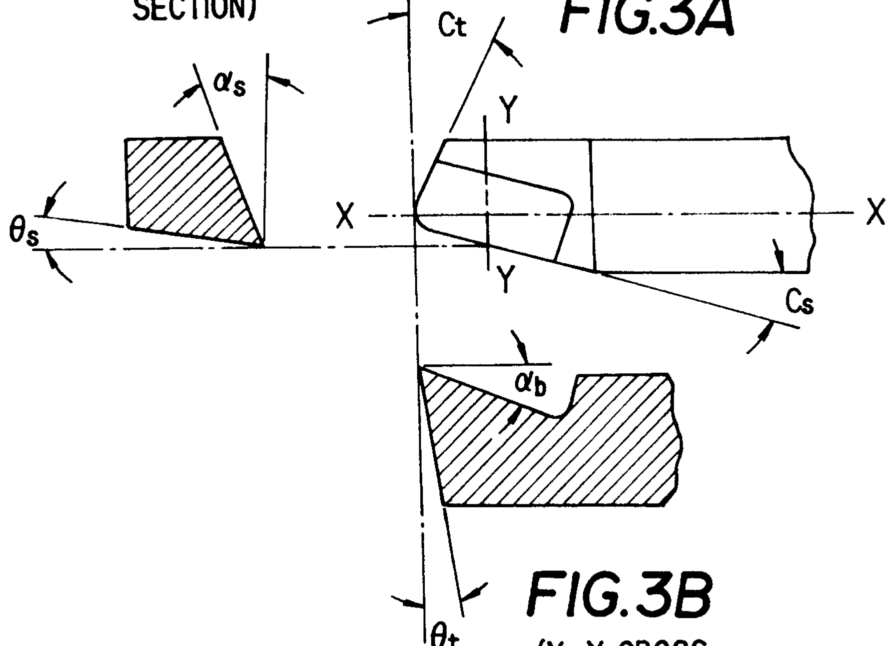


FIG.3C (Y–Y CROSS SECTION)

FIG.3A

FIG.3B (X–X CROSS SECTION)

BITS BLADE TIP CONFIGURATION

FIG.3D

(CUTTING CONDITION)

REVOLUTION VELOCITY	2.000rpm
FORWARDING AMOUNT	0.1mm/rev
CUTTING AMOUNT	1.5mm

FIG. 3E

(BITS CONFIGURATIN)

BITS BLADE TIP CONFIGURATION	ANGLE (°)
UPPER SKIMMING ANGLE (α_b)	0
SIDE SKIMMING ANGLE (α_s)	6
FRONT BLADE ANGLE (C_t)	8
SIDE BLADE ANGLE (C_s)	0
FRONT EVASION ANGLE (θ_c)	6
SIDE EVASION ANGLE (θ_s)	6
NOSE RADIUS (R)	0.5
MATERIAL	W.C.

FIG. 4

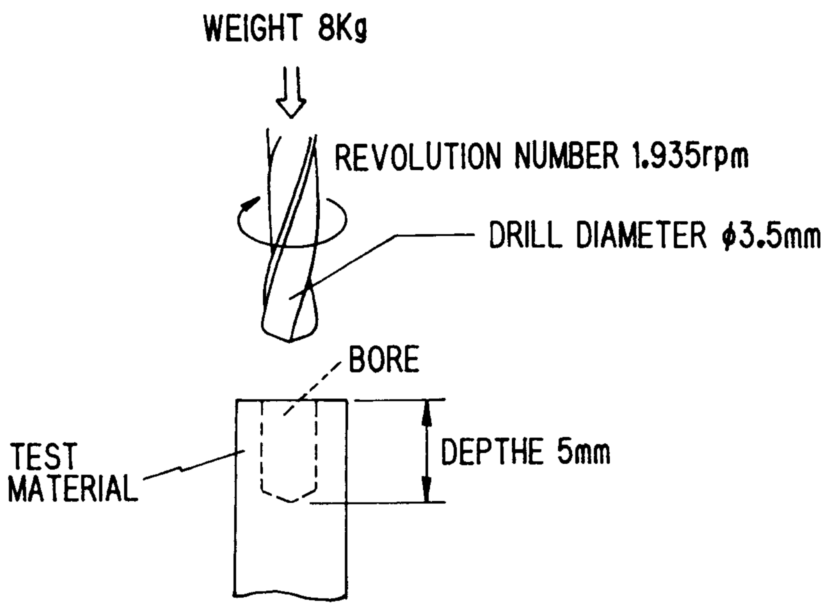
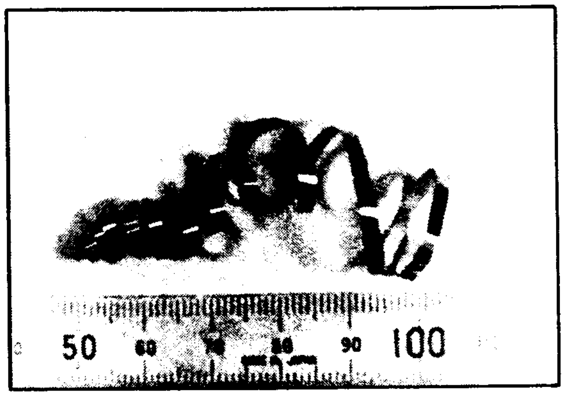

WEIGHT 8Kg
REVOLUTION NUMBER 1.935rpm
DRILL DIAMETER ϕ3.5mm
BORE
TEST MATERIAL
DEPTHE 5mm

FIG. 5A



TEST MATERIAL A-1

60/40 BRASS
Pb : 0
Bi : 0

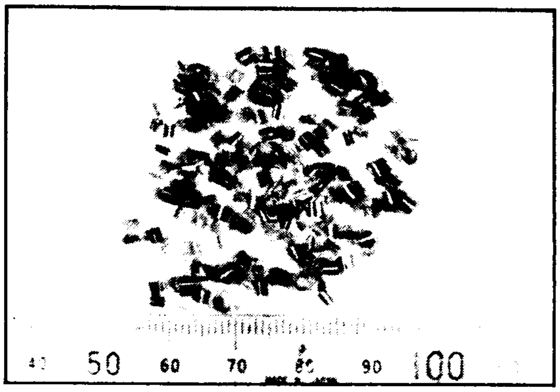
APPEARANCE OF CHIP FOR
Cu-Zn-Bi-M.M. SYSTEM ALLOY

FIG. 5B

TEST MATERIAL A-2

CONVENTIONAL FREE CUTTING BRASS
Pb : 3.22%
Bi : 0

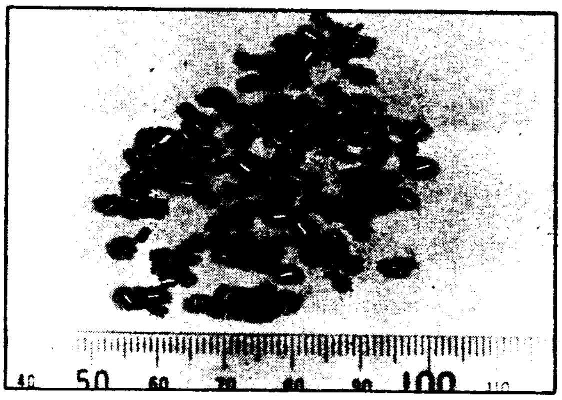
FIG. 5C



TEST MATERIAL	A-4
Pb	: 0
Bi	: 0.51%
M.M	: 0.14

APPEARANCE OF CHIP FOR
Cu-Zn-Bi-M.M. SYSTEM ALLOY

FIG. 5D



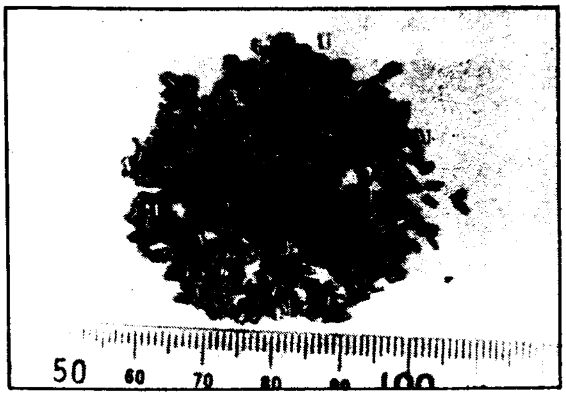
TEST MATERIAL	A-5
Pb	: 0
Bi	: 1.04%
M.M	: 0.23%

FIG. 5E

TEST MATERIAL A-6	
Pb	: 0
Bi	: 1.30%
M.M	: 0.47%

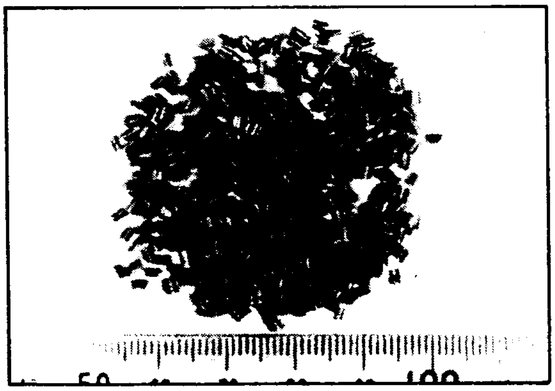
APPEARANCE OF CHIP FOR
Cu–Zn–Bi–M.M. SYSTEM ALLOY

FIG. 6A



TEST MATERIAL C-1	
Pb	: 1.48%
Bi	: 1.52%
M.M	: 0.10%

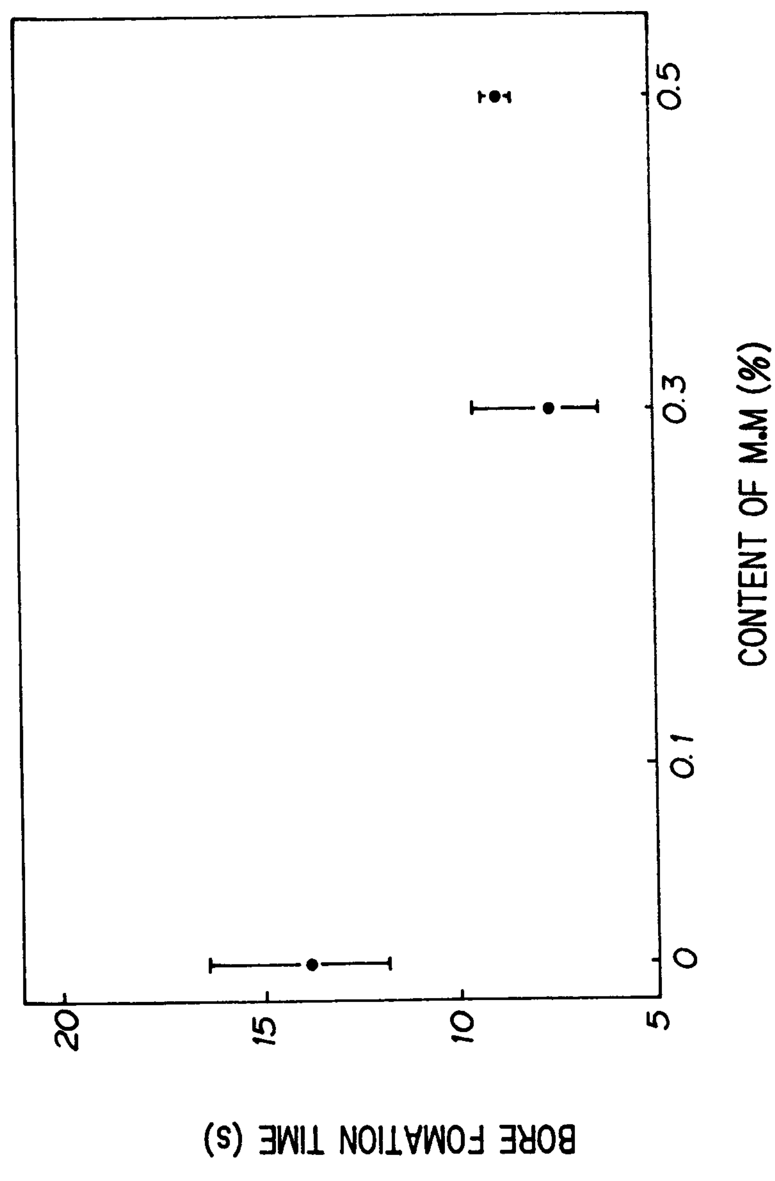
FIG. 6B



TEST MATERIAL C-2	
Pb	: 1.52%
Bi	: 1.51%
M.M	: 0.27%

APPEARANCE OF CHIP FOR
Cu-Zn-Bi-Pb-M.M. SYSTEM ALLOY

FIG. 7



Bi CONTENT OF 2.5% IS CONSTANT FOR Cu-Zn-Bi-M.M. SYSTEM ALLOY