Mitsubishi Shindoh Co.,Ltd.
4-7-35, Kita-Shinagawa, Shinagawa-ku, TOKYO 140-8550
TEL +81-3-5449-2511 // FAX +81-3-5449-2525

Abstracts

1) S. Tanaka,"Cavitation-Erosion Resistance of C6932", J.JRICu ,53,2013,139-144.

JIS C6932 (76Cu-3Si-Zn alloy) is used in water supply equipment such as water meters because it is a lead-free alloy with excellent corrosion resistance and good machinability. It was suggested that there is a possibility of cavitation erosion at the bend and ramp of joint in water supply equipment. Cavitation resistance of various copper based alloys including C6932 were studied by directly vibratory cavitation test using a magnetostrictive generator. Compared to bismuth-bearing bronze and dezincification corrosion resistance brass typically used in water supply equipment, the mean erosion rate of C6932 was 1/10 or less. C6932 was also found to have excellent cavitation resistance comparable to aluminum bronze CAC703 with excellent cavitation resistance in copper alloys. The metal structure of C6932 and CAC703 have κ phase in their matrix giving them excellent cavitation resistance. The mean erosion rate of Cu-Zn-Si alloy with α single phase is about 1/5 compared to dezincification corrosion resistance brass. Therefore C6932 has excellent cavitation resistance because of solid solution of silicon and κ phase presence in the matrix.

2) M. Takasaki,"Wear Characteristics of Free Cutting Copper Alloys", J.JRICu ,53,2013,88-94.

The relation of machinability and wear behavior that centered on no lubrication of free cutting copper Cu-Zn-Pb alloys and Cu-Zn-Si alloys are investigated. We have conducted a ball-on-disc wear test, and evaluated the wear loss, the damage state of stainless steel ball, observation of the cross-section, the surface of the wear track of the specimen, the chip shape and machinability ratio of the specimen.

The adhesion to the stainless steel ball acts as a built-up edge during cutting, surface is removed as wear particles before plastic deformation or adhesion layer is formed. Therefore, C3604 is significantly worn.

In the case of Cu-Zn-Si alloys of 17% or more kappa ratio, chips become to be divided. And same as C3604, surface is removed as wear particles before plastic deformation or adhesion layer is formed. Nevertheless, since κ-phase has good wear resistance, wear progress is suppressed.

Because the stainless steel ball is not damaged and abrasion loss is also small, ECOBRASS is lead free cutting copper alloy with desirable properties as a bearing material.

3) K. Oishi,"Development of Lead Free Copper Alloy "ECOBRASS® "", Proceedings of the sixth International Copper-Cobre Conference,August 25-30,Toronto,Ontario,Canada,vol.1,2007,325-340.

We have developed a 76Cu-3Si-21Zn alloy "ECOBRASS®" containing no lead. When 3% Si is added to a 78Cu-22Zn alloy, kappa and gamma phases participate uniformly in the alpha matrix. When being machined, stress concentrates on these hard phases, namely kappa and gamma, and thereby lowering the required cutting force and yielding segmentalized chips without

lubricant. Kappa and gamma phases transform into beta phase under high temperature, which makes it easier to extrude and/or forge the alloy. When 0.08% P and 50ppm Zr are co-added, the grains of ECOBRASS® castings are refined significantly to become as small as several dozens of micrometers. The grain refinement by the co-addition of P and Zr improves castability, tensile strength and elongation of ECOBRASS® castings. Meanwhile, the lead leachate from an ECOBRASS® water meter, field-tested in pH6.8 drinking water for one year, was less than 5ppb without correction. No indication of dezincification corrosion was observed, either.
ECOBRASS® is equally suitable for rods, forgings and castings, and makes it possible to produce a complete set of plumbing parts (valves, faucets, etc.) by its own. This way, not only improving recyclability, ECOBRASS® also realizes size and weight reduction due to its good corrosion resistance and high strength.

4)K. Oishi,"The development of lead-free free-cutting alloyed copper "75.5Cu-3.0Si-0.1P-Zn"" ,The Minerals, Metals and Materials Society 2003.11.

We study the influence of Si addition on the machinability of Cu-Zn alloys. κ and γ phases precipitate as the amount of added Zn decreases and the amount of added Si increases. During cutting, these phases are the sites of stress concentration, and they improve the separation of chips. When Cu-Zn-Si alloy consisting of α+κ+γ phases is machined, the resulting chips are fine and thin and the cutting resistance is low. By taking the advantage of this effect, we develop a lead-free free-cutting copper alloy 75.5Cu-3.0Si-0.1P-Zn. The developed alloy possesses good stress-corrosion-cracking resistance and dezincification corrosion resistance, which are advantageous for practical use; the stress-corrosion-cracking sensitivity depends on the concentration of Zn-3Si, and both κ and γ phases have excellent dezincification corrosion resistances.

5) K. Oishi,"Development of ECOBRASS® Castings with Fine Grain", Copper, Ed. by Jean-Marie Welter, WILEY-VCH Verlag GmbH & Co. KGaA, 2006, 185-193.

Our developed alloy ECOBRASS®, a lead-free free-cutting copper alloy, has gained a high reputation and is commercially used as a casting material due to its good castability and corrosion resistance. Aiming to further improve its performance and quality as a casting material, our work has now been accomplished to introduce ECOBRASS® castings with fine grain consisting of 3% Si, 76% Cu, 0.08% P, 0.005% Zr and remaining part Zn. The grains of ECOBRASS® castings with fine grain can be completely refined by the addition of 25ppm Zr when the content ratio between Zr and P is properly controlled, and thereby greatly improves its mechanical properties as well as castability. The mechanical properties of ECOBRASS® permanent mold castings with fine grain show 530N/mm^2 for tensile strength and 35% for elongation. In addition, the solid phase of castings with fine grain in the molten state is granulated, making ECOBRASS® castings with fine grain suitable for semi-solid metal casting as well.

6) K. Oishi, "Development of Human and Environment- Friendly Copper Alloy "ECOBRASS " for Machining, Forging, and Casting", J.JCBRA,39,2000,8-14.

Brass bars and bronze castings containing 2-7 wt% lead are widely used for water system appliances, like water supply fittings and valves, and for machine/electrical parts, like nuts, bolts and gears, in a variety of industries, because they have excellent machinability, hot forgeability and castability. However, the problem of lead elution from the water system appliances into tap water which we take in every day has been posed and, from the viewpoint of global environmental preservation, the development of a lead- free copper alloy has strongly been required throughout the country. We have developed a new lead- free copper alloy "ECOBRASS", friendly to humans and the environment, in accordance with three concepts of safety, recyclability and high performance. It is outlined as follows: 1. ECOBRASS is a new brass alloy containing 3wt% Si, harmless to humans and rich in resources, and it contains greatly less Zn than conventional brass. 2. ECOBRASS has a metallic structure in which K and T-phases are dispersedly precipitated in the a matrix. It shows cutting resistance and chip shape nearly equal to brass containing 2wt% lead and is superior in cut surface to the same brass. 3. Because of its excellent hot forgeability and castability, one type of ECOBRASS can be worked into many shapes of products(cutting, forging and casting), thus facilitating the recycling of it. 4. ECOBRASS solves the dezincification corrosion and stress corrosion cracking problems of brass. It has strength comparable to stainless steel, thus making its products compact and lightweight.

7)S. Iwasaki, “Evaluation of the Selective Leachability of Lead in the Copper Alloys into Tap Water”,J.JCBRA,40,2001,140-146.

The water quality standard for the tap water established by the Ministry of Health, Labour and Welfare was partly revised in 1992, reducing the standard of lead content from the prior value of not more than 0.1 mg/L to a value not more than 0.05 mg/L. Further, the Ministry stated its clear intention to reduce the value of the standard to not more than 0.01 mg/L, the value given in the Guidelines of WHO, by 2003. There is a danger of dissolution of lead from the water supply equipment installed before revision of the standard and still in use, and measures with regard to materials used are indispensable in the future in order to satisfy the strengthened water quality standard. The present research examined the quantity of dissolution of lead into the tap water from the copper alloys most used in Japan for water supply equipment such as faucet and piping parts. The alloys examined for lead dissolution were mainly bronze types, brass types and silicone brass types. In examination of the relationship between the quantity of lead contained in each of the alloys and the quantity of dissolution into the water supply, following interesting results were obtained. The relationship between the lead content in the alloy and the dissolution into the water supply is not a simple proportional relationship. In cases of low lead concentration, with further increases in lead concentration the dissolution rapidly increases whereas in cases of high lead concentration, with further increases in lead concentration the increase in dissolution is slight. Further, even when the lead content in the alloy is the same, the dissolution of lead into the water supply differs depending on the alloy type, that is to say the alloy composition and the metal structure which constitute the base in which the lead is incorporated. The degree of selective dissolution of lead from the alloys is in the following decreasing order. Bronze type ＞ Silicone brass type ＞ Brass type. Further, it is known that there is selective dissolution of zinc among alloy components in brass, but it has been recognized that lead takes precedence along with zinc in dissolution from brass containing lead.

8)T. Okubo, "Influence of Pb, Bi and Si Impurities in Free Cutting Copper Alloys on the Embrittlement at the Intermediate Temperature Range", J.JCBRA,40,2001,147-152.

The effect of a mixed element such as lead, bismuth or silicon on the embrittlement in a intermediate temperature range of free cutting copper alloys was examined in this study, assuming that scraps of free cutting alloys are mixed through recycling. Three kinds of free cutting alloys, Cu-Zn-Pb, Cu-Zn-Bi and Cu-Zn-Si with and without impurities, are cast and extruded into rods with diameter of 15mm. In addition, lead red brass alloys and copper-bismuth alloys were also cast. Test specimens were made from the rods and from the castings, and subsequently subjected to impact test at elevated temperatures. The results are summarized as follows: 1) Impurity bismuth as low as 0.1 mass% contained in free cutting brass C3771 lowered a starting temperature of embrittlement for about 50K. On the other hand, impurity lead as low as 0.05 mass% contained in free cutting brass Cu-Zn-Bi was lower the starting temperature of embrittlement for about 150K than C3771. A similar effect was observed in casting bronzes of Cu-Sn-Zn-Pb and Cu-Sn-Zn-Bi. 2) The lowering of the starting temperature of the embrittlement corresponds to a fall of the solidus temperature of a lead-rich or bismuth- rich phase owing to alloying bismuth impurity or lead impurity, respectively. 3) Silicon mixed into the free cutting brass C3771 brings about almost no effects on its impact property. Lead mixed up to 0.2 mass% into the Cu-Zn-Si alloy rods show a similar effect on impact property of C3771. But impact values in the intermediate temperature are higher compared to those of C3771. However, embrittlement was not observed in the Cu-Zn-Si casting even when the alloy is contaminated with lead.

9)T. Matsumoto, "Drilling of Lead Free Brass Alloy "ECOBRASS"", J.JRICu,41,2002,76-80.

It is believed that tool life is shortened during dry cutting of the lead free brass alloy "ECOBRASS" because it does not contain soft, lubricating particles such as lead. However, it is expected that ECOBRASS is well suited for dry thin wall drilling because of the absence of low melting metal particles such as lead. In this research, a dry drilling test of φ10×53mm holes was performed using an NC lathe with a bar feeder. The chip forms, the tool life and the thin wall drilling characteristics of the ECOBRASS were evaluated using C3604 and a Cu-Zn-Bi alloy as the comparison material. The results are summarized below. 1）The chip form of the ECOBRASS is fine during the feed rates 0.2mm/rev. and 0.3mm/rev., regardless of the drilling speed and the chip control is also fine. The drilled surface of the ECOBRASS is smoother in comparison with C3604. 2）The cutting power load during the drilling when using ECOBRASS, which uses an NC lathe, is about 60％ higher than C3604, however, ECOBRASS can drill 6000 pieces of φ10×53mm holes with a high-speed steel drill, and it shows very good tool life characteristics, in which continuous operation for several days can be endured. 3）ECOBRASS can be drilled with a thin wall of thickness 0.3mm, even if 0.1％ mass lead is contained as impurities. Moreover, the thickness of the damaged layer of the ECOBRASS caused by the drilling is about 50％, as compared with C3604.

10)Y. Fukuda, "Soil Corrosion Test of Lead-Free Copper Alloy 「ECOBRASS®」", J.JRICu,42,2003,280-284.

Copper alloys with 2-6% lead added are widely used as the main parts of piping for water fittings, meters and water tap faucets. However, from the viewpoint of toxicity of lead on the human body, reexamination of the materials is now in progress. As lead-free free-cutting alloys, ”ECOBRASS”, a Cu-Zn-Si alloy developed by us, and Cu-Zn-Bi alloys have been announced. These components are often used in soils, but very few repots exist on corrosion in soils.

In this research, in order to study the corrosion resistance of ECOBRASS and conventional materials in soil, accelerated tests were carried out on the test pieces buried in two types of soil through repetition of spraying corrosive solution based on artificial acid rain, drying and wetting, and the corrosion resistance of material was evaluated by the depth of corrosion. Also, the possibility of occurrence of galvanic corrosion in the case where ECOBRASS and comparative materials were brought into contact in surface area proportions of 1 : 1 was studied.

As a result, the corrosion resistance in 9 months of exposure by the accelerated tests was in the order of CAC406≒ECOBRASS>Cu-Zn-Bi>C3604. The difference in the depth of corrosion according to the type of soil was slight between ECOBRASS and CAC406, while the depth of corrosion of C3604 and Cu-Zn-Bi increased in the order of air, clayey and sandy soil.

As for galvanic corrosion, the corrosion of ECOBRASS itself did not develop even if it was brought into contact with SUS304 and CAC406. However, there was a tendency wherein ECOBRASS corroded C3604 when it was in contact with C3604. Also, the galvanic corrosion occurred at specific positions of the samples.

The above are almost identical to the results having been obtained by the filed test.

11)S. Tanaka,”Chronological Changes of the Behavior of Lead Leaching into Tap Water from Copper Based Alloys”, J.JRICu,43,2004,240-245.

Countermeasures against lead leaching into tap water from copper based alloys used in water supply equipments are taken by surface treatment for conventional materials containing lead, or using lead-free copper alloys. Very few reports exist on long-term lead leaching of these countermeasure materials. In this research, we examined the behavior of lead leaching of countermeasure materials and conventional materials in normal tap water and in tap water whose pH was adjusted to 6.8±0.2 by blowing carbon dioxide gas into tap water for four months. As a result, the amounts of lead leaching into both cases of tap water were C3604 > CAC406 (no treatment) > CAC406 (surface treatment) > Cu-Si-Zn alloy, which was affected by the amount and distribution of lead contained in alloys, dezincification of materials, or corrosion resistance of matrices. The amount of lead leaching of the Cu-Si-Zn alloy satisfies the value of the criterion for end faucets in both cases of tap water without correction, and it is judged that the 0.02mass% lead contaminated in this alloy as impurities hardly affected lead leached. With the CAC406 surface-treated material greatly decreased in the amount of lead leaching at an early stage of exposure compared with the non-treated material, the effect of retarding lead leaching was recognized. However, the retarding effect declined for the exposure periods, and also declined in tap water with carbon dioxide gas.

12) T. Matsumoto,”Deep-Hole Dry Drilling of Lead-Free Copper Alloy “ECOBRASS””, J.JRICu,43,2004,285-290.

In non step deep hole dry drilling by using JIS standard drills, the chip jamming easily arises as the depth of cut increases. As the workpiece diameter

increases with respect to the drill diameter, the tightening force to the drill from the workpiece increases. Due to these phenomena, there are cases where the machine may stop or the drill may break under an overload. We attempted to solve these problems with deep hole dry drilling by using a drill with an expanded flute width（Step-free drill）, a same type of drill with a large back taper, and a same type of drill with a reduced width of margin and increased depth of body clearance.
As workpieces, we prepared ECOBRASS of 8 – 100mm in diameter. The results are summarized as shown below.
1）In the case of deep hole dry drilling of ECOBRASS, the chip jamming is alleviated by using Step-free drill with an expanded flute width, which allows that the depth of cut is 10 – 12 times as deep as the drill diameter.
2）In the case of 8mm-diameter deep hole dry drilling of ECOBRASS 30mm or more in diameter, the tightening force to the drill from the workpiece can be alleviated by making back taper of Step-free drill large, or by reducing the width of margin and increasing the depth of body clearance of Step-free drill .
3）In the case of continuous drilling multiple holes in a workpiece by using an NC milling machine, it is effective to reduce the width of margin and increase the depth of body clearance of Step-free drill（the width of margin; about 60% decrease, and the depth of body clearance; about 0.05mm increase）to the length corresponding to the depth of cut.

13) S. Tanaka,"Effect of Water Quality on Lead Leaching into Tap Water from Copper Based Alloys", J.JRICu,44,2005,219-224.

Amount of lead leaching from copper based alloys used in water supply equipment is affected by pH of tap water. Although the pH of tap water varies depending on amount of dissolved carbonate and/or purification methods at waterworks, there have been few reports about such pH effect on the lead leaching.

In this research, We examined lead leaching behavior of Cu-Si-Zn alloy, CAC406 with or without treatment to remove lead from the surface and corrosion-resistance brass containing 0.2, 0.9 and 1.8 mass % of lead. Specimens were immersed in the tap water, pH of which was adjusted from 6.0 to 7.0 by carbon dioxide, sulfuric acid or hydrochloric acid.

As pH becomes lower, the amount of lead leaching from each specimen increases. The degree of such increase is larger for the test water with carbon dioxide than with sulfuric or hydrochloric acid. This becomes more obvious in case of CAC406 without the treatment to remove lead or corrosion-resistance brass containing higher lead.

The amount of lead leaching also increases with increasing the amount of lead on the surface of specimen. On the contrary, the ratio of lead leaching to lead content becomes large as the lead content decreases. From these findings, we assume that lead leaching is affected by the area of lead presence on the surface.

14) T. Matsumoto,"Cutting of Lead-free Copper Alloy "ECO BRASS®"", J.JRICu ,45,2006,250-255.

The effect of tool material and tool geometry on the machinability of ECO BRASS®(Cu-Zn-Si based lead-free copper alloy) has been examined in various continuous cutting methods under dry conditions. Emphasis was placed on the contribution to cutting technologies on shop floors. The results are summarized as follows:

(1) Turning
Power loads and the form and size of chips vary depending on the tool materials. K10 tools are most suitable. TiN coated carbides and cermet are inappropriate for machining the alloy in terms of power load, chip shape, and tool life.
(2) Drilling
Power loads are greatly affected by chip disposability which depends on drill geometry and surface modification. Twist drills coated with AlTiN showed good results with considerably low power loads.
(3) Threading
Although external threading can be conducted smoothly even in dry cutting when using carbide tips, it is necessary to apply oil mist for internal threading with tap.

15) K. Oishi,"Development of 76Cu-3Si-21Zn alloy castings with fine grain", J.JRICu ,46,2007,289-293.

This study is directed to the development of 76Cu-3Si-21Zn alloy castings with fine grain by using fine grain control technology, aiming to further improve the quality and performance of ECOBRASS. The metal structure of continuous cast rod made of 76Cu-3Si-0.08P-Zn with the increasing addition of Zr in a small amount is dramatically changed from dendrite to grain refined structure, which occurs between the Zr content of 21ppm and 25ppm. As the structure changes, both tensile strength and elongation are improved from $490N/mm^2$ to $540N/mm^2$ and from 32% to 45%, respectively. The continuous cast rod where the average grain size becomes as small as 20μm is free from anisotropy because of the random orientation of each grain and therefore, comes to have almost the same mechanical properties as those of extrusion rod. In addition, sand castings, billets for hot extrusion and quenched castings all come to have grain refined structure by the technology, which will ensure its adaptations to various casting methods and conditions. A new age of manufacturing, which should be safe and environmentally friendly, is anticipated for drinking water applications such as plumbing, valves and faucets by using a combination of the technology and the flexibility of casting.

16)T. Yoshikawa,"The Effect of Minute Impurities, Lead and Bismuth, on the Embrittlement Phenomena of Leaded and Lead-Free Free-Cutting Brass Rods", J.JRICu ,47,2008,78-82.

A major concern has been raised in brass rod industries with regard to a possible contamination from scrap materials, which is expected to happen amid the ongoing progress in lead-free trend for free-cutting copper alloys. In this study, impact test was conducted to evaluate how impurities such as lead and bismuth in minute amounts from 0.01 mass% to 0.1 mass%, which are contained in lead-free free-cutting brass rod and leaded cutting-free brass rod, would affect the embrittlement phenomena of said alloys in the middle temperature range. The results are summarized as follows:
1) An acute embrittlement can be seen for bismuth-bearing brass rod at 423K when more than 0.031 mass% of lead is added. Meanwhile, leaded brass rod becomes brittle at 573K when more than 0.027 mass% of bismuth is added.
2) Impact value of copper-zinc-silicon alloy rod at 623K is maintained at 100 kJ/m2 when lead and bismuth are added in the amount of 0.101 mass% and 0.054 mass%, respectively.
3) The temperature where embrittlement would start corresponds to the solidus

temperature of bismuth particles or lead particles. An acute embrittlement is observed at 423K when a small amount of lead is added to bismuth-bearing brass rod, due to the formation of eutectic compounds in the bismuth particles.

17) Y. Tsugawa,"Crystal Orientation Relationships between phases in a cast copper alloy CAC804", J.JRICu ,47,2008,29-33.

EBSD (Electron backscatter diffraction) was first put to practical use in 1980's. Since then, it has rapidly spread as a method of analyzing local grain orientation of a material in combination with SEM (Scanning Electron Microscope).
While EBSD is mainly used to analyze the texture of a rolled material and super fine structure, almost nothing has been reported on its application for a cast material, especially copper alloys, to date.

We then studied the structure of ECOBRASS cast material (CAC804) by EBSD, which resulted in some interesting findings where a certain relationship in its orientation was observed.
In the meantime, the metal structure of CAC804 is composed of alpha phase, kappa phase and a small amount of gamma phase, each of whose crystal structure is fcc (face-centered cubic), hcp (hexagonal close-packed) and bcc (body-centered cubic), respectively.
Further studies were conducted by using EBSD on the high ductility of CAC804 despite several dozen percent of hcp structure, which is poor in slip system, being contained therein.

18) T. Oka,"Metal Structure and Mechanical Properties of Grain Refined CAC804", J.JRICu ,47,2008,83-87.

Lead use in water pluming applications becomes further restricted due to the tightening of regulations such as California Assembly Bill 1953 approved in September 2006 and the revised NSF 61 introduced in September 2007. In line with this trend, "Lead-free" in materials is expected to be accelerating. On various occasions, copper alloys used in plumbing are provided in the form of casting such as continuous cast rod, as well as extrusion rod.

Characteristics of CAC804C alloy, which was produced by the use of fine grain control technology to give ECOBRASS casting mechanical properties equivalent to those of extruded material, were evaluated. The metal structure of CAC804C changes to randomly-oriented alpha-phase grains of 0.03mm in average diameter by adding zirconium in the amount of more than 24ppm. Due to such grain refinement, tensile strength and elongation are improved by 30N/mm^2 and 15%, respectively, both of which are higher than those of lead-free bismuth alloy continuous cast rod. In addition, material anisotropy, fatigue property and stress corrosion cracking resistance are improved, thereby imparting the material higher reliability as continuous cast rod. Such excellent properties of grain refined CAC804C will provide cost advantage in thin-walled products etc. Grain refined CAC804C is thus believed to be the most suitable material for water plumbing applications.

19) S. Tanaka,"Corrosion resistance of CAC804 after a long-term use as a drinking water apparatus", J.JRICu,49,2010,264-268.

Lead-free copper alloys have come into wider use for drinking water applications due to various regulations on lead. However, apart from laboratorial evaluation made on corrosion resistance of lead-free copper alloys, almost no report has been made for evaluation under the actual environment of usage. In

this study, corrosion resistance was evaluated for silicon-bearing lead-free copper alloy CAC804 water meters after eight-year use in the average Japanese water quality along with lead-bearing copper alloy CAC406 water meters for comparison. In addition, dezincification corrosion test according to JBMA T303 was also conducted for these two alloys in order to compare the results with those from the actual environment.
It is observed from the cross-sectional macrostructure of water contacted area that CAC804 meters have no sign of dezincification corrosion even after eight years in service, while it exhibits minor general corrosion with the maximum corrosion depth of 60 μm or less. It is shown that the CAC804 meters have almost the same level and form of corrosion resistance as the CAC406 meters used in the equivalent water quality. CAC804 was categorized as an alloy having the first-grade corrosion resistance based on the test results pursuant to JBMA T303. It is noted that a material showing excellent corrosion resistance under JBMA T303 test has also excellent corrosion resistance under the actual environment.

20) K. Suzaki,"Fatigue Property of Lead-free Copper Alloy "ECO BRASS"", J.JRICu ,51,2012,76-80.

Regulations on lead in copper alloys have been limited to the standards for lead leaching into portable water, mainly for water-related appliances. Recent regulations, however, are rather imposed on the lead amount itself contained in a material to be used for such products. It is also expected that lead regulations on copper alloys used for automobile and electrical/ electronic fields be strengthened in near future. Meanwhile, it is desirable for machine structure parts used in electrical/electronic fields to minimize a decrease in fatigue strength caused by notch (i.e. notch sensitivity) since said parts are normally processed into complicated shapes.
Our research was conducted on conventional copper alloys C3604, free-cutting brass with 3% lead and C6782, high-strength brass with 0.3% lead, as well as lead-free copper alloys C6932 containing 3% of silicon and C6801 containing 2% of bismuth, in order to study fatigue properties and fatigue notch sensitivity factor. While the notch sensitivity factor t for C6932 is low because of the absence of lead, the fatigue strength of its notch material, combined with its high tensile strength, is almost twice as high as C3604 and C6801. For comparison between C6932 and C6782, both alloys have low notch sensitivity since the former contains no lead and the latter does but only a small amount. However, C6932 has double the fatigue strength of C6782 despite their equivalency in tensile strength, as C6932 shows the $\alpha>\beta$ type of fatigue properties while C6782, $\alpha<\beta$type.

21) T. Oka,"Form Rolling of Lead-Free Copper Alloy「ECOBRASS®」", J.JRICu ,51,2012,103-107.

Regulations on lead contained in copper alloys have been strengthened in electrical/electronic fields and other industrial fields as well as in water faucet fields. In 2015, a revision of the exclusionary clause in RoHS・ELV for lead in copper alloys will be considered.

Lead-free copper alloy ECOBRASS® is widely used for various machine parts and slide member parts. There exist many kinds of products where form rolling, which produces no chips, is combined with cutting work. Although form rolling is expected to be difficult for ECOBRASS® due to its lower cold workability compared to leaded free-cutting brass, improvement methods have been explored in terms of metal structures and mechanical properties.

For ECOBRASS®, kappa/gamma phases, which contribute to cutting properties, adversely affect cold workability. However, it is confirmed that the production by form rolling can be realized when the amounts of kappa/gamma phases are optimized by way of annealing at 550C. In general, there are concerns over a decrease in stress corrosion cracking resistance for form rolling products. On the contrary, ECOBRASS® is expected to enter into electric/electronic and automobile fields as a highly reliable material with no risk of stress corrosion cracking.