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COPPER-BASE CASTING ALLOY

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This invention relates generally to a new non-ferrous casting alloy, and more specifically to a new copper-base alloy which is characterized by unusual resistance to oxidation and improved founding and physical properties.

The invention is particularly concerned with the provision of a casting alloy which can be used as a substitute for the conventional high strength brasses and bronzes and which overcomes the defects and shortcomings thereof. As will be appreciated by those familiar with non-ferrous founding, the usual brasses and bronzes are difficult to cast. In general such alloys are difficult to cast because of the extreme tendency toward porosity shrinkage and because of the tendency to form harmful oxides.

In attempts to improve the founding characteristics of brasses, it has been the practice to increase the zinc content. The addition of zinc is beneficial in that it lowers the melting point of the alloy, improves strength and corrosion resistance, and, when in excess of approximately 20%, reduces the susceptability to gas absorption when the melt is flared. However, because of its high vapor pressure, zinc also has the adverse effect of producing a heavy, tenacious dross which is difficult, if not impossible, completely to remove from the metal. As a result, the oxides are trapped in the metal when it is poured, thereby causing porosity, a reduction in the physical properties, and general unsoundness in the castings.

Oxide inclusions in the metal are particularly serious in precision casting work, since it is difficult to obtain smooth as-cast surface finishes. Further, because of the oxide inclusions and resulting porosity, such castings are characteristically hard to plate. It has been found that, during electroplating, the plating solution is absorbed into the castings. Subsequently, these solutions bleed from the castings and loosen or completely lift off the surface plating.

Prior work in the founding of brasses has also suggested the use of aluminum as a deoxidizer to reduce the extreme tendency of zinc toward the formation of oxides. The addition to a clean melt of even relatively small amounts of aluminum, for example, 0.1%, results in a thin oxide film which, when unbroken, reduces the evolution of zinc vapor and rapid oxidization. Consequently, small amounts of aluminum theoretically will result in smoother and cleaner surfaces then can be obtained with pure brasses.

Nevertheless, it has been recognized that, in actual practice, the addition of aluminum is not a satisfactory answer to the problem of molten brass oxidation, since it presents additional casting difficulties. The thin aluminum oxide film that is formed on the melt is itself extremely tenacious and difficult to remove, and care must be taken during pouring not to break this film. If the film is broken, the oxide inclusions tend to congregate in the molten metal, thereby again resulting in poor mechanical properties and surface finishes.

The present invention overcomes the foregoing problems and disadvantages of conventional brasses by providing a novel, complex copper-zinc alloy which includes beryllium and tin. As will hereinafter be explained in

more detail, the new alloy of this invention has good pouring properties, including excellent fluidity and a low melting temperature of approximately 1700° F. The product of the invention also has the important characteristic of being resistant to harmful oxide formations. Other advantages are that the alloy is susceptible to solution heat treatment and precipitation hardening, machinable, platable, and exhibits no detrimental shrinkage and only mild piping. The physical properties of the new alloy are characterized by its strength, toughness, and resistance to corrosion.

Because of the foregoing advantages, the alloy of this invention is especially useful for precision casting. Since the alloy is highly resistant to the formation of detrimental oxides, cleaner and smoother surfaces can be obtained than with conventional brasses and bronzes heretofore used for this purpose. The usefulness of the alloy for precision casting work is further enhanced by its low melting point, good fluidity, and other excellent pouring characteristics. In addition, the alloy is suitable for permanent mold casting, sand casting, and plaster mold casting.

Castings formed of the new alloy also can be easily electroplated due to the fact that the absence of oxide inclusions and general soundness of the castings precludes absorption of the plating solutions. The alloy is also useful as a hob material and for applications requiring toughness, hardness, or resistance to corrosion.

Accordingly, it is a general object of the invention to provide a new copper-base alloy which is useful as a substitute for conventional brasses and bronzes and which overcomes the defects and shortcomings thereof.

Another object of the invention is to provide a new copper-base casting alloy which is characterized by excellent founding and physical properties and by a marked resistance to harmful oxide formations.

A more specific object of the invention is to provide a new copper-base alloy which is particularly suitable for precision casting work and which also can be used to advantage in permanent mold casting, sand casting, and plaster mold casting.

Other objects and advantages of the invention will become apparent from the following detailed description.

The present invention is based on the discovery that a complex copper-zinc alloy containing tin and at least 0.6% beryllium exhibits an oxide formation which makes it possible to obtain a cast product having improved properties that cannot be obtained with conventional copper-base casting alloys. In general, the oxide formation which characterizes the novel non-ferrous alloy of this invention is light, powdery, and less tenacious in forming a film on the melt than aluminum oxide and the oxides of other conventionally employed reducing agents. At the same time, the light, powdery oxide formed during melting protects the melt against the further formation of detrimental oxides or drosses. Although this protective oxide film may thicken slowly with time, it is removed easily prior to casting because of its non-tenacious nature.

It is because of the foregoing advantageous characteristics that the alloy of this invention is ideally suited for precision casting work. The nature of the powdery oxide film which occurs and the ease with which it can be removed from the melt assures castings having minimal oxide inclusions and porosity, while the uniform distribution of any oxides that remain in the metal makes it possible to obtain sound castings having smooth surface finishes. Due to the soundness of the castings, they can be plated readily without danger of the plating solution being absorbed into the castings and subsequently causing

the plating to loosen. In other applications, the absence of large oxide inclusions and the congregation of such oxides in the metal assures good mechanical properties.

The exact nature and the mechanism of the oxide formation characterizing this invention has not been clearly established; however, for purposes of explanation, it is believed that the new alloy may be considered as comprising a copper-zinc system and a zinc-beryllium-tin system. When present in amounts in excess of approximately 3%, the zinc is preferentially oxidized in the copper-zinc system and protects the copper against oxidation.

The beryllium in the zinc-beryllium-tin system acts as a reducing agent and thus greatly inhibits the otherwise excessive zinc oxidation occurring in conventional copper-zinc alloys. Thus, to obtain the powdery oxide formation described above, the critical lower limit of beryllium is that which will protect the zinc and prevent the formation of an objectionable heavy dross on the melt. As previously noted, the critical lower limit of beryllium has been found to be about 0.6%. From the standpoint of oxide formation, the upper limit of beryllium is not critical and depends primarly on the fact that excessive use of beryllium is expensive and may cause brittleness.

It will be seen from the foregoing that the addition of beryllium makes it possible to vary the zinc content of the new alloy over a wide range to obtain all of the advantages of zinc without the attendant disadvantages which heretofore have been encountered. A further important advantage is that the beryllium provides excellent corrosion resistance due to the fact that beryllium oxide is a non-conductor of electrons. Hence, when castings formed of the new alloy of this invention are exposed to oxidizing conditions, a protective, non-conducting film of beryllium oxide develops which prevents pitting due to electrochemical action.

The marked resistance to corrosion which characterizes castings formed of the new alloy also makes it possible to employ the alloy in conventional ceramic shell molding processes of precision casting wherein the castings are immersed in molten caustic completely to remove the shell material. Heretofore, the caustic cleaning operation has caused serious pitting of castings formed of conventional brasses and bronzes and has been generally inimical to obtaining smooth surface finishes. On the other hand, castings of the alloy provided by this invention can be cleaned in the conventional manner without pitting.

The oxide complex characterizing the casting alloy of this invention is still further improved by the addition of tin, preferably at least 1.5% tin. While the action of the tin is not wholly understood in this regard, the resulting oxide complex is more powdery and less tenacious than that formed without tin, and, at the same time, retains its protective action on the melt. Another advantage is that he melt slags off beter so that it is possible to obtain cleaner castings without oxide inclusions. Still further, as distinguished from the known beryllium-copper alloys, the addition of tin makes it possible to obtain excellent corrosion resistance without using relatively large amounts of beryllium. Consequently, the alloy of this invention is less expensive than conventional beryllium alloyed copper-base alloys.

Composition ranges and typical properties

In accordance with the foregoing general description, this invention provides a new complex copper-zinc-beryllium-tin casting alloy having a preferred composition falling in the alloy limits:

Zinc	from about 8.0% to about 20%.
Beryllium	from about 0.75% to about 1.5%.
Tin	from about 1.5% to about 4.5%.
Phosphorus	.10% max.
Silicon	.25% max.
Aluminum	.25% max.
Manganese	.25% max.
Iron	

A more preferred working range of the alloy which has been found suitable for most applications is as follows:

	Percent
Zinc	13.00–18.00
Beryllium	0.90–1.05
Tin	2.50–4.00
Phosphorus	.10 max.
Silicon	.25 max.
Aluminum	.25 max.
Manganese	.25 max.
Iron	.25 max.
Copper	Balance

Castings having compositions within the preferred ranges indicated above generally exhibit the following average properties:

Property	As Cast	Solution Heat Treat at 1,400° F.	Solution Heat Treat at 1,400° F.—Age Harden at 800° F. (1 hr.)
Tensile strength, p.s.i.	7,000	74,500	108,000
Yield Strength, p.s.i.	50,000	50,300	62,000
Percent Elongation in one inch	8.0	7.5	4.0
Percent Reduction in area	10.0	9.0	4.0
Hardness	Rb 80	Rb 90	Rb 100
Machinability	Good	Good	Good

Examples

In order that the inventon will be clearly understood by those skilled in the art, reference is made to the following table which lists the compositions of three casting alloys made in accordance with the invention.

Alloy	Percent Zn	Percent Be	Percent Sn	Percent Cu	Percent Others
1	20.07	1.4	1.5	77.05	0.34 Mn.
2	16.93	1.4	2.89	79.13	Phos. <.01.
3	13.65	1.03	3.63	81.11	0.19 Al; 0.16 Mn; 0.23 Si.

In each instance, customary precaution was taken in preparation of the melt to use materials free of oil, dirt, moisture, moisture bearing sand, and foundry refractories. The charge was melted in a silicon-carbide crucible using a slightly oxidizing gas flame. During melting care was taken not to disturb the dross or oxide cover over the melt until it was ready to pour. As will be appeciated by those skilled in the art, this illustrative melting procedure and the equipment used are subject to wide variation without departing from the teachings of the invention. By way of example, the charge may be melted in different types of crucibles, such as graphite crucibles, or in induction furnaces.

Each alloy was de-gassed prior to pouring to eliminate hydrogen gas by bubbling gaseous nitrogen through the melt. The bubbling depth was made as great as possible in order that the time and extent of bubbling was as long as necessary to effect an effective de-gassing operation. In each instance, deoxidation of the melt was not necessary, since the metal contained enough zinc and beryllium for this purpose.

The listed examples of the invention had sharp melting points of approximately 1700° F., and only small amounts of dross formed on the melts. The small amount of oxide film that did form was easily slagged off prior to pouring and apparently fully protected the metal, since there was no copious evolution of zinc vapor.

The alloys were cast in heated ceramic shell molds and the resulting castings had excellent surface finishes that required only polishing. No detrimental shrink porosity was found and only mild piping occurred. Equally important, examination of the castings indicated that there was no tendency toward congregation of oxide inclu-

sions, as is customary in alloys containing aluminum as a reducing agent.

Summary

As will be apparent from the foregoing, the invention provides a new complex copper-zinc-berryllium-tin casting alloy which has good mechanical properties in the as-cast condition, and which is susceptible to heat treatment to improve the properties for special applications requiring toughness or hardness. Because of the relatively low, sharp melting point and the characteristic nature of the powdery oxide film that forms during melting, the new alloy has been found easier to cast than conventional copper-base alloys.

One particularly important feature is that the alloy of this invention is ideally suited for precision casting work. Excellent surface finishes are obtained in the as-cast condition which require little or no finishing operations. Since the resulting castings are sound and free of harmful oxide inclusions, the alloy is further superior to conventional copper-base alloys in that it can be plated with consistently excellent results.

As generally discussed above, the alloy of this invention has the further advantage of being relatively inexpensive compared to conventional beryllium alloyed copper-base alloys. This is because the known beryllium-copper alloys lose their corrosion resistance at a cut-off point in the range of from about 1.5% to about 2.0% beryllium. Therefore, in order to assure good corrosion resistance, it has been necessary to use a relatively large amount of beryllium, usually 2.0% or more, which materially adds to the cost of the alloy. In accordance with the present invention which provides for the addition of tin, the beryllium content can be maintained in a significantly lower range of from about 0.6% to about 1.5%, while still obtaining the desired excellent corrosion resistance in addition to the advantageous properties previously discussed.

Although the invention has been described in specific detail, many variations and modifications will be apparent to those skilled in the art. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically disclosed.

What is claimed is:

1. A complex copper-zinc alloy consisting essentially of zinc in the range of from 8.0% to 20%, tin in the range of from 1.5% to 4.5%, at least .6% beryllium, a trace to 1.10% of the combined elements phosphorus, silicon, aluminum, manganese and iron, and the balance copper, said alloy being devoid of other elements materially active as reducing elements to prevent the formation of a powdery, non-tenacious oxide complex.

2. A complex copper-zinc alloy consisting essentially of zinc in the range of frame 13% to 18%, tin in the range of from 2.5% to 4%, at least .6% beryllium, a trace to 1.1% of the combined elements phosphorus, silicon, aluminum, manganese and iron, and the balance copper, said alloy being devoid of other elements materially active as reducing agents to prevent the formation of a powdery, non-tenacious oxide complex.

3. A complex copper-zinc alloy consisting essentially of zinc in the range of from about 3% to about 20%, sufficient beryllium to protect the zinc against oxidation during melting and to form a complex, non-tenacious, powdery oxide film, said beryllium being present in an amount of at least .9%, tin in the range of from about 1.5% to about 4.5%, and the balance copper.

4. A complex copper-zinc alloy consisting essentially of zinc in the range of from about 8% to about 20%, sufficient beryllium to protect the zinc against oxidation during melting and to form a powdery, non-tenacious oxide film, said beryllium being present in the range of from about .6% to about 1.5%, tin in the range of from about 1.5% to about 4.5%, and the balance copper.

5. A complex copper-zinc casting alloy characterized by the formation during melting of a powdery, non-tenacious oxide film, said alloy consisting essentially of at least 1.5% tin, at least .6% berryllium, zinc in the range of from about 8% to about 20%, and the balance copper.

6. A complex copper-zinc casting alloy characterized by the formation during melting of a powdery, non-tenacious oxide film, said alloy consisting essentially of at least 8% zinc, at least .9% beryllium, at least 1.5% tin, and the balance copper.

7. A complex copper-zinc alloy consisting essentially of zinc in the range of from 8% to 20%, sufficient beryllium to protect the zinc against oxidation during melting, said beryllium being present in an amount of at least .6%, at least 2.5% tin and the balance copper, said alloy being characterized by the formation during melting of a powdery non-tenacious oxide film.

8. A complex copper-zinc casting alloy consisting essentially of zinc in the range of from .8% to 20%, 1.5% to 4.5% tin, sufficient beryllium to protect the zinc against oxidation during melting, said beryllium being present in an amount of at least .9%, and the balance copper, said alloy being characterized by the formation during melting of a powdery, non-tenacious oxide complex.

9. A complex copper-zinc casting alloy consisting essentially of zinc in the range of from 8% to 20%, 2.0% to 4% tin, sufficient beryllium to protect the zinc against oxidation during melting, said beryllium being present in an amount of from .9% to 1.5%, and the balance copper, said alloy being characterized by the formation during melting of a powdery, non-tenacious oxide complex.

10. A complex copper-zinc alloy consisting essentially of zinc in the range of from 8% to 20%, beryllium in the range of from .9% to 1.05%, tin in the range of from 2.5% to 4%, and the balance copper, said alloy being characterized by the formation during melting of a powdery, non-tenacious oxide complex.

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