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NICKEL BRASS HAVING A RELATIVELY LOW LIQUIDUS TEMPERATURE

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The present invention relates to alloys and, more particularly, brasses adapted for use in die casting.

It is well known that many factors contribute importantly to the production of sound, economical and useful die castings. Among the many factors are properly designed die-casting apparatus, well-constructed die structures and suitable alloys. All of the aforementioned factors, as well as several others of lesser importance, must be considered in combination whenever the production of good die castings is to be assured. Thus, good, sound castings cannot be produced if any one or more of the factors is below standard. For example, even if both the die-casting equipment and the die itself are of the highest quality, an unsatisfactory die casting will result if the alloy has poor properties and/or characteristics.

To produce alloys having good die-casting properties and/or characteristics, a number of physical, metallurgical and economic considerations must be carefully weighed. Included in these considerations are (1) the adaptability of the alloy to the die-casting process, e.g., fluidity, castability, shrinkage on cooling; (2) the mechanical properties of the alloy such as ductility, strength, etc.; (3) the cost of the alloy; and (4) the freezing point and freezing range (liquidus-solidus range) of the alloy. Generally, no one of these considerations is more essential than any other. Thus, what is required is an alloy that meets the standards of each and all the aforementioned considerations.

Heretofore, difficulties have been encountered in arriving at a proper balance of alloying ingredients which will satisfy each of the aforementioned considerations. For instance, oftentimes the attainment of good mechanical properties and/or characteristics in a die-casting alloy is at the expense of the adaptability of the alloy to the die-casting process, and conversely. Furthermore, many of the present-day die-casting alloys having good mechanical properties and/or characteristics also have the detrimental features of having high liquidus temperatures and, frequently, wide temperature differences between the solidus and liquidus. The principal detriment associated with a high liquidus temperature is that the cost of the die-casting process is increased with the attendant decrease in the die life as compared to the die casting of an alloy having a lower liquidus temperature. Of course, the die life could conceivably be increased by changing the composition of the die material. Almost invariably, if such a change could be made, it would be accompanied by an increase in the cost of the die.

In the production of copper-containing die-casting alloys, e.g., brass (a copper-zinc alloy), the aforementioned problems are particularly difficult to solve since the present injection temperatures for the commercially available die casting brasses are quite high, e.g., 1700° F. and higher. Necessarily, such high injection temperatures have an adverse affect on the die life and at present there is no commercially available die material which can increase the yield of satisfactory die castings over the yield presently obtained. Attempts to solve the problems by the addition of constituents which ordinarily depress the liquidus temperature have been fruitless since these constituents, while they do lower the liquidus temperature somewhat, do so only at the expense of some other desirable

characteristics such as mechanical properties, e.g., ductility.

Although many attempts were made to overcome the foregoing difficulties and other disadvantages, none, as far as I am aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that brasses having a relatively low liquidus temperature in combination with good mechanical properties and/or characteristics may now be produced.

It is an object of the present invention to provide new brasses having a unique combination of properties and/or characteristics.

Another object of the present invention is to provide novel brasses which are particularly adapted for die casting.

The invention also contemplates providing new copper-zinc alloys having relatively low liquidus temperatures.

It is a further object of the invention to provide new die-casting brasses having good ductility in combination with high strength.

Among the further objects of the present invention is the provision of a special economic process for die casting brass.

Other objects and advatnages will become apparent from the following description:

Generally speaking, the present invention contemplates the production of unique brasses which are particularly suitable for die casting. The brasses of this invention contain, in percent by weight, about 2% to about 3.75% silicon, about 4% to about 11% nickel with the nickel content being about 1.75 to about 3.5 times the silicon content, about 32% to about 45% zinc and the balance, apart from incidental elements, including impurities, being copper in amounts of at least about 45%. In addition, the zinc, silicon and nickel in the brasses of the present invention are so correlated that

$$\text{Percent Zn} + 10 \times \text{Percent Si} - 1.5 \times \text{Percent Ni}$$

is between about 51 and about 66. The alloys of this invention containing copper, nickel, zinc and silicon in the ranges hereinbefore set forth are characterized by having liquidus temperatures below about 1605° F. e.g., 1600° F. and even lower, while also possessing good ductility as well as good strength.

The alloys according to this invention contain copper, zinc, nickel and silicon in specially controlled amounts and each of these elements in combination with each other element plays an important part in controlling the properties of the alloys. For example, the silicon content is in the range of about 2% to about 3.75% and, advantageously, between about 2% to about 3.5%. The inclusion of silicon in the alloys of the present invention causes a desirable lowering of the melting point and substantially inhiibts zinc-fuming, i.e., volatilization of zinc. In addition, silicon acts as a deoxidizer. However, if too much silicon is used (more than about 3.75%) the ductility of the alloy is very low. If too little silicon is used, the liquidus temperature is too high.

In general, the ductile nickel-containing alloys of this invention possess chill-cast microstructures which are characterized by a continuous matrix of a beta brass phase and a precipitate of a nickel-silicon-containing intermetallic phase having a globular morphology. On the other hand, whenever the nickel is outside the heretofore defined ranges and relationships, the alloys possess a chill-cast microstructure comprising an embrittling phase which resembles the brittle gamma brass phase. Thus nickel, when used in combination with the other ingredients of the alloys and in the aforementioned interrelated amounts, has a beneficial effect on the microstructure which imparts or contributes importantly to the

ductility. The nickel and silicon contents in the alloy are very sensitive and are so interrelated that, in all cases, the nickel content is between about 1.75 to about 3.5 times the silicon content. The nickel content should not exceed about 11% as the liquidus temperature is undesirably raised at nickel contents above this value. Furthermore, if silicon is above about 3.75%, higher nickel additions have no apparent effect in alleviating the brittleness of the alloy. If too little nickel is present in the alloy, the ductility of the alloys suffers adversely. Advantageously, the nickel content is between about 5% and 9% since the alloys containing such amounts have even a better combination of a low liquidus temperature together with good ductility characteristics and/or properties. Cobalt may be substituted for part or all of the nickel since it behaves similarly to nickel although it does not render the alloy as ductile as does a nickel addition. Thus, although nickel is advantageously contained in the alloys of the present invention, they may contain, by weight, about 4% to about 11%, e.g., about 5% to about 9%, of a metal selected from the group consisting of nickel, cobalt and combinations thereof.

The zinc content must be in the range hereinbefore set forth. If too much zinc is used, the ductility suffers, and if too little is used, the liquidus temperature detrimentally rises. In addition, the zinc, silicon and nickel are so interrelated in the copper-containing alloys of this invention that the zinc content, plus 10 times the silicon content and minus 1.5 times the nickel content lies between about 51 and about 66. If these relationships are not satisfied, the alloys have either poor ductility or high liquidus temperatures or both. Advantageously, the zinc content is between about 35% and about 43% to assure that the alloy has the better combination of mechanical properties in conjunction with relatively lower liquidus temperatures.

When the copper-containing alloys contain interrelated amounts of silicon, nickel and zinc as hereinbefore set forth they are characterized by having good fluidity in a permanent mold at temperatures as low as 1550° F. or lower, without any indication of hot-shortness even though there is restraint in the mold. In addition, the alloys of this invention have good resistance to stress-corrosion cracking.

The alloys of this invention may also contain incidental elements and/or ingredients such as lead, titanium, zirconium, aluminum and iron in amounts of up to about 0.5% of each and up to about 1% tin provided that the sum of such incidental ingredients is below about 1.5%, by weight of the alloy. Thus, preferably, the incidental elements are kept below their solubility limits in the alloy. In particular, oxidizable elements such as titanium and aluminum should be kept below about 0.5% of each because of their dross-forming characteristics during the casing operation. Tin should be kept below about 1% since it tends to render the alloy hot-short in the mold. On the other hand, the fact that the alloys of this invention can tolerate up to about 0.5% lead, e.g., up to about 0.25%, is a quite important practical advantage since it permits the use of scrap in melting the alloy. Advantageously, each of the aforementioned incidental elements is kept below about 0.25% in order to achieve optimum characteristics in the alloys.

In carrying the invention into practice, particularly unexpected results are obtained when the alloys contain, in percent by weight, about 2% to about 3.5% silicon, about 5% to about 9% nickel with the nickel content being about 1.75 to about 3.5 times the silicon content, about 35% to about 43% zinc, the zinc, silicon and the nickel being so correlated that the zinc percentage, plus 10 times the silicon percentage and minus 1½ times the nickel percentage is between about 51 and about 66, and the balance, apart from incidental elements including lead, titanium, zirconium, aluminum, tin and iron in amounts up to about 1.5% in all, being copper in amounts of at least about 45%. Such alloys have a superior combination of physical, mechanical and/or metallurgical properties and/or characteristics.

For the purpose of giving those skilled in the art a better understanding of the invention and a better appreciation of the advantages of the invention, a number of alloys in accordance with the teachings of the present invention are set forth in Table I wherein all amounts are in percentages by weight.

Table I

Alloy Designation	Percent Copper (Cu)	Percent Zinc (Zn)	Percent Nickel (Ni)	Percent Silicon (Si)
A	Balance	35	4.5	2.47
B	do	42	5	2.6
C	do	38	7.53	3.74
D	do	37	11	3.46
E	do	43	8.4	2.80
F	do	37	8.18	3.33
G	do	39	5.56	2.09

The alloys of the present invention exhibit good mechanical properties and/or characteristics as well as low liquidus temperatures as is clearly shown in Table II.

Table II

Alloy Designation	Ultimate Tensile Strength, Lbs. Per Sq. Inch	Elongation in 1", percent	Reduction in Area, percent	Liquidus Temperature, ° F.	0.2% Offset Yield Strength, Lbs. Per Sq. Inch
A	96,600	2.5	4	1,562	71,300
B	85,000	1.5	2	1,525	71,700
C	93,100	1	2.5	1,556	81,600
D	76,800	1	2.5	1,558	62,700
E	97,400	6.5	10	1,600	48,500
F	92,400	3.5	4	1,548	65,500
G	98,100	8	12	1,580	67,100

Each of the alloys set forth in Table II has an ultimate tensile strength of at least about 75,000 pounds per square inch and good ductility while also possessing a desirable low liquidus temperature of about 1600° F. or less. In addition, the freezing range (liquidus-solidus) of alloy G was determined to be about 1580° F. to about 1564° F. which is quite narrow for brass alloys.

To illustrate the advantageous characteristics and/or properties attributable to the novel, nonobvious features of the present invention, a number of alloys not in accordance with the present invention were prepared and compared with alloys within the contemplation of the present invention. The compositions, in percent by weight, of the alloys not in accordance with the invention are set forth in Table III.

Table III

Alloy Designation	Percent Cu	Percent Zn	Percent Ni	Percent Si
Z	Balance	40.9	Nil	3.03
Y	do	45	4.58	0.3
X	do	36	4.12	3.32
W	do	47	6.51	2.74
T	do	40	4.71	4.10
S	do	40	8.35	4.11
R	do	33	8.18	2.43

Each of the alloys of Table III is outside the scope of the present invention in at least one important feature. For example, alloy Z is not within the present invention with regard to the nickel content and, of course, the ratio of nickel to silicon as well as the correlation of zinc, silicon and nickel. This alloy was so brittle that it shattered in the mold after freezing. Alloy Y, on the other hand, is low in silicon and the ratio of nickel to silicon is too high while the correlation of zinc, silicon and nickel is too low. This alloy had a liquidus temperature of about 1660° F. which is too high for economical die casting. Alloy X

does not satisfy the heretofore mentioned relationship of nickel to silicon and was found to have an elongation of only 0.4% and substantially no reduction in area. Thus, alloy X is considered to have inadequate ductility. Alloys T and S are outside the contemplation of the present invention with regard to the silicon content and the correlation of zinc, silicon and nickel while alloy T also does not have the feature of possessing a nickel to silicon ratio of between about 1.75 and about 3.5. Alloy W is too high in zinc. Each of these alloys (T, S and W) was so brittle that castings made of each alloy shattered when dropped. Alloy R is not within the present invention in that it does not satisfy the interrelationship of zinc, silicon and nickel. Alloy R had a high liquidus temperature of 1678° F. In contradistinction thereto, the alloys of the present invention possess low liquidus temperatures, have good ductility and good mechanical strength, as is illustrated in Table II, supra.

The alloys of the present invention, by virtue of their lower liquidus temperature in combination with good ductility, allow a greater use to be made of brass alloys as die castings, i.e., a production method possessing a number of inherent economic advantages such as machining costs, production rates, etc. Moreover, the alloys of this invention can be die cast at temperatures which are about 25° F., or less, higher than their liquidus temperatures. Thus, the injection temperatures of the alloys of the present invention in the die-casting process can be held to below about 1630° F. e.g., about 1550° F. for an alloy similar to alloy B. In addition, the nickel-containing brass alloys of this invention are useful in those applications in which certain properties such as corrosion resistance and/or strength are particularly attractive but where previously, when produced by other methods, e.g., sand castings, were prohibitively uneconomical. Such uses include plumbing, hardware, architectural articles, automotive equipment, marine fittings, etc.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. An alloy particularly adapted for die casting which consists of, by weight, about 2.8% silicon, about 8.4% nickel, about 43% zinc and the balance essentially copper.

2. An alloy particularly adapted for die casting which consists of, by weight, about 2.1% silicon, about 5.5% nickel, about 39% zinc and the balance essentially copper.

3. An alloy consisting of, by weight, about 3.3% silicon, about 8.2% nickel, about 37% zinc and the balance essentially copper.

4. An alloy consisting of, by weight, about 3.75% silicon, about 7.5% nickel, about 38% zinc and the balance essentially copper.

5. An alloy particularly adapted for die casting which consists of, by weight, about 2.6% silicon, about 5% nickel, about 42% zinc and the balance essentially copper.

6. An alloy consisting essentially of, by weight, 2% to 3.5% silicon, 5% to 9% nickel with the nickel content being 1.75 to 3.5 times the silicon content, 35% to 43% zinc, the zinc, silicon and the nickel being so correlated that the zinc percentage, plus 10 times the silicon percentage and minus 1.5 times the nickel percentage is between 51 and 66, not more than 1% tin and the balance, apart from incidental elements, being copper in amounts of at least 45%.

7. An alloy consisting essentially of, by weight, 2% to 3.75% silicon, 4% to 11% nickel with the nickel content being 1.75 to 3.5 times the silicon content, 32% to 45% zinc, the zinc, silicon and nickel being so correlated that the zinc percentage, plus 10 times the silicon percentage and minus 1.5 times the nickel percentage is between 51 and 66, not more than 1% tin and the balance, apart from incidental elements, being copper in amounts of at least 45%.

8. An alloy consisting essentially of by weight, 2% to 3.75% silicon, 4% to 11% of a metal selected from the group consisting of nickel, cobalt and combinations thereof with the amount of said metal being 1.75 to 3.5 times the silicon content, 32% to 45% zinc, the zinc, silicon and the metal selected from the group consisting of nickel, cobalt and combinations thereof being so correlated that the zinc percentage, plus 10 times the silicon percentage and minus 1.5 times the percentage of the metal selected from the group consisting of nickel, cobalt and combinations thereof is between 51 and 66, not more than 1% tin and the balance being copper in amounts of at least 45%.

9. A die casting made of an alloy according to claim 8.

10. In the process for die casting brass alloys the improvement which comprises employing as the casting alloy an alloy consisting essentially of 2% to 3.75% silicon, 4% to 11% nickel while maintaining the nickel content at levels which are 1.75 to 3.5 times the silicon content, 32% to 45% zinc, not more than 1% tin correlating the zinc, silicon and nickel such that the zinc percentage, plus 10 times the silicon percentage minus 1.5 times the nickel percentage is between 51 and 66 with the balance of the alloy being essentially copper in amounts of at least 45% of the alloy, and die casting said alloy at a temperature that is less than 25° F. higher than its liquidus temperature and below 1630° F.

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