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[54] **NEW PROCEDURE FOR CHILL CASTING BERYLLIUM COMPOSITE**
 15 Claims, 1 Drawing Fig.

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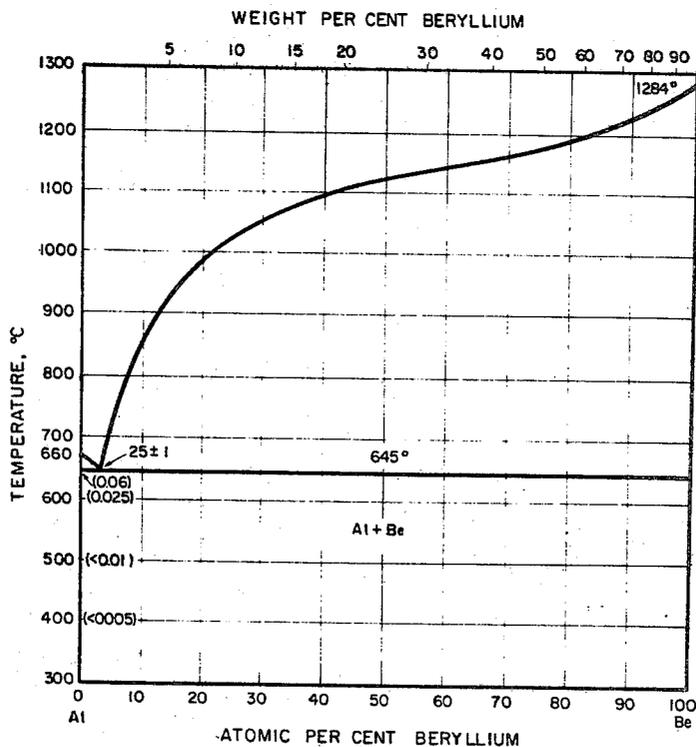
[50] Field of Search..... **75/138;**
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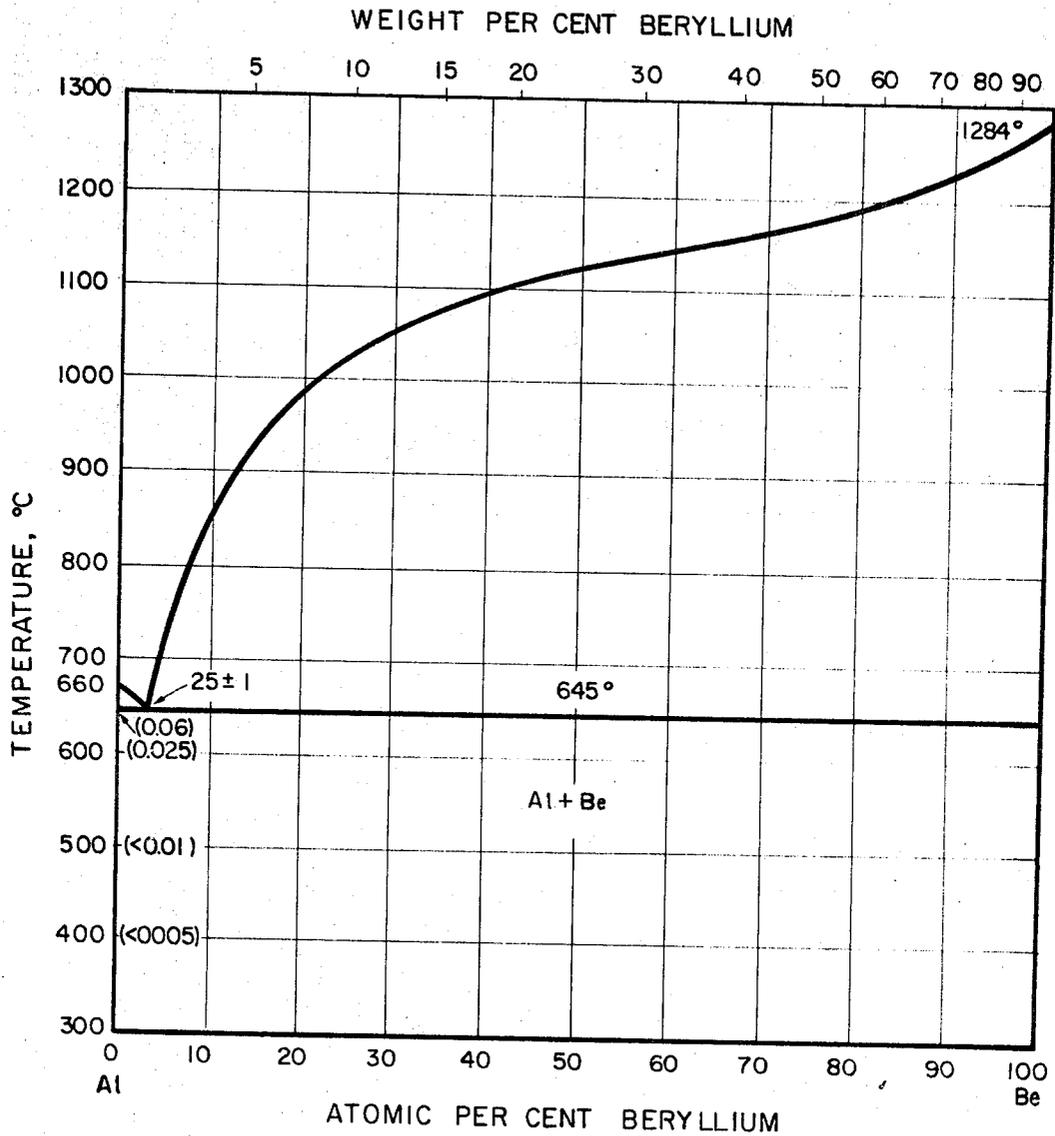
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ABSTRACT: A process for casting aluminum-beryllium alloys comprising, charging a crucible with an aluminum base alloy placed at the bottom of a crucible, placing thereon a charge of beryllium in which the beryllium is in discrete chunks, lumps or particles, evacuating the furnace chamber for example to remove oxygen and other impurities from the atmosphere, raising the temperature of the charge sufficient to melt the aluminum but insufficient to melt the beryllium, maintaining the aluminum molten for a time sufficient to effect substantially degassing of the aluminum, changing the vacuum to an atmosphere of inert gas at a pressure below atmospheric, raising the temperature of the charge sufficient to melt the beryllium for the particular Be-Al alloy composition being cast, and rapidly transferring the charge at a temperature at least approximately as low as the liquidus temperature into a mold and rapidly cooling said charge.

ALUMINUM - BERYLLIUM PHASE DIAGRAM



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NEW PROCEDURE FOR CHILL CASTING BERYLLIUM COMPOSITE

This application is a continuation-in-part of application Ser. No. 793,398, filed Jan. 23, 1969.

Several processes for casting Be-Al alloys have been reported comprising heating a charge of beryllium chunks and aluminum alloy chunks in the presence of a fluxing agent selected from the group consisting of alkali and alkaline earth halides to a temperature above the melting point of beryllium. The flux destroys the beryllium oxide film and enables the casting of a microstructure of beryllium grains interspersed within an aluminum or aluminum alloy matrix.

However, under some casting conditions, particularly where the atmosphere has high humidity, it has been found that some porosity has been observed in the castings.

Furthermore, it would be advantageous to avoid the flux because of its corrosive nature, including its tendency to attack crucibles, the fumes it creates on volatilization and to avoid the cost outlay for the flux material.

Because of the corrosive nature of the flux, beryllium oxide crucibles are preferred which are expensive.

Furthermore the microstructure obtained has not always been as fine as desired and the aluminum matrix has sometimes contained undesirable impurities.

It is therefore an object of the present invention to provide a process which avoids impurities in the aluminum matrix.

It is still another object of the present invention to provide a process which avoids the use of a halide flux.

It is still another object of the present invention to provide a process which permits the use of crucibles less expensive than beryllium oxide crucibles.

It is still another object of the present invention to provide a process which results in a very fine as-cast microstructure.

Other objects will appear from the following description and drawing in which:

The FIG. is a view of the aluminum-beryllium binary phase diagram.

In order to achieve the foregoing objects the following procedure is utilized.

The mold to be used for casting is preferably preheated for example, a temperature within the range of about 700° F. to 1000° F., is 800° F. for a period of time of about .5 to 3 hours, or longer. Furthermore, other temperatures and times may be used. Moreover this step may be eliminated, depending upon the shape being cast, the cast properties desired and other metallurgical variables.

The inside of the mold preferably is coated with amorphous carbon. This may be done before or during the preheating, if preheating is carried out. This operation can be carried out for example with an acetylene torch adjusted to a reducing flame or by spraying the mold with an amorphous carbon. It is often advantageous to reheat the mold at for example 20 to 30 minutes at elevated temperature for example about 700°—800° F.

The melting crucible, which may be made of MgO, Al₂O₃ or other refractory oxide rather than expensive BeO, is charged with beryllium in small chunks, lumps or particles. Preferably the size of the chunks is such that they will not pass through a one quarter inch mesh screen but will pass through three quarter inch mesh screen. However for many applications particulate material considerably smaller than one quarter inch may be used with good results.

The amount of Be in the charge is preferably above 40 percent by weight, more preferably about 68 to 85 percent by weight. It is often desirable for the beryllium in the charge to have at least some of the following characteristics. For nuclear applications the cobalt is preferred to be very low, for example below 0.0005 percent. The iron content is usually preferred to be below about 0.1 percent. Other impurity elements should usually be less than about 0.1 percent and the total of the other impurities should usually be not more than about 1 percent.

The remainder of the charge is aluminum or an alloy of aluminum. For example, silicon and/or magnesium may be present as alloying elements in the aluminum. One aluminum alloy which may be used contains about 0.5 to 1.5 percent magnesium and about 0.5 to 1.5 silicon with the balance being aluminum. The aluminum to be used is preferably quite pure, most preferably having a purity of 99.99 percent or higher with a maximum content of impurities other than alloying elements of about 0.01 percent total. It is to be emphasized that other alloying elements instead of, and/or in addition to magnesium and silicon may be desirable for certain properties and characteristics of the material. It is to be understood that the process of the present invention is to include such additional alloying elements in the aluminum charge. It should also be pointed out that some beryllium will end up in solid solution within the aluminum matrix, for example 0.2 to 0.5 percent by weight of the aluminum.

In charging the aluminum or aluminum alloy is preferably placed at the bottom of the crucible and the beryllium on top. The reason for this will become apparent hereinafter.

The mold preferably after preheating as described above is placed in a furnace which has provisions for evacuations, preferably to as low as 150 microns and more preferably to as low as 100 microns, and below. Additionally, the furnace should preferably have provisions for changing the evacuated system to a system utilizing an inert gas such as argon, or helium (argon is preferred).

The melting crucible is preferably placed on a rotatable axis or other device inside the furnace whereby the crucible can be rotated from outside the furnace and molten metal poured or otherwise rapidly transferred into a mold which is situated within the furnace, often below the crucible. After placing the mold in the furnace, the furnace is evacuated, preferably to a pressure of below 150 microns, more preferably below 100 microns. It is believed that the evacuation removes oxygen and other impurities from the atmosphere. In addition, it is believed that the vacuum treatment also substantially degasses the aluminum matrix. Heat is gradually applied, for example by means of an induction coil, or other type of heating such as electrical resistance heating. The heat is applied at a rate so that the aluminum is melted. After the aluminum is melted, it is believed that the vacuum degasses the molten aluminum alloy to a substantial extent. The beryllium remains substantially unmelted.

In the case where magnesium is present in the aluminum alloy, "sparking" or visual evolution of particles from the partially melted charge is observed. It is believed that the particles at least in part contain magnesium in either an elemental or combined state. The beryllium charge must have sufficient space between chunks, lumps or particles so that there will be adequate space for particles and/or impurities in the molten aluminum to escape. The evolution of "sparking" marks the point wherein degassing has been substantially completed. The sparking can be observed, for example, through a window in the furnace.

If desired, in order to observe the pressure at which degassing is completed, an alloy containing about 0.5 to 1.5 percent magnesium in aluminum, together with beryllium chunks, lumps or particles may be processed through the furnace and the pressure determined at which "sparking" takes place. Then aluminum alloys not containing magnesium may be processed and the pressure at which "sparking" occurred relied on to indicate when degassing has been substantially completed. For example, in one furnace a pressure of about 450 microns signifies the point where the degassing has taken place. However, it is apparent that the pressure at which degassing has taken place will depend on such variables as the construction of a particular furnace, the type of vacuum pump used, etc.

After the degassing operation has been concluded, the vacuum is shut off and the chamber is filled with an inert gas such as argon or helium, preferably argon, to a pressure which is preferably at least about 5 inches of mercury below at-

mospheric to prevent additional evaporation of alloying elements, particularly magnesium and the furnace temperature is raised in order to melt the beryllium. The heating is continued until the beryllium has melted. For example, it can be observed through the furnace window when all the beryllium chunks have melted. For example, temperatures above about 1,200° C. preferably above about 1,300° C. are usually sufficient to melt substantially all of the beryllium. In some cases if induction heating is used, it is believed that an electric field may be created around the melt by the heating coil. It is believed that the melt and therefore the beryllium does not melt quickly. If this problem exists it can be solved by turning the heating coil off so that there is no longer an upward force acting on the beryllium and the beryllium can go down into the aluminum and be melted.

After beryllium has melted, the liquid is slowly cooled to the pouring temperature. The pouring temperature must be below the liquidus temperature shown on the Al-Be phase diagram for the particular aluminum-beryllium composition being used. It will be observed from FIG. 1 that Be contents of above 40 weight percent including 68—85 percent are on the Be side of the Be-Al eutectic point. For example, the pouring temperature may be 0° to about 50° C. below the liquidus. This results in the formation of beryllium nuclei in the melt. As the temperature is lowered below the liquidus, a thermal arrest or a point where no change in temperature with time occurs, is observed. The temperature may be observed for example, from a thermocouple placed in the melting crucible or with an optical pyrometer. A pouring temperature of from about 1,185° to about 1,215° C. has been found to be particularly effective for alloys within the 68 to 85 weight percent range.

After the pouring temperature is reached, the charge is poured or transferred quickly into the mold in order to obtain turbulence. For example, this can be done by rotating the crucible about its axis to pour the molten metal into a mold located therebelow, or by the use of pressure or vacuum to quickly transfer the molten metal into the mold. It is believed that this procedure results in a fine microstructure because as the liquidus temperature is reached a certain number of beryllium nuclei are formed in the melt and begin to grow dendrites. In the pouring and/or transferring and/or casting turbulence, the dendrite arms break off and form new nucleation sites. It is therefore desirable to pour and/or transfer as rapidly as possible and still avoid substantial amounts of metal splashing out of the mold. Thus a microstructure of fine Be grains in an aluminum matrix is obtained. For example, about .1 to .3 millimeter average diameter grain size may often be obtained.

It is important that the casting is cooled very rapidly. The rate of cooling is dependent upon several variables including the conductivity of the mold and the thickness or mass of the mold. Materials having a relatively high thermal conductivity should be used for the mold. Exemplary materials are as follows: copper, copper alloys such as brass, bronze, iron base materials including carbon and alloy steels, and graphite or other carbonaceous materials. In the shapes which are difficult to cast and which are subject to hot tearing, it is usually preferred to use graphite or other carbonaceous material for the mold and for any cores which would be used.

The mold also preferably has relatively large thickness or mass. It has been found, for example, that 1¼ inch thick mold can be used to form castings 2 × 4 × ½ inch and a fine microstructure is obtained, but the thickness and mass will vary according to the shape and size of the casting, the cast properties desired and/or how fine a microstructure is desired. Castings having higher minimum dimensions than one-half inch have been successfully cast.

Also if desired additional heat dissipating features may be employed including for example water or other fluid heat ex-

tracting mediums upon or within the mold and/or fins or other shapes designed for heat dissipation.

Yield strengths (0.2 percent offset yields) of about 18,000 to about 26,000 p.s.i. and ultimate tensile strengths of about 28,000 to about 40,000 p.s.i. have been obtained, with the higher values being obtained with more rapid pouring and/or transfer rates.

According to another embodiment of the invention platinum is added to the melt. Platinum is believed to increase the nucleation rate and thus aid in obtaining a fine grain structure. The platinum may be added in the elemental form with the charge or, alternatively, it may be after the entire charge has been melted for example by the use of a strand which is guided into the melt from outside the furnace. The amount of platinum added is for example from about 0.05 to about 0.5 percent by weight of the total charge preferably 0.1 to 0.4 percent by weight. If platinum is added to the charge, the pouring and/or transfer rate does not have to be quite so rapid as if platinum were not to be used.

We claim:

1. A method for casting aluminum-beryllium alloys comprising, charging a crucible with an aluminum or an aluminum base alloy placed at the bottom of a crucible, placing thereon a charge of beryllium in which the beryllium is in discrete lumps, chunks or particles evacuating the furnace chamber, raising the temperature of the charge sufficient to melt the aluminum but insufficient to melt the beryllium, maintaining the aluminum molten for a time sufficient to effect substantial degassing of the aluminum, changing the vacuum to an atmosphere of inert gas at a pressure below atmospheric, raising the temperature of the charge sufficient to melt the beryllium at a temperature at least approximately as low as the liquidus temperature for the particular Be-Al alloy composition being cast, and rapidly transferring the charge into a mold and rapidly cooling said charge.

2. The method according to claim 1 in which the beryllium content of the charge is above at least about 40 percent by weight beryllium.

3. A method according to claim 1 in which during the degassing visible evolution of the particles occurs.

4. A method according to claim 1 in which the molten charge is up to 50° C. below the liquidus prior to transferring the charge to a mold.

5. A method according to claim 1 in which the aluminum charge also contains an element selected from the group consisting of magnesium, silicon and mixtures thereof.

6. A method according to claim 1 in which the mold is preheated.

7. A method according to claim 1 in which an addition of platinum is present in the molten charge at the time of transferring the charge to a mold.

8. A method according to claim 1 in which the furnace is evacuated at least as low as 150 microns.

9. A method according to claim 1 in which the inert gas atmosphere is at least 5 inches of mercury below atmospheric.

10. A method according to claim 8 in which the charge is heated to a temperature above about 1,200° C.

11. A method according to claim 3 in which inception of sparking is used to determine the point when the atmosphere of the furnace is changed from a vacuum to an inert gas.

12. A method according to claim 10 in which the charge is heated to a temperature above about 1,300° C.

13. A method according to claim 3 in which the charge contains magnesium.

14. A method according to claim 12 in which the charge is cooled to a temperature of about 1,185° to 1,215° C. prior to transferring the charge to a mold.

15. A method according to claim 2 in which the beryllium content is about 68 to about 85 percent by weight.