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

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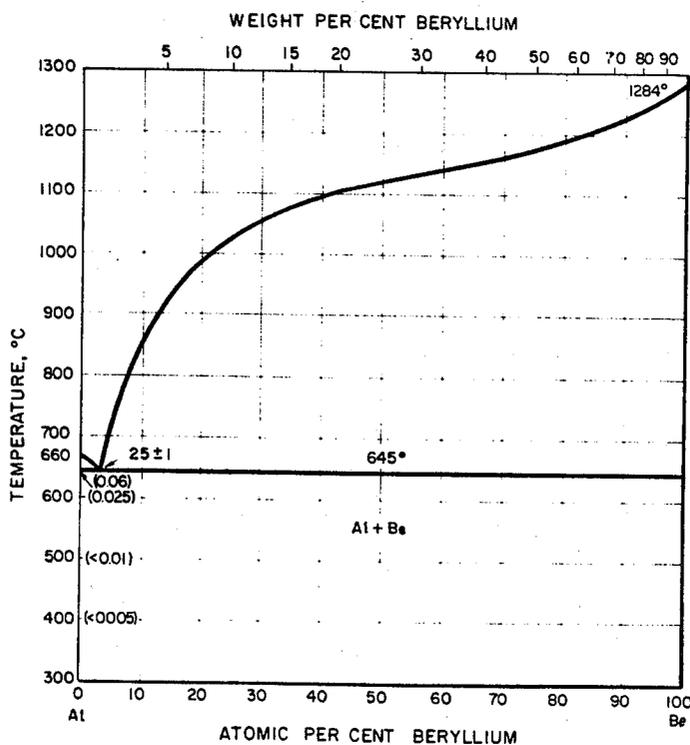
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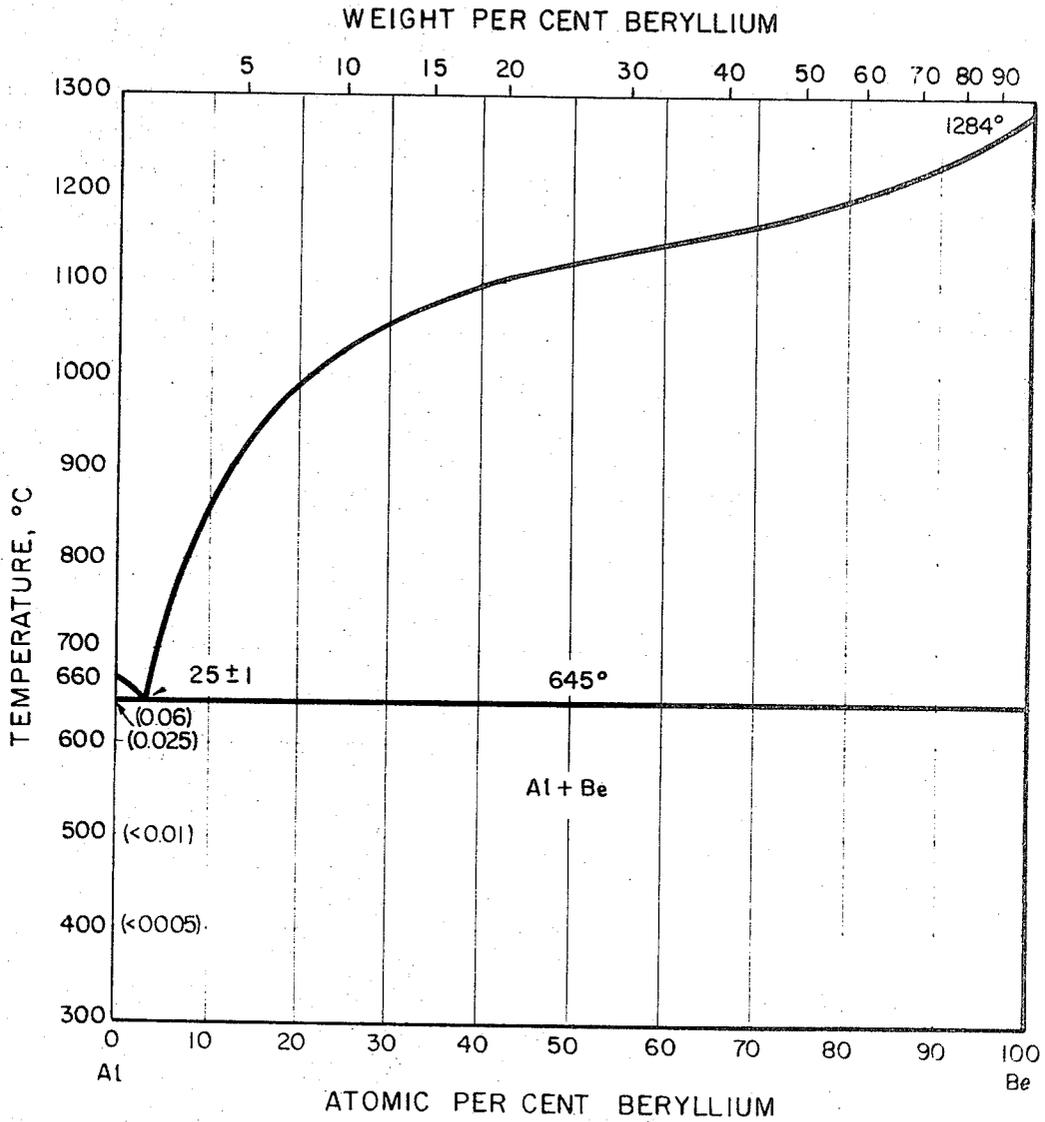
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ABSTRACT: A process for casting aluminum-beryllium alloys comprising, charging a crucible with an aluminum base alloy placed at the bottom of a crucible, placing thereon a charge of beryllium in which the beryllium is in discrete lumps or chunks, evacuating the furnace chamber for example to as low as 150 microns 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 degass 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, cooling the charge to below the liquidus temperature for the particular Be-Al alloy composition being cast, and rapidly pouring the charge into a mold made of a material having high thermal conductivity and having a large mass, thereby rapidly cooling said charge.

ALUMINUM-BERYLLIUM PHASE DIAGRAM



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PROCEDURE FOR CHILL CASTING BERYLLIUM COMPOSITE

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 porosity in the castings.

It is another 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:

FIG. 1 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 preheated in a furnace, for example, a temperature within the range of 700° F. to 800° F. for a period of time of .5 to 1.5 hours. However, obviously other temperatures and times could be used. This step may be eliminated if desired.

After the preheating, the inside of the mold is coated with amorphous carbon. This can be done for example with an acetylene torch adjusted to a reducing flame or by spraying the mold with an amorphous carbon. The mold may then be reheated for 20 to 30 minutes, for example.

The melting crucible, which may be made of MgO or other refractory oxides rather than expensive BeO, is charged with beryllium in small chunks. Preferably the size of the chunks is such that they will not pass through a one quarter mesh screen but will pass through a 1/2 inch mesh screen.

The beryllium in the charge preferably has the following characteristics. For nuclear applications the cobalt is preferred to be very low, for example below 0.0005 percent. The iron content is preferred to be below 0.1 percent. Other impurity elements should be less than 0.1 percent and the total of the other impurities should be 1 percent.

The amount of Be in the charge is preferably 68 to 85 percent by weight. The remainder of the charge is aluminum or an alloy of aluminum. For example, one aluminum alloy which may be used contains 0.5 to 1.5 percent magnesium and 0.5 to 1.5 silicon with the balance being aluminum. The aluminum to be used is preferably 99.99 percent pure with a maximum content of impurities other than alloying elements of 0.01 percent total. Furthermore, other alloying elements 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 matrix charge. While the matrix alloy has been described as an aluminum alloy, it

will be appreciated that some beryllium will end up in solid solution within the aluminum matrix.

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

The preheated mold is placed in a furnace which has provisions for evacuation to as low as 150 microns and preferably to as low as 100 microns, and below. Additionally, the furnace must have provisions for changing the evacuated system to a system utilizing an inert gas preferably of argon, but helium could also be used.

The melting crucible is placed on a rotatable axis inside the furnace whereby the crucible can be rotated from outside the furnace and molten metal poured very rapidly into a mold which is situated below the crucible. After placing the mold in the furnace below the rotatable crucible, the furnace is evacuated to a pressure of below 150 microns, preferably below 100 microns. The purpose of the evacuation is to remove oxygen and other impurities from the atmosphere. In addition to removing oxygen and other impurities from the furnace atmosphere, the vacuum treatment also degasses the aluminum matrix. Heat is gradually applied, for example by means of an induction coil. However, other types of heating such as electrical resistance heating could also be used. The heat is applied at a rate so that the aluminum is melted. After the aluminum is melted, the vacuum degasses the molten alloy. The beryllium chunks remain substantially unmelted. In the case where magnesium is present in the aluminum alloy, the magnesium causes "sparking" or the visual evolution of metallic particles from the partially melted charge. The beryllium charge must have sufficient space between chunks so that there will be adequate space for these metallic particles and impurities in the molten aluminum to escape. The evolution of "sparking" marks the point wherein degassing has been completed. The sparking can be observed through a window in the furnace.

If desired, in order to observe the pressure at which degassing is completed, an alloy containing 0.5 to 1.5 percent magnesium in aluminum, together with beryllium chunks, may be processed through the furnace and the pressure determined at which the 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 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 the particular furnace and vacuum pump in which the operation is being carried out.

After the degassing operation has been concluded, the vacuum is shut off and the chamber is back filled with an inert gas such as argon or helium, preferably argon, to a pressure of at least 5 inches of mercury below atmospheric to prevent additional magnesium evaporation and the furnace temperature is raised in order to melt the beryllium. It can be observed through the furnace window when all the beryllium chunks have melted. In some cases if induction heating is used it may be observed that an electric field created around the melt by the heating coil holds the beryllium chunks partially above the surface of the melt and therefore the beryllium does not melt quickly. This can be avoided 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 all the 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 68-85 percent are on the Be side of the Be-Al eutectic point. For example the pouring temperature is 0 to 50° C. below the liquidus. As the temperature is lowered below the liquidus, a thermal arrest or a point where no change in temperature with time occurs, is observed. Also the tempera-

ture may be observed from a thermocouple placed in the melting crucible prior to pouring.

After the pouring temperature is reached, the charge is poured quickly into the mold in order to obtain turbulence. This can be done by rotating the crucible about its axis from outside the furnace. 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 casting turbulence the dendrite arms break off and form new nucleation sites. It is therefore desirable to pour 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.

It is important that the casting is cooled very rapidly. The rate of cooling is dependent upon the conductivity of the mold and the thickness or mass of the mold. Materials having sufficiently high thermal conductivity to be used for the mold are as follows: copper, steel and graphite or other carbonaceous materials. In the case where shapes which are difficult to cast and which are subject to hot tearing are to be cast, it is preferred to use graphite or other carbonaceous material for the mold and for any cores which would be used.

The mold must also have adequate thickness or mass. It has been found, for example, that one and one quarter inch thick mold can be used to form castings $2 \times 4 \times 1/2$ inch and a fine microstructure is obtained, but the thickness and mass will vary according to the shape and size of the casting.

In addition to rapid cooling, another embodiment of the invention involves adding platinum to the melt in order to increase nucleation and obtain a fine grain structure. The platinum may be added in the elemental form with the charge or, alternatively, it may be added after the entire charge has been melted 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 0.05 to 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 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 base alloy

placed at the bottom of a crucible, placing thereon a charge of beryllium in which the beryllium is in discrete lumps or chunks, 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 degass 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, cooling the charge to below the liquidus temperature for the particular Be-Al alloy composition being cast, and rapidly pouring the charge into a mold made of a material having high thermal conductivity and having a large mass, thereby rapidly cooling said charge.

2. The method according to claim 1 in which the beryllium content of the charge is from 68 to 85 percent by weight beryllium.

3. A method according to claim 1 in which the aluminum charge contains magnesium and during the degassing visible evolution of the particles occurs.

4. A method according to claim 1 in which the molten charge is cooled up to $50 \pm 5^\circ \text{C}$. below the liquidus prior to pouring.

5. A method according to claim 3 in which the Al charge also contains silicon.

6. A method according to claim 1 in which the mold is preheated prior to being placed in the melting and casting furnace.

7. A method according to claim 1 in which an addition of platinum is included in the molten charge prior to pouring to increase the rate of nucleation.

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 atmosphere is at least 5 inches of mercury below atmospheric.

10. A method according to claim 8 in which the furnace is evacuated to below 100 microns before the aluminum is melted.

11. A method according to claim 3 in which inception or 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 1 in which the inert gas is selected from the group consisting of argon and helium.

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