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Structure and Properties of Centrifugally Cast α-Brass

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ABSTRACT

A comparative study has been carried out in this investigation in order to evaluate the differences between the products obtained by centrifugal casting and that of the sand casting. Properties like hardness, density, percentage porosity, tensile strength, yield strength and percentage elongation together with microstructural differences have been investigated. Effects of annealing on the microstructures of the product have also been studied in the present investigation.

INTRODUCTION

Modernday casting industries employ the Centrifugal casting process because of it's economic viability as well as it's capability of delivering dense, strong and inclusion free products. Usual products of this process include cylindrical pipes, piston liners, pressure vessels, bush-bearings, steam and gas reformer tubes, pulleys etc. When compared to sand casting process, the centrifugal casting method imparts some essential qualities in the products as high tensile strength, high density, consequently low porosity and necessary hardness. It is normal to anticipate that the properties and the solidification characteristics of centrifugally cast components will be quite different from static castings. However, the success of centrifugal casting process depends on a number of factors viz., mould spinning speed, heat transfer characteristics, mould material, mould coat, pouring temperature, pouring rate, mould preheat temperature, the composition of the alloy cast and the dimensions and geometry of the casting (1). In order to obtain the optimum conditions for attaining various important properties, a thorough study of centrifugally cast products under different conditions of speed of rotation, solidification time, pouring temperature and pouring rate of the melt is imperative (2). With this end in view, investigation has been carried out to study the effects of some process variables on microstructures and properties of centrifugally cast products (3). This paper describes the results of the investigation which include

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a comparative study of the properties of α-brass pipes obtained by centrifugal casting and that of the conventional sand casting.

DESCRIPTION OF THE EXPERIMENTAL SET-UP

The present centrifugal casting unit is the modification of previous set-up (4) which consisted of a permanent barrel-like mould, mould holder, a hollow mild steel shaft, a gauge ring, pulley and a motor. This machine is also incorporated with a four wheel trolly on two rails. The trolly includes a ladle and a ladle holder with a hemispherical shaped spout lined with fire clay. The whole experimental set-up is schematically shown in Figure 1.

The permanent mould was made of cast iron and was horizontally inclined with the three feet long mild steel shaft. The dimensions of the mould were: length 350mm, outer diameter 150 mm, thickness 12.5 mm. A ring was fixed at the end of the mould to hold the casting while it is in motion. There were two slots on both ends of the shaft one for key arrangement with the flange and another for locking with the pulley.

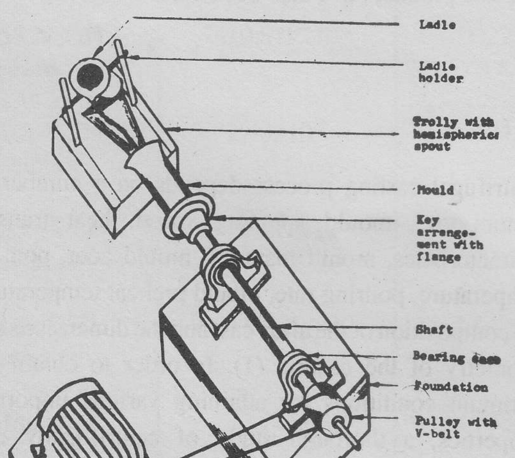

Fig. 1. Schematic diagram of the experimental set-up.

A 18.75 mm bore was made throughout the entire length of the shaft and a mild steel rod was inserted through it for gripping the end plate within the metallic mould. The end plate was used for end measure of the axial length and ejecting the casting from the mould.

The trolly was an essential part of the experimental set-up. Its main purpose was to make an arrangement for uniform and regular pouring of metals and alloys into the rotating mould. It could move backward and forward on two rails. The dimensions of the trolly were about 375 mm long and 300 mm wide. About 600 mm long hemispherical shaped spout was attached with the trolly. It was moved on a slopy rail track and its entry into the mould could thus be regulated. The main function of the spout was to transfer the molten metal into the revolving mould uniformly from the ladle which was placed above it. The ladle was made of mild steel sheet over which fire clay lining was imparted to withstand massive thermal shock. The ladle holder, made of cast iron pipe, had a bracket end and an extended handle to ease the pouring manually yet safely by simply rotating the handle. The length of the handle was extended to tilt the ladle between 0° to 90° by simply rotating the other end of the handle from a far distance. This arrangement also avoids the risk of having any split of melt from the rotating mould.

The gauge ring is employed to determine and maintain the required thickness of the product.

A 7 HP electric motor was used for rotating the casting machine and its speed was about 2800 revolutions per minute. The required spinning speed of the mould was achieved by changing pulleys of different diameters which were connected with shaft of the machine utilising a V-belt.

EXPERIMENTAL PROCEDURE

(a) Charge Materials

A series of experiments were carried out using brass, whose composition was 73.0% Cu, 25.5% Zn, 1.0% Sn and 0.5% other elements. The weight of total charge material for each casting was about 10 kg.

(b) Moulding Materials

For centrifugal casting, cast iron mould was chosen since the casting conditions are more constant and controllable with this type of mould. The mould was dressed with graphite powder along the gauge length before pouring the melt. For sand casting, green sand was used as the moulding material to make sand moulds and cores. In the present work the moulding mixture consisted of natural silica, clay, coal dust to which about 5-6% water was used. The A.F.S. grain fineness number of the sand was measured by Tyler's sieve shaker and was found to be about 69.

(c) Melting and Casting

The charge material was taken in a graphite crucible and melted in a natural gas fired pit furnace. In order to remove the slag from the molten brass, borax was added and stirring was continued for sometime. Finally, skimming from the top of the melt was necessary prior to pouring into the ladle. The pouring temperature of the melt was measured with the help of Digital Thermometer which gave a direct reading of ± 2°C accuracy. The melt was then poured into the mould at about 1080°C and the rotational speed of the mould was about 1800 rpm(5). The speed was measured with the help of a Digital Techometer which gave the direct reading in revolutions per minute. Mention may be made here that the mould was heated to about 200°C to 250°C before pouring the melt.

(d) Heat-treatment

Annealing of brass was accomplished by heating to about 538°C in a muffle furnace and holding it at that temperature for about 1 hour. The specimen was then cooled slowly to room temperature in the furnace(6).

(e) Metallography

Mettallographic specimens were prepared from the cast hollow cylinders. These were polished in the usual manner. Final polishing was carried out with fine alumina powder(0.1 micron) by hand to remove the micro-scratches from the specimens. The specimens were etched in 20 ml NH_4OH and a few drops of fresh H_2O_2 (0.3%) by swabbing the specimen for 1 minute. The microstructures were examined under optical microscope to see the structural difference at different magnifications. Wetzlar Universal microscope and Swiftmaster photographic microscope were used for the examination and photographically recording of the representative microstructures, respectively.

(f) Determination of tensile properties

Tensile testing was conducted using a 24 Kg Hydraulic Testing machine with a screw type operating cylinder using 15 kN scale. The standard 6.25 mm diameter round test specimen (Fig.2) was used for tensile testing. The U.T.S. in newtons per square mm and percentage of elongation were obtained. The yield strength in newtons per square mm was measured by the

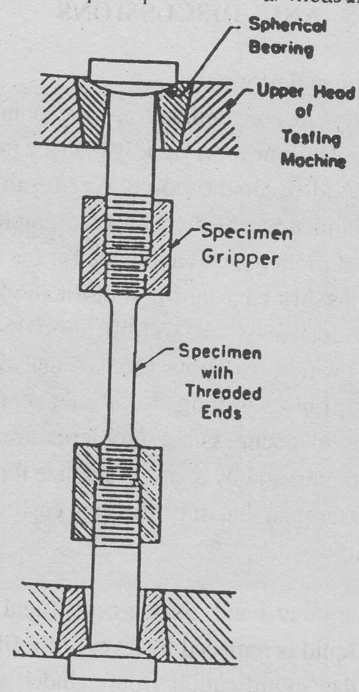

Fig. 2. Gripping device for threaded-end specimen.

offset method using specified value of set (= 0.2%) from stress-strain curve. The results were averaged from three determinations.

(g) Determination of percentage porosity

In order to calculate the percentage porosity of the casting, it is necessary to determine both the bulk and the true density. The former is determined by obtaining the mass of the dried specimen and its exterior volume. The bulk density (d), obviously, is equivalent to the relation m/v, where m is the mass of the specimen and v its volume. The true density is found by grinding the material, passing it through the 100 mesh sieve, and determining the values sought out by means of a Pycnometer in the usual manner. The percentage porosity (p) of the casting is then computed from the following relation:

$$p = 100(1-d/D),$$

where, d = bulk density,
D = true density

RESULTS AND DISCUSSIONS

(a) Structure and properties

Usually, in conventional casting pouring of the molten metal is done more rapidly than the rate at which the metal solidifies in the mould. As a result, a sump of liquid accumulates which ensures that, there is always an excess of molten metal available for feeding which compensates shrinkage during solidification. However, the excess metal above the solidification front becomes segregated with most alloys because the solidification time is sufficiently long for major compositional differences to occur. Other problems are caused by porosity, piping and by a cast grain size that is usually much coarser than that of centrifugal casting of similar composition.

On the other hand, during centrifugal casting the sump of liquid is replaced by a very thin film covering most of the solidification front. Under an optimum rotational speed of the mould, the thin film of molten metal will land over the entire length just after the solidification of the prior splat. In this way, the liquid metal is supplied constantly and the portion of which freezes almost immediately, causing an incremental change in the dimensions of the casting. The final structure is a fine-grained, equiaxed structure with low porosity. Segregation is also at a very low level in centrifugal casting and is confined within areas approaching towards the centre. Therefore, the potential benefits from this situation are very considerable, including near-zero segregation and rapid solidification, the latter leading to enhanced mechanical properties.

Figures 3(a) and 3(b) show the micro-structures of sand cast and centrifugally cast specimens, respectively. It can be seen that the sand cast structure includes fir-tree like dendrites of α-brass with pores in the vicinity, whereas the centrifugally cast structure specimen, traces of coring effects are prominently visible (Fig.4a) near the grain boundaries. When centrifugally cast brass specimen is annealed, the microstructure shows (Fig.4b) twin grains with strain bands. It is envisaged that in case of centrifugal casting, dense and all the impurities are flashed out towards the centre. As a result, higher physical and mechanical properties are obtained during centrifugal casting (Table 1).

(b) Effects of annealing on structures

When annealing is carried out on sand cast brass includes fine and equiaxed grains with negligible pores. Actually, the high rotational speed of the mould breaks up the dendrites during first stage of solidification, favouring fine equiaxed grains. Besides, the melt is held together due to centrifugal force, making the structure the growing crystal undergo some sort of partial deformation due to imposition of centrifugal force, and the phenomenon can be considered similar in effect as partial deformation in the sand casting. Because when sand cast specimen is annealed after partial deformation, bent twins with strain bands are visible in the structure(7).

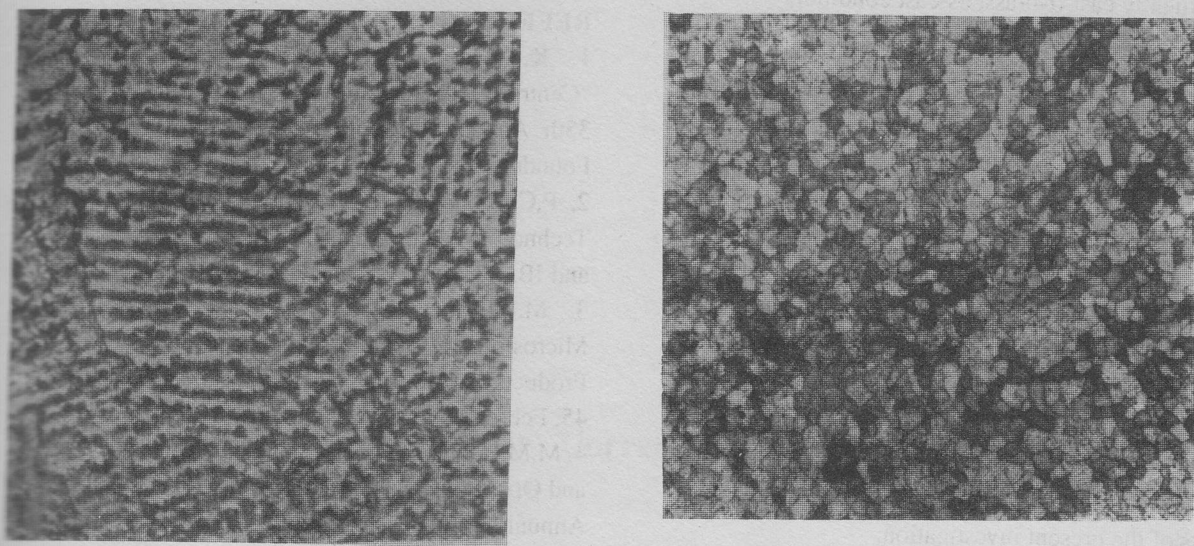

Fig. 3. Showing structures of (a) sand cast and (b) centrifugally cast brass specimen, as-cast condition, x 100.

Fig. 4. Showing structures of (a) sand cast and (b) centrifugally cast brass specimen, annealed at 538°C for 1 hour; x 100.

Table 1

Comparison of various properties of sand cast and centrifugally cast α-brass, as-cast condition.

Properties	Sand Casting	Centrifugal Casting
Yield Strength(N/mm^2)	86.5	125
Ultimate Tensile Strength (N/mm^2)	170	235
Elongation (%)	13.0	17.0
Hardness (BHN)	55	70
Density (gm/cc)	8.15	8.39
Porosity (%)	5.50	2.70

CONCLUSIONS

The following conclusions may be drawn from the results of the present investigation:

(i) The brass containg about 26% Zn offers dense and compact structure when cast centrifugally and hence better physical and mechanical properties are obtained than that of the conventional casting.

(ii) Annealing has also shown a great influence on the microstructure of the α-brass. The centrifugally cast annealed specimen shows equiaxed twins with strain bands but do not show any coring effect near the grain boundaries, whereas the sand cast specimen shows prominent coring effect.

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