Influence of Centrifugal Force on the Microstructure and Hardness of ZA-8 Alloys

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Abstract

In the present work, ZA-8 alloy is processed through centrifugal casting process at different rotational speed of the mould as 400 rpm, 600 rpm and 800 rpm. The effect of rotational speed of the mould on the microstructure and hardness are studied. It is observed that, at 600 rpm complete cast tube with fine microstructure is obtained and at 400 rpm, 800 rpm coarse and dendrite structure is been observed. Uniform hardness values are obtained at inner, middle and outer layer for the cast tube processed at 600 rpm compared to other cast tubes.

Keywords— *Centrifugal Casting, Rotational Speed, Microstructure, ZA-8 alloy*

I. INTRODUCTION

Centrifugal casting is a process of pouring the melt in to the rotating mould, which is used for producing hollow castings, disc, and cylindrical shaped objects such as railway carriage wheels, pipes, boilers, pressure vessels flywheels, cylinder liners and sleeve valves for piston engines.In this process, feeding of melt and distribution of melt into mould depends on the rotational speed of the mould. Solidification is fast process and during solidification also centrifugal force will be acting on the melt, hence good metallurgical quality is attained as solidification starts from inner surface of the mould and moves towards casting outer surface, promoting directional solidification resulting in fine grain structure. Gas porosity if present will be forced out along with the impurities due to density differences. The centrifugal casting process has several advantages over the conventional gravity casting and many other casting processes [1]. Due to high degree of metallurgical purity, minimum shrinkage cavities, closer grain structure due to chilling effect of the melt coming in contact with mould surface and homogeneous fine microstructure are obtained due to which, the centrifugally cast products generally show superior mechanical properties .Some of the special features of this process are it permits simultaneous patterning of multiple sides of a component and allows control of thickness of part in a closed mould without entrapment of air bubbles, used to produce newer advanced materials like metal matrix composite reinforced with ceramic particles, bulk metallic glasses, and functionally graded materials**.**

Flow pattern of the melt has great influence on microstructure.i.e. Fluid flow behaviour plays an important role especially during the filling, and lifting of melt in the rotating mould.The properties of the cast tube depend on the melt flow pattern which in turn depends on rotational speed of the mould [2].

Much research work has been done on centrifugal casting of Aluminium based alloys [3] [4] and hybrid Composite of Aluminium and Magnesium based alloys [5]. But much work is not been done on centrifugal casting of ZA based alloys which are used as bearing material and are replacing the conventionalbearing material like Babbitt metal, alloy of Aluminum, Tin, Cemented Steel, Copper-Tin-Lead alloys, Bronze etc. because of their low cost, high as-cast strength, excellent bearing properties, thin wall cast ability characteristics, as well as low energy consumption for melting [6]. These bearings are processed by gravity or permanent mould casting; Bahaa BALOUT has studied modeling of phases and particles segregation of ZA-8 alloy and composite A356/SiC processed by centrifugal casting [7]. In present work, effect of rotational speed on microstructure of ZA-8 alloy is studied as microstructure reflects the mechanical properties of cast.

II. EXPERIMENTAL DETAILS

The experimental alloy i.e. ZA-8 is prepared as per ASTM B669-82 standard for Zinc-Aluminium (ZA) Alloy, by liquid Metallurgy route. Figure 1 shows centrifugal casting connected to a shaft of 2 hpDC motor for varying rotational speed from 20 to 2000 rpm with high accurate speed controller. The motor rpm is indicated by a digital speed indicator. The speed of mould has also been cross-checked with a tachometer. The mould can be rotated without vibrations. The machine is grounded rigidly as shown in fig. Electric resistance furnace is used for melting the alloy and the melt is poured in to the mould with 200 °C as super heat temperature maintained for all the cast tubes. After a few seconds, the motor was turned off and casting is pulled out. The thickness of the cast was controlled by taking calculated amount of metal. These castings were made for different speeds and for same cast thickness. The different speeds are 400, 600, 800rpm. The cast tube of a true cylinder had a dimension of Φ80x120mm and 6mm thick.

Figure1:Horizontal Centrifugal Casting Machine

III. RESULTS AND DISCUSSIONS

A. Appearance of Cast Tube

Figure 2: Cast Tubes (cut pieces) of ZA-8 Alloys at 400rpm, 600rpm and 800rpm.

From the Fig. 2, it is understood that a uniform cast tube is formed at rotational speed of 600 rpm. More over complete cylinder of uniform thickness is not seen for 400 rpm and 800rpm. Viscosity of the melt plays a major role in formation of uniform thick cylinder. A complete cast tube is formed with irregular patterns inside the cast tube when rotated at 400 rpm. Since the viscosity and the driving force of the melt is low, it moves axially and get lifted from the inner walls of the mould during teeming process. The melt takes more time for solidification which leads to the formation of lumps in the final casting. Further with gradual increase in the magnitude of viscosity, the melt moves easily along the circumference of the mould and impression of the bands is formed in the final casting. The solidification rate and driving force of melt finds more dependent onthe viscosity and rotational speed of the mould. The melt must rotate at larger rotational speed after pouring, since it has low viscosity during teeming process. A uniform full cylinder is observed, when the mould is rotated at a speed of 600rpm. At 800rpm, the driving force guides the molten metal to move along the circumference rather than moving along the axis. Finally, an irregular cast tube is formed.

B. Microstructure of the Cast Tubes

Microstructure is found for inner, middle and outer layers of the cast tube.The microstructure of ZA8 alloy for various rotational speed of the mould is shown in Fig. [3].It is found that for ZA-8 alloy a fine micro structure is observed across the section for the cast tuberotated at 600 rpm. The structure is typically dendritic at the inner, middle and outer surface of the cast tube. Dendrites formed here are of complex shape and the growth of dendrite is moved from outer to inner surface of the mould. Here the liquid metalfinds difficult to move along the circumference of the mould during teeming. It probablyoscillates along the axis and when it becomes viscous, it moves along the circumference ofthe mould. This could be imagined and observed from the final cast tube. The process herehas a lower solidification rate of the liquid metal in cast tube and finally improper structures are seen in the cast tube.

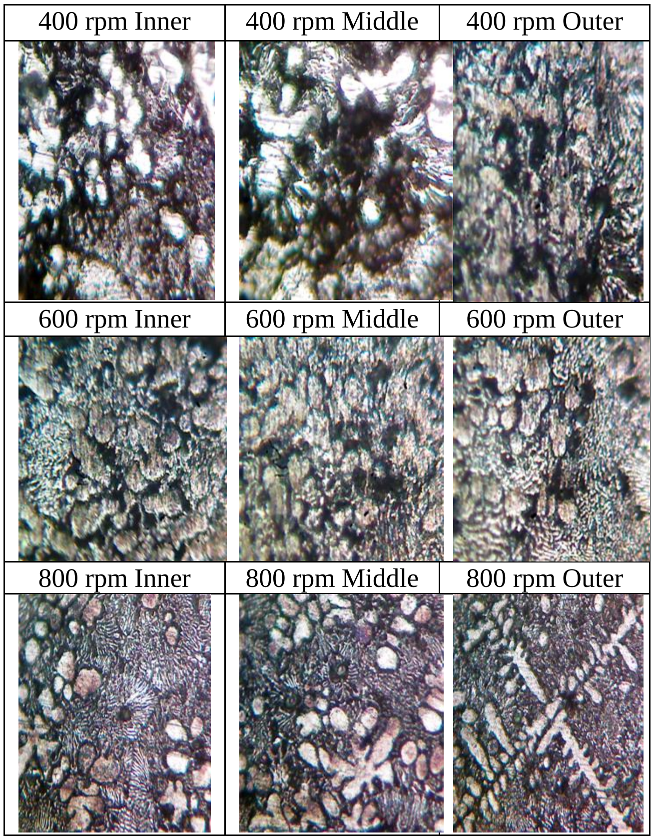

Figure 3: Microstructure of ZA-8 Cast Tube at Various Rotational Speed of the Mould

Transformation of the dendritic structure into a fine structure is seen, when the rotational speed of the mould is increased to 600rpm.The solidification rate here is comparatively more since the liquid metal moved along the axis and simultaneously rises along the circumference of the mould forming a good cast tube. Increase in rotational speed to800rpm, the liquid metal moves along the circumference of the mould after teeming into it.The driving force is too high, so that the melt has limited axial movement. Since the lump ofmelt is accumulated in one portion of mould, the solidification is low and hence dendrite structure is formed at the middle and inner surface of the mould. Due to sudden quenching of melt into mould during pouring, fine structures are seen at the outer surface of the mould.

C. Hardness of the Cast Tube

In the present work hardness of ZA-8, cast tubeat different rotational speeds is found out.Vickers hardness tester of model MMT-X7A was used for measuring micro Hardness of the cast tube with an applied load of 1kg. Hardness is measured on 10mm square which is radially cut from the cast tube. Averages of three readings were taken on three layers i.e. outer, middle and inner layers of cast tube specimen**.** The hardness values for ZA-8 alloy are as shown in Fig.4. It is found that at 600rpm, uniform hardness at allthe three layers is recorded, as the flow of melt in the rotating mould is uniform. But at 400 rpm and 800 rpm, hardness isnot uniform across the cross section of the cast tube. Atlower rotational speed of the mould, melt flow is not uniform over the inner surfaceof the mould. Due to this, the solidification rate of the cast tube is less and hence lowershardness. In the case of higher rotational speed, themould itself lifts the liquid metal over its inner surface making limited movement in axial direction, lowering hardness values due to lower solidification rate.

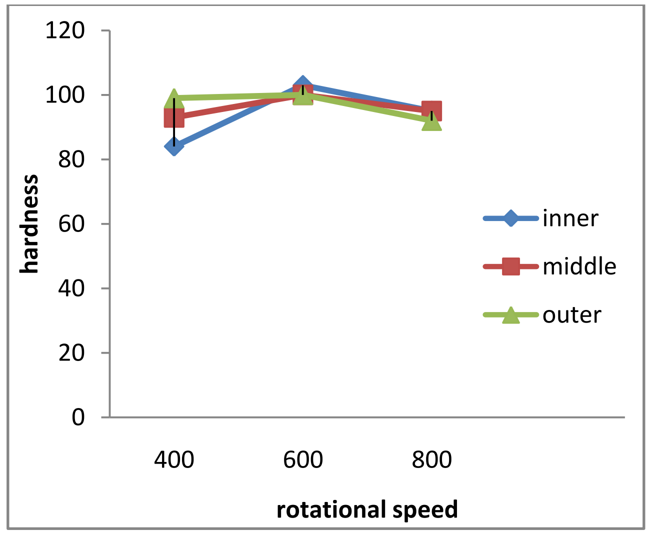

Figure 4: Hardness Values of ZA-8 Cast Tube at Various Rotational Speed of the Mould

IV. CONCLUSION

From the above, it can be concluded with the following points

1. A uniform cast tube for ZA-8 alloy is observed at 600rpm
2. With the increase and decrease in rotational speed, the melt gets a lift by the inner circumference of the mould, forming irregular shaped pattern and non-satisfying mechanical properties.
3. Hardness values are uniform in the cast tube processed at 600 rpm, due uniform flow of melt along the inner surface of the mould beside with axial flow simultaneously.

REFERENCES

[1] Chirita G, Stefanuscu I, Soares D and Silva F S, "Centrifugal versus gravity casting techniques over mechanical properties", Anales de Mecánica de la Fractura 1, 2006, pp 317–22

[2] ShaileshRaoAgari, P. G. Mukunand, Shrikanth S. Rao, K. G. Sudhakar, "Inference of optimal speed for sound centrifugal casting of Al-12Si alloys", JOM,Volume 63, Issue 5, 2011,pp

25-29

[3] D. Vojtìch, "Challenges For Research And Development Of New Aluminum Alloys", METALURGIJA 49 (2010) 3, 181-185

[4] Jian Zhang, Zhongyun Fan, Yuqing Wang, Benlian ,Zhou "Hypereutectic aluminium alloy tubes with graded distribution of Mg Si particles prepared by centrifugal casting", Materials and Design 21 ,2000 149-153

[5] Z. Kiss and B. Varga, "Functionally Graded Aluminium Alloys", Bulletin of the *Transilvania* ,University of BraşovSeries I: Engineering Sciences. Vol. 7 (56) No. 1 - 2014

[6] Calayag T. S, "The practicality of using the Zinc-Aluminium alloys for friction-type bearings", 25th Annual Conference of Metallurgists, 1986,pp. 305-313

[7] Bahaa BALOUT "centrifugal casting of ZA-8 alloy and composite A356/SiC: study and Modeling of phases and particles segregation", PhD Thesis May 2010