Impact of ZrO2 Reinforcement on the Mechanical Properties of Al-5%Si Alloy Produced by Vertical Centrifugal Casting

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ABSTRACT

To obtain a cast of better quality through vertical centrifugal casting, it is essential to optimize the process parameters like rotational speed, volume fraction, aspect ratio etc. In the present investigation casts of eutectic Al-5%Si alloys with zirconia(ZrO_2) reinforcement were obtained with mould wall thickness 4mm, 6mm and 8mm at rotational speed of 300 rpm, 400 rpm and 500 rpm. Hardness and tensile strength were measured However, hardness of casts with higher wall thickness was found greater.When Al-5% Si is reinforced with Zirconia at 500 rpm highest tensile strength has been observed whereas the cast obtained at 300 rpm has the lowest tensile strength.

KEYWORDS: Vertical Centrifugal Casting; Hardness; Tensile Strength; Microstructure;Rotational Speed.

I. INTRODUCTION

One of the main benefits of centrifugal casting is that the centrifugal force enables castings with thinner wall as compared to those obtained by conventional static casting [1]. Centrifugal casting can be carried out with the axis of rotation of mould either vertical or horizontal. In vertical centrifugal casing, molten metal achieve the rotational speed of mould soon after pouring and the resultant centrifugal force remain constant. While in horizontal casting, difference of velocity between mould and molten metal could be nullified by providing acceleration to molten metal [2].

The quality of centrifugal casts primarily depend on flow behaviour and its process parameters such as rotational speed, pouring temperature, mould thickness, aspect ratio, viscosity of melt etc. [3-4]. The speed required to form the full cylinder of melt is directly proportional to thickness required [5] and that result in coarse grains, while slower speed and fasterrate of solidification fine equi-axed grains [6]. The rate of solidification in turn increases with increase in mould wall thickness due to chilling effect. According to the published work [7], micro structure of the centrifugal cast changes from fine to coarse along the mould wall thickness from outer to inner surface. Whereas, the formation of equi-axed zone increases with increase in mould rotation speed and decrease in melt superheat [7]. Importantly, aspect ratio also influence the hardness and it has been found better with increase in aspect ratio [8].

The viscosity of the melt in the mould increases during solidification [9]. Further, it was confirmed that, to form a complete cylinder of melt, lower rotation speed of mould is required for the liquids of higher viscosity and vice-versa.

In the current scenario, the suitability of aluminum alloys, in manufacturing industries, in particular for the automobile industries has been increased owing to high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion

II. EXPERIMENTAL SETUP

A required quantity of metal (Al-5%Si) based on the dimension of cast was melt in the clay graphite crucible of diameter 110mm in a pit type resistance furnace as shown in figure 1 of capacity 3kg under the cover flux (45%NaCl +45%KCl + 10%NaF). The temperature was maintained at 850 $^{\circ}$C and the slags were removed at regular interval of time.


Fig 1. Melting of metal **Fig 2.Vertical Centrifugal setup**

The vertical centrifugal casting setup shown in figure 2 consist of mild steel mould of dimension ϕ80 mm×88 mm x 5mm which was rotated by 1HP DC shunt motor at a speed range of 20 to 2000 rpm. Casts were obtained for different mould wall thickness i.e 5mm,7mm and 9mm rotational speed of 500 rpm for three different composition of the alloys i.e Al-5%Si,with zirconia reinforcement respectively as depicted in fig.3.

Fig 3.1. Cast of 4mm thickness of Al 5% Si with 1% Zirconia reinforcement

Fig 3.2. Cast of 6mm thickness of Al 5% Sii with 1% Zirconia reinforcement

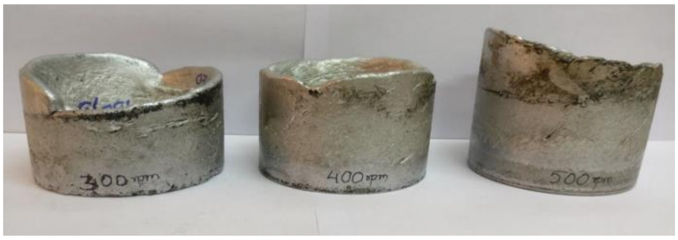

Fig 3.3. Cast of 8mm thickness of Al 5% Si with 1% Zirconia reinforcement

Figure 3.Formation of different cast structure in vertical centrifugal casting at different cast thickness at rotational speed of 300rpm, 400rpm and 500rpm.

The hardness of the materials was measured using Brinell hardness Tester. The test was carried on brinell hardness testing machine using a load of 250 kgf. The resulting measurement is converted to a brinell value using the brinell formula. The tesnsile test was done in extensometer. The dimension of the specimen is shown in the figure 4 which is as per ASTM standard.

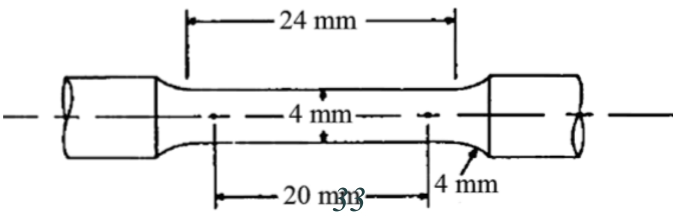

Fig.4 Tensile Test Specimen

III. RESULT AND DISCUSSION

Primarily, it was observed that the physical appearance of the cast was found to be better for higher cast thickness. Table I depict the hardness of specimens measured at outer surface of the cast and comparision BHN in cast obtained at different rotational speed Has been presented in Figure 5

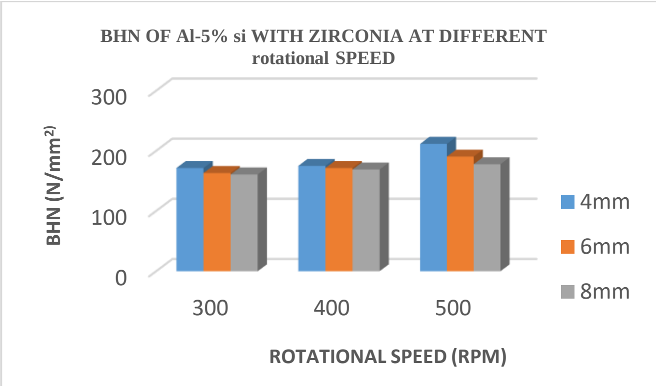

Figure5.Comparison of BHN, for different cast thickness at different speed.

Table I- BHN of different cast obtained at outer surface for different cast thickness at different speed.

SL .N	Thickness (mm)	Speed (rpm)	BHN(trials) (mm)			BHN (N/mm^2)
			Trial 1	Trial 2	Trial 3	
1.	4	300	4.2	4.3	4	171.3
2.		400	4.1	4.2	4.1	174.8
3.		500	3.7	3.8	3.8	211.5
4.	6	300	4.5	4.2	4.1	163.0
5.		400	4.1	4.2	4.2	171.3
6.		500	3.9	4.1	3.9	190.3
7.	8	300	4.3	43	4.3	160.6
8.		400	4.2	4.1	4.2	168.8
9.		500	4	4.2	4.1	177.5

By analysing the above graph, we can infer that the hardness depends on speed and grain structure.The base metal Al-5% Si is when reinforced with Zirconia at 500 rpm has the highest hardness value whereas the same cast obtained at 300 rpm has the lowest hardness value i.e. due to the deposition of the zirconia at the outer surface.

The tensile strength of different casts measured is tabulated in table-II

Table II- Tensile test of Al-5% Si with Zirconia reinforcement at different speed

SL .N.	Thick-ness	Speed (rpm)	Engg. UTS (N/mm^2)	True UTS (N/mm^2)	Break Load (N)	Proof Stress (N/mm^2)
1.		300	105.3	109.6	1039.	74.9

	4				5	
2.	mm	400	96.7	99.3	1069	82.6
3.		500	100.6	103.4	1225.9	83.3
4.	6 mm	300	96.5	100.2	1046.7	61.7
5.		400	98.3	101.7	1090.5	62.9
6.		500	98.3	101.1	1176.8	76.2
7.	8 mm	300	67.9	69.2	627.6	67.3
8.		400	99.9	103.1	1196.5	71.6
9.		500	117	122.9	1255.3	66

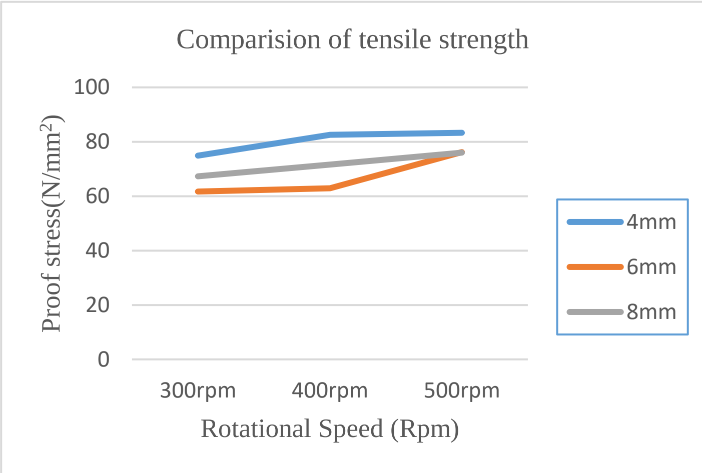

Figure 6. Comparison of tensile strength of Al-5% Si alloy with zirconia

By analysing the above graph, we can infer that the tensile strength depends on speed and grain structure.The base metal Al-5% Si is when reinforced with Zirconia at 500 rpm has the highest tensile strength whereas the same cast obtained at 300 rpm has the lowest tensile strength.

IV. CONCLUSION

Al-5%Si alloys are cast centrifugally with varying rotational speed and constant mould wall thickness.The following are the concluding remarks from the present investigation. The cast obtained at lower rotating speed was having better surface finish. In the alloyed metal, fine microstructure was obtained at high processing speed but in lower rotating speed it is found to be coarser. When operated in high rotational speed, the cooling rate was found to be more, which in turn resulted in more hardness. Hardness of the specimen was more at the outer side of the specimen than at the inner side, where it is less broad and compact than the bottom surface. Higher rotational speed gives harder material. Break load increased with the increase in speed and thickness

V. REFERENCES

[1] Zhang , ‘Centrifuagal casting’ 1st edition, 298-309, 2009
[2] Janco,Centrifugal casting ,1988
[3] Shailesh Rao Agari, S. R., Mukunda, P. G., Rao, S. S., & Sudhakar, K. G. 2011 . “Interence of optimal speed for sound centrifugal casting of Al-12Si alloys”. JOM, 63(5), 25-29.
[4] Amit M Joshi , “Centrifugal casting”, Dept. of Metallurgical Engg. &Material Science, Indian Institute of Technology – Bombay, India.
[5] P G Mukunda, A Shailesh Rao, “An understanding of fluid behavior in Centrifugal casting ”,AFT / TFI -2007, Commemoration of the 100th Anniversary of Tohoku University, December 14-15, 2007, Sendai, Miyagi, Japan.

[6] Madhusudhan, Narendranath S, Mohan kumar G C , Experimental study on cooling rate of centrifugal casting based on grain size. International Journal of scientific & engineering research,Volume 3, Issue 1, January-2012 1 ISSN 2229-5518
[7] Sufei Wei, “Centrifugal casting” the centrifaugal casting machine company, & Steve Lampman, ASM International, Vol 15, (2008) p 667-673.
[8] P. G. Mukunda, R. A. Shailesh, A.S. Kiran, and S.R. Shrikanth, “Experimental studies of flow patterns of different fluids in a partially filled raotating cylinder” Vol.2, No, pp. 39-43,2009.
[9] K S Keerthi Prasad,M.SMurali,P G Mukunda “Analysis of fluid flow in Centrifugal casting”, Front. Mater.Sci.China 2010, 4(1): 103-110.
[10] Madhusudhan,NarendranathS,S.Mohankumar G C,Mukunda P G“Effect of mould wall thickness on rate of solidification of centrifugal casting ” ,International Journal of Engineering Science and Technology Vol. 2(11), 2010, 6092-6096.
[11] P G Mukunda,ShaileshRao,Shrikanth S Rao,“Influence of rotational speed of Centrifugal casting Process on appearance, Microstructure and sliding Wear behavior of Al-2Si Cast alloy metal”. Mater. Int. Vol 16, no. 1 (2010). 137-143.
[12] Chirita, G., Stefanescu, I., Barbosa, J., H., Soares, D., & Silva, F. S. (2009). “On assessment of processing variables in vertical centrifugal casting technique” International Journal of cast Metals Research, 22(5), 382-389.
[13] K S Keerthi Prasad,M S Murali, S C Sharma & P G Mukunda, ‘Characterization of Microstructure of Al-Si Alloy in Centrifgal casting’, ISSN 0973-4589 Vol 4, (2009) pp, 151-155.
[14] Madhusudhan, Narendranath S, G C Mohan kumar,“Properties of Centrifugal casting at different rotational speeds of the die” International journal of Emerging Technology and Advanced Engineering, Jan-2013, vol.3