Analysis of Wear Performance of Al-5%Si Alloy Reinforced with Zirconia and Alumina Using Vertical Centrifugal Casting

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ABSTRACT

Al 5%Si alloy was reinforced with zirconia and alumina respectively and casts were obtained at 300, 400 and 500 rpm of the vertical centrifugal casting machine. Specimens were cut from both the top and bottom regions of these casts. The specimens were flattened with an emery paper and were subjected to wear tests on pin on disc machine (tribometer). The track diameter was set to 100mm, with a load of 1kg and the tests were carried out for 20 min each. The wear vs. time graphs were obtained for each specimen tested and the specific wear rate was calculated. It was observed that the specimens from the top of the casts experienced the highest wear rates as compared to the specimens cut from the bottom of the casts. Also, Al-5%Si alloy with Zirconia reinforcement was found to experience the least wear rate as compared to Al-5%Si alloy with alumina reinforcement and Al-5%Si alloy with no reinforcement.

KEYWORDS: Vertical Centrifugal Casting; Zirconia, alumina, wear rate, Al-5%Si alloy

I. INTRODUCTION

The major use of aluminium-silicon alloys are in producing casts. This is because the addition of silicon reduces the melting temperature and improves the fluidity of the molten metal. Due to the excellent castability, complex shapes can be produced. The minimum mechanical properties obtained in poorly fed regions are higher than in castings made from low castability alloys. Wear resistance of high silicon alloys (20-25%) is very good. The industrial applications of aluminium and its alloys were restricted because of their poor tribological properties. Thermal spraying, laser surfacing, and electron beam welding were the most widely used techniques to alter the surface morphology of base metal. Preliminary studies revealed that the coating and layering of aluminium alloys with ceramic particles enhanced the ballistic resistance. [8] In this work, experiments have been conducted to test the wear properties of low silicon alloys (5%). Also, the wear properties of Al-5%Si alloy with reinforcements of alumina and Zirconia respectively have been tested.

II. EXPERIMENTAL SETUP

The material for casts were procured in the form of ingots which were later melt in a furnace and cast into the vertical centrifugal casting machine. 3 casts of Al-5%Si were obtained for 300, 400 and 500 rpm, respectively, of the vertical centrifugal casting machine.

Stir casting was employed to produce Al-5%Si casts with zirconia and alumina reinforcements .The cut metal was melted in a furnace which was set at a temperature of 650℃. To this liquefied metal, reinforcements such as zirconium and alumina were added at the rate of 1% of the weight of the molten metal and were stirred for a few minutes. After proper stirring, the graphite plug was lifted along with the stirrer which caused the flow of the mixture through the hole drilled at the bottom of the crucible through a funnel placed at the other end. The molten mixture was discharged from the funnel into the vertical centrifugal casting machine which was rotated at 300, 400 and 500 rpm respectively yielding three different casts for each reinforcement.

Fig. 1: Stir Casting Setup

WEAR TESTING

By using rolling-sliding wear tester (tribometer), (shown in fig 2) wear behavior of materials was investigated. The apparatus consists of two discs (wheels) fixed to two parallel shafts pressed against each other under contact load.

Fig. 2: Pin-on-disc Setup and Wear Monitor

One specimen was cut from each of the casts. The specimens which are cut from the casts were filed. Then, both the surfaces (Top and Bottom) of the specimen was manually finished by Emery paper. The speed of rotation of the disc was set at of 400 rpm, friction force of 10 N, time of 20 minutes was set in the apparatus. The graph was displayed on the monitor.

The graphs were obtained by using a WINDUCOM 2006 Software. From the graph, the specific wear rate was calculated using the formula:

$$\text{Specific wear rate} = \frac{\text{Wear value (from the graph)} * \text{cross section of the specimen}}{\text{Weight} * \pi\text{DN}} \text{in } m^3/N-m$$

Where,
'D' is Track diameter in 'm'
'N' is Speed of the disc in rpm

III. RESULT AND DISCUSSION

The specimens were cut from both top and bottom portions of the cast. The following results were obtained after subjecting the specimens to a wear test.

Table 1: Table showing the specific wear rates for the casts obtained at 300 rpm of vertical centrifugal casting machine

300 rpm	Type of Cast	Region of cast from which specimen was cut	Specific wear rate X10^{-14} m^3/Nm
1	Without reinforcement	top	18.3
		bottom	10.68
2	With Zirconia	top	9.54
		bottom	8.68
3	With Alumina	top	12.3
		bottom	8.68

Histogram 1: Showing Specific Wear Rate for Specimen prepared at 300 RPM

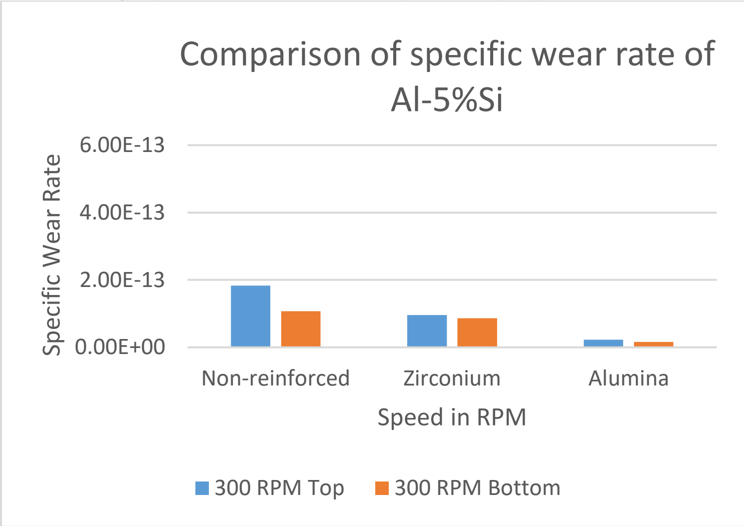


Table 2: Table showing the specific wear rates for the casts obtained at 400 rpm of vertical centrifugal casting machine.

Histogram 2: Showing Specific Wear Rate for Specimen prepared at 400 RPM

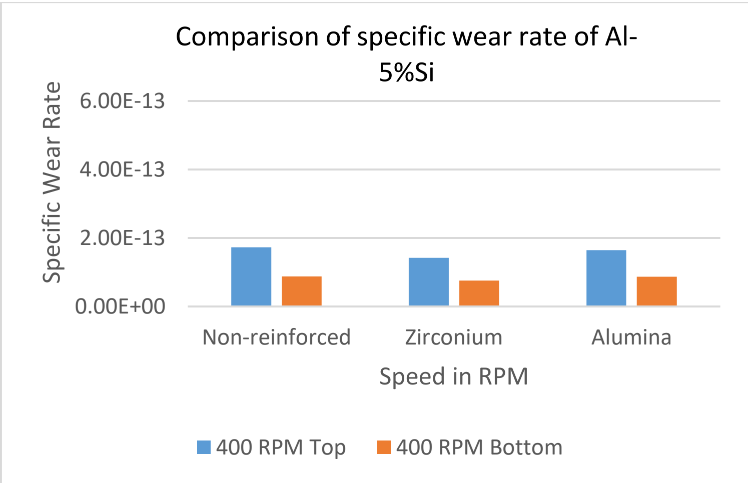
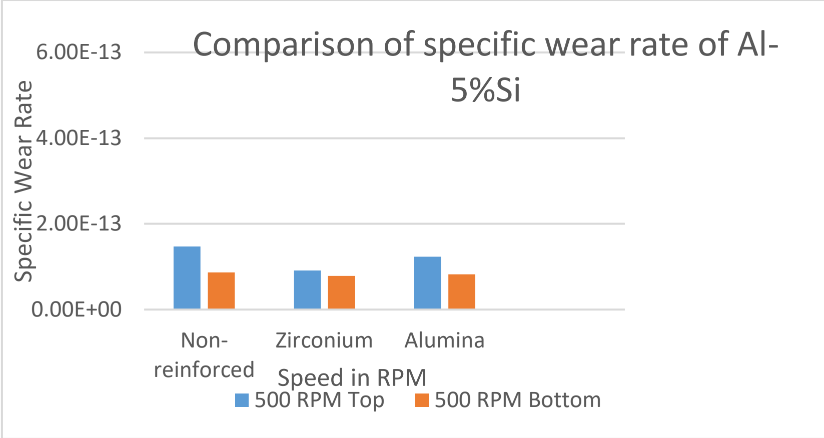


Table 3: Table showing the specific wear rates for the casts obtained at 500 rpm of vertical centrifugal casting machine

500 rpm	Type of Cast	Region of cast from which the specimen was cut	Specific wear rate X10^{-14} m^3/Nm
1.	Without Reinforcement	top	14.7
		bottom	8.68
2.	Zirconia	top	9.11
		bottom	7.81
3.	Alumina	top	12.3
		bottom	8.24

Histogram 3: Showing Specific Wear Rate for Specimen for prepared at 500 RPM



From the above tables, it can be seen that specimens cut from the top of the casts have experienced more wear rate than the specimens that were cut from the bottom of the cast. This is probably because of the non-uniform particle distributions at the top of the cast.

Also, Al-5%si alloy with Zirconia reinforcement was found to experience the least wear rate and Al-5%si alloy with no reinforcement was found to experience the highest wear rate. This is perhaps due to the fact that the hardness of Zirconia is higher than Alumina. Hence, because of the presence of hard particles, the wear rate was found to be the least.

Contradictorily, Al-5%Si alloy does not possess any hard particles and hence was found to experience the maximum wear rate.

IV. CONCLUSION

The specimens tested from the top of the casts were found to have more specific wear rate than the specimens tested from the bottom of the cast. This is probably because of the non-uniform distribution of grains during the lift of the molten material.

The specimens with alumina reinforcements were found to have higher specific wear rate as compared to zirconia. Specimens without any reinforcement were found to have the highest wear rates. This is perhaps the reinforcements alumina and zirconia increase the hardness of Al-5%Si alloy. Also, the hardness of zirconia is greater than alumina, alumina experiences more wear than zirconia.

V. REFERENCES

[1] I.M. El-Galy, M.H. Ahmed, B.I. Bassiouny, “Characterization of functionally graded Al-SiCp metal matrix composites”, Alexandria Engineering Journal(2017) 56, 371-381

[2] Pardeep Sharma, Satpal Sharma, Dinesh Khanduja, “Production and some properties of Si3N4 reinforced aluminium alloy composites”, Journal of Asian Ceramics Societies 3 (2015), 352-359

[3] Bhargavi Rebba, N.Ramanaiah,“Evaluation of Mechanical Properties of Aluminium Alloy (Al-2024)”, Procedia Materials Science 6 (2014), 1161-1169

[4] Davies Oladayo Folorunsoa, Seun Samuel Owoeye, M. Vijayananda, R.lansezhian,“Influence of quarry dust-silicon carbide weight percentage on the mechanical properties and tribological behavior of stir cast ZA-27 alloy”, Journal of King Saud University-Engineering Sciences xxx(2017), xxx-xxx

[5] M. Vijayananda, R.lansezhian, “Effect of Different Pretreatments and Heat Treatment on Wear Properties of Electroless Ni-B”, Procedia Engineering 97(2014),1707-1717

[6] J.Allwyn Kingsly Gladston, I. Dinaharan, N. Mohamed Sheriff, J. David Raja Selvam, “Dry sliding wear behavior of AA6061 Aluminium alloy composites”, Journal of Asian Ceramic Societies 5 (2017),127-135

[7] S. Rajesh, A. Gopala Krishna, P. Rama Murty Raju, M. Duraiselvam, “Statistical Analysis of Dry Sliding Wear Behavior of Graphite Reinforced Aluminium MMCs”, Procedia Material Science 6 (2014),1110-1120

[8] I. Sudhakar, V. Madhu, G. Madhusudhan Reddy, and K. Srinivasa Rao, “Enhancement of wear and ballistic resistance of armor grade AA7075 Aluminium alloy”, Defence Technology 11 (2015),10-17

[9] B.Q. Ochieze, C.C. Nwobi-Okoye, P.N. Atamuo, “Experimental study of the effect of wear parameter on the wear behavior of A356 alloy”, Defence Technology 14 (2018), 77-83

[10] Kenneth Kanayo Alaneme, Tolulope Moyosore Adewale, Peter Apata Olubambi, “Corrosion and wear behavior of Al-Mg-Si Alloy matrix hybrid composite”, J MATER RES TECHNOL. 2014;3(1),9-16

[11] Michael Oluwatosin Bodunrin, Kenneth Kanayo Alaneme, Lesley Heath Chown, “Aluminium matrix hybrid composites”, J MATER TECHNOL.2015;4(4), 434-445

[12] P. Shailesh, S.Sundarrajan, M.Komaraiah, “Optimization of process parameters of Al-Si alloy by centrifugal casting technique”, Procedia Material Science 6 (2014), 812-820

[13] Sijo M.T., K R Jayadevan,“Analysis of stir cast aluminium silicon carbide metal matrix composite”, Procedia Technology 24 (2016),379-385

[14] Eckhart Uhlmann, Karsten Flögel, Fiona Sammler, Iris Rieck, Arne Dethlefs, “Machining of hypereutectic Aluminium Silicon Alloy”, Procedia CIRP 14 (2014),223-228

[15] V.Mohanavel, K. Rajan, S. Suresh Kumar, A. Chockalingam, Aquila Roy, T.Adithiyaa,“Mechanical and tribological charactization of stir-cast Al-SiCp composites”, Materials Today Proceedings 5 (2018),1740-1746