Study of Microstructure and Sliding Wear Behavior of Al (7075) Reinforced with Bottom Ash in Metallic Mould with Water Chill

Suresh Rathod
P.G Scholar
Department of Mechanical Engineering
Siddaganga Institute of Technology, Tumkur Karnataka, India-572103

Umashankar
Professor
Department of Mechanical Engineering
Siddaganga Institute of Technology, Tumkur Karnataka, India-572103

Abstract

The mechanical properties of composite materials are strongly dependent on micro structural parameters of the system. Faster cooling of casting is done by metal mould as well as water circulation uniformly at the end of the casting which carries heat at faster rate and gives finer micro structure and improves mechanical properties. The evaluation of microstructure depends largely on the cooling rate during phase change. Though the microstructure evolution depends on many process parameters, the final structure is decided by the cooling conditions during solidification. The mold material has a decided effect on the structure formation. The use of water chills during casting not only favors directional solidification but also accelerates solidification. In this work an attempt is made to the cooling of Al (7075)-bottom ash composites cast using mild steel mould with water chill. The microstructure and dry sliding wear cast specimens are analyzed and reported. It was observed that the water chill and mild steel mould material has a significant influence on the microstructure and properties of the cast specsimens. Finer structure and better mechanical properties were observed with the specimens cast using water chills, whereas, casting without water chill gave rise to coarse structure with reduced mechanical properties. Composite is produced by stir casting method. It was observed that chill effect has significant improvement in wear properties are noticeable as the wt % of the bottom ash increases as compared to unreinforced matrix.
Keywords: Al 7075, Bottom Ash, Stir Casting, water chill, metal mould.

I. Introduction

Now a day the particulate reinforced aluminium composites are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys.

Generally, a Metal Matrix Composite (MMC's) is composed of reinforcement (fibers, particles, flakes) embedded in a matrix (metals). The matrix is monolithic material into which reinforcement is embedded & which is completely continuous. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, bottom ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with bottom ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of bottom ash particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products.

In the present work, bottom -ash which mainly consists of refractory oxides like silica, alumina, and iron oxides is used as reinforcing phase. Composite was produced with stir casting route 3% , 6%, 9% & 12 wt.% bottom-ash as reinforcing phase.

Commercially pure Al (7075) was melted in electrical resistance furnace, after melting of aluminium pre heated reinforcement bottom ash is poured into the crucible and well stirred by stirrer at 300 rpm and poured in to metallic water cooled mould . Microstructure and wear properties of the composite were evaluated and compared with the commercially pure aluminium 7075. Mechanical properties of composites are affected by the weight fraction of the reinforcement, composite material. These aspects have been discussed by many researchers Anilkumar H.C[2] determined the effect of particle size of fly ash particles on mechanical and tribological properties of fly ash reinforced aluminium alloy (Al 6061) composites samples, processed by stir casting route and found that the wear rate decreased with the increase in particle size of fly ash particles.

Dr. Selvi.S[3] investigated the mechanical properties of AL-MMCs theoritically and experimentally and also concluded that the fly ash particles improve the wear resistance of the Al MMC and the presence of SiO2 in fly ash increase wear resistance of Al MMC and that changes of wear rates are observed in the sliding wear test.

M. Ramachandra[4] studied the wear and friction characteristics of the Al (12 wt% Si) up to 15 wt% of flyash composite in the as-cast conditions by conducting sliding wear test, slurry erosive wear test and concluded that the effect of increased reinforcement on the wear behavior of the MMCs is to increase the wear resistance and reduce the coefficient of friction.PrabhakarKammer[5] carried experimental investigation of Al7075 with Fly ash & E-glass fibers.Compression strength which is carried out on constant Eglass& varying fly ash wt fraction yields into increasing trend over al alloy.Sudharshan, M.K.Surappa, [6] studied the dry sliding wear of fly ash particle reinfoeced Al356 composites reported that wear rate decrease with increasing fly ash. Mahanthesh G. [7]Discussed Effect of bottom ash particle size on tensile properties of aluminium-bottom ash Composite" reported that with the increase in volume percentages of bottom ash, increases the tensile strength value Al–bottom ash composites.

A. *Aluminium 7075 alloy (matrix)*

Al 7075 is an aluminum alloy, with zinc as the alloying element. It is strong, with good fatigue strength and average machinability, but is not weld able and has less resistance to corrosion than many other alloys.

Table - 1
Chemical composition of Al 7075 wt. %

Composition Details	*% Composition*
Zinc	*5.1 - 6.1*
Magnesium	*2.1 – 2.9*
Copper	*1.1 – 2.0*
Chromium	*0.18 - 0.28*
Fe	*<=0.50*
Si	*<=0.40*
Mn	*<=0.30*
Ti	*<=0.20*
Zr+Ti	*<=0.25*
Total other	*<=0.15*
Aluminium	*Remainder*

B. *Reinforcement material as Bottom ash*

Bottom Ash/Boiler Slag Bottom ash consists of heavier particles that fall to the bottom of the furnace (Fig 1). Bottom ash is also composed primarily of amorphous or glassy alumina silicate materials derived from the melted mineral phases. Most bottom ash is produced in dry-bottom boilers, where the ash cools in a dry state, Boiler slag is a type of bottom ash collected in wet-bottom boilers (slag tap or cyclone furnaces, which operate at very high temperatures), where the molten particles are cooled in a water quench.

Whether collected from dry-bottom or wet-bottom boilers, bottom ash is usually mixed with water and conveyed away from the furnace in a sluice pipe. Bottom ash is coarser than fly ash, with a sandy texture and particles ranging from about 0.1 mm to 50 mm in diameter. Bottom ash from dry-bottom boilers is generally dull black in appearance. It typically has the consistency of coarse sand to gravel and higher carbon content than fly ash. Boiler slag is black and angular, and has a smooth, glassy appearance. The properties of bottom ash make them useful for a variety of construction applications.

Table - 2
Chemical composition of Bottom ash wt. %

SiO2	*Al2O3*	*Fe2O3*	*TiO2*	*MgO*	*CaO*	*K2O*	*LOI*
54.8	*28.5*	*8.49*	*2.71*	*0.35*	*4.2*	*0.45*	*Remaining*

OBJECTIVE

- To prepare the low weight composite.
- Micro structural analysis Al7075 & Bottom ash composite.
- To study the effect of Al7075 &Bottom ash composite addition on wear properties

II. EXPERIMENTAL WORK

A. *Heat Treatment of bottom ash*

Before directly using the bottom ash in the composite heat treatment or preheating is done on it to remove impurities and water content. For the surface treatment of ash it is heated in the furnace at a temperature. of 300°C.

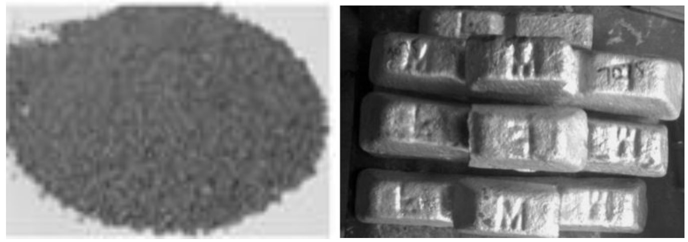

Fig. 1: Bottom Ash and Al7075 ingot

B. Fabrication of Al7075-Bottom Ash Composites

As we done the heat treatment of bottom ash that taken from the thermal plant to reduce its moisture in the induction furnace. After it we have to melt the Al 7075 in the furnace having a capacity of 1000°C and then added preheated bottom ash into it. For increasing wettability, we also added the Mg that decreases the surface tension of the bottom ash. For better mixing of all materials, a mechanical stirrer arrangement is adjusted which stirs the molted composite material. Also stir casting technique yields relatively homogenous and fine microstructure which improves the addition of reinforcement material in the molten metal. In addition, the porosity level of composite minimized and the chemical reaction between reinforcement and matrix avoided also an Hexachloro-ethane tablets are using here to remove the slag from the molten composite. The proper selection of process parameter such as pouring temperature, stirring speed, pre-heat temperature of reinforcement can produce good quality composites. Typical stir casting set up is shown in fig.1. After all of these, this molten material will be poured into the metallic mould with water end chill and fabricate the required shape of slab and rods.

Fig 2 Stirring & reinforcement adding

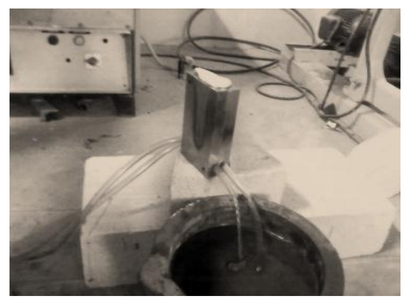

Fig 3 After casting with water chilling

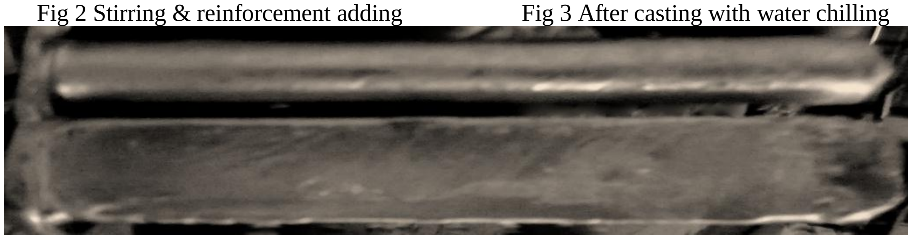

Fig 4 Cast Rod and and Slab of Aluminium Matrix Composite

C. Characterization of Al 7075- Bottom Ash Composites

1) Microstructure

The microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy. Microstructure characterization was carried out by optical microscopy with zooming capacity of 100x. In general polishing is done by the emery paper of grit size 250µ to 1200µ to get the good surface finish on specimen grit SiC emery paper and the grinding rate should steadily decrease from one stage to the next. Proper grinding involves the rotation of the sample between stages while the grinding angle must be held constant during the grinding at any on stage. Wet grinding is usually applied in medium and fine grinding to avoid possible side effects due to heating such as tempering, transformation, aging ,incipient melting and many more. Wet grinding also provides a flushing action for loose particles and keeps sharp edges of the grinding medium exposed at all times. The final fine grinding surface layer resulting from the previous grinding procedure should be completely removed with a rotation rate of 150-200rpm. The specimen is initially held at one position on the wheel, until most of the previous grinding marks are removed. Again the specimens are to be polished on velvet cloth to get the mirrored surface. During the initial polishing stage, moderate pressure can be applied to the specimen and the entire stage should generally take 30 to40 minutes. Finally etching is done on to specimen before micro structural study. The purpose of etching is to optically enhance micro structural features such as grain size and phase features.

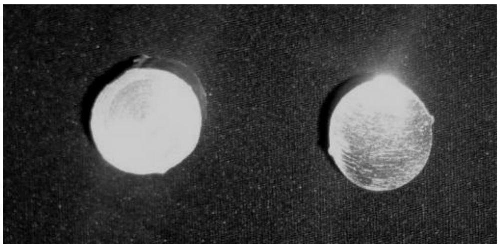

Fig 5 Polished specimen used for microstructure

2) Wear

A pin-on-disc tribometer is used to perform the wear experiment. The wear track, alloy and composite specimens are cleaned thoroughly with acetone prior to test. Each specimen is then weighed using a digital balance having an accuracy of ±0.0001 gm. After that the specimen is mounted on the pin holder of the tribometer ready for wear test. For all experiments, the sliding speed is adjusted to 1.6 m/s, track diameter 120mm, load 20kg to 50kg and speed 300rpm to 600rpm and total time is 5minute under room temperature.

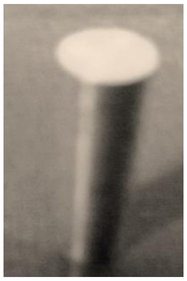

Fig 6 Wear specimen

A pin-on-disc test apparatus is used to investigate the dry sliding wear characteristics of the selected material as per ASTM G99 standards. The wear specimen with 8mm of diameter and 30mm height was cut from as cast then machined and polished metallographically. The initial weight of the specimen was measured in a single pan electronic weighing machine. During the test the pin was pressed against the counterpart rotating against EN31 steel disc with hardness of 60 HRC by applying the load. After the test, the specimens were removed, cleaned with acetone, dried and weighed to determine the weight loss due to wear. The difference in the weight measured before and after test gives the dry sliding wear of the selected specimen and then the volume loss was calculated. The wear of the selected material was studied as a function of the sliding speed, applied load and the sliding distance.

III. RESULTS & DISCUSSIONS

The specimens used were of diameter 8mm and 30mm length machined from the cast composites. The wear tests were conducted on these samples according to as per ASTM –E99 standard at room temperature, using wear testing machine.

A. Microstructure

The micrographs shown in Figure (7) depict the microstructure of as cast Al7075 and bottom ash reinforced Al7075.shown in figure-(7) (8) (9) (10) composites containing 3 % -12 wt.% of bottom ash. The grain size of the matrix alloy is some what larger than pure Al7075. Clustering of reinforcements was observed in the matrix, and the dispersion of bottom ash particles at 12% bottom ash. And 3% to 9% was seen to be almost uniform no gap is observed between the particle and matrix and between the reinforcement and the matrix.

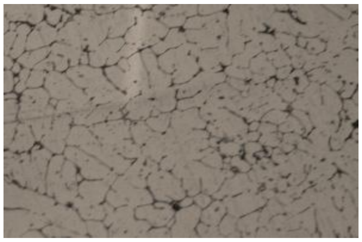

Fig. 7: Microstructure of pure Al 7075

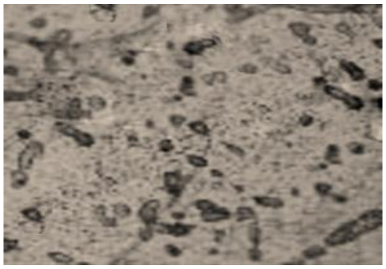
Fig. 8 : 3 wt. % of bottom ash

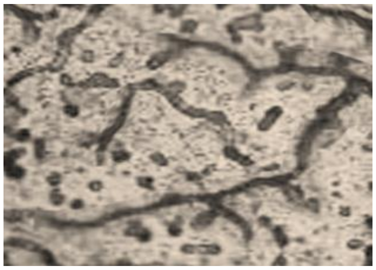
Fig. 9 : 6 wt. % of bottom ash

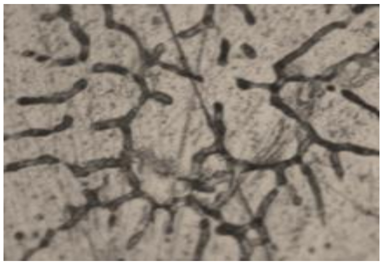
Fig. 10 : 9 wt.% of bottom ash

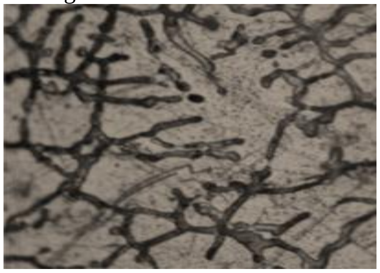
Fig. 11 : 12 wt. % of bottom ash

A uniform distribution of bottom ash particles without voids and discontinuities can be observed from these micrographs. It was also found that there was good bonding between matrix material and bottom ash particles; however no gap is observed between the particle and matrix.

B. Wear

1) Effect of wear rate at varying speed at room temperature

Load (N)	*30*			
Speed (rpm)	*300*	*400*	*500*	*600*
Al7075	*0.0144*	*0.0154*	*0.0157*	*0.0168*
3 wt.% Bottom ash	*0.0136*	*0.0142*	*0.0150*	*0.0159*
6 wt.% Bottom ash	*0.0132*	*0.0138*	*0.0141*	*0.0153*
9 wt.% Bottom ash	*0.0118*	*0.0125*	*0.0132*	*0.0140*
12 wt. % Bottom ash	*0.0126*	*0.0134*	*0.0138*	*0.0147*

Table 5.4 wear rate at varying speed

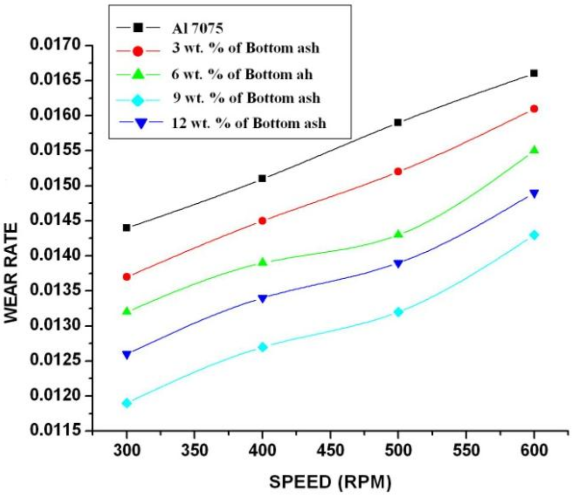

Fig. 12: Effect of wear rate at varying speed

In figure 12 clearly show that at constant load condition the addition of bottom ash particles to Al7075 alloy result in less wear rate under different speed condition 300rpm, 400rpm,500rpm and 600rpm and other parameter load 30N and sliding distance 1500m kept constant for room temp condition. The wear rate is more for Al7075 alloy & less for prepared composites. In this case also wear rate is maximum for Al7075 and minimum for 9% of bottom ash particles. At room temperature condition the wear rate is more for A17075 because of smooth surface and it forms more tribolayer as compared to prepared composite. By increasing pressure at the pin-disc interface, A17075 undergo more wear rate. In case of prepared composite the hard bottom ash particles resist the applied pressure avoids removal of material which reduces wear rate prepared composites.

2) Effect of wear rate at varying load at room temperature

Table - 5.5
wear rate at varying load

SPEED (rpm)	300			
LOAD (N)	20	30	40	50
Al7075	0.0068	0.0105	0.0164	0.0229
3 wt.% Bottom ash	0.0051	0.0086	0.0152	0.0220
6 wt.% Bottom ash	0.0043	0.0078	0.0147	0.0189
9 wt.% Bottom ash	0.0024	0.0053	0.0128	0.0148
12 wt. % Bottom ash	0.0033	0.0066	0.0133	0.0167

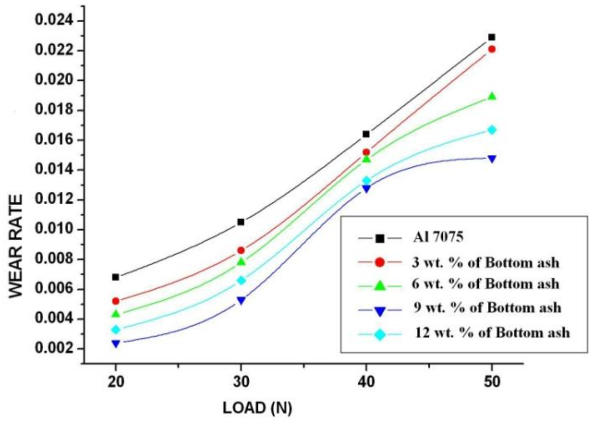

Fig. 13: Effect of wear rate at varying load

The variation of wear rate of Al7075 alloy and the composites with loads of 20,30,40and 50N where as other parameter are speed 300 rpm and sliding distance 1.6m/s kept constant was shown in figure 13. It clearly show that at all load condition the addition of bottom ash particles to Al7075 alloy result in less wear rate under different load condition& at a sliding speed 300rpm for room temp condition. The wear rate is more for AL7075 alloy & less for prepared composites. In this case also wear rate is maximum for Al7075 and minimum for 9% of bottom ash particles. At room temperature condition the wear rate is more for A17075 because of smooth surface and it forms more tribolayer as compared to prepared composite. By increasing pressure at the pin-disc interface, A17075 undergo more wear rate. In case of prepared composite the hard bottom ash particles resist the applied pressure avoids removal of material which reduces wear rate prepared composites.

The wear rate increases with increased applied loads, because the oxidation of aluminium plays a significant role in formation of the wear debris and hence the tribolayer. At higher applied loads, high wear rates are observed.

IV. Conclusions

Here we successfully fabricated the Al 7075bottom ash Composites by using Stir Casting arrangement with proper distribution of bottom ash particles all over the specimen. We have drawn various conclusions from the various calculations based on the diff. experimental testes:

(1) The grain size of the Al 7075-Botton ash composite is larger than pure Al7075
(2) Micro structural observation shows that addition of Bottom ash above 12 wt. % leads to agglomeration.
(3) Microstructures of the chilled composites are finer than that of the un-chilled matrix alloy with uniform distribution particles
(4) Metal matrix composite of Al 7075 reinforced with Bottom ash particulates is found to have improved wear resistance property when compared to the Al 7075 alone.

From the above results we find the optimum wear resistance value at 9 wt. % of bottom ash having an good wear resistance compared Al 7075 alloys without reinforcement. So that these composites could be used in those sectors where light weight and good wear resistance properties are required as like in automobile and space industries.

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