Effect of Water Chill in Metallic Mould During Solidification of Al Alloy (7075) Reinforced With Bottom Ash

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

Composites are most successful materials used for recent works in the industry. Metal composites possess significantly improved properties including high tensile strength, toughness, hardness, low density and good wear resistance compared to alloys or any other metal. There has been an increasing interest in composites containing low density and low cost reinforcements. In this work an attempt is made to the casting of Al-bottom ash composite using mild steel mould with water as chill. In our research work pure Al 7075 took as the matrix material and bottom ash as the reinforcing material. The composite is produced by stir casting technique. It is observed that chill effect has significant improvement in tensile properties and hardness are noticeable as the wt. % of the bottom ash increases in comparison with unreinforced matrix. Solidification time is one of the important parameter used for obtaining the different properties of materials. The using of metallic mould (mild steel) which causes reduces the shrinkage, porosity and faster cooling rate and produces higher strength casting than sand mould. 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.

Keywords: Al 7075, Bottom Ash, Stir Casting, water chill, metal mould.

I. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these short comings and to meet the ever increasing demand of modern technology, composites are most promising materials of recent interest. Metal composites possess significantly improved properties including high specific strength, specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. 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.

Now a days 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.

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.% of bottom-ash as reinforcing phase.

Mechanical properties of the composite were evaluated and compared with the commercially pure aluminium 7075. Mechanical properties of composites are affected by the volume fraction of the reinforcement, composite material. These aspects have been discussed by many researchers. P.K. Rohatgi[1] reports that with the increase in volume percentages of fly ash, hardness value increases in Al–fly ash composites. He also reports that the tensile elastic modulus of the ash alloy increases with increase in volume percent (3–10) of fly ash. .Babu Rao[2] studies that Metal matrix composites (MMCs) possess significantly improved properties compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements.. In the present investigation, pure aluminium – 5 to 15% (by weight) fly ash composites were made by stir casting route. P.Shanmughasundaram[3] studied the Development of light weight materials has provided the automotive industry with numerous possibilities for vehicle weight reduction.R. Escalera-Lozano[4]. Most of energy needs in the century is relied on the fossil fuels. Combustion of coal energy produces waste by product, fly ash in abundance. The disposal of this fly ash is a major challenging task.Mahanthesh.G.[5] Discussed effect of Bottom Ash particle size on tensile properties of Aluminium-Bottom Ash Composite" reported that with the as increase in weight percentages of bottom ash, increases the tensile strength value of Al–bottom ash composites.

A. *Aluminium 7075 alloy (matrix)*

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

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 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 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 and engineering 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 of Al7075 & Bottom ash composite.
- To study the effect of Al7075 -Bottom ash composite on tensile properties, hardness

II. EXPERIMENTAL WORK

A. *Heat Treatment of bottom Ash*

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

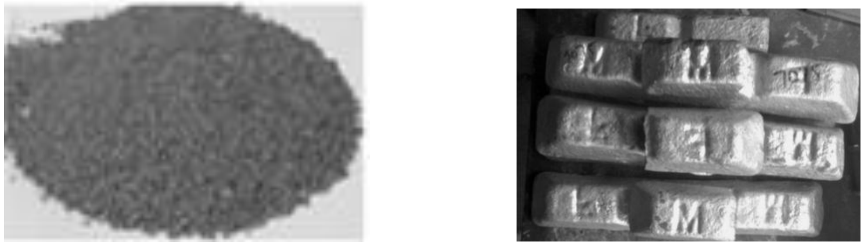

Fig 1: Bottom Ash and Al 7075 ingot

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 means it 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 MMC. 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 figure 2. 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

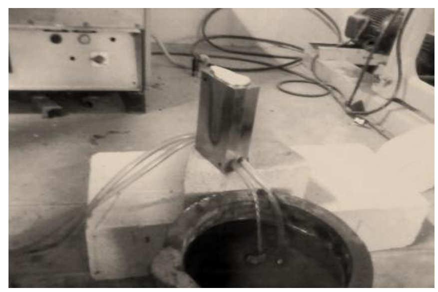

Fig 3:After casting with water chilling

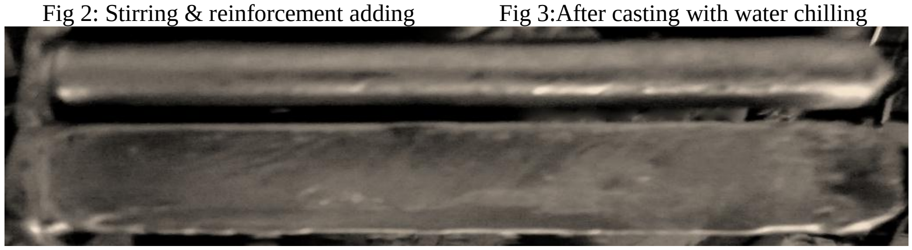

Fig 4: Cast Rod and and Slab of Aluminium Matrix Composite

C. Characterization of Al 7075- Bottom Ash Composites

1) Microstructure

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. Then the samples were tested to Brinell hardens.

2) Hardness test

Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we considered only Brinell hardness test. Test specimens were prepared according to ASTM E10 standards. The Brinell test determines the hardness by measuring the depth of penetration of an indenter under a 60kg load. The test was carried out at six different locations and the average value was taken as the hardness of the as cast composite specimens.

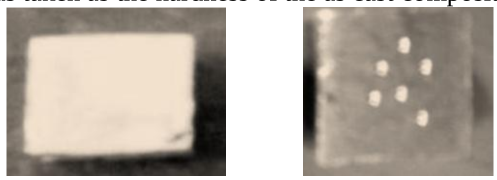

Fig 5: Before and after testing

3) Tensile Test

Test specimens were prepared according to ASTM E8 standards, each specimen having 12.5mm in diameter and 75mm gauge length, as shown in fig-6. The specimen was loaded in Universal Testing Machine until the failure of the specimen occurs. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength and ductility were measured.

For conducting a standard tensile test, a specimen that has been measured for its cross-sectional area and gauge length before and after testing placed in the testing machine. Simultaneous readings of load and elongation are taken at uniform intervals of load. Uniaxial tensile test is conducted on the fabricated specimen to obtain information regarding the behavior of a given material under gradually increasing stress strain conditions. figure-6 shows tensile test specimen before and after testing.

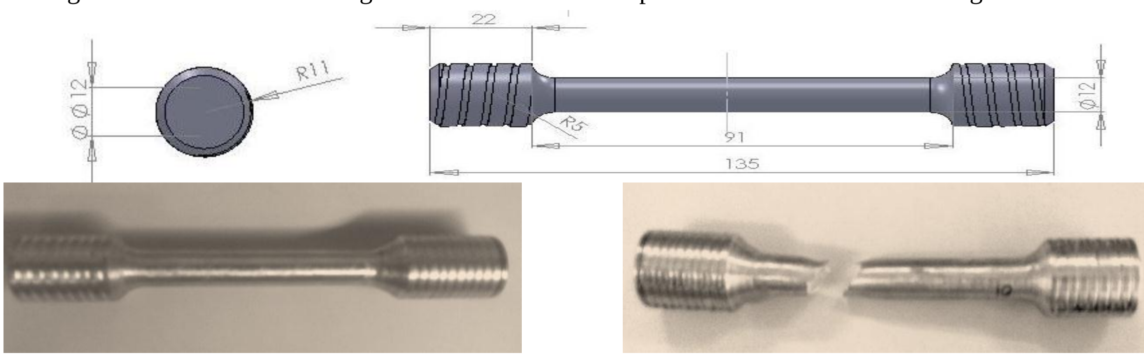

Fig 6 Tensile Test Specimen before and after testing

III. RESULTS & DISCUSSIONS

A. Mechanical Properties

The tensile tests were conducted on these samples according to ASTM E8 standard at room temperature, using a universal testing machine. The Brinnell hardness tests were conducted in as per to ASTM E10 standard using Brinell hardness testing machine.

B. Microstructure

As 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, prepared samples were examined using optical microscopy to study the distribution pattern of bottom ash in the matrix. The micrographs shown in figure (7) depict the microstructure of as cast Al7075 and bottom ash reinforced in Al7075 shown in figure-(8) (9) (10) (11)composites containing 3 wt.% to 12wt.% 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 at 12% bottom ash. And 3% to 9% was seen to be almost uniform no gap is observed between the reinforcement and the matrix.

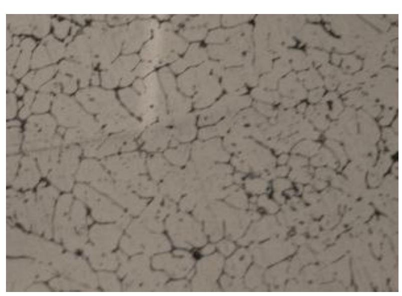

Fig. 7: Microstructure of pure Al 7075

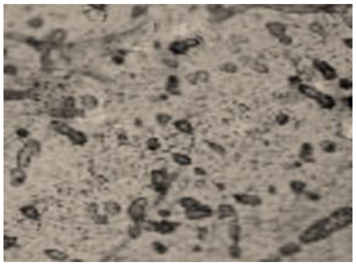
Fig. 8: 3 wt.% of bottom ash

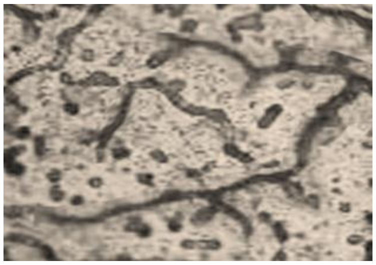
Fig. 9: 6 wt.% of bottom ash

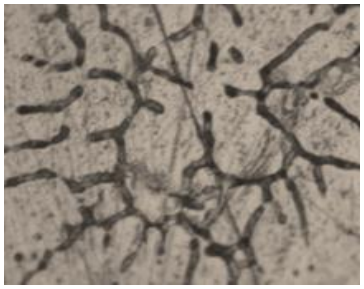
Fig. 10: 9 wt. % of bottom ash

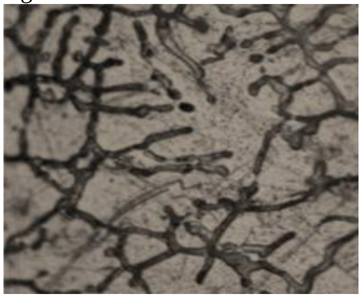
Fig. 11: 12 wt. % of bottom ash

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.

C. Tensile Properties

The tensile strength was carried out as per ASTM E8 standard. The tensile properties, such as, tensile strength and % elongation were extracted from the stress strain curves and are represented in Table-3.

SI NO.	*% of composition*	*Tensile strength (MPa)*	*% of elongation*
01	*Pure Al7075*	*228MPa*	*10*
02	*Al+3 wt.% of bottom ash*	*232MPa*	*7.83*
03	*Al+6 wt. % of bottom ash*	*256MPa*	*7.32*
04	*Al+9 wt.% of bottom ash*	*263MPa*	*6.61*
05	*Al+12wt.% of bottom ash*	*251MPa*	*6.56*

Table3: Tensile strength and % of elongation

Fig. 12 shows the variation of tensile strength of the composites with the different weight fractions of bottom ash particles. It can be noted that the tensile strength increased with an increase in the weight percentage of bottom ash. From the graph it is also evident that the yielding point of the composite samples also increased substantially with increase in reinforcements. Therefore the bottom ash particles act as barriers to the dislocations when taking up the load applied. The hard bottom ash particles obstruct the advancing dislocation front, thereby strengthening the matrix.

Tensile strength increases with increasing weight percentages of reinforcements up to 9 wt. % of bottom ash. Tensile strength of as cast specimen is without reinforcement is 228MPa. and by adding different weight percentages the tensile strength is increased to 263MPa at 9 wt. % of Bottom ash.

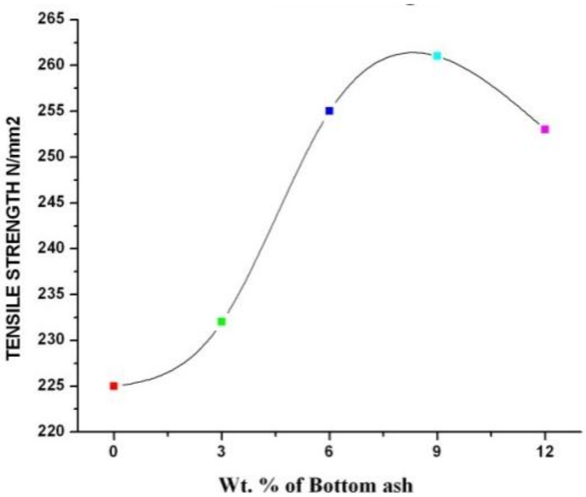

Fig. 12: Variation of tensile strength with the weight fraction of bottom ash

D. Ductility

Fig. 13 shows that the ductility of the composite decreased with the increase in weight fraction of the bottom ash. This is due to the hardness of the bottom ash particles or clustering of the particles. The various factors including particle size, weight percent of reinforcement affect the percent of the elongation composites.

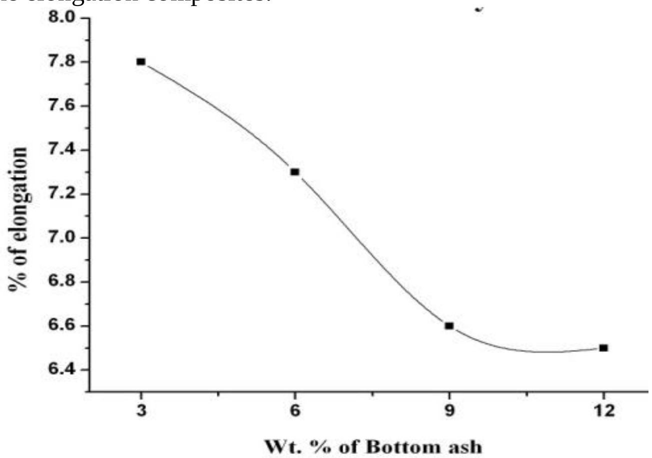

Fig. 13: Effect of the weight fraction of bottom ash on Hardness

E. Hardness

Table - 4
Brinell hardness

SI NO.	% of composition	BHN
01	Pure Al7075	87
02	Al+3 wt.% of bottom ash	98
03	Al+6 wt.% of bottom ash	109
04	Al+9 wt.% of bottom ash	119
05	Al+12 wt.% of bottom ash	102

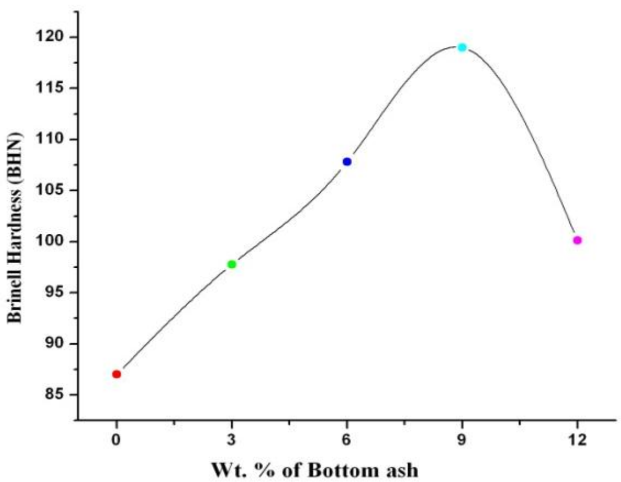

Fig. 14: BHN v/s % of Bottom ash

From Fig.14 it can be noted that the hardness of the composite increased with the increase in weight fraction of the bottom ash particles. Thus the hard bottom ash particles help in increasing the hardness of the aluminum alloy matrix. Brinell hardness of the cast composite 87 BHN without reinforcement and the hardness increases with increase in Bottom ash content reaches a maximum value 119 BHN at 9 wt. % of Bottom ash and then decreases at 12 wt. % of Bottom ash addition due to non uniform distribution of Bottom ash in the matrix.

F. Brinell hardness from chill end

Table - 5
Brinell hardness from chill end

SI NO.	Distance from chill end	BHN
01	10	119
02	20	118
03	30	116

04	*40*	*115.5*
05	*50*	*113.5*

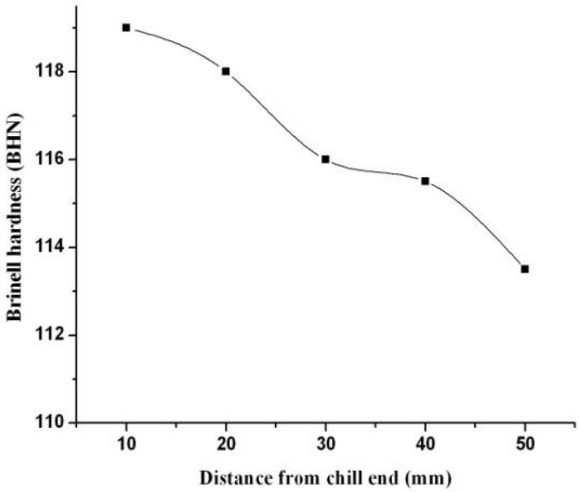

Fig 15:BHN v/s Distance from chill end

Figure 15 shows the brinell hardness of the specimen using water as an end chill in mettalic mould observed that Brinell hardness number decreses with increasing in in distance from chill end, reaches peak value 119 BHN at distance 10mm from chill end and then decreases. The graph also indicate that the hardness value is affected by water chill and metallic mould. The rate of heat extraction is more due to water chill and metallic mould than the sand mould and it couses fine grained structure that results in increasing the hardness number.

IV. Conclusions

Here Al 7075-bottom Ash Composites were successfully fabricated by using Stir Casting arrangement with proper distribution of bottom ash particles all over the specimen. Metal matrix composite of Al 7075 reinforced with Bottom ash particulates is found to have improved tensile strength & hardness when compared to the Al 7075 alone. So that these composites could be used in those sectors where light weight and good mechanical properties are required as like in automobile and space industries.

Various conclusions were drawn based the different experimental tests.

(1) Micro structural observation shows that addition of Bottom ash above 12 wt. % leads to agglomeration.
(2) The grain size of the Al 7075-Botton ash composite is larger than pure Al7075
(3) Brinell hardness of the cast composite increases with increase in Bottom ash content reaches a maximum value 119 BHN at 9 wt. % of Bottom ash and then decreases.
(4) Tensile strength of the composite also increases with the increase in Bottom ash content, reaches a maximum value 263MPa. at 9 wt. % of Bottom ash and then decreases.
(5) Brinell hardness number decreses with increasing in in distance from chill end
(6) Both Brinell hardness and tensile strength decreases at 12 wt. % of Bottom ash addition due to non uniform distribution of Bottom ash in the matrix.
(7) The ductility of the composite decreased with increase in the weight percentage of bottom ash
(8) Metal matrix composite of Al 7075 reinforced with Bottom ash particulates is found to have improved tensile strength, hardness when compared to the Al 7075 alone.

From the above results we find the optimum value having good hardness, tensile strength and also low ductility as compare to alloy without reinforcement.

References

[1] SHANMUGHASUNDARAM, P. (2011):- "Some studies on Aluminium- Fly Ash composites fabricated by two step stir casting method",european journal of scientific research, vol. 63, issue no.2, pp. 204-218, 2011.
[2] ROHATGI, P.K (2006):- "Applications of fly ash in synthesizing low cost Metal Matrix Composites for automotive and otherengineering applications", JOM, vol. 58, issue no.11, pp.71-76,2006.
[3] RAO, J.BABU (2010):- "Development of light weight ALFA composites", interntional journal of engineering, science and technology.Vol.2,issue no.11, pp. 50-59, 2010.
[4] R. Escalera-Lozano, C.A. Gutiérrez, M.A. Pech-Canul, M.I. Pech-Canul. 2006. Corrosion characteristics of hybrid Al/SiCp/$MgAl_2O_4$ composites fabricated with fly ash and recycled aluminum.
[5] Mahanthesh G. "Effect Of Bottom Ash Particle Size On Tensile Properties Of Aluminium-Bottom Ash Composite"
[6] Mahanthesh G "Preparation and Property Evaluation of Aluminium alloy (6061) Reinforced with Bottom Ash Particulate composite" (ALBAP Composite)
[7] K.V.Mahendra, "fabrication of al–4.5% cu alloy with fly ash metal matrix composites and its characterization", material science, 2007, vol.25