

Behaviour of Al-7075 Reinforced with Fly Ash by using Chill Casting

Dipak Nandkumar Bhosale¹, Dr. G. B. Rudrakshi², Dr. S. M. Jigajinni³

P.G. Student, Department of Mechanical Engineering, Basaveshwar Engineering College, Bagalkot, Karnataka, India¹

Professor, Department of Mechanical Engineering, Basaveshwar Engineering College, Bagalkot, Karnataka, India²

Associate Professor, Department of Mechanical Engineering, Basaveshwar Engineering College, Bagalkot,
Karnataka, India³

ABSTRACT: Various researches are going on aluminium metal matrix composites (AMMC) because of its various advanced applications in various fields like aerospace, automotive, structural, marine, transport applications, etc. Waste fly ash is used as the reinforcement in the formation of an aluminium alloy Al-7075 based metal matrix composites. In this work aluminium metal matrix composite (AMMC) is produced by stir casting technique as well as chill casting technique. Here chill casting technique means by circulating liquid nitrogen around the slots of specimens to be produced in mould causes chilling effect to the mould because of low temperature liquid nitrogen (LN₂). The need of technology is composite material should be produced by good quality and reinforcement should be of low cost from industrial wastes. The main advantage by using fly ash is density of AMMC gets reduced. Addition of fly ash is done by using weight percentage of Al-7075. In first case Al-7075 reinforced with 0% of fly ash, it means only Al-7075 will be produced. In second case Al-7075 reinforced with 2% of fly ash and in third case Al-7075 reinforced with 3% of fly ash. In this work various mechanical properties like hardness, tensile strength, impact strength and microstructure of AMMC have been studied.

KEYWORDS: Al metal matrix composites, fly ash, chill casting, stir casting, mechanical properties.

I. INTRODUCTION

Aluminium is prepared commercially firstly in France in 1855. In the boron group aluminium is the chemical element. The symbol of aluminium is Al and 13 is the atomic number. Aluminium is produced from bauxite. Aluminium is ductile, silvery white, soft and nonmagnetic metal. Aluminium is identified with metals as low density and high corrosion resistance. Aluminium has low melting point which is about 660.32°C (933.47K or 1220.58°F) and density is 2.70gm/cc. Therefore aluminium and its alloys are used in various advanced applications like transport, marine, aerospace, structural, military, etc. Principal aluminium alloys: Al-Cu, Al-Cu-Mg, Al-Mg-Si, Al-Zn-Mg, Al-Zn-Mg-Cu be the age hardening alloys, Al-Si, Al-Si-Cu be the casting alloys, and Al-Mg, Al-Mn be the work hardening alloys.

Aluminium alloys are classified into two types: 1) Wrought aluminium alloys: - a) heat treatable, b) non heat treatable 2) Cast aluminium alloys: - a) heat treatable, b) non heat treatable. Designation system of aluminium alloys: First digit indicates major alloys. Last two digits indicate which one in family. A second digit usually zeros, but indicates modification of base alloy. In this current work, aluminium alloy selected is Al-7075 as a matrix material and reinforcement selected is fly ash which is the industrial waste product. Generally the composite is formed by stir casting method, which is most significant method. In current work, metal matrix composite is formed by stir casting method as well as chill casting method. Here chill casting method means, the liquid nitrogen (LN₂) will be circulated in mould around the specimen slots. Therefore mould gets chilling effect because liquid nitrogen (LN₂) has very low temperature about -3210F; therefore this method is called as chill casting method.

1.1 Composites: Composite material means material will be formed from two or more distinct materials. Composite material shows applicable properties than original base material. Composite materials are classified into three types: -1)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

Metal matrix composites (Metal + Reinforcement) 2) Ceramic matrix composites (Ceramic + Reinforcement) 3) Polymer matrix composites (Polymer + Reinforcement). If surface energy of matrix material is less than reinforcement material, then only composite material will formed. In metal matrix composites (MMCs) metals have low surface energy therefore reinforcement materials are used with low surface energy i.e. small fibres.

1.1.1 Metal matrix composites (MMCs): Generally metal matrix composites (MMCs) consist of lightweight metal alloys of aluminium, titanium, or magnesium and reinforcement will be ceramic particulate, whiskers, or fibres. Reinforcement estimates cost, mechanical properties, and performance of given composite, therefore it is very important. Metal matrix composites have many advantages compared to monolithic metals as: high strength to density ratio and stiffness to density ratio, good wear resistance and fatigue resistance, good properties at elevated temperatures. Also metal matrix composites have advantages compared to polymer matrix composites: temperature capability will be high, good fire resistance and good radiation resistance, it will have high thermal and electrical conductivities.

1.2 Material selection

1.2.1 Matrix material: In this current work the matrix material selected for the formation of metal matrix composites is Al-7075. This is an aluminium alloy. In this alloy zinc is the first alloying element. Al-7075 is strong in strength as compared to many other steels. This alloy has fatigue strength is good but machinability is average. Also as compared to other aluminium alloys Al-7075 has low corrosion resistance. This alloy has one limitation; its cost is high as compare to other aluminium alloys. Therefore mostly it is used in applications when cheaper alloys are not suiting that application. This aluminium alloy 7075 is formed in tempers as 7075-0, 7075-T6, 7075-T7, 7075-T651, and 7075-RRA. Density of Al-7075 is 2.810gm/cc. For this work this Al-7075 is collected from Bangalore.

1.2.2 Reinforcement material: In United Kingdom (U.K.), the fly ash is also called as “pulverized fuel ash”. Fly ash is the combustion product of coal. Fly ash is the waste product from industries. For this purpose in this work fly ash is used. Because reinforcement estimates the cost of the composites and fly ash gets easily from industrial wastes. Therefore cost of the composites gets reduced. In this work, fly ash is collected from “Bagalkot cement industry, Bagalkot”. Fly ash has fine particles which are composed and that are coming out from the boiler with various flue gases. Bottom of the boiler, amount of ash falls, called as bottom ash. Now days there are various modern power plants which are coal fired. In these power plants, fly ash is collected with the help of electrostatic precipitators. Rather than electrostatic precipitators now there are various filtering equipments which collect the fly ash before it will going to chimneys. From the bottom of the boiler bottom ash is collected and it is known as coal ash. Fly ash mainly consist the mineral compounds that are aluminium oxide (Al₂O₃), silicon dioxide (SiO₂), and calcium oxide (CaO). In previous days, from the chimneys fly ash goes into atmosphere. Therefore to prevent pollution from fly ash, firstly it may be filtered before it may reach to chimney and finally gets out from the chimney. Now day’s fly ash is used in the production of Portland cement, hydraulic plasters, concrete, and also in making bricks.

II. LITERATURE REVIEW

Mohammed Imran and A.R. Anwar Khan (2016) have created the hybrid composite with Al-7075 as matrix material and bagasse ash, graphite as reinforcement materials. They have added reinforcement in three cases. In first case, 2% bagasse ash and varying percentage of graphite as 1%, 3% and 5%. In second case, 4% bagasse ash and same graphite percentage as in first case is used. In third case, 6% bagasse ash and same graphite percentage as in first and second case is used. They have achieved various mechanical properties by using this hybrid MMC. S. G. Kulkarni and J. V. Meghnani (2014) produced hybrid composite with aluminium 356 alloy as a matrix material and fly ash with alumina as a reinforcement material. In this work they have been observed that, fly ash is successfully mixed with aluminium 356. Also they have been studied various mechanical properties like tensile, compression strength, hardness etc. Also they have been observed that density of aluminium 356 gets reduced. Viney Kumar and Rahul gupta (2014) investigated two MMCs. In first MMC, Al-6061 and Mg 4% are used as a matrix material and fly ash with 10%, 15%, 20% used as a reinforcement material. In second case, Al-6061, Mg 4% and graphite 4% as the matrix material and 10%, 15%, 20% fly ash as the reinforcement material. In his study, they observed that, with addition of fly ash tensile strength of MMC increases. Mohan Kumar and Pramod R (2014) studied the mechanical properties, fracture toughness of Al 7075-T6 coated with electro less nickel (EN). They chooses this topic because of huge application of electro less nickel plating in automobile, aerospace, electronics and in other industries. During this study they observed that,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

fracture behavior is improved and it possess very good adhesive properties. Zhihao Zhao and Jie Dong (2006) studied the effect of magnetic field with low frequency on microstructures by using chill cast Al-7075. In his study they studied that, the electromagnetic field with low frequency improves the quality of surface, reduces microstructure which is inhomogeneous and reduces macro segregation.

III. EXPERIMENTAL WORK

3.1 Stir casting: Stir casting is the process of casting which is commonly used for casting of “Aluminium Metal Matrix Composites (AMMCs)”. In this current work also stir casting method is used. The resistance furnace is used to create molten metal of Al-7075. Crucible used for this casting is made up of graphite. Aluminium foil is used to add the reinforcement material into molten metal of matrix material. Hexachloro ethane (C_2Cl_6) degasifier is used to driven out residual gases from the molten metal. Firstly measurement of weight of Al-7075 pieces is carried out and then fly ash is taken as weight percentage of Al-7075. The fly is taken as varying percentage of 0%, 2%, 3%. In first case 474gm Al-7075 and 0% i.e. no fly ash is used. In second case 485gm Al-7075 and 2% i.e. 9.7gm is taken. In third case 490gm Al-7075 and 3% i.e. 14.7gm fly ash is taken. Firstly piece of Al-7075 is placed in graphite crucible and crucible is placed in resistance furnace and furnace gets started. Temperature is set at $740^{\circ}C$ and wait for 2-3 hours up to Al-7075 gets melted. Then fly ash is added into molten metal of Al-7075 with the help of aluminium foil. After that stirring process is done. For the removal of residual gases present in the molten metal, degasifier (C_2Cl_6) will be added in molten metal and stir for some more time. Then wait for some more time for mixing of Al-7075 and fly ash. Then molten metal will be poured into mould. After some time solidification is completed and then components are taken out from the mould.

3.2 Chill casting: It is the process of casting in which liquid nitrogen is used for chilling effect to promote solidification. In this process MMC of Al-7075 and fly ash is produced. In this process Al-7075 is used as a matrix material and fly ash as a reinforcement material with varying percentage of 0%, 2%, 3%. In first case, 465gm Al-7075 will be used with 0% fly ash means only Al-7075 is used. In second case, 460gm Al-7075 and 9.2gm of fly ash is used. In third case, 495gm of Al-7075 and 14.85gm of fly ash is used. In this method firstly graphite crucible is kept in furnace and Al-7075 is kept in the crucible. Then start the furnace and set the temperature at $740^{\circ}C$ and wait for 2-3 hours until Al-7075 gets melted. At the same time die coat is sprayed on mould to avoid sticking of molten metal to the mould. In this work SAE 90 grade gear oil is used. Then mould should get preheated. After that fly ash is packed in aluminium foil and will be added in the molten metal and stir the mixture. Then C_2Cl_6 degasifier will be added in the molten metal to remove the residual gases from the molten metal. At the same time mould setup will be prepared by joining the steel flask to the mould with the help of steel pipe. After some time molten metal gets prepared and will be poured into mould. At the same time liquid nitrogen is also poured into steel flask and will get circulated into mould. Then wait for some time until the complete solidification and finally we get the solidified components with chilling effect from liquid nitrogen.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

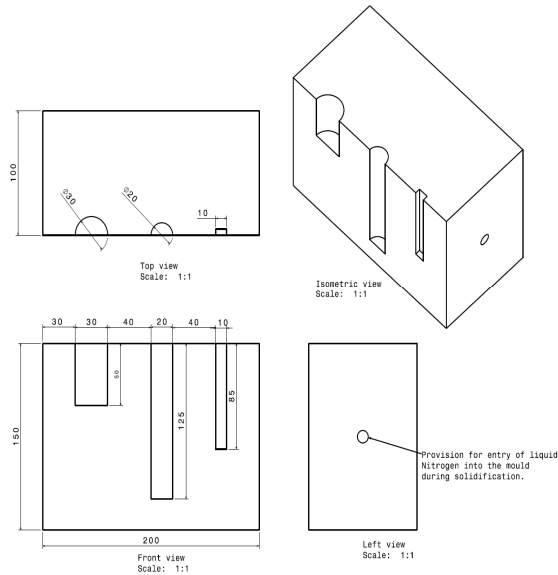


Figure 3.1 Design of mould



Figure 3.2 Pouring of molten metal and liquid nitrogen

IV. RESULT AND DISCUSSION

Table 4.1 Mechanical properties without chilling effect

Material	Hardness	Impact strength	Ultimate strength(N/mm ²)
Al-7075 + 0% fly ash	89.33	0.02	162.36
Al-7075 + 2% fly ash	94.67	0.03	254.69
Al-7075 + 3% fly ash	96	0.07	269.19

Table 4.2 Mechanical properties with chilling effect

Material	Hardness	Impact strength	Ultimate strength(N/mm ²)
Al-7075 + 0% fly ash	80	0.01	146.44
Al-7075 + 2% fly ash	84.33	0.02	215.30
Al-7075 + 3% fly ash	91	0.04	248.67

4.1 Hardness test:

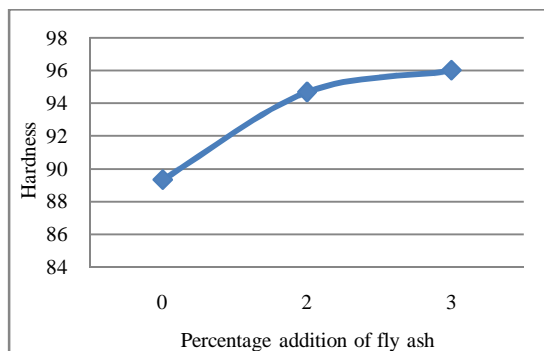


Fig.4.1 Variation of hardness without chilling effect

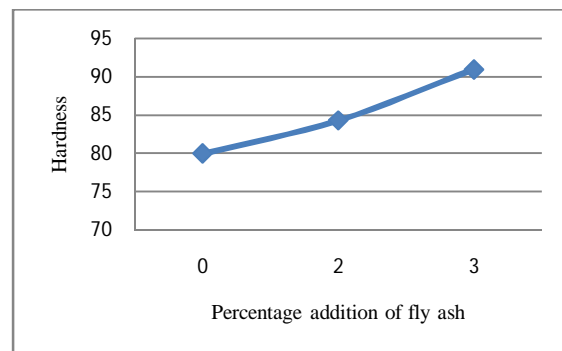


Fig.4.2 Variation of hardness with chilling effect

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

The hardness of MMC made without chilling effect increases with varying reinforcement of fly ash as 0%, 2%, and 3%. The hardness of MMC made with chilling effect increases with varying reinforcement of fly ash as 0%, 2%, and 3%. But if we compare the hardness of MMCs without chilling effect and with chilling effect, then it is observed that the hardness of MMC with chilling effect is lower than the hardness of MMC without chilling effect.

4.2 Impact test:

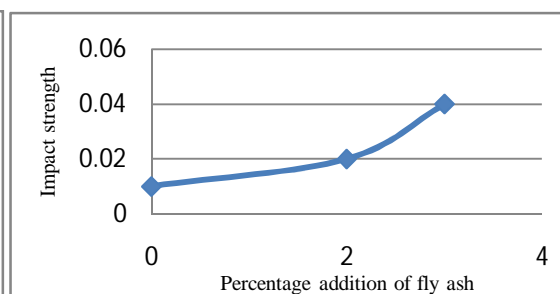
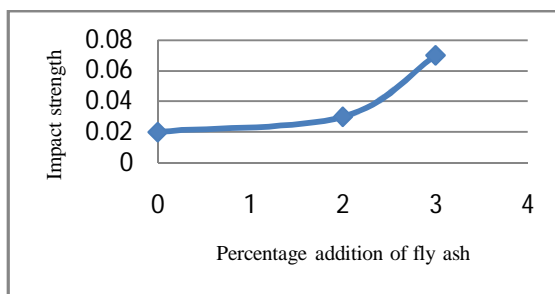


Fig.4.3 Variation of impact strength without chilling Fig.4.4 Variation of impact strength with chilling

Impact strength of MMC prepared without chilling effect increases with addition of fly ash as 0%, 2%, 3%. The impact strength of MMC prepared with chilling effect increases with addition of fly ash as 0%, 2%, and 3%, but it is lower than the MMC without chilling effect.

4.3 Microstructure test:

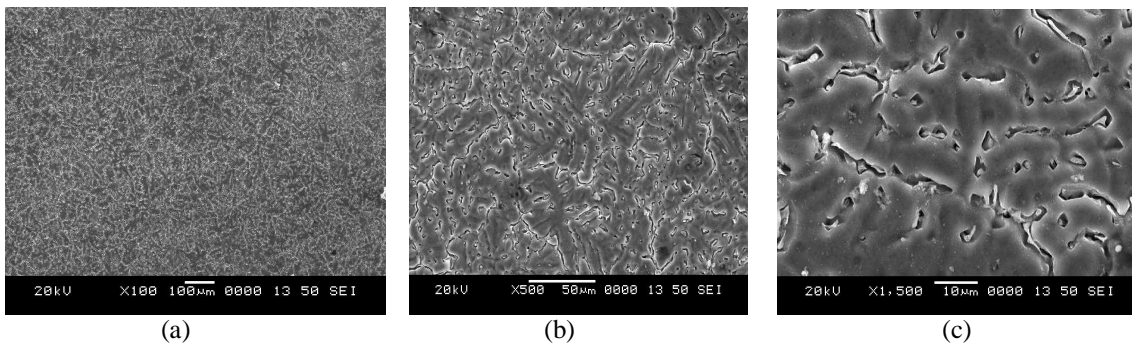


Figure 4.5 Microstructures of Al-7075 + 0% fly ash without chill casting

Above figures are the SEM analysis of Al-7075 + 0% fly ash without chilling effect in which figure (a) is analysed with $\times 100$ magnification, figure (b) with $\times 500$ magnification and figure (c) with $\times 1500$ magnification. These figures indicate the columnar grain structure because in this composition there is no any addition of reinforcement.

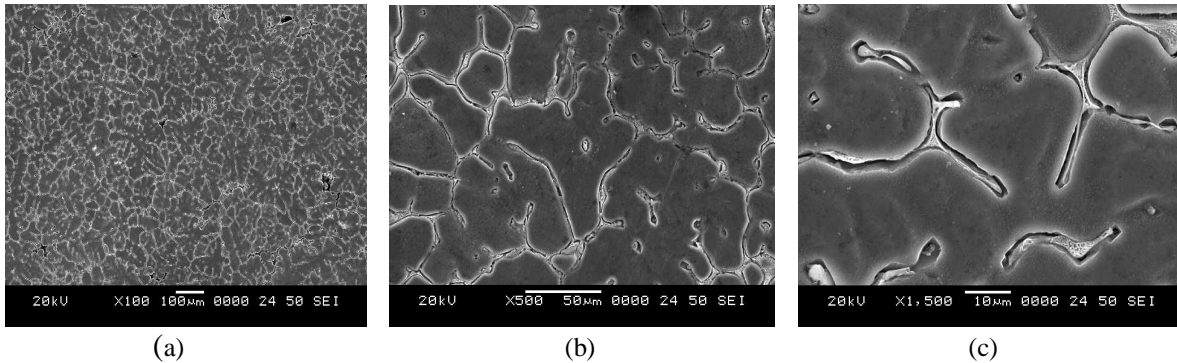


Figure 4.6 Microstructures of Al-7075 + 0% fly ash with chill casting

Above figures indicate the SEM analysis of Al-7075 + 0% fly ash with chilling effect. Figure (a) is captured with $\times 100$ magnification, figure (b) with $\times 500$ magnification and figure (c) with $\times 1500$ magnification. If we compare the microstructures of Al-7075 + 0% fly ash with chilling effect and without chilling effect, then it is observed that the grain size is increased in Al-7075 + 0% fly ash with chilling effect.

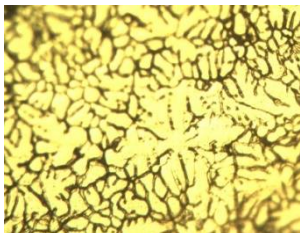


Figure 4.7 Microstructure of Al-7075 + 2%
Fly ash without chill casting

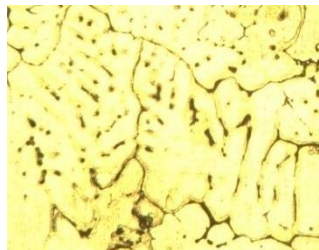


Figure 4.8 Microstructure of Al-7075 + 2%
Fly ash with chill casting

The above figures (4.7 and 4.8) are the microstructures of Al-7075 + 2% fly ash without chilling effect and with chilling effect. These microstructures are analysed with the help of optical microscope. These microstructures indicate that the grain size is more in Al-7075 + 0% fly ash with chilling effect.

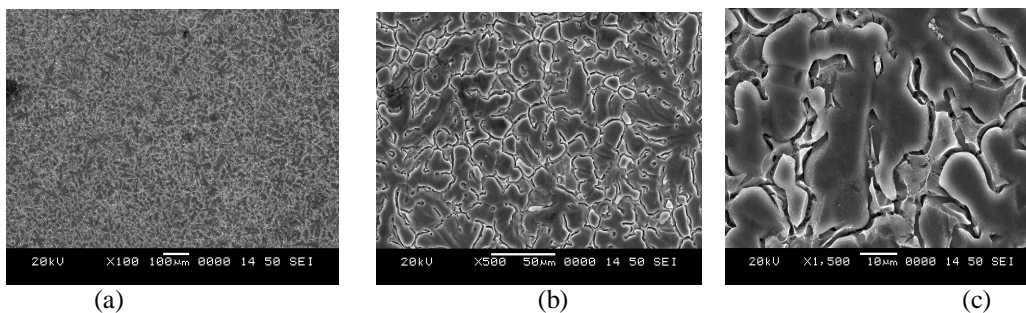


Figure 4.9 Microstructures of Al-7075 + 3% fly ash without chill casting

The above figures (a), (b), and (c) are the microstructures of Al-7075 + 3% fly ash without chill casting. These figures are captured with $\times 100$, $\times 500$ and $\times 1500$ magnification respectively. This composition has fine grain structure as compare to 0% and 2% fly composition.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

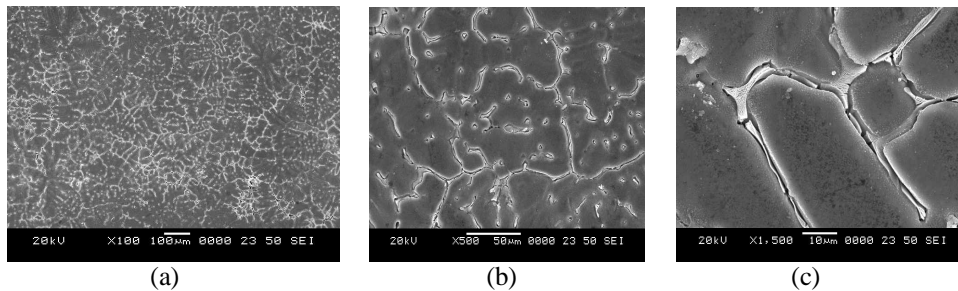


Figure 4.10 Microstructures of Al-7075 + 3% fly ash with chill casting

The above microstructures are the SEM analysis of Al-7075 + 3% fly ash with chilling effect. The figures (a), (b) and (c) are taken with $\times 100$ magnification, $\times 500$ magnification and $\times 1500$ magnification. If we compare the microstructures of Al-7075 + 3% fly ash without chilling effect and microstructures of Al-7075 + 3% fly ash with chilling effect, then it shows that the grain size is increased in Al-7075 + 3% fly ash with chilling effect. Therefore because of increase in grain size the mechanical properties are changed.

V. CONCLUSIONS

Al-7075 and fly ash MMC specimens are prepared by stir casting method and chill casting method. It means MMCs specimens are produced without chilling effect and with chilling effect. Hardness of MMC without chilling effect increases with varying percentage of fly ash as 0%, 2%, 3%. Also hardness of MMC with chilling effect increases with addition of fly ash as 0%, 2%, and 3% but it is lower than the hardness of MMC without chilling effect. Impact strength is increased in MMCs made without chilling effect and with chilling effect but it is lower in MMC with chilling effect. Tensile strength is also increased with addition of 0%, 2%, 3% fly ash in both MMCs with chilling effect and without chilling effect, but tensile strength is more in MMC without chilling effect than the MMC with chilling effect. Grain size of MMC with chilling effect gets increased compare to MMC without chilling effect. Here Hall-Petch relationship is satisfied i.e. hardness decreases with increasing grain size and strength, toughness also decreased with increasing grain size.

REFERENCES

- [1] S.G. Kulkarni, J.V. Meghnani, Achchhe Lal, Effect of fly ash hybrid reinforcement on mechanical property and density of aluminium 356 alloy, *Procedia materials science* 5 (2014) 746-754
- [2] Mohammed Imran, A.R. Anwar Khan, Sadananda Megeri, Shoaib Sadik, Study of hardness and tensile strength of aluminium-7075 percentage varying with graphite and bagasse-ash composite, *Resource-efficient technologies* 2 (2016) 81-88.
- [3] Viney kumar, Rahul Dev Gupta, N K Batra, Comparison of mechanical properties and effect of sliding velocity on wear properties of Al-6061, Mg 4%, fly ash and Al-6061, Mg 4%, graphite 4%, fly ash hybrid metal matrix composite, *Procedia materials science* 6 (2014) 1365-1375.
- [4] Dyi-Cheng Chen, Ci-Syong You, Fu-Yuan Gao, Analysis and experiment of 7075 aluminium alloy tensile test, *Procedia engineering* 81 (2014) 1252-1258.
- [5] Zhihao Zhao, Jianzhong Cui, Jie Dong, Beijiing Zhang, Effect of low frequency magnetic field on microstructures and macrosegregation of horizontal direct chill casting 7075 aluminum alloy, *Journal of materials processing technology* 182 (2007) 185-190.
- [6] B. Venkataraman, G. Sundararajan, Correlation between the characteristics of the mechanically mixed layer and wear behavior of aluminium, Al-7075 alloy and Al-MMCs, *Wear* 245 (2000) 22-38.
- [7] Mohan Kumar S. Pramod R, Shashi Kumar M E, Govindaraju H K, Evaluation of fracture toughness and mechanical properties of aluminium alloy 7075, T6 with Nickel coating, *Procedia engineering* 97 (2014) 178-185.
- [8] Prakash Rao C.R., Bhagyashekhar M S, Narendravswanath, Effect of machining parameters on the surface roughness while turning particulate composites, *Procedia engineering* 97 (2014) 421-431.
- [9] Murat Aziz Ozdemir, Improvement in bearing capacity of a soft soil by addition of fly ash, *Procedia engineering* 143 (2016) 498-505.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

- [10] X. Y. Li, K. N. Tandon, Micro structural characterization of mechanically mixed layer and wear debris in sliding wear of an Al alloy and an Al based composite, *Wear* 245 (2000) 148-161.
- [11] Himanshu Kala, K.K.S mer, Sandeep kumar, A review on mechanical and tribological behaviors of stir cast aluminium matrix composites, *Procedia material science* 6 (2014) 1951-1960.
- [12] Farid M. Mohammed, Raed N Razooqi, Safana M. Essmaeil, Effect of grain size for aluminium and its alloys on attenuation coefficients of X-ray at voltage values of (20,25,30,35) KN, *Australian journal of basic and applied sciences*, 7(2) (2013) 796-803.
- [13] M.R. Rosenberger, C.E. Schvezov, E. Forlerer, Wear of different aluminium matrix composites under conditions that generate a mechanically mixed layer, *Wear* 259 (2005) 590-601.
- [14] Raja Mistry, Tapas Kumar Roy, Effect of using fly ash as alternative filler in hot mix asphalt, *Perspectives in science* (2016) 8, 307-309.