Fabrication and mechanical behaviour evaluation of A7075 basalt fly ash MMCs prepared by stir casting method

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Abstract. In this work an attempt is made to evaluate the behaviour of A7075 MMC strengthened using fly ash and basalt prepared by means of stir-casting method. Combination of strength with better resistance to corrosion, makes metal matrix composites as an attractive choice for engineering applications like connecting rod, pistons, cylinder liner and etc. The relatively economical stir casting technique is used for the production of fly ash/Basalt ash/aluminium alloy MMCs. Three Combinations of compound MMCs are processed by changing the weight fraction of the additives (3% basalt + 7% fly ash, 5% basalt + 5% fly ash, 7% basalt + 3% fly ash). The effect of strengtheners (reinforcements) upon the mechanical properties of the compounded composites such as tensile strength, Wear and hardness is analysed. The outcomes affirm that tensile strength and wear is increased proportional to weight fraction of fly ash and basalt, results also suggests that hardness is proportional to weight fraction of the basalt. Microscopic Examination confirms the even dispersion of the basalt and flyash reinforcements in the Al7075.

1. Introduction
MMCs are known to significantly improve the properties like strength & stiffness. It also results in weight savings compared to other conventional compatriots. Availability of relatively cheaper reinforcements and developments in material processing, boosts its use as MMCs for automotive vehicles, aerospace and other structural applications [1]. Amidst the plenty of available reinforcements, fly ash is the cheapest reinforcement as it enhances the tensile strength and low density [2]. Fly ash and basalt can be effectively implemented to fabricate hybrid composite using stir casting method. Improvements are observed in tensile, compressive and hardness with increase in wt. % of fly ash and basalt [3]. The aluminium alloys 7075 are commonly used in aircraft structures and automobiles due to their notable strength-to-weight ratio, machine ability, improved wear resistance and low cost. In the current scenario reinforced aluminium composites were capturing attention in light of their low cost with advantages like tensile strength properties and wear properties [4]. Cost was the major thing for the producing components of even complex shapes. Casting is wide technology for key thing to rectify this problem. For achieving high mechanical properties, it is important to achieve the even dispersion of reinforcement within the matrix [5]. Reinforced aluminium matrix fragment have higher specific strength, modulus and good wearing resistance in comparison with unreinforced alloys. Due to the compositions these alloys were susceptible to corrosion in structural integrity of aircraft structures and automobile parts [6].The investigation was to study the mechanical and physical properties of A7075/basalt fiber with various percentages of reinforcements [7]. The hybrid MMCs were build using the stir casting method. Mechanical
properties like tensile, hardness, impact strength were investigated and microstructure of hybrid MMCs is also analysed [9].

2. Material selection

2.1. Al 7075 alloy

Al 7075 alloy with zinc has excellent fatigue strength and reasonable machinability, but very less weld ability and it is prone to corrosion compared to other alloys. The aluminium 7075 matrix base metal is shown in Figure 1. The stir-casting approach was used to fabricate the aluminium 7075 metal matrix composites as it is being one of the cost effective methods in industrial field. The results showcases nearly an even distribution and good distribution of reinforced particles within aluminium metal matrix composite. Both tensile strength and hardness of composite is improvised by incorporation of additive particles into the matrix. The heat treatment of reinforcement particles enhanced its wet ability with molten Al 7075 alloy.

![Figure 1. Al7075 alloy.](image1)

2.2. Fly ash particle

Fly ash or flue-ash is added as strengtheners in molten metal for its unique property to reduce the overall weight and density. The combination of fly ash being used is given in the Figure 2 given below. The waste residue from thermal power plant is fly ash has been used as reinforcement in geo polymers. Fly-ash can be applied as filler materials, the following key properties such as Tensile Strength, Compressive Strength, Hardness, Wear rate and density were improved. Combination of fly ash [wt. %] is shown in Table 1.

![Figure 2. Fly ash.](image2)
2.3. Basalt particle
Basalt is a common volcanic rock formed by decompression melting of the earth’s mantle. It contains a fine matrix of quartz and used to create alternative building material to metal reinforcements like steel and aluminium. Basalt mesh is used for frameworks, structural reinforcement and material integrity. The Various Composition of Basalt as shown in the Table 2.

| Elements       | Wt. % |
|----------------|-------|
| Oxides(O)      | 31.2  |
| Sodium oxide(Na)| 2.60  |
| Magnesium (Mg) | 3.77  |
| Silicon (Si)   | 27.1  |
| Potassium (K)  | 0.49  |
| Calcium(Ca)    | 6.89  |

2.4. Fabrication of MMCs
Basalt and fly ash with aluminium alloy (Al7075) composites, prepared using stir casting method (Liquid metallurgy route) was used in this work. With meticulous care 3 different compositions of composites were prepared from the casting process as shown in the Table 3.

| S. No | Composites with Various ratio of reinforcements                  |
|-------|------------------------------------------------------------------|
| 1     | Sample 1- Al7075 +3% Basalt + 7% Fly ash                        |
| 2     | Sample 2- Al7075 +5% Basalt + 5% Fly ash                        |
| 3     | Sample 3- Al7075 + 7% Basalt + 3% Fly ash                       |

Another name for stir casting technique is vortex method, which is the most popular as well as relatively low cost liquid processing method to fabricate Metal Matrix Composites. This technique is straightforward, effortless as well as very attractive to fabricate large number quantity of production. This method is generally used for producing composite castings, with pure matrix metal interface. This type of processing assures the securing of intact reinforcement materials along with high strength. The stir casting operation of equipment setup is shown in Figure 3 (a-b). Aluminium alloy is processed inside the container at temperature of 750°C for 1 hour.
The reinforced particles (fly ash and basalt) are preheated initially at 500°C for one hour inside the furnace to demoisturise the particles surface for better adhesiveness. Researchers established that preheated fly ash and basalt removes the efficient surface impurities, desorption of gases and modifies surface compositions due to the accumulation of an oxide layer on the surface. The molten MMC is trembled for the 2 minutes to create a vortex after that it is added to preheated particulates. Vortex method is recommended to disperse the particles evenly among the metal matrix. Post vortex molten matrix is mixed for 3 minutes a t the speed of 200rpm in order to alleviate void formation and impurities on the surface to make it porous. Stirring rpm is the significant process parameter as stirring is necessary to help in promoting wet ability, i.e. bonding between matrix and reinforcement. As solidifying rate is faster it will increase the percentage of wet ability. The stirring temperature is a major important process parameter to fabricate the new product. It is related to the melting temperature of metal matrix composites, i.e. Aluminium. Aluminium generally melts at 600°C - 650°C. The processing temperature is determined by viscosity of melting point of Al matrix composite. The viscosity influences the particle distribution in the matrix of the composite.

2.5. Mechanical testing
Mechanical behaviour of composite material is investigated using required standard dimension specimens which were prepared for tensile test, hardness test, wear test and microstructure analysis. The tensile test was taken using UTM as per ASTM E8. The specimens were prepared for measuring Vickers hardness indenter by polishing them with suitable grades of emery and etching them finally. Wear testing was done using pin on disc tribometer for the Al 7075 MMC composite specimens. ASTM G99 standards was followed for conducting wear test. The composite alloy pins were made up of circular cross section of 9 mm diameter and 25 mm length. The composites prepared were examined under optical microscope after they were belt grinded and polished by different grades of emery papers.

3. Results and discussion

3.1 Tensile test

Computerized UTM (Universal Testing Machine) is used to find out the tensile strength. The samples were machined as per the ASTM E8M-13A specification. The tensile testing of Aluminium with the different % of basalt and fly ash reinforcement is depicted in Figure 4.
Addition of weight % of fly ash and basalt increases tensile strength of composites. The specimen prepared to be a two end jaws of the universal testing machine. Point load is progressively applied on the specimen with movable cross head, until the specimen breaks. Figure 6 Composites Vs. Ultimate Tensile Strength. Volume fraction affects the tensile strength. The tensile strength of sample1 is 88.437N/mm2, sample2 is 104.221N/mm2, sample3 is 175.619 N/mm2, and this effect is due to the hardening of the aluminium alloy in composition of fly ash and basalt particles. The composites Vs % Elongation graph as shown in the Figure 6.

**Figure 4.** Tensile test specimens before and after testing.

**Figure 5.** Percentage of elongation for different composites.

**Figure 6.** Different composites % vs. ultimate tensile strength (Mpa).
3.2 Chemical composition

Chemical constitution is verified before and after reinforcement (sample 2 composite) of aluminium composites as shown in the Table 4. Basalt and fly ash reinforcement maximizes the percentage of silicon, copper, ferrous and zinc. Silicon increases the hardness value up to 70Mpa and the ultimate tensile strength is increased due to addition of copper. The presence of ferrous increases the mechanical property such as ductility and presences of zinc having high density precipitates.

Table 4. Chemical composition of A7075 before and after reinforcement (sample 2).

| Element | Before Reinforcement | After Reinforcement |
|---------|----------------------|---------------------|
| Si      | 0.138                | 0.181               |
| Fe      | 0.334                | 0.336               |
| Cu      | 1.49                 | 1.53                |
| Mn      | 0.0830               | 0.079               |
| Mg      | 2.68                 | 2.58                |
| Zn      | 5.86                 | 5.66                |
| Al      | Balance              | Balance             |

3.3 Hardness test

Hardness test pieces were made as per the dimensions shown in the Figure 7. Hardness testing using Vickers machine were used to find the hardness value with applied load of 500gm and 10sec as dwell period. The maximum value of hardness occur at the composition of Al7075+7%basalt+3% fly ash as shown in the Figure 8.

Figure 7. Hardness specimens.

Figure 8. Different composites vs. hardness.
3.4 Wear test

Figure 9 depicts the pin on disc wear testing apparatus on which the wear testing is carried out, the sample for wear test was prepared with standard dimension of 9mm diameter and 50mm height was shown in the Figure 10. Wear test were conducted using pin on disc machine. The wear test was conducted at three different loads, with increments 1Kg, 2Kg then the speed, time and track radius keeping constant. The minimum value wear occur at the Al7075+3%basalt+7%fly ash as shown in the Table 5.

![Figure 9. Pin on disc apparatus.](image)

![Figure 10. Wear test specimens.](image)

| Compositions | Wear Rate (µm) | Coefficient of Friction (µ) |
|--------------|---------------|---------------------------|
|              | Load (1 Kg)   | Load (2 Kg)               | Load (1 Kg) | Load (2 Kg) |
| Sample 1     | 45            | 157                       | 0.44        | 0.49        |
| Sample 2     | 57            | 165                       | 0.49        | 0.57        |
| Sample 3     | 44            | 149                       | 0.45        | 0.49        |

4. Microstructure

The voids are obtained by the amount of gas rejected by the melting. If the gas is released in large amount, it results in sphere shaped pores, it continues to grow through diffusion before coherency of dendrite is finally reached as shown in the Figure 11 (a) & 11 (b). Their size will be the order of tenths
of millimeter to 1 millimeter. This kind of defect is termed as gas porosity. A lower amount of gas rejection softens the metal. After dendrite coherency pores formation occurs during subsequent stages of solidification. The concurrent build-up of shrinkage cavities nucleated by pores results in micro shrinkage.

Figure 11 (a). Microstructure of Al7075 alloy.

Figure 11 (b). Microstructure of Al7075+3%basalt+7%fly ash.

5. Conclusion
Combination out of Aluminium 7075-fly ash and basalt blends were fabricated by means of Stir-casting method along with perfect diffusion of fly ash and basalt particles spread evenly through the specimen. MMCs (7075) reinforced with fly ash and basalt particles considerably improved the mechanical properties.

- In comparison to the Al7075 + 3% basalt + 7% fly ash and Al7075+5%basalt+5%fly ash, the reinforced Al7075 + 7% basalt + 3% fly ash exhibits more tensile strength. It is due to the hardening of aluminium alloy by basalt and fly ash particles.
- With Al7075 + 3% basalt+7% Fly Ash composite, hardness of composite is maximized. It happens because of the presence of basalt along with addition of 7% of flyash helps to enhance the hardness value of the material.
- The third composition (Al 7075+3% Basalt Ash +7% Fly Ash) reduced the wear rate value of the composite material. Existence of fly Ash and basalt helps to increasing wear resistance value of hybrid material in both 1kg and 2kg loading condition.
- Microscopic evaluation affirms that interfacial bonding between Al 7075+basalt 3%+flyash7%.
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