Mechanical properties of Fly ash reinforced Aluminium matrix composites

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Abstract The present work aims to develop Fly ash (FA) reinforced Aluminium Alloy (AA6063) matrix composites using stir casting route and reporting their mechanical properties. The FA content is applied in the ranges of 0-9 weight percentage with the step of 3 % each. The mechanical properties such as hardness, tensile strength (UTS) and compressive strength (CS) of the composite and alloy samples have been studied. Results showed that addition of FA content up to 6 wt.% improved the mechanical properties and then decreased.

1. Introduction
Aluminium matrix composites (AMC) are widely used materials since they have better mechanical, physical and thermal properties [1-11]. Aluminium matrix composites have been reinforced by various reinforcement materials such as titanium carbide, titanium oxide, aluminium oxides, Silicon carbide, Silicon dioxide, Boron carbide, molybdenum trioxide, Aluminium nitride, Titanium diboride, graphite, Silicon nitride, Zirconium oxide, Zirconium diboride, Tungsten carbide and carbon nanotubes [12-19]. Recently FA content has been used as reinforcement materials for fabrication of different composites [20]. Ramachandra and Radhakrishna reported the impact of FA in the AMCs on the wear property and reported that wear resistance improved for the increase in the content of FA but the corrosion resistance decreased [21]. Soorya Prakash Kumarasamy et al. investigated the machining behaviour of FA reinforced AMCs and they produced this composite using compo casting. They also concluded that the mechanical property of the composites has been improved because of reinforcement inclusion [22]. Rajesh et al. studied the wear and mechanical property of the Graphite and FA reinforced AMCs and reported that FA improves the properties of the composites. They used stir casting route to
manufacture the composites for testing [23]. Pramod Kumar et al. made an attempt to produce Aluminium composites with FA content and reported that the addition of FA improved the hardness property. But the tensile and impact strength has been decreased due to FA. They used stir casting route for fabricating this composite samples [24]. Sathishkumar et al. produced SiC and FA reinforced composite using stir casting route and reported that reinforcement addition improved the properties. The forging process further improved the properties of the composites [25]. Devanathan et al. developed AMCs with the inclusion of FA. SiC and Coconut ash and reported that the mechanical properties have been improved due to these reinforcements in the matrix materials [26]. Vipin Sharma et al. fabricated AMCs with FA content and studied the wear behaviour of the composite. They reported that less wear is observed for the FA reinforced samples. Stir casting route can be the right choice for fabricating the composites [27]. AMCs can be manufactured by various methods such as solid-based and liquid-based methods. But stir casting is the widely used method since it has an economical advantage [28,29]. Ezatpour et al. used stir casting process to produce the alumina reinforced AMCs and reported the mechanical properties and the metallurgy structure of the AMCs [30]. Suswagata Poria et al. reported the wear behaviour of the AMCs which has been reinforced by titanium diboride particles. They suggested stir casting is the choice for producing AMCs with good properties [31].

2. Experimental details

Aluminium alloy (AA6061) is used as a matrix material for the present work. The composition of the matrix is Al: 98.6, Cr: 0.04-0.35, Cu: 0.15-0.4, Fe: Max 0.7. Stir casting method is used for the fabrication of composite samples. FA is used as reinforcement materials. The content is added with the matrix in the step of 3% up to 9%. The matrix is heated up to the molten stage and then preheated FA added into the matrix. The stirring was done for 10 mts and stirrer was motor controlled. Then the molten metal is poured in to suitable die and samples were used for further testing. The tensile test was conducted at computerized UTM to find the UTS and compressive strength of the samples. Vickers hardness test was used to find the hardness for the prepared samples. Three readings were taken for each sample and the average value was taken. The complete experimental detail is provided in Fig. 1.

![Experimental Details Diagram](image)

Figure 1. Experimental details

3. Results and discussion

3.1. Hardness

Figure 2 shows the effect of FA content on the hardness in the AA6061 matrix. The increase in FA content increases the hardness of the composite. Reasonable improvement in hardness is observed. This is due to the hard nature of FA content in the soft matrix. Highest hardness was obtained for the sample contains 9 weight percentage of FA content. This is due to the high amount of FA content in the matrix distributed in the matrix. The indenter penetrates very hard when it faces the FA content rather than the AA6061 matrix. Many researchers found that the addition of ceramic or oxide particles improves the hardness of the composite samples than the unreinforced aluminium matrix [20].
3.2. Tensile strength
Figure 3 expresses the outcome of FA content on the UTS in AA6061 matrix. The increase in FA content increases the UTS of the composite. Judicious improvement in strength is observed. This is due to the uniform distribution of hard nature of FA content in the soft matrix. Maximum strength was obtained for the sample contains 6 weight percentage of FA content. The decrease in strength was observed after the 6 wt.% of FA content. This is due to the high amount of FA content in the matrix might not distributed properly in the matrix. The addition of ceramic or oxide particles improves the strength of the composite samples than the unreinforced aluminium matrix. The reason is that the load is transferred by the reinforced particles to the matrix. Hence the high strength FA particles act as load-bearing element [32]. Matrix– FA interfacing, bonding also the reason for the improvement in strength [33].

3.3 Compressive strength
Figure 4 displays the effect of FA content on the CS in AA6061 matrix. The rise in FA content rises the CS of the FA reinforced composite samples. Low CS was observed for the 9 FA content samples. This is due to the improper mixing of FA content in the matrix. High CS was obtained for the sample
contains 6% FA content in the AA6061. This is due to the even distribution of FA content in the soft matrix [22]. The improvement in strength is up to 6% only further decreases. The improvement in strength is due to the grain refinement and secondary particle strengthening mechanism [34].

![Figure 4](image_url)

**Figure 4** Effect of FA content on CS

### 4. Conclusions
- AA6061-FA composite with 0, 3, 6, and 9 weight percentages have been produced by using stir casting method.
- The hardness of the composite was increased up to 9 weight percentage of addition of the FA content in the matrix. Vickers hardness testing machine was used to find the hardness of the samples.
- The UTS was increased up to 6 weight percentage and then decreased in the AA6061 matrix.
- The CS of the composite samples increased up to 6 weight percentage of FA addition and then decreased in the AA6061 matrix.

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