Recent developments in Al7075 hybrid composites and study on its microstructure and mechanical characteristics

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Abstract. Hybrid composites are formed by incorporating more than one reinforcement into the parent alloy and these are considered to be one of the significant materials used for aerospace, automobile, defence applications. Even nano hybrid composites are also evolving as materials to be considered with prominence. Aluminum metal matrix hybrid composites especially Al7075 hybrid composites are known for superior strength to weight ratio and good wear resistance, that’s why those are considered as most useful materials in the field of mechanical applications. Ease of manufacturing, low cost of production paved the way for aluminum hybrid composites to emerge itself in to one of the potential material for future applications in aerospace, automobile, defence sectors. In order to develop aluminum hybrid composites several reinforcements were been added along with the metal matrix. Reinforcements enhance the mechanical, physical and micro structural characteristics of the hybrid composites. Mechanical properties would get enhance with varied wt % of reinforcements. This article provides an overview on recent developments on aluminum metal matrix hybrid composites.

Keywords: Aluminum metal matrix composites, reinforcements, characterization, Al7075, Microstructure

1. Introduction

Aluminum metal matrix hybrid composites are extensively used in most light weight-high strength applications. Excellent features like high strength to weight ratio, good wear resistance and better mechanical properties extend the usefulness and applicability of aluminum composites in several sectors. Adding more number of reinforcements in the same aluminum matrix bring more potential for the material to possess adaptability towards many mechanical applications. Researchers are been going on in the development of newly reinforced aluminum hybrid composites. Method of fabrication of these composites also needs to address since several liquid state and solid state techniques are available currently to explore. Table 1, shows the composition of Al7075. Al7075 is considered as the first choice in aerospace industry because of its high strength compared with other aluminum alloys,
Al7075 possess better machinability also that's the reason why this aluminum alloy is considered as one of the potential alloy which could be used in many low weight applications.

The purpose of this study is to understand the characteristic features of Al7075 Aluminum alloy and the effect of reinforcements in the development of Al7075 composites, thereby understanding its mechanical and micro structural behaviour.

Table 1. Wt% of alloying elements in composition of Al7075

| Al7075 alloy elements | Cu   | Mg   | Si    | Mn   | Fe    | Zn    | Cr    | Sn    | Al    |
|----------------------|------|------|-------|------|-------|-------|-------|-------|-------|
| % in composition     | 1.52 | 2.20 | 0.227 | 0.009| 0.157 | 5.94  | 0.19  | 0.005 | Rem   |

2. Al7075 Hybrid composite reinforcements

Aluminum hybrid composites are made by adding reinforcements even of nano size into the metal matrix. Some of the reinforcements used are SiC, TiC, fly ash, B4C, TiO2, Cu, ZrO2, TiB2, BN, bagasse ash, graphite, CDA, Beryl, Graphene, MoS2, Al2O3, SiO2, etc. After optimizing the right proportion of the reinforcements, experiments can be done to improve the properties and the microstructure. Investigations had been done on the properties and microstructure of Al7075 by varying the wt % of reinforcements as well.

3. Mechanical and metallurgical properties of Aluminum hybrid composites

[1] Conducted investigation on Al7075 metallurgical and mechanical properties after adding reinforcements such as zircon sand and tungsten carbide and a rise from 0.5 % to 1.5 % was recorded for the tensile strength. But the trend no longer be the same because strength decreases for further increase in reinforcement. Similarly, compressive strength also showed the same pattern of increment for addition of tungsten carbide, which indicates that there is an optimum quantity that has to included in the alloy i.e., exactly 1.5 % which would enhance the characteristics of Al7075. SEM image, figure 1, shows the dispersion of tungsten carbide constituents within the aluminum alloy matrix.

[2] Discussed about the effect of Cu and TiO2 (grain size 200-300 mesh) on Aluminum metal matrix composite. Only slight improvement was recorded when Cu particles been added into the alloy to make the composite. But somehow with the addition of 15 wt% of Copper, tensile strength increased. Ductility and impact strength seen be adversely affected with the Cu and it showed a decreasing trend while adding the reinforcement. One of the important thing to be noted is the dispersion of particles into the matrix and from the microstructure study, it was found out that dispersion happened without the indication of agglomeration.

[3] Explored the wear characteristics of aluminum composite reinforced with Boron Carbide and Zirconium Dioxide. Among the different fabrication methods of aluminum composites, liquid metallurgy was adopted, that is, stir casting method.

Figure 1. SEM image Al7075 hybrid samples [1]
By stir casting up to 3% of ceramic particles were added and under optimum stirring speed the casting process was taken place. Figure 2 shows the stir casting setup.

![Stir casting equipment](image)

**Figure 2.** Stir casting equipment

Studies on microstructure were carried out. Using pin on disc test apparatus wear study of the composite was done. Resistance to wear decreased with the addition of Boron Carbide was compensated by the addition of ZrO2. So, overall wear resistance increased in the aluminum composite.

![Microstructure and XRD peaks](image)

**Figure 3.** (a) SEM image of composite (b) XRD peaks of composite with Boron Carbide

Figure 3 shows microstructure and XRD peaks of the composite with 3 % B4C. The peak obtained in the XRD clearly indicates the presence of reinforcements and its dispersion within the metal matrix.

[4] focused more on the parametric study of the Al by taking consideration of the parameters like size, type, % of inclusion of reinforcements. Parameters directly influence the liquid processing technique which was used as the manufacturing technique. Identified that the parameters like low porosity and high ultimate tensile strength needs to take care to obtain a sound casting. For the graphical representation of these factors fishbone diagram (figure 4) was considered. Later using screening design the significant parameters were found out and it would help researchers to carry out experiments on the basis of the results from screening design. Influential factors from common factors were found out using Failure mode effect analysis (FMEA). Then most influential factors from influential factors were found out using Plackett Burman design by adopting factorial design to find the optimum value for the factors.

[5] Done Investigations on the mechanical properties like strength, hardness of Al7075 after adding reinforcements such as Silicon Carbide and Titanium Carbide (SiC and TiC). The study indicated that, apart from impact strength, remaining properties actually increased.
39 % increase in hardness, 32 % increase in ultimate tensile strength was recorded, and also 10.5 % increase in yield strength. Superior properties were shown by the addition of TiC and SiC in to the matrix.

[6] Utilized TiO2 (avg. size 5–50 μm ) and fly ash (10–100 μm) as reinforcements for AA7075 alloy which was made by liquid metallurgical route. Figure 5 shows the SEM image of Titanium Dioxide and fly ash and figure 6 shows SEM image of hybrid composite. SEM micrographs showed the presence of TiO2 and fly ash and its uniform dispersion in to the metal matrix. Study indicated that the compression strength increased while incorporating mentioned reinforcements and showed an increasing trend even when the reinforcement gets added upon during the process. Dispersion without aggregation of particles results in better strength.

[7] Presented the mechanical characterization of Al7075 added with Silicon Carbide and Titanium Carbide. Composite was manufactured by solid processing route which is one among different solid state processing techniques. The optimum amount of SiC and TiC was found out initially by a tool called Response Surface Methodology (RSM).
Different weight % of reinforcements were considered and the right optimum amount has been taken for the experimentation. The presence of reinforcements elevated the properties like micro hardness, wear resistance, etc.

[8] Mechanism involved in the enhancement of mechanical properties was described through the study. FSP process was used for the manufacturing of composite. In this experiment, micro sized (avg. size 20–60 μm) and nano sized (30–80 nm) SiC particles were used as reinforcements. Figure 7 shows Scanning electron microscopy and Transmission electron microscopy images of Silicon Carbide particles which were added into the matrix and a better diffusion which is the potential reason behind the enhancement of mechanical properties. Composite was made primarily using liquid metallurgical technique later secondarily processed by FSP process to overcome the problems such as porosity, dendrite structures, poor strength, etc which are common problems with cast products. After FSP process, SiC particles found to be properly dispersed into the metal matrix which made a composite with superior properties. FSP ensures the grain refinement and non existence of pores inside the composite.

[9] Hybrid surface composites fabricated after adding Boron Carbide (50 μm) and Titanium Diboride (10 μm) as elements possessed superior interfacial joint with parent alloy, uniform dispersal of ceramic particles. It showed more hardness and wear resistance. Friction stir processing was the fabricating technique used. Plastic deformation and material flow were more of a difficult task with hybrid composites because of the presence of different sized multiple particles as reinforcements.

[10] Investigations were made on Al7075 with SiC and BN nano powders (avg. size of 50 nm) as reinforcements via FSP method. Silicon Carbide and Boron Nitride powders were used for experimentation. Grain refinement occurred while carrying out FSP process also enhanced the tribological characteristics and hardness. There was no impact on the wear resistance and hardness due to the addition of BN nano powders but its presence reveals that it could
improve the machinability of composite. Figure 8 shows Dispersion of Boron Nitride and Silicon Carbide nano powders in parent alloy.

Figure 7. a) Scanning electron microscopy and b) Transmission electron microscopy images of Silicon Carbide and SE and BSE images of micro and nano composites (c,d,e,f) [8]

Figure 8. Dispersion of Boron Nitride and Silicon Carbide nano powders in parent alloy - Scanning Electron Microscopy [10].

[11] Hardness, ultimate tensile strength and yield strength were investigated by adding bagasse-ash (0.1-100 μm) and graphite (20–60 μm) as reinforcements which was found to be improved. Liquid metallurgical route was adopted for the manufacturing of
composite. But Ductility decreased when the composite been added with graphite and bagasse ash.

[12] Used cow dung ash (CDA) as one of the reinforcement together with B₄C to make Al7075 hybrid composite. Microstructure, mechanical and tribological studies revealed that hardness of the material decreases while adding CDA and it was compensated by the addition of B₄C. Tensile strength also found to be enhanced by presence of Boron Carbide particles. Somehow presence of CDA enhanced impact strength of aluminum alloy.

[13] Investigated the effect of incorporation of alumina (53 μm) with fly ash (53-106 μm) and also done a comparative study with SiC (53 μm) and fly ash combination. Research work was reported that the silicon carbide with fly ash reinforcement showed superior mechanical properties in contrast to alumina and fly ash added composites and there was a rise in strength and hardness by the addition of the elements.

![Figure 9](image)

**Figure 9.** SEM images (a) Silicon Carbide (b) Alumina (c) FA [13]

SEM tests revealed uniform dispersion within the matrix. Figure 9, shows SEM images of the reinforcements used. Figure 10 shows SEM images of hybrid composites.

[14] Prepared Al7075 Beryl Graphene hybrid composite after studying the impact of parameters like amount of reinforcement content, loading, sliding factors on the weight reduction of composites. Experiment plans were created using DoE Taguchi Technique, L₂₇ array. From ANNOVA results, it was found out that weight % of reinforcement has more relevance in the weight loss which is one of the potential feature of aluminum composites.

![Figure 10](image)

**Figure 10.** SEM images of hybrid composites [13]

[15] Conducted experiments on Al7075 by adding SiC and Molybdenum Disulphide (MoS₂) as reinforcements. From the experiment it was found out that with 90 % alloy, 9 % SiC and 1 % MoS₂ provided with a composite of high strength. In addition to that, hardness also increased and lowered the strain rate as well.

[16] Combination of micro and nano sized particles were been used to make Al7075 hybrid composite, in which alumina particles are of nano size (30-50 nm) and SiC particles are of micron size (5-10 μm). Tensile strength and density was found to be enhanced in the presence of reinforcements. Upto 60.1% increase in UTS was observed.
[17] Had reported an interactive study on the factors which are prominent for the efficient execution of the experimental process. Taguchi technique-L9 orthogonal array approach was used. Relation of hardness, structure and strength and its role in the final product which could be applied for mechanical applications was studied. Taguchi optimization methodology was used for making decision on factors in concern.

[18] Reviewed the reinforcements’ effect on Aluminum hybrid composites and discussed about the different ways by which composites are been fabricated. Also pointed out that metallurgical properties clearly have an prominent effect on the properties like strength, hardness, etc. [19] Quartz and Carbon was used as reinforcing elements for the hybrid composites and studied on its effect on the hardness and tensile strength. Aluminum hybrid composites were affected by the dispersions and materials used as chills which will favour the solidification. Mechanical properties taken for the investigation was found to be dependent upon the metals used as chills and diffusion percentage.

4. Conclusion

Aluminum metal matrix hybrid composites have been investigated by many researchers with various types and wt % of reinforcements. The inclusion of the reinforcements found out to be useful in enhancing the mechanical characteristics of the aluminum composites. Mechanical properties are directly influenced by the micro structural characteristics of the hybrid composites. Grain refinements, homogeneous dispersion, proper interfacial bonding are mandatory for the development of useful aluminum metal matrix hybrid composites. Reinforcements like SiC, alumina, Boron Carbide are extensively used as addition to the metal matrix. It is due to the fact that the presence of these reinforcements directly influences the mechanical properties. Dispersion without agglomeration or clustering has to be ensured in the fabrication of aluminum hybrid composites.

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