Aluminium (Al7050) Metal Matrix Composites: A Review of Reinforcement and Mechanical Characteristics

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Abstract. Al7050 is distinct among the Al – 7xxx alloy series due to its remarkable features. The rudimentary properties of Al7050 can be improved with the addition of appropriate reinforcing materials to further increase in its adaptability as various structural components. Extensive research is being carried out using different forms (metallic, non-metallic and organic compounds) of reinforcing materials to obtain suitable Aluminium metal matrix composites (AMMC) for specific applications. This review aims to provide an overview of two different reinforcement materials viz., Graphene and Silica utilized in Al7050 MMC and elaborates on the change in characteristics of the composite due to reinforcement inclusion.

INTRODUCTION

Two or more materials being mixed in order to achieved robust properties over any conventional material is commonly termed as composite materials. The classification of composite materials can be done with respect to matrix and the reinforcement used for casting. The matrix classification includes metal, ceramic, polymer and carbon matrix composite [1]; likewise, reinforcement classification falls under fiber, laminar, flake and particulate reinforced composite. Metal matrix composite has an edge over other types of composites because of their overall performance characteristics such as high temperature resistance, electrical conductance and im-proved mechanical properties. In the recent past, Aluminium metal matrix compo-site has proven to be promising material for application in various industries such as aerospace, automobile, structural engineering field and also in medical field due to their excellent characteristics ahead of conservative alloys [2,3]. Among Al 7xxx series, Al7050 is broadly adopted and appropriate alloy for various applications. The material process of Aluminium alloy and fabrication technology can be improved by adding particulate reinforcement materials to achieve superior microstructure and mechanical properties such as high specific strength, toughness, hardness, low density, light weight and resistance to corrosion [4].

Over the last few decades, most of the researchers focused on improving the characteristics of Al7050 with appropriate reinforcing material such as Graphene [5-10], Si [11-14], TiB2 [15-24], TiC [25, 26], Ni-Ti [27], Ti [28] Al2O3 – B4C [29]. This article provides an extensive report on two types of reinforcement viz., Graphene and Silica used in Al7050 composite, optimum percentage of reinforcement and how it affects the physical and mechanical properties of Al7050 MMC.

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REINFORCING MATERIALS IN ALUMINUM METAL MATRIX (Al7050)

Graphene

Recently, researchers have demonstrated that 2D graphene/nano graphene exhibit high strength, toughness, elasticity, thermal conductivity and self-lubrication.

Liyun Wu [5] explored the tribological characteristics and microstructure of Al matrix composites reinforced with 0.5 wt % nano graphene which is fabricated through Selective Laser Melting (SLM). Friction and wear experiments were carried out on Al-graphene composite to examine the tribological properties by choosing sliding speed (0.3, 0.6, 0.9 m/s) and normal load (10, 20, 30 N) as process parameters. The consistent dispersion of graphene particles strengthens the load carrying capacity and hardness of the composite. Wear rate, coefficient of friction and surface roughness evaluated from the experiments reveals the self-lubricating property of the composite which enables interlayer sliding and thus reduces friction to great extent. The different chemical composition of Aluminium alloy (Al7050) used in earlier studies were listed in Table 1.

TABLE 1. Chemical composition of Al7050

Composition %	Zn	Zr	Si	Mg	Fe	Cu	Ti	Mn	Cr	Al
Reference										
[8] – [9]	5.7 – 6.7	-	-	1.9 – 2.6	-	2 – 2.6	-	-	-	Bal
[10]	5.7	0.08	0.12	1.9	0.15	2	0.06	0.10	0.04	Bal
[12]	6.2	-	0.1	2.41	0.12	2.2	0.05	0.1	0.05	Bal

Venkatesan et al. [6 - 10] performed both stir casting and squeeze casting to fabricate Al7050 reinforced with nano graphene particles. The composites comprise of varying percentage of Graphene content such as 0.3, 0.5 and 0.7 wt% with average Graphene size of 50 – 100 nm. Along with the Brinell Hardness Number and Flexural strength, tensile behavior of the composite was studied by varying the melting temperature as 775°C, 800°C, 825°C and stirring speed as 300 rpm, 400 rpm, 500 rpm. The parameters influencing the tensile strength of the specimens were determined using analysis of variance ANOVA on the experimental values. The ANOVA results reveal that graphene content and temperature are the dominating parameters on the tensile strength. In addition to the mechanical properties, the authors have also studied the wear behavior of Al7050 composites by considering load applied, sliding velocity and distance as parameters and examined the wear loss and friction co-efficient. Graphene proved to be an excellent reinforcement in the Aluminium metal matrix composite through uniform dispersion of particles without any voids. The mechanical properties and microstructure characterization reveal that graphene content of 0.3% through squeeze casting process as optimum graphene content. The authors have validated and confirmed all the experimental results with the developed regression equations for influencing parameters. Table 2 shows the type of reinforcement and production methods used in previous literatures for fabrication of reinforced Al7050 composite.

Silicon

Sathish et al. [11] investigated wear behaviour and microstructure of Al7050 - SiC composites with different percentage levels such as 0, 4 and 6%. The process parameters such as sliding velocity (1, 2, 3 m/s), SiC composition and sliding distance (1000, 1400, 1800m) were optimized through Taguchi analysis. The sliding velocity was the most influencing parameter on the wear rate and optimum percentage of SiC was suggested as 6%. The microstructure study before the wear test shows the uniform distribution of SiC particles in the AL7050 composite. However, there is an increase in wear rate due to increase in the percentage of reinforcement due to poor stir casting process.

TABLE 2. Type of reinforcement and production methods

Ref. No.	Matrix	Type of reinforcement	Percentage replacement	Optimized content %	Production technique
[5]	Al7050	Graphene	0.5	0.5	Selective Laser Melting
[6], [7], [9]	Al7050	Graphene	0.3	0.3	Stir and Squeeze Cast Processes
[8] – [10]	Al7050	Graphene	0.3, 0.5, 0.7	0.3	Stir and Squeeze Cast Processes
[12]	Al7050	SiC	3	3	Vortex casting
[13]	Al7050	SiC	10	10	Two steps casting processing
[14]	Al7050	Si	10, 20, 30	30	Friction stir processing

Mousavi Anijdana [12] et al. evaluated microstructural and mechanical properties of Al7050-3 wt% SiC composite fabricated through vortex casting. The pouring temperature (700 and 800°C) and surface angles (45°, 90°) were varied during the vortex casting. Microscopic study revealed uniform dispersion of reinforcement particles can be achieved at 800°C with surface angle of 45°. Uniaxial tensile test, Charpy impact test and Microhardness results pointed out that mechanical properties are being increased by reducing the surface angle and increase in pouring temperature while vortex casting.

Lihua Zhang and Fujun Jiao [13] performed two steps casting process for the uniform distribution of SiC particles in Al 7050 base metal matrix. They focused on the ultrasound application in producing the Al composite by using 10 vol% of SiC as reinforcement. The process variables considered for the study were mechanical stirring time (10, 20, 30, and 40 min) and ultrasonic time (20, 40, 60 and 80 min). There is a homogenous dispersion of SiC particles during first step of casting process (mechanical stirring) but exhibits higher porosity due lack of protective measure. However, ultrasonic treatment during second step affects the wettability and increases the mechanical performance such as tensile strength, micro hardness and wear rate of the Al7050 composite.

Lee et al. [14] produced Silicon particles reinforced Al7050 matrix through friction stir processing FSP. The silicon content with average size of 1.5 μm was varied between 10 – 30 % with an increment of 10%. The non- reactive Silicon and Aluminium powders were mixed using multiple step FSP and optimum percentage can be achieved up to 30%. Microstructure study indicate that uniform dispersion of Si particles in Aluminium alloy which makes it dense and exhibit enhanced strength and modulus due to dislocation strengthening.

The mechanical properties of AL7050 composite experimented by various researchers are depicted in Table 3.

TABLE 3. Mechanical properties of Al7050 metal matrix composite

Ref. No.	Density g/cm^3	Yielding stress MPa	Elongation %	UTS MPa	Hardness	Modulus of Elasticity GPa
[7]	-	77.05	-	-	24.21	-
[10]	2.82	320	11	-	147	71.7
[13]	-	138.4	-	-	83.3 (Hv)	77.8
[14]	-	87	30	117	-	70

CONCLUSION

This article presents an overview of nano Graphene and Silica in the form SiC and Si, as reinforcing material in manufacture of Al7050 composite and their change in characteristics due to the reinforcement addition. From the literature study, the following points were summarized to increase the scope of the future study.

- The optimum percentage of addition of nano graphene platelets to AL7050 composite can be suggested as 0.3%.
- Further, with the addition of graphene particles, the friction gets reduced and exhibit superior strength properties.
- Out of the two forms of Silica as reinforcement, SiC achieved superior performance compared to Silicon particles in Al7050 alloy.
- Stir casting process is most widely adopted method for casting Al7050 composite.

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