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Original Article

Comparative study on the mechanical and microstructural characterisation of AA 7075 nano and hybrid nanocomposites produced by stir and squeeze casting

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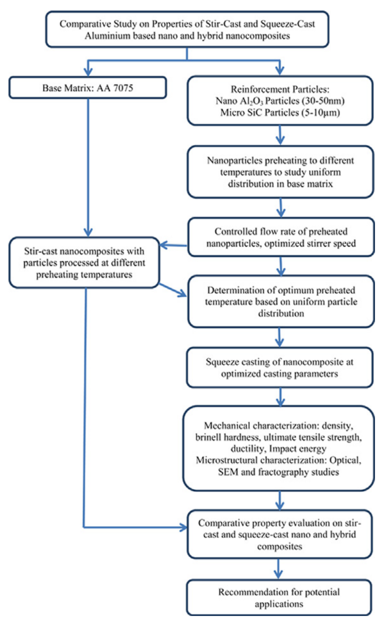
GRAPHICAL ABSTRACT



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ABSTRACT

In this research work, a comparative evaluation on the mechanical and microstructural characteristics of aluminium based single and hybrid reinforced nanocomposites was carried out. The manufacture of a single reinforced nanocomposite was conducted with the distribution of 2 wt.% nano alumina particles (avg. particle size 30–50 nm) in the molten aluminium alloy of grade AA 7075; while the hybrid reinforced nanocomposites were produced with of 4 wt.% silicon carbide (avg. particle size 5–10 μm) and 2 wt.%, 4 wt.% nano alumina particles. Three numbers of single reinforced nanocomposites were manufactured through stir casting with reinforcements preheated to different temperatures viz. 400 °C, 500 °C, and 600 °C. The stir cast procedure was extended to fabricate two hybrid reinforced nanocomposites with reinforcements preheated to 500 °C prior to their inclusion. A single reinforced nanocomposite

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Silicon carbide
Squeeze casting
Stir casting

was also developed by squeeze casting with a pressure of 101 MPa. Mechanical and physical properties such as density, hardness, ultimate tensile strength, and impact strength were evaluated on all the developed composites. The microstructural observation was carried out using optical and scanning electron microscopy. On comparison with base alloy, an improvement of 63.7% and 81.1% in brinell hardness was observed for single and hybrid reinforced nanocomposites respectively. About 16% higher ultimate tensile strength was noticed with the squeeze cast single reinforced nanocomposite over the stir cast.

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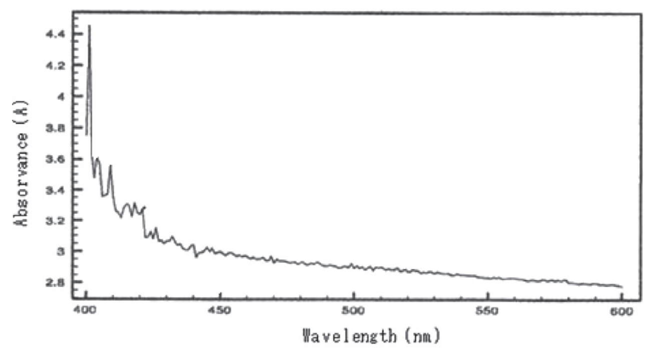
Introduction

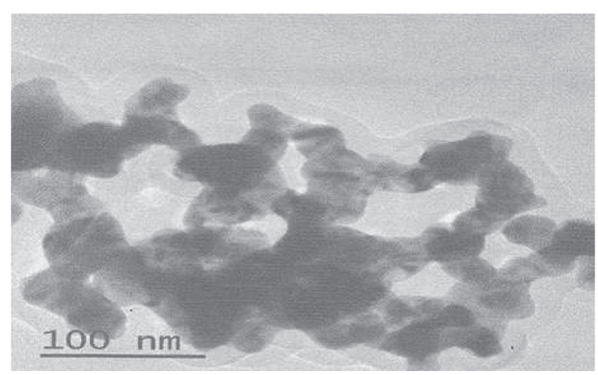
Aluminium metal matrix composite (AMMC) is being preferred for numerous engineering applications like aerospace, marine, automobile and mineral processing due to their lightness associated with remarkable specific strength and thermal properties [1–5]. In aluminium composites, the properties like high toughness and ductility associated with aluminium matrix are combined with superior properties of ceramics such as high strength and elastic modulus by adding ceramic reinforcements in the base matrix [6,7]. Alumina (Al_2O_3), silicon carbide (SiC) and graphite (Gr) are the most common reinforcing materials [8,9] which can be incorporated in the base aluminium matrix in the form of whiskers or particles. However, manufacturing complexity and low cost favour the particle reinforced composite over whisker-reinforced [10,11].

Metal matrix nano composites (MMnC) are a new category of materials, in which the reinforcements in the range of nanometer size are being used [12]. Increased surface area offered by nano scale reinforcements at the matrix interface leads to superior properties in composites such as increased mechanical strength, higher fatigue life and better creep resistance at elevated temperature without much compromise on ductile characteristics [13–15]. However, the end properties of MMnCs are greatly influenced by the size, shape, uniform distribution, hardening mechanism and thermal stability of nano reinforcements [16,17]. Hybrid metal matrix composite (HMMC) is being investigated by various researchers around the world due to their enhanced properties over single reinforced composites. These composites are formed either by a combination of two or more reinforcements in different forms like particulates, whiskers, fibres and nanotubes or two different reinforcements of the same form. The primary and secondary reinforcements can be blended in a way to optimise the properties of hybrid composites. Improved mechanical properties were observed with hybrid reinforced nanocomposites over single reinforced nanocomposites due to a significant reduction in meniscus penetration defect and inter-metallic component formation [18–23].

At present, the vehicle manufacturers are trying various methods to enhance the efficiency. This necessitates the automobile components to be manufactured from lightweight materials. Across the globe, the researchers are putting their efforts to develop light materials in the form of composites for aerospace and automobile applications [24,25]. Despite their efforts, limited research is available on hybrid reinforced nanocomposites that are based on aluminium alloy AA 7075, which has zinc as a primary alloying element. It has excellent strength to weight ratio. The fatigue strength of this material is comparatively better than many other aluminium alloys [26]. The limited exploration on AA 7075 hybrid reinforced nanocomposite demands further investigation. Hence, in this investigation, single and hybrid reinforced nanocomposites were manufactured with the incorporation of nano alumina and micro silicon carbide particles as reinforcements in base matrix of AA 7075. High hardness, excellent stability and better insulation are the most interesting properties of Al_2O_3 [27];



(a) UV- Vis spectrometer reading



(b) TEM analysis

Fig. 1. Spectrometric and TEM analysis of nano Al_2O_3 particles.

Table 2
Properties of reinforcements [26,27].

Property	Al_2O_3	SiC
Particle size	30–50 nm	2–5 μm
Colour	White	Black
Density (g/cm^3)	3.97	3.1
Elastic Modulus (GPa)	375	410
Melting point (°C)	2055	1650
Thermal conductivity (W/m K)	35	83.6
Coefficient of thermal expansion ($\times 10^{-6}$/°C)	8.4	4.3

Table 1
Chemical composition of AA 7075 [8,9].

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.13	0.42	1.42	0.12	2.42	0.21	5.4	0.11	Bal.

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