Fabrication and Mechanical Characterization of Aluminium 7075 Reinforced with Nano Graphene / B₄C / Inconel alloy 625 using Ultrasonic Stir Casting Method

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Abstract

Aluminium 7075 widely used in aerospace and defence applications. At the present time, hybrid composite material utility is refining in all engineering areas as a result of high strength /weight ratio, good corrosive and wear resistance. In this research work deals with the fabricating of hybrid metal matrix composite of aluminium 7075 as base metal reinforced by varying weight percentage of Nano graphene (0.5,1,1.5,2) , B₄C (2,4,6,8,) and Inconel alloy 625 (2,4,6,8). This boron carbide, Inconel alloy 625 particles having particle size of 50µm. The hybrid aluminium composite material fabricated utilizing liquid metallurgy ultrasonic stir casting method. Tension test, compression test, hardness test and flexural test were conducted to determine mechanical properties of the hybrid composite material. Morphology of the hybrid metal matrix composite were analysed by using SEM.

Keywords metal Matrix composite, Ultrasonic stir casting ,Reinforcement.

1. Introduction

In the past 7 periods (1943), aluminum 7075 series alloy materials used for the construction of desired components of automobile, aerospace and marine applications are in line skating-frames, shafts for lacrosse sticks, hang glider air-frames, camping knife and fork sets, fuselage, turbine casing, missile tail cone, bicycle components, automobile engine casing. [1]. These materials have high strength/weight ratio [2,3], also desired light weight and strength. In other fields, worldwide needs are high performance rate, low cost and superior quality materials have been prepared by researchers which transfer from monolithic to hybrid composite material. A Martinet al. [4] from the studies of the tribological behavior of Al 6061–Al₂O₃ composites resolved, that a characteristic physical mechanism is involved in the wear method. Yu et al. [5] established the special effects of applied load and temperature on the dry sliding wear behavior of the Al 6061–SiC composites, and ended that the wear rate reductions with increased applied load. Reda et al. [6] and Clark et al. [7], in their studies on Al 7075 reported, that pre-aging at various retrogradation temperatures improves the hardness, tensile properties and electrical resistivity. Kim et al.[8] ended that the hardness of aged Al 7075 alloy rises. Doel and Bowen [9] reported the enhanced tensile strength and lesser ductility of the Al 7075 reinforced with 5 and 13 lm SiC particles, than that of unreinforced material. Komai et al. [10] reported on the higher mechanical properties of Al 7075–SiC W composites. It is detected that not enough data is available on the mechanical and wear resistance of particulate reinforced Al 7075 composites. Particulate reinforced aluminium matrix composites are auxiliary materials because of their strength, ductility and toughness as well as their capability to be treated by conventional methods. AMCs are applied successfully to structural components importantly in automobile and aviation industries. This research

work have been emphasized on fabrication of high strength /weight ratio hybrid aluminium composite material with low density using ultrasonic stir casting method.

2. Experimental Procedure

In this research work, a commercial grade aluminium alloy Al 7075 was used as the matrix material, with the reinforcement of Nano graphene , B₄C and Inconel alloy. The hybrid composites were fabricated with reinforcement of (0.5,1,1.5,2) Nano graphene, B₄C(2,4,6,8), Inconel alloy 625 (2,4,6,8) Wt.%. The chemical composition of Al 7075 analysed and shown in Table 1. The base metal weighing 1250g of aluminium was melted in a graphite crucible. Magnesium reinforced with a base metal to improve wettability between base metal and reinforcements. The mixture of reinforcement and 1 wt % of magnesium were added into melt within 10 min at 850 °C with mechanical stirring at the speed of 600 rpm. An ultrasonic probe made of titanium was used to generate a frequency of 20 kHz with 2 kW power. The titanium probe was 20 mm in diameter and 200 mm long. After this stirring process, the ultrasonic stirring conducted for 15 minutes. The mould was preheated to 450 °C then the molten aluminium was finally poured into preheated mould at 850 °C casting temperature.

Table 1
Chemical compositions of AA7075

Elements	Zn	Cu	Mn	Mg	Fe	Cr	Ti	Si	Al
Weight%	5.4	1.42	0.12	2.42	0.42	0.21	0.11	0.13	Remaining

3.Characterization of composites

3.1 Tensile test

A tensile test, also known as tension test, is prepared using a Universal Testing Machine. The machining of the specimens was prepared according to ASTM-E8. The UTM's maximum test load was 100,000N load resolution 5 N , displacement resolution was 0.1mm,and its cross –head speed varied from 0.1 to 500mm/min.

3.2 Hardness test

Hardness is known as the resistance to penetration. It is determined by evaluating depth of the indentation. The fabricated hybrid composite were machined according to the ASTM E92 standard. The Brinell hardness test carried on samples by 250kgs load for 10 seconds.

3.3 Compression test

A compression test determines the characteristics of materials under compressing loads. The specimen is crushed, and deformed at various loads are noted. The compression tests were performed on the cylindrical sample machined as per ASTM E9 at room temperature (25 °C). It is performed on the universal testing machine with compressive fixtures at a constant feed rate of 1mm/mm. The displacement of each sample was exactly measured by the load cell.

3.4 Flexural strength

Flexural test defines the characteristics of material under 3 point bending load. The specimen is crumpled, and distorted at different loads are noted. The flexural tests were performed on the rectangular sample machined as per ASTM E290 at room temperature (25

⁰C). It is performed on the universal testing machine with 3 point bending fixtures at a constant feed rate of 1mm/mm.

4. Results and Discussion

4.1 Tensile Test

Ultimate tensile strength of the hybrid composite material showed by tensile strength experimental evaluation on universal testing machine as per ASTM E8 standard. The Fig.1 shows the difference of ultimate tensile strength respectively with respect to the Nano graphene, B₄C and Inconel alloy 625. The ultimate tensile strength values are decreasing with the increase of hybrid reinforcement wt. percentage but variation in the values is nominal. The moderate variation in tensile strength while increase of hybrid reinforcement wt. percentage. The maximum value of 178 MPa of tensile strength at the wt % of 0.5 % Nano graphene , 2% B₄C and 2% Inconel alloy 625. It was 21.91% less than base metal 7075.

Fig.1 Variation of Ultimate tensile strength

4.2 Yield Strength

Yield strength of composite material exhibited by conducting tensile strength on universal testing machine as per ASTM E8 standard. Fig 3 The yield strength is gradually decreasing with the increase of wt % of hybrid reinforcements but the variation is nominal and maximum value of yield strength 165 MPa is observed at the wt % of 0.5 % Nano graphene , 2% B₄C and 2% Inconel alloy 625. It was 15.81 % less than base metal 7075. The stable variation take place in yield strength while enhancement in wt % of hybrid reinforcements.

Fig.2 Variation of Yield strength

4.3 Elongation percentage

Elongation % of the hybrid composite material showed by conducting tensile strength on universal testing machine as per ASTM E8 standard. Fig 3 displays about elongation percentage. Elongation percentage maintains constant level at the variation of wt percentage of reinforcement only 1 % elongation % occurred at all amount of wt. percentage of reinforcement but the minimal variation appeared while compare base metal aluminium 7075. Elongation percentage of pure aluminium 7075 is 2.5%. It was 60 % comparatively higher than all other wt. % of aluminium hybrid materials. Due to cluster formation and poor wettability in hybrid material elongation the percentage reduced to 1.5 %.

Fig.3 Variation of Elongation percentage

4.4 Compression test

The compression strength of the specimen obtained by conducting compression test on Universal testing machine as per ASTM E9 Standard. The compression strength is decreasing with the increase of wt % of hybrid reinforcements but the variation is minimal and the maximum value of compression strength 330 MPa is noticed at the wt % of 0.5 % Nano graphene ,2% B₄C and 2% Inconel alloy 625. It was 50.68 % higher than base metal 7075. The variation of compression strength are shown in Fig 4.

Fig.4 Variation of compression strength

4.5 Hardness test

Hardness of the hybrid composite material was evaluated by Brinell hardness testing machine as per ASTM 10 standard. The result of hybrid reinforcement particle of matter of Nano graphene, B₄C and Inconel alloy 625 on the composites hardness acquired from Brinell hardness test appears in Fig.5. hardness of the hybrid composite decreasing increase with the hybrid reinforcements. Table 4. displays about hardness of the hybrid composite material. The maximum value of 148 B.H.N at the wt % of 0.5 % Nano graphene , 2% B₄C and 2% Inconel alloy 625. It was 144.62 % higher than base metal alloy 7075.

Fig 5.Variation of Brinell Hardness

4.5 Flexural test

Flexural strength of the hybrid composite material was determined by universal testing machine with 3 point bending fixture as per ASTM E290 standard. The maximum value of flexural strength 447.25 Mpa noticed at 1.5 % Nano Graphene +6 % Boron carbide + 6 % Inconel alloy 625. It was 95.30% higher than base metal alloy 7075 and minimum value of flexural strength 389 Mpa noticed at 0.5 % Nano Graphene + 2 % Boron Carbide 2 % Inconel alloy 625. Fig.6 displays deviation in flexural strength of the hybrid composite material increasing increase with the hybrid reinforcements.

Fig.6 Variation in Flexural strength

4.7 Density and porosity

Density of the hybrid composite material moderately decreases with increase in Wt % of reinforcements. Due to poor wettability between matrix and reinforcement density of composite material decreases. Fig. 7 displays variation of density with respective Wt % of reinforcements. The maximum value of 2.83 kg/mm^3 density noted at the wt % of 1.5 % Nano graphene , 6% B_4C and 6% Inconel alloy 625 and minimum value of 2.81 kg/mm^3 noticed at the wt % of 2 % Nano graphene , 8% B_4C and 8% Inconel alloy 625. During solidification sometimes excessive contractions occurs, this makes the composite with porosity. The maximum value of 40.767 % porosity noticed at the the wt % of 2 % Nano graphene , 8% B_4C and 8% Inconel alloy 625 and minimum value of 14.080 % porosity noticed at the wt % of 0.5 % Nano graphene , 2% B_4C and 2% Inconel alloy 625 . Fig.8 shows variation in porosity of composite material gradually increases with increase in Wt % of reinforcements. Due to improper wettability and gas entrapment in composite increases porosity.

Fig.7 Variation of density

Fig.8 Variation of porosity

4.8 Microstructure Analysis

The microstructure specimen were polished using different kind of emery paper. After every polish cycle were cleaned, dried and cleaned by using a velvet cloth.

The composite was analyzed in the scanning electron microscope to find the cast structure. Fig 9 there was indication of clustering of reinforcement in Metal matrix composites, So some reinforcements are not uniformly dispersed in the hybrid metal matrix composites. Associated to the base alloy, samples with boron carbide and nano graphene reinforcement showed a blackish appearance. Boron carbide small amount of clustering was noticed at 6 % percent reinforcement sample. Due to this clustering reduces strength of hybrid aluminium metal matrix composite. Addition of boron carbide more than 6% reduces density of the composites and it was less the pure aluminium 7075.

Pure Al7075
625

0.5 % Nano graphene + 2 % boron carbide % + 2% Inconel alloy

1% graphene +4 % Boron carbide + 4% Inconel 625 alloy

1.5 % graphene + 6% Boron carbide +6% Inconel 625 alloy

2% graphene 8% boron carbide 8 % Inconel alloy 625

Fig 9 Composites Microstructure

Conclusion

The hybrid aluminium composite material were successfully made by Ultrasonic stir casting method. Ultimate tensile strength moderately decreases owing to cluster formation, poor wettability and porosity. The maximum value of 178 MPa of tensile strength at the wt % of 0.5 % Nano graphene , 2% B₄C and 2% Inconel alloy 625. It was 21.91% less than base metal 7075. Some other properties such as compression strength and hardness also moderately decreases this due to porosity and cluster formation. The maximum value of compression strength 330 MPa is observed at the wt % of 0.5 % Nano graphene ,2% B₄C and 2% Inconel alloy 625. It was 50.68 % higher than base metal 7075. The maximum value of hardness 148 B.H.N noticed at the wt % of 0.5 % Nano graphene , 2% B₄C and 2% Inconel alloy 625. It was 144.62 % higher than base metal alloy 7075. The maximum value of flexural strength 447.25 Mpa noted at 1.5 % Nano Grapehene +6 % Boron carbide + 6 % Inconel alloy 625 It was 95.30% higher than base metal alloy 7075. Density of the composite material gradually decreases due to poor wettability of reinforcement. The maximum value of

2.83kg /mm³ density noted at the wt % of 1.5 % Nano graphene , 6% B₄C and 6% Inconel alloy 625 and minimum value of 2.81 kg /mm³ noticed at the wt % of 2 % Nano graphene , 8% B₄C and 8% Inconel alloy 625. The maximum value of 40.767 % porosity detected at the wt % of 2 % Nano graphene , 8% B₄C and 8% Inconel alloy 625 and minimum value of 14.080 % porosity noted at the wt % of 0.5 % Nano graphene , 2% B₄C and 2% Inconel alloy 625 . Porosity gradually increases with increase in reinforcement. Due to cluster formation between matrix and reinforcement material and other important reasons for porosity was gas entrapment and excessive contractions during solidification.

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