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Investigative Analysis of the Tensile and Impact Strengths of Hybridized Aluminum Metal Matrix Composite Materials

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

New developments in material technology aids in the investigations, reinforcements of new materials which replaces existing materials for various applications. Among those, composite materials play an important role which is a combination of two or more materials with different physical and chemical properties. This research focused on developing an aluminium metal matrix composite (AMMC) material made by wrought aluminium alloy with various weight fractions of aluminium oxide to make five different forms of composites. In this research stir casting process was used. The reinforced composites were tested for their tensile and impact strength properties. The results show that composite with a higher percentage of aluminium oxide has high tensile and impact strength properties than other composites.

Keywords: Wrought aluminum alloy; titanium carbide; composites; stir casting process.

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1. INTRODUCTION

Nowadays automotive industries are focusing on developing new materials in order to increase the life and durability of the products. Hence, lot of research is also going on in developing new materials. Karamis et al. examined the wear behavior of different aluminium matrix composites namely Al 5083 and Al 6063 with different proportions of silicon carbide and concluded that the frictional behavior of the composite is influenced by the contact between projectile and the matrix [1] . Ozden et al. studied the impact behavior of Al matrix composites reinforced with Sic particles under different temperature conditions varying from -176°C to 300°C using Charpy impact test with different sizes of silicon carbide and found that impact strength increases with the increase in particle size [2]. Ezuber et al. [3] studied the corrosion behavior of two aluminum alloys AA1100 and AA 5083 in sea water and found that AA1100 alloy having better corrosion resistance than AA5083.Vijaya Ramnath et al. evaluated the mechanical properties of Aluminum alloy-Alumina-Boron Carbide MMCs fabricated by stir casting with three different compositions of alumina and boron carbide and concluded that aluminum with 2% alumina-3% boron carbide have tensile strength [4]. El-Sabbagh et al. studied the effect of rolling and heat treatment on the tensile behavior of wrought Al/SiC particle metal matrix composite produced by stir casting and found that annealing improves percentage elongation at break [5]. Padmavathi et al. studied the tribological behaviour of the AMMC using Al 6061 alloy with MWCNT and SiC particles prepared by stir casting method followed by die casting. They found that CNTs could have a negative impact on the wear characteristics [6]. Bharath et al. prepared Al 6061-Al_2O_3 metal matrix composite [7] by using stir casting technique and evaluated the mechanical and wear properties of the same and they concluded that increase in the amount of reinforcements increased the hardness and tensile strengths. Abhishek Kumar et al. fabricated a 359/Al_2O_3 MMC using hardness and tensile strength increased linearly with increase in weight % of alumina [8]. Vijaya et al. reviewed work done on aluminum metal matrix composites [9]. Dimensional analysis is a technique in which the parameters of a physical system like material properties, processing conditions and geometry are grouped in dimensionless numbers. This analysis was conducted by Zlokamik et al. [10], and Osswald et al. [11]. Vijaya Ramnath et al. reviewed CNT based aluminum matrix composite and also conducted experiment on it [12,13].

2. EXPERIMENTAL MATERIALS AND METHODS EMPLOYED

In this, materials used, experimental procedures and composition of composites are discussed.

2.1 Materials Employed

In this investigation, wrought aluminium alloy is the matrix material and aluminium oxide is the reinforcement. Their properties are as depicted in Table 1.

2.2 Production Method

In this investigation, stir casting method was used to fabricate the metal matrix composites. In this procedure, reinforcement was heated separately and near to the main process temperature of 450°C. The wrought aluminium alloy also was melted in a crucible in an induction furnace to a temperature of 830°C. Then, the preheated reinforcement was mechanically mixed with the molten aluminium and reinforcement was distributed into a molten matrix by vigorous mechanical stirring. Then the composite was poured into a steel die. The casting was allowed to solidify for 24 hours for complete curing of the mixture. The composite produced was then machined into samples for tensile and impact strength test. The matrix and reinforcement composition are given in Table 2.

Table 1. Properties of Al and Al_2O_3

Density (gm/cm^3)	Aluminium (Al)	Aluminum Oxide (Al_2O_3)
Tensile Strength (MPa)	2.70	3.98
Coefficient of thermal expansion (10^{-6}/°C)	185	416.0
Modulus of Elasticity (GPa)	23	7.4
	70	380

Table 2. Matrix and reinforcement composition

Sample notations	Aluminum (%)	Aluminum oxide (%)
1	98.9000	0.9000
2	97.6000	1.5000
3	96.5000	2.8000
4	95.7000	3.7000
5	94.8000	4.5000

3. TESTING METHOD

The tensile and impact tests were performed on the aluminium metal matrix composite as per ASTM standard to find their strength properties. For the tensile test, a Universal testing machine was used and the test samples were prepared as per ASTM: B557M, while the samples were prepared as per IS 1757 standard for carrying out impact test.

4. RESULTS AND DISCUSSION

4.1 Tensile Test

The tensile test was performed by holding and loading the samples up to fracture. The tensile properties are tabulated in Tables 3 to 5 and also in Figs. 1 to 4. From the graphs, it was concluded that the tensile strength increases with increase in percentage weight of aluminium oxide.

Table 3. Tensile properties

Sample notations	Break load (kN)	Tensile strength (N/mm^2)
Notation 1	3.1700	38.4700
Notation 2	3.3900	41.8267
Notation 3	6.2500	90.4231
Notation 4	6.3700	90.6724
Notation 5	6.4500	92.8947

Table 4. Analysis table for fit of break load against percentage weight of samples

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	Integral $f(X_i)$
1	3.23	0	0.427036	0
1.4	3.26266	0.159526	0.370593	1.2964
1.8	3.35461	0.296474	0.31415	2.61803
2.2	3.75778	2.81436	9.18553	4.00488
2.6	5.28728	4.00548	-3.22995	5.79801
3	6.3	0.2304	-0.419782	8.1658
3.4	6.36494	0.110243	-0.181004	10.7004
3.8	6.40093	0.0855971	0.0577745	13.2539
4.2	6.44148	0.105709	-00174545	15.8221
4.6	6.48231	0.0982909	-0.0196364	18.4069
5	6.52	0.09	-0.0218182	21.0075

Table 5. Analysis table for fit for tensile strength against percentage weight of samples

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	Integral $f(X_i)$
1	38.5	0	8.73033	0
1.4	39.1623	3.22085	7.37393	15.4895
1.8	41.0043	5.89915	6.01753	31.4871
2.2	48.0206	46.7925	148.106	48.7133
2.6	73.18	65.4894	-54.6215	72.7041
3	89.6	3.0953	-6.41362	106.092
3.4	90.4346	1.35138	-2.30599	142.122
3.8	90.9002	1.25051	1.80164	178.391
4.2	91.5757	1.93919	0.594595	214.876
4.6	92.3968	92.3968	0.513514	251.667
5	93.3	2.35	0.432432	288.804

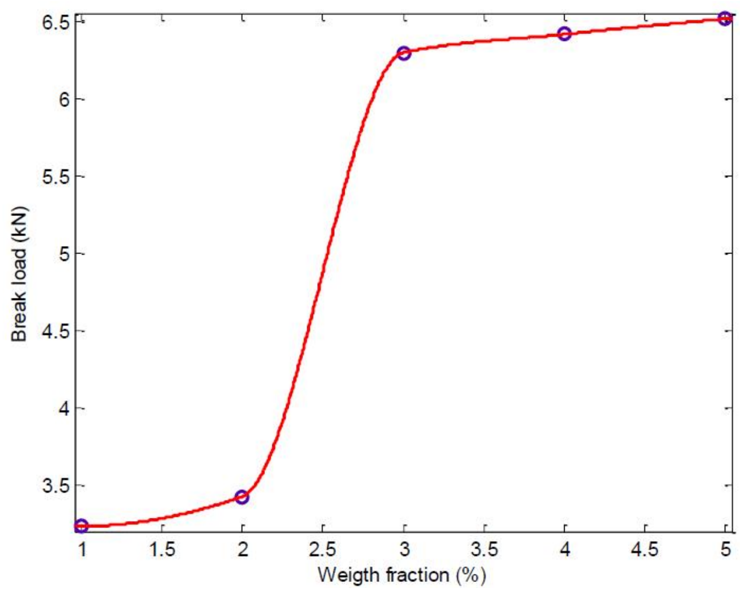

Fig. 1. Fit for break load against percentage weight of samples

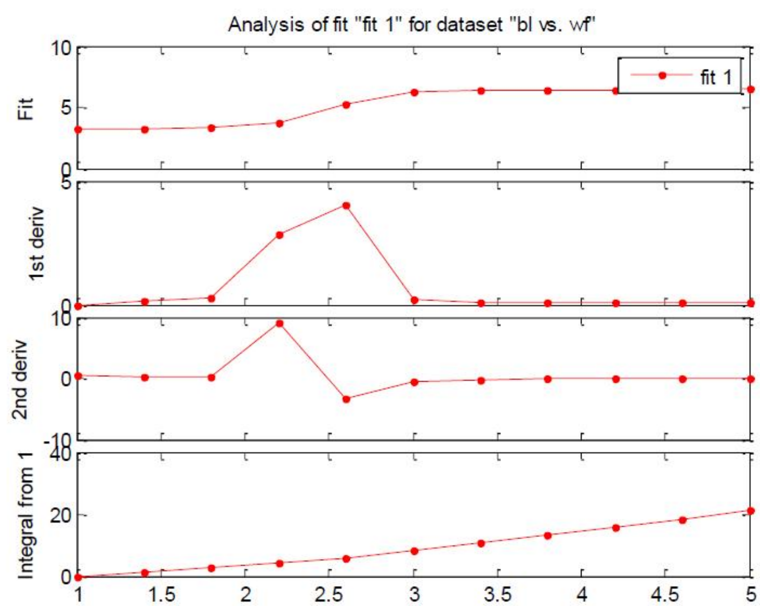

Fig. 2. Analysis fit for break load against percentage weight of samples

Table 6. Impact property of composites

Sample notations	Energy absorbed (Joules)
Notation 1	4.3541
Notation 2	4.4378
Notation 3	4.4206
Notation 4	2.3512
Notation 5	2.0614

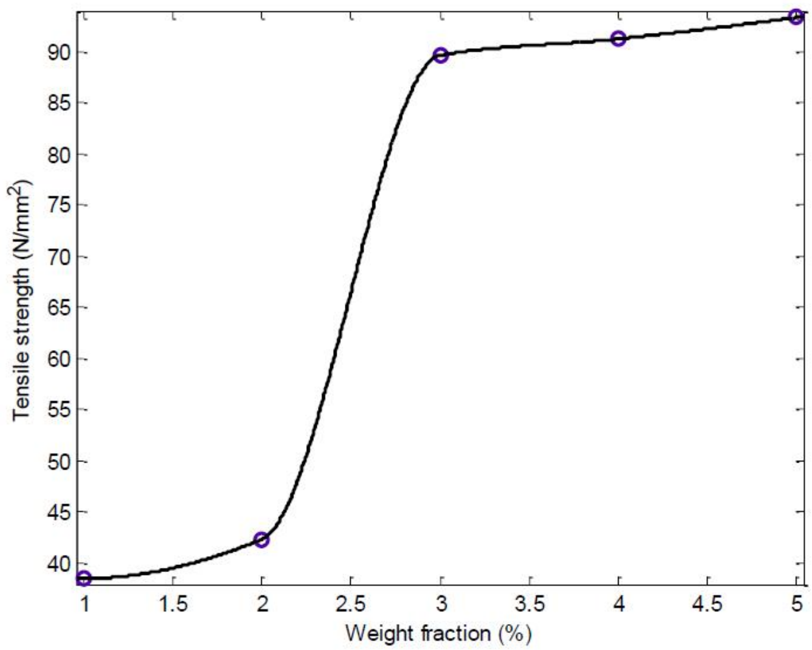

Fig. 3. Fit for tensile strength against percentage weight of samples

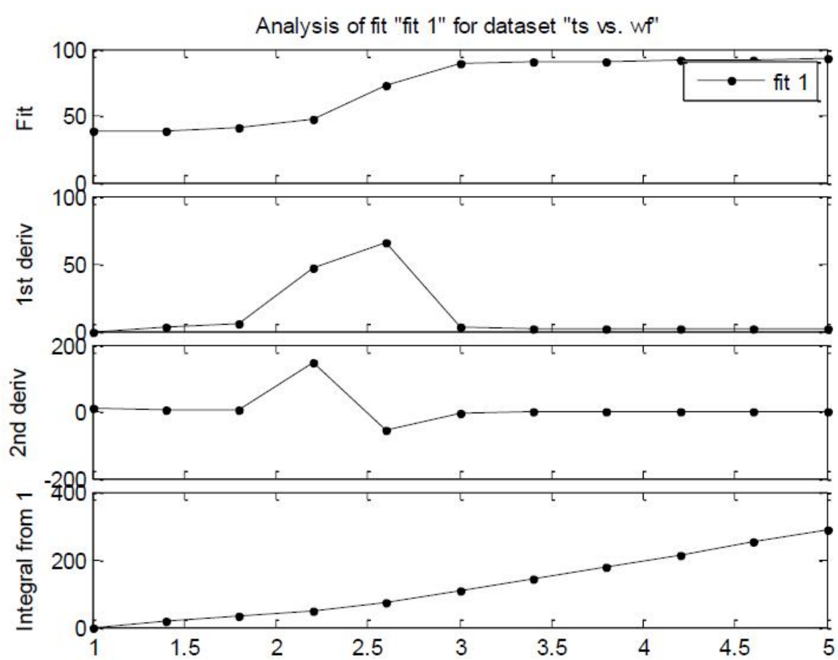

Fig. 4. Analysis fit for tensile strength against percentage weight of samples

4.2 Impact Test

The Charpy test was performed by preparing the samples as per IS: 1757 standard. The impact property is shown in Tables 6 and 7 and shown in Figs. 5 and 6. From Table 6, it was found that the notation 2 absorbs more energy than the other four notations since it contains less amount of aluminium oxide.

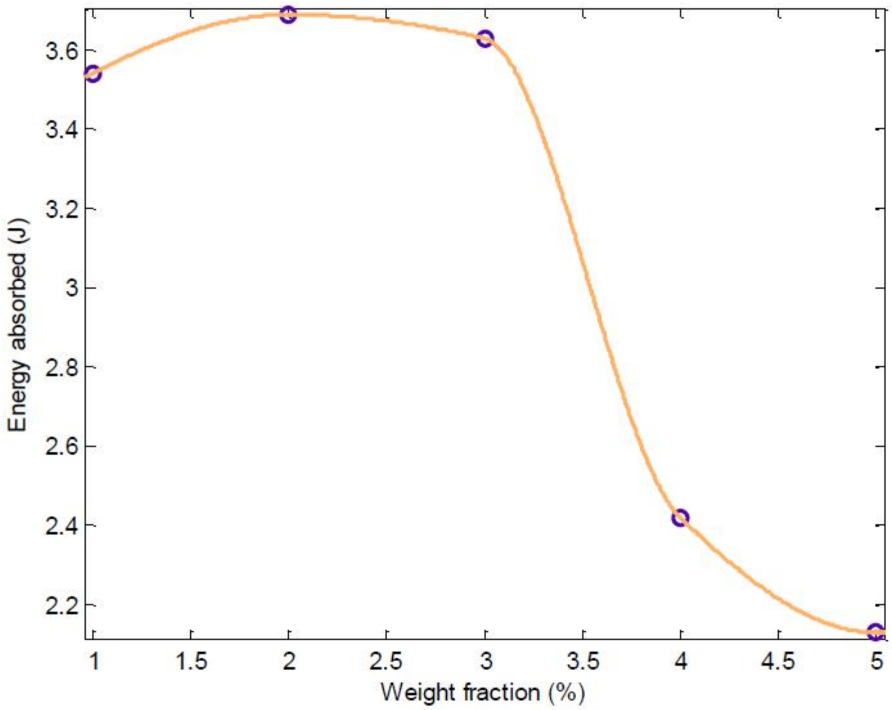

Fig. 5. Fit for energy absorbed against percentage weight of samples

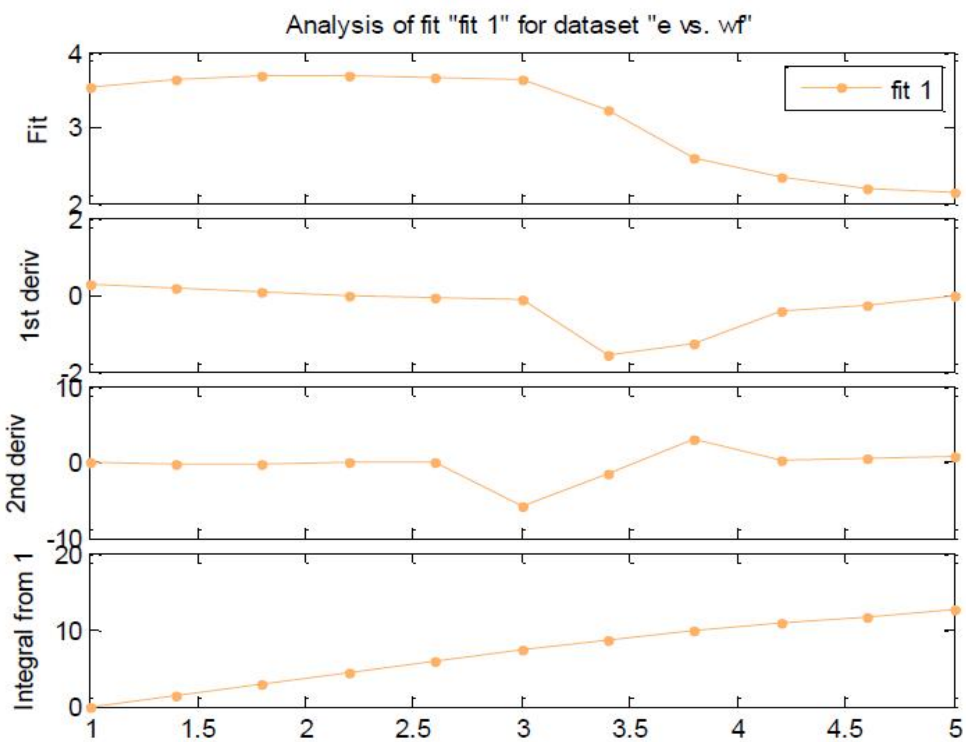

Fig. 6. Analysis fit for energy absorbed against percentage weight of samples

Table 7. Analysis table for fit of energy absorbed against percentage weight of samples

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	Integral $f(X_i)$
1	3.54	0.255	-0.12	0
1.4	3.62952	0.1854	-0.228	1.43483
1.8	3.68256	0.0726	-0.336	2.89875
2.2	3.68742	-0.0255874	-0.124535	4.37408
2.6	3.66758	-0.0726803	-0.110929	5.84571
3	3.63	-0.114331	-5.86694	7.30578
3.4	3.23253	-1.57896	-1.45622	8.69781
3.8	2.60207	-1.2793	2.95451	9.86074
4.2	2.32995	-0.428117	0.266027	10.8351
4.6	2.18716	-0.26883	0.535147	11.7364
5	2.13	0	0.804267	12.5962

5. CONCLUSIONS

In this paper, hybrid composite is fabricated by stir casting process with different proportions of aluminium oxide. It is concluded that the tensile strength of the notation 5 is greater than the other four notations. Notation 2 absorbs more energy than other notations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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