AN EXPERIMENTAL INVESTIGATION ON TENSILE PROPERTIES AND ENERGY ABSORPTION CAPABILITIES OF HYBRID NANO METAL MATRIX (AL 6061+B_4C+SIC) COMPOSITES

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ABSTRACT

Recent advances in automotive, military and aerospace industries require high strength-to-weight ratio, lighter and less expansive, crashworthiness of materials. In this present study, the test samples were manufactured using Al 6061 as base metal by adding 2% Boron Carbide nanopowder by weight fraction and varying composition of Silicon Carbide nanopowder in the matrix of 5%, 10%, 15%, 20% by weight fraction manufactured by in-situ stir casting technique. This paper investigates the tensile properties of UTS, 0.2% yield strength and fracture strength, % elongation and crashworthiness properties initial peak load, average crush load, energy absorbed during the crush and specific energy absorption capabilities. Experimental results revealed that yield strength, elongation % and average crush load, specific energy absorption capacity was increased by reinforcing 5% SiC to Al 6061 + 2% B4C. 20 wt% SiC reinforcement shows that good result in UTS and fracture strength and initial peak load, energy absorbed during the crush.

KEYWORDS: *Al 6061, Silicon Carbidenano powder, Boron Carbide nanopowders, specific energy absorption.*

I. INTRODUCTION

Usage of hybrid nano Aluminium metal matrix composites in military, aerospace, and automotive industries increased tremendously in the recent years due to their superior mechanical properties than ordinary materials, and also due to their good control over the mechanical properties. Hybrid metal matrix composites are cheaper and easy to fabricate. Due to reinforcement of nano ceramic particles the properties of the metal matrix composites shown good results in mechanical properties such as strength, stiffness, modulus of elasticity, hardness, elastic modulus, energy absorption during the crashworthiness and good distribution of nano particles in the matrix due to their size. The commonly used reinforced ceramic particles for the fabrication of metal matrix composites are Silicon Carbide (SiC), Aluminium Oxide (Al_2O_3), Boron Carbide (B4C) and Titanium diboride (TiB_2) in the form of particles or whiskers. The use of single reinforcement to the matrix shown poor results than multiple reinforcements.

Thus, it is essential to identify the properties of the Silicon Carbide for satisfying the requirements of the industries. The mechanical properties of the Al and its alloys greatly influenced by SiC reinforcement. Metal matrix composites were manufactured by in-situ stir casting shows good results than ex-situ methods due to their good wet ability, uniform distribution of particles in the matrix and thermodynamic stability of the particulate phases. Ultimately, the objective of the engineers is to design new materials to absorb more energy during failure of the vehicle structures. The properties of the aluminium metal matrix composites can provide good results than ordinary materials and therefore, aluminium composites are used as a substitute for more traditional materials in crashworthiness applications.

K.L. Tee shown that an improvement in tensile strength up to 61%, 58% in yield strength and 23% in modulus Al-TiB_2 synthesized by the stir casting technique. Addition of Copper improves the mechanical properties of Al metal matrix by not less than 2.5 times. P. Subramanyam Reddy [2] reports on hybrid metal matrix consists of Al-Al_2O_3-SiC tested for flexural and impact properties shows superior properties than base metal by stir casting technique. T. Bergmann [3] investigated energy absorption capabilities of tensile energy absorber element by experimental and numerical study shown that there is a considerable reduction in SEA values while strain effects during high-rate loading tests and quasi static load tests given good results. D.Ramesh [4] Al6061 was reinforced with different reinforcement ratios of sic by stir casting method to evaluate and compare the results with al6061 for better improvement in mechanical properties. The results were shown that there was significant improvement in tensile properties and compressive strength and hardness as the wt% of reinforcement of particles increases as compared to the unreinforced matrix

Investigating the energy absorption capability of a composite tensile energy absorber element, an experimental study was conducted pulling a metallic bolt in in-plane direction through a composite structure. For the quasi-static load case SEA values of 65-195 kJ/kg were achievable, while strain rate effects during high-rate loading tests resulted in considerable reduction in SEA values of 20-40 %. SiC hybrid composites shows less wear rate than unreinforced alloy and Al-Gr composites and graphite particle was a good solid lubricant for improvement in triboligical performance carried out by S. Vinoth kumar [4]. The present investigation focused on different reinforcing nano particles of Silicon Carbide used in the development of hybrid AMCs and how it influences the overall performances of the composites.

II. EXPERIMENTAL PROCEDURES

2.1. Fabrication of the composites

Hybrid nano metal matrix with Al 6061 as the matrix and B4C (2 wt%) nano powder as fixed amount added to matrix and adding different amounts Silicon Carbide nano powder ranging from 5 wt%, 10 wt%, 15 wt%, 20 wt% as the reinforcements introduced in-situ by the stir casting technique. Al ingot was carried out in graphite crucible heated by electrical resistance furnace heated at 950^{o}C and B4C+SiC mixture was preheated separately and adding to the molten aluminium. The mixture was heated to raise the temperature to 1060 ^{o}C and stirred by graphite rod before the temperature was raised to 1080^{o}C. The melt was maintained for 30 min to complete the reaction. Argon was supplied during the melting for trapping the hydrogen. The melt was poured into the mould to produce the size of 25 mm diameter and 150 mm. Specimens were machined according to ASTM E08 standards.

2.2. Testing Procedure

Tensile tests were carried out on ASTM E08 standard specimens. Static tensile tests performed by machine model Tue-Cn-400 universal testing machine. The tests were performed in quasi-static condition with cross head speed of 30 m/min. The tensile and energy absorption properties of the composites were investigated during tensile testing of the composites.

III. RESULTS AND DISCUSSION

3.1. Tensile properties

The test specimens are designated by A, B, C, D, and E given in the table 1. The mechanical properties of the metal matrix composites reinforced with 5, 10, 15, 20 wt% of SiC are shown in table 1. Comparison has been made with Aluminium reinforced with 2 wt% of B4C shown that tensile and fracture strength of the composites was increased by 20.81 % and 18.17 % by adding 5 wt% and 20 wt% SiC to the matrix. Elongation % and yield strength was increased by 70.89% and 5.4% compared to the composite A for the reinforcement of 5wt% of Sic to the matrix. However at high wt% (20 wt %) of SiC to the matrix, both the yield strength and elongation % were lowered compared to 5 wt% composite. This is because of their poor wet ability property which affects the mechanical properties. Fig.1. shows that variation of UTS and % Yield strength of the composites. There is a gradual increment of strength of the composites form B to E expect composite D. This is due to high wt % SiC reinforcement to the matrix. Fig.2. shows that elongation % was increased more for composites B through E than that of composite A. This reveals SiC reinforcement gives more elongation for the composites for the applied load than Al 6061/ B4C composite.

Table 1. Tensile properties for reinforced composites

Test specimen	Designation of the composite	UTS (pa) [% of increment]	0.2% yield strength (pa) [%increment]	Fracture strength (pa) [%increment]	Elongation (%) [%increment]
Al 6061-2wt% B_4C	A	156.86	140	151.02	3.40
Al 6061-2wt% B_4C - 5wt% Sic	B	165.34(+5.1)	148(+5.4)	158.23(+4.5)	11.68(+70.89)
Al 6061-2wt% B_4C - 10wt% Sic	C	183.04(+14.30)	142(+1.4)	175.34(+13.87)	6.72(+49.40)
Al 6061-2wt% B_4C - 15 wt% Sic	D	161.01(+2.5)	100(-40)	153.76(+1.78)	5.30(+35.84)
Al 6061-2wt% B_4C – 20 wt% Sic	E	198.09(+20.81)	102(-37.25)	184.56(+18.17)	7.84(+56.63)

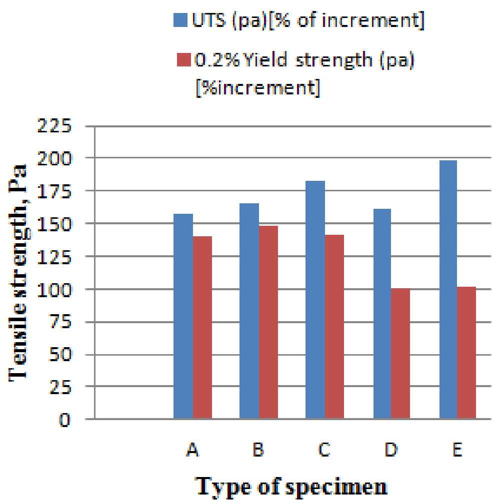

Fig 1.UTS and 0.2% Yield strength of the composites

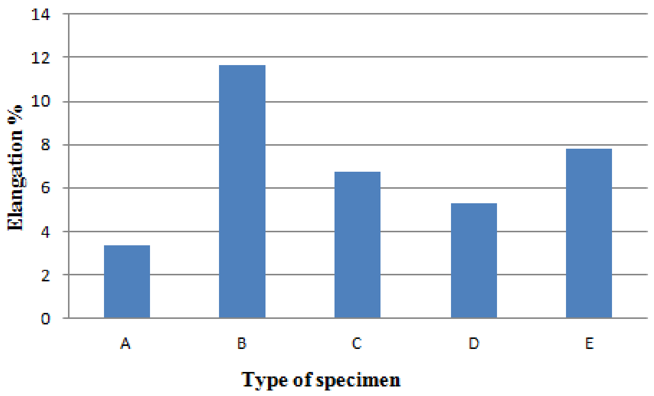

Fig 2. Elongation % of the composites.

3.2 Crashworthiness characteristics

The average tensile load was calculated as, follows:

$$F_a = \frac{\int_0^s F.ds}{s} \quad (1)$$

To get the SEA, the energy absorbed during the tensile loading was divided by the mass of the material.

$$SEA = \frac{\int_0^s F.ds}{m} \quad (2)$$

The experimental results were displayed in the table 2. Average load was calculated by using equation 1 and specific energy of the composite from equation 2. The initial peak load 24.700 kN energy absorbed during the tensile loading was 1235 Joules for composite E. At higher wt% of SiC to the matrix was given more values than that composites from A to D. But there was a decrement in values in mass of the crushed specimen for adding to SiC to the Aluminium metal matrix. Mass of the crushed composite was very high (224g) than for reinforcing the SiC to the matrix. Reinforcement 5 wt% Silicon Carbide to the matrix given more values in average crush load 5.45 kN and specific energy absorption capacity was 10.73 J/kg compared to the composite A.

Table 2. Energy absorption parameters

Test specimen	Type	Initial peak load (kN)	Average tensile load (kN)	Energy absorbed during crush (Joules)	Mass of the crushed material (gms)	Specific energy absorption (Joules per gram)
Al 6061-2wt% B_4C	A	19.560	3.93	978	224	4.39
Al 6061-2wt% B_4C-5wt% SiC	B	20.780	5.45	1039	96.85	10.73
Al 6061-2wt% B_4C-10wt% SiC	C	22.860	4.68	1143	134.80	8.48
Al 6061-2wt%B_4C-15wt% SiC	D	20.140	4.14	1007	192.85	5.22
Al 6061-2wt% B_4C-20wt% SiC	E	24.700	4.94	1235	168.25	7.34

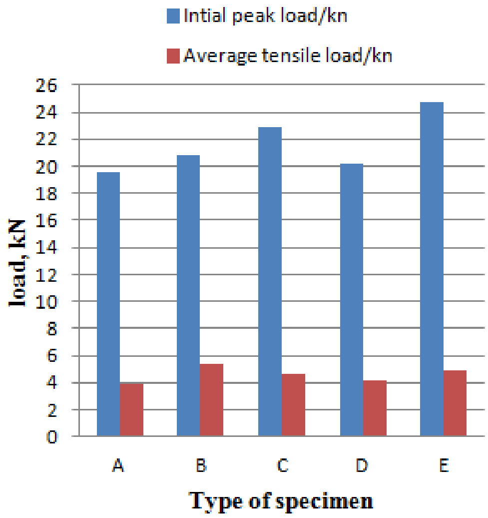

Fig 3. Peak and average load characteristics

Increase in the reinforcement % gives more values of initial peak load and average tensile load of the composites than composite A as shown in fig.3. SEA of the composite increases compared to the composite A for the reinforcement of sic to the matrix.

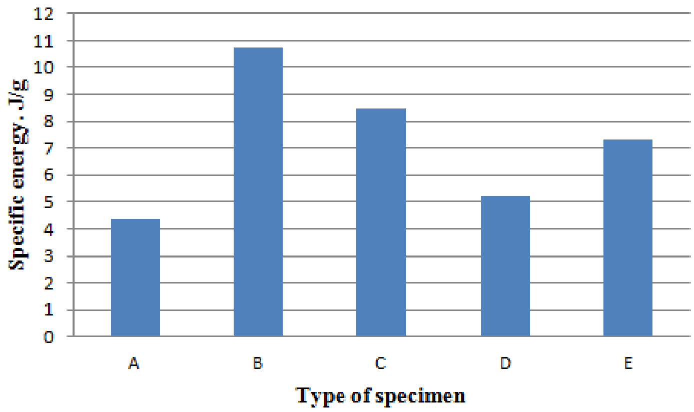

Fig 4. Specific energy characteristics

IV. CONCLUSIONS

In this investigation, tensile and SEA properties of the (Al 6061+B_4C+SiC) hybrid nano metal matrix composite have been evaluated. Specimens are fabricated by in-situ stir casting technique, machined according to the ASTM E08 standard for tensile testing.
Based on the experimental results, it can be concluded that:

- Ultimate Tensile Strength and fracture strength was increased by 20.81 % and 18.17 % for the reinforcement of 20 wt% Silicon Carbide to the matrix.
- Composite B shown that higher values for the reinforcement of 5wt% SiC.
- The highest specific energy absorption and average tensile load was obtained for 5wt% reinforcement.
- Energy absorbed during the crush and initial peak load was high for the composite E.

V. SCOPE FOR FUTURE WORK

The scope for future is to conduct the damage evolution during the tensile loading by scanning electron microscopy for the better understanding of agglomeration of particles in the matrix and failure mode of composites during the loading.

ACKNOWLEDGEMENTS

I would like thank to my guide Dr.Y.Hariprasad Reddy garu and B.Chandra Mohan Reddy garu supported to me to complete my entire work.

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