Investigation of mechanical properties ofAl7068/ SiC/ Al_2O_3 / Fly ash Hybrid Composite

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Abstract
Hybrid composites displays significantly enhanced properties including high specific strength; specific modulus, damping capacity and good wear resistance than unreinforced alloys and common Metal Matrix Composites (MMC). The mechanical properties of Hybrid Aluminum Metal Matrix Composites of Aluminum Alloy AA7068 with reinforcements like Silicon Carbide (SiC), Aluminium oxide (Al_2O_3) and Fly Ashin various compositions are discussed in this study. The AA7068 is combined with 2-6% SiC, 2-6% of Al_2O_3 and a constant of 2% of Fly ash powder in varying configurations using stir-casting process.Experimental results revealed that the tensile strength of the hybrid metal matrix composite (HMMC) with more than two reinforcements in a particular weight percent combination is found to be 20% higher than that of cast AA7068 alloy. It is also found that it is also with an increase of 21.5% more in impact strength and 12.4% more in hardness strength than that of cast alloy without reinforcement.

Keywords—Metal Matrix Composite, Hybrid composite, Al 7068, SiC, Al_2O_3, Fly Ash, Stir Casting

1. Introduction

Hybrid Metal Matrix composites (HMMC) fabrication has become new trend in developing new materials for various applications. Al 7068 is rapidly gaining traction in a variety of technological fields, including automotive and aerospace. The most often used reinforcing materials for aluminium alloy composites are silicon carbide (SiC), aluminium oxide (Al_2O_3), boron carbide (B_4C), titanium carbide (TiC), Tungsten Carbide (WC) Zirconium di-oxide (ZrO_2), and graphite (Gr) in the form of powders or whiskers.Madhusudhan M et al [2017] reported that addition of Zirconium dioxide particles in 2-8 wt% as reinforcement with Al7068 improved the tensile strength and hardness properties.Mohammad Alipour et al [2017] in his work synthesised AA7068 composite by Stir casting method with ultrasonic waves using graphene nanoplatelets as reinforcement, reported that ultimate tensile strength and wear resistance of the composite is better than the alloy.

K. Maruthi Varun [2019] studied the behaviour of Hybrid Metal Matrix Composite (HMMC) prepared by adding reinforcements like Silicon Carbide(3%, 6% & 9%) and Molybdenum Disulphide (1%) in various proportions and reported that AA7075 + SiC(9%) + MoS_2(1%) had better hardness and tensile strength.Anton Yu. Nalivaiko et al [2020] used hydrothermal oxidation process to develop aluminum powder composites and discussed the improvement of mechanical properties of AA7068 alloy. C. Sivakandhan et al [2020], fabricated Metal Matrix Composite (MMC) by adding tungsten carbides (WC) with AA 7068 using Spark Plasma sintering technique and optimized the parameters like temperature, pressure and holding time for fabrication to maximise the tensile strength.J. Lakshmipathy et al [2017], found that the mechanical behaviours of HMMC can be improved by powder metallurgy technique using Al7068 as matrix with Molybdenum disulphide and Tungsten carbide powder as reinforcements.

Thella BabuRao [2021] addressed the effect of using nanoparticles of 2% SiC in improving the yield strength and wear resistance of Al7075/SiCnp Composite. S.Kolappan et al [2022] have found that Al7068 HMMC fabricated with SiC, coconut shell fly ash and nano magnesium improved the tensile strength and hardness.R.Srinivasan et al [2022] developed a HMMC by adding Titanium carbide (TiC) and Graphite (Gr) to Al7075 at various compositions and found that Tensile strength and Hardness have improved well in the hybrid composite.C. Ramesh Kannan et al [2022] fabricated Hybrid composite using AA8014/ SiN_4/ $ZrO_2$by conducting experiment with various combination of process parameters and found the optimum reinforcement percentage, stir speed and molten temperature.

Thus studies showed that the Hybrid matrix fabrication proves to be stronger and better in mechanical properties so fabrication of Aluminium Hybrid Metal Matrix Composite is done in this research. Alalloy 7068 (AA7068)is selected as the matrix material in this study to fabricate a Hybrid Metal Matrix Composite (HMMC), since very less studies are conducted using it.Al 7068 is rapidly gaining traction in a variety of technological fields, including automotive and aerospace.Hybrid Metal Matrix Composites can be made via the accretion of reinforcing phase to the matrix (MMCs).Powder metallurgy, spray atomization and co-deposition, plasma spraying, stir casting, and squeeze casting are all viable options.

The HMMC in this investigation is made using the stir casting method.Stir casting is commonly regarded as one of the most efficient ways for manufacturing discontinuous metal matrix composites, and it is frequently employed in industry.Its benefits stem from its ease of use, versatility, and cost-effectiveness in large-scale production.The key issue in this process is acquiring enough liquid metal to wet the particles and achieving a uniform particle dispersion. Reinforcements chosen for this study are Silicon Carbide (SiC), Aluminium oxide (Al_2O_3) and Fly Ash because of their property enhancement quality and to enable us to compare the result with already existing studies.

2. Experimental Procedure

Aluminiumalloy AA7068 with Fly ash, Aluminium oxide, and Silicon Carbide as reinforcements at varied compositions are used in this research to improve mechanical properties.Table 1 shows the chemical composition of Aluminum Alloy 7068.

Table 1:Aluminum Alloy 7068chemical composition

Element	Zn	Mg	Cu	Fe	Zr	Si	Others	Al
Weight %	8.3	3	2.4	0.15	0.15	0.12	0.3	Balance

The AA7068 was melted at 800°C using a graphite crucible inside an electric heating furnace.The reinforcements SiC, Al2O3 and Fly Ash are preheated to 550°C in the furnace separately. The preheated reinforcements are added in the crucible containing molten AA7068and stirredusing a motorized stirrer running at 600 rpm speed. Magnesium (1%)is introduced into the crucible while adding reinforcements to facilitate wettability of reinforcing particles on the matrix material.

Variable weight percentages of reinforcements are introduced to the molten metal and swirled at a uniform speedwith a ceramic coated stirrer to produce consistent reinforcement distribution.This enables basic reinforcements to move around in liquid metal. The various combinations of AA 7068 with reinforcements are listed in Table 2.

Table 2: Composition of Specimens

HMMC's with various reinforcements and their composition in wt%				
Sample No.	**Al 7068 wt%**	**FA wt%**	**SiC wt%**	**Al_2O_3 wt%**
Sample 1	100	0	0	0
Sample 2	90	2	2	6
Sample 3	90	2	3	5
Sample 4	90	2	4	4
Sample 5	90	2	5	3

Sample 6	90	2	6	2

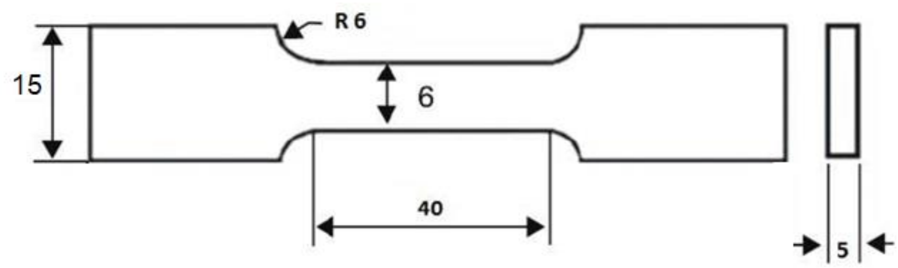

Figure1. ASTM- B557M standard specimen

The tensile test specimens were prepared as per ASTM B557 M standards for testing as shown in the Figure1. Also Hardness Test specimens were produced to the specifications and polished at room temperature prior to getting tested with a SAROJ RAB-250 Hardness Tester.

3. RESULTS AND DISCUSSION

3.1 MICROSTRUCTURE EVALUATION

Microstructural Characterization of the Cast samples were done using Scanning Electron Microscope (SEM) for various composition of samples. The microstructure with a magnification of 350X of Cast AA7068 along with all the other HMMCs fabricated by adding the reinforcements are shown in Figures. 2–7.

The microstructural study revealed that the reinforcement particles were evenly distributed throughout the cross-section and that they were concentrated in one area and at the primary alpha aluminium matrix's grain boundaries.

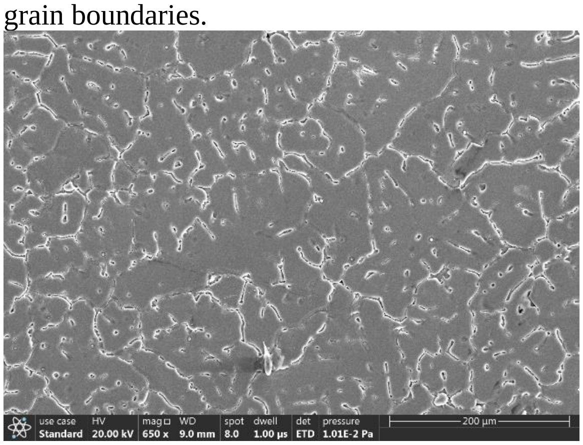

Figure2. AA7068 Cast Alloy

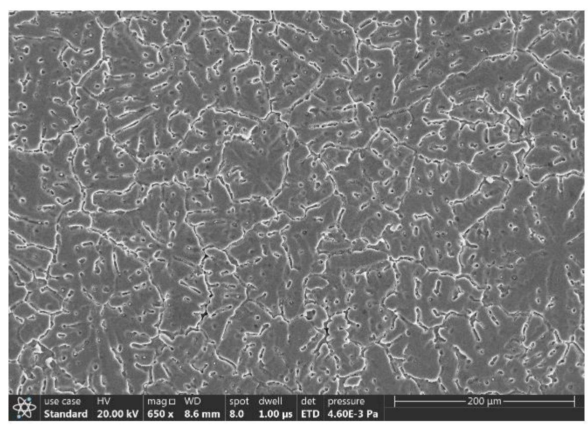

Figure3. AA7068+ 2 Wt.% FA+ 2 Wt.% SiC+ 6 Wt.% Al_2O_3

Vol 12 Issue 03 2023
ISSN NO: 2230-5807

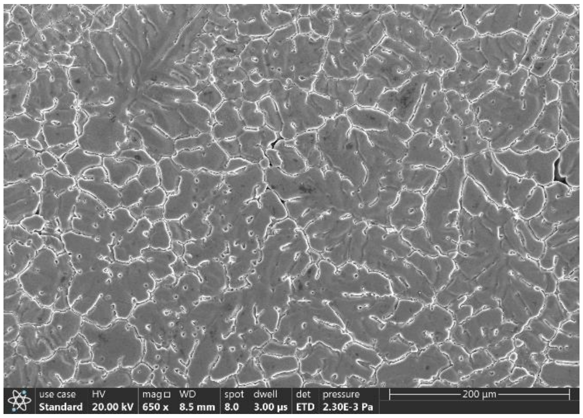

Figure4. AA7068+ 2 Wt.% FA+ 3 Wt.% SiC+ 5 Wt.% Al_2O_3

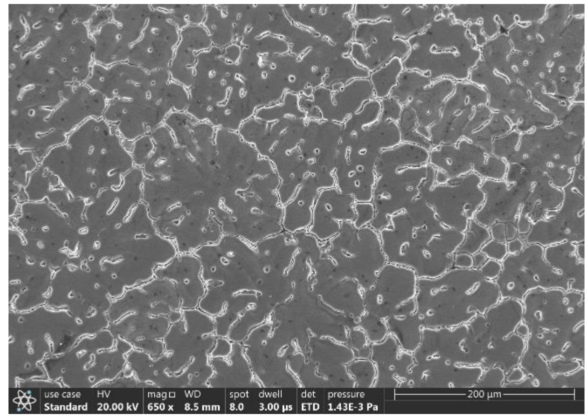

Figure6. AA7068+ 2 Wt.% FA+ 5 Wt.% SiC+ 3 Wt.% Al_2O_3

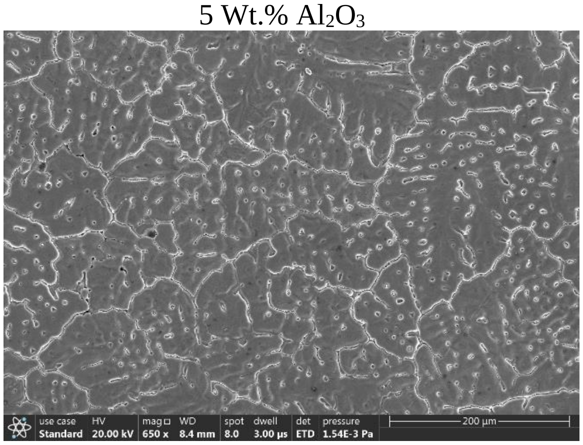

Figure5. AA7068+ 2 Wt.% FA+ 4 Wt.% SiC+ 4 Wt.% Al2O3

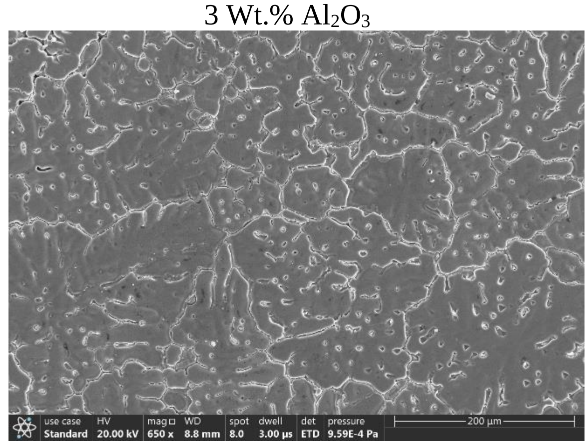

Figure7. AA7068+ 2 Wt.% FA+ 6 Wt.% SiC+ 2 Wt.% Al_2O_3

3.2 Tensile test

The tensile test was conducted on all the six samples and the test values are noted down. Cast AA7068 has a tensile strength of 202 MPa, with specimens includingAA7068+ 2 Wt.% FA+ 4 Wt.% SiC+ 4 Wt.% Al_2O_3having a maximum of 242 MPa.The Figure8 illustrates that as the weight percentage of reinforcement is increased, the tensile strength improves.The tensile strength of AA7068 reinforced composites is 19.8 percent higher than that of AA7068 alloy. The experimental elongation curve of a reinforced aluminium metal matrix is also shown in Figure9.Experimentally, it was revealed that as the weight percentage of reinforcements in AA7068 MMC rose, the elongation of HMMCs fell.The elongation of the specimen AA7068 alloy is 6.44 percent, but it is only 4.16 percent for the specimen AA7068 with reinforcement (AA7068+ 2 Wt.% FA+ 4 Wt.% SiC+ 4 Wt.% Al_2O_3).

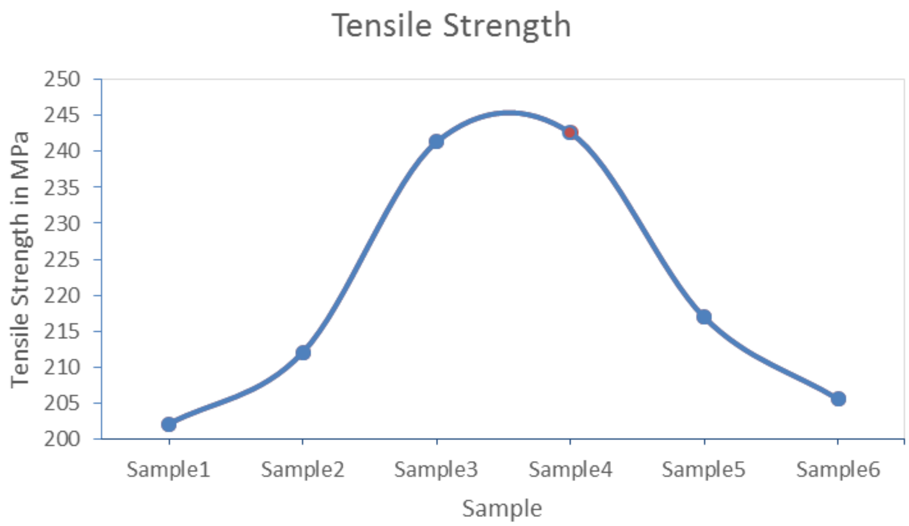

Figure8. Tensile strengths of Test Specimens in MPa

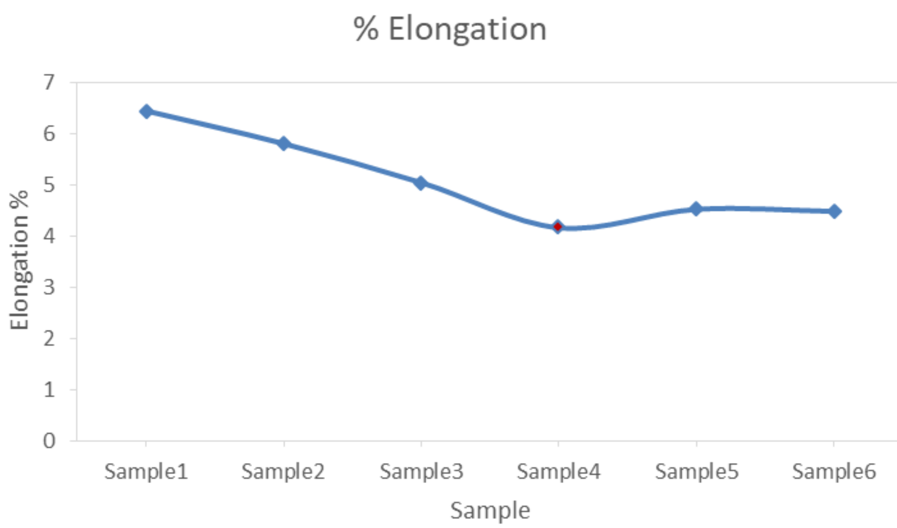

Figure9. Elongation% of Test Specimens

3.3 Impact Test

ASTM E23 standard is used to test the impact strength of the samples. Measured impact strength for the each specimen mentioned as bar chart in Fig. 10. Maximum impact strengthof 7.9 Joules is obtained for sample 4 withAA7068+ 2 Wt.% FA+ 4 Wt.% SiC+ 4 Wt.% Al_2O_3.

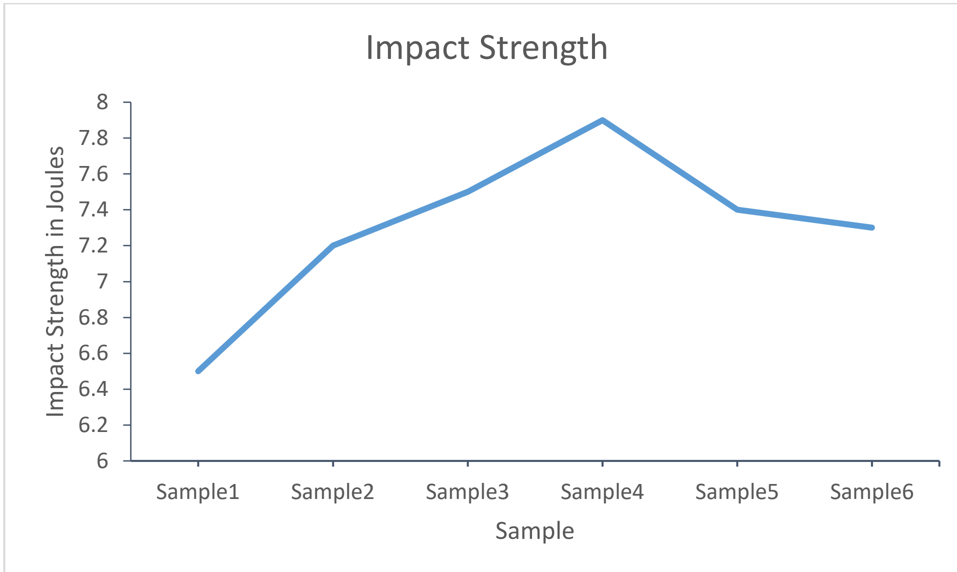

Figure10. Impact Strength of Test Specimens

3.4 HARDNESS TEST

The test is carried under load of 187.5kgf with ball dia of 2.5mm and dwell time of 15 seconds. The variation of average hardness in BHN has been plotted on a graph. The Figure10 demonstrates that the hardness increases as the weight percentage of reinforcement increases, showing good bonding between the aluminum matrix and the reinforcements and that the hard particles are appropriately distributedin the matrix.

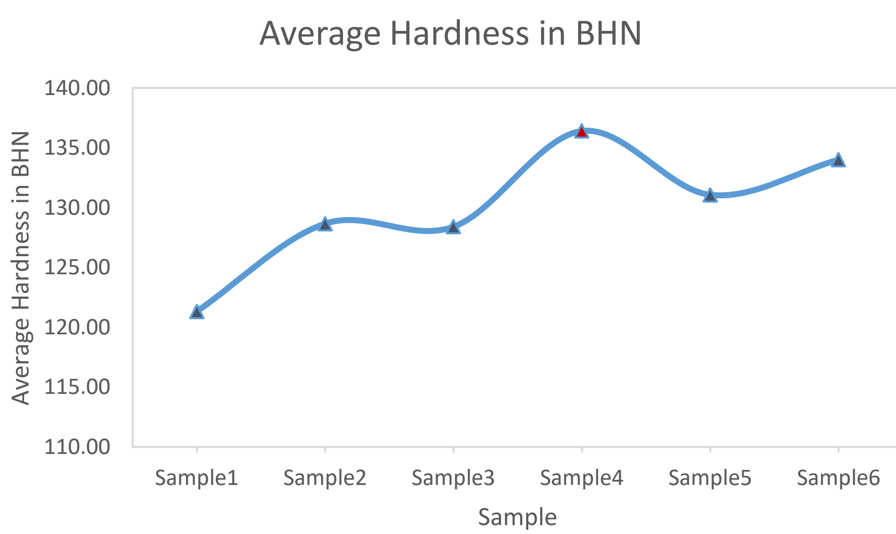

Figure10. Average Hardness of Test Specimens in BHN

The sample 4 containing AA7068+ 2 Wt.% FA+ 4 Wt.% SiC+ 4 Wt.% Al_2O_3has a higher hardness value than the other samples**.**

Conclusion

Hybrid composite fabricated have provided better properties with enhancement in Tensile strength and hardness of the AA7068 composite reinforced with SiC, Al2O3and Fly ash. The reinforced composites

- The microstructure images reveals that the reinforcements were distributed evenly in the Composite.

- In particular, the addition of Al_2O_3 higher than SiC with constant Fly ash have good improvement on the tensile strength (20%), Impact Strength(21.5%), and hardness value (12.4%). Thus Al_2O_3 wt% increase affects the mechanical properties of AA7068 more compared to the SiC addition.
- The elongation % seems to be reduced on addition of reinforcements, particularly SiC addition seems to impact the elongation % more than that of Al_2O_3.
- The sample 4 with **AA7068+ 2 Wt.% FA+ 4 Wt.% SiC+ 4 Wt.% Al_2O_3**have better tensile strength, elongation %, impact strength and hardness number when compared to other samples**.**

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