Karunya INSTITUTE OF TECHNOLOGY AND SCIENCES
Deemed-to-be University

MECHANICAL CHARACTERIZATION OF AA5083(O) ALUMINUM METAL MATRIX COMPOSITE REINFORCED WITH RECYCLED CERAMIC POWDER

Done by
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Motivation for the research

To synthesize and characterize of aluminium metal matrix composite in a sustainable manner. In the sustainable manner i used recycled fuse carrier ceramic particulates for reinforcement.

Problem Definition

Recycling of wasted fuse carrier by adding with aluminium AA5083 and recycled ceramic powder mixture.

Literature Survey

SL.NO.	TOPIC	EXPLANATION	DATE	AUTHOR
1.	Experimental Evaluation of Mechanical, Wear and Corrosion properties of AA5083/Graphite Metal Matrix Composite Prepared using Compocasting Process	In the present research work an experiment was developed to synthesize metal matrix composite adopting Aluminium Alloy (AA) 5083 as matrix material reinforced with graphite particulates (6 wt %, 8 wt % & 10 wt %) using two stage in-situ stir casting process	November 30, 2019	J.Pradeep Kumar, D.S.Robinson Smart, Erick C. Jones

SL.NO.	TOPIC	EXPLANATION	DATE	AUTHOR
2.	A SURVEY ON EFFECTS OF REINFORCEMENT ON ALUMINIUM METAL MATRIX COMPOSITES	In the present industrial scenario Aluminium and its alloy based composites are having importance in the elevating fields of engineering. Aluminium metal matrix composite (AMMC) are mostly preferred for their density, high strength to weight ratio, hardness, corrosion resistance, fatigue and creep resistance.	9, September 2017	G.Sivakaruna, Dr. P.Suresh Babu

SL.NO.	TOPIC	EXPLANATION	DATE	AUTHOR
3.	Characterization and mechanical properties of stir-rheo-squeeze cast AA5083/MWCNTs/GNs hybrid nanocomposites developed using a novel preform-billet method	To control the problem of segregation of the nano dispersoids, the study successfully employs a novel approach of making nano-preform billets of the reinforcements by green compacting and then introducing their sections to the alloy melt having compositions 0.5, 1, 1.5, 2, and 2.5% by weight, while stirring. MWCNTs and GNs in 1:1 ratio mixed and milled with ten times the high purity Aluminum (Al) powder volume.	29 December 2020	Abou Bakr Elshalakany, Vineet Tirth, Emad El-Kashif, H.M.A. Hussein, W. Hoziefa

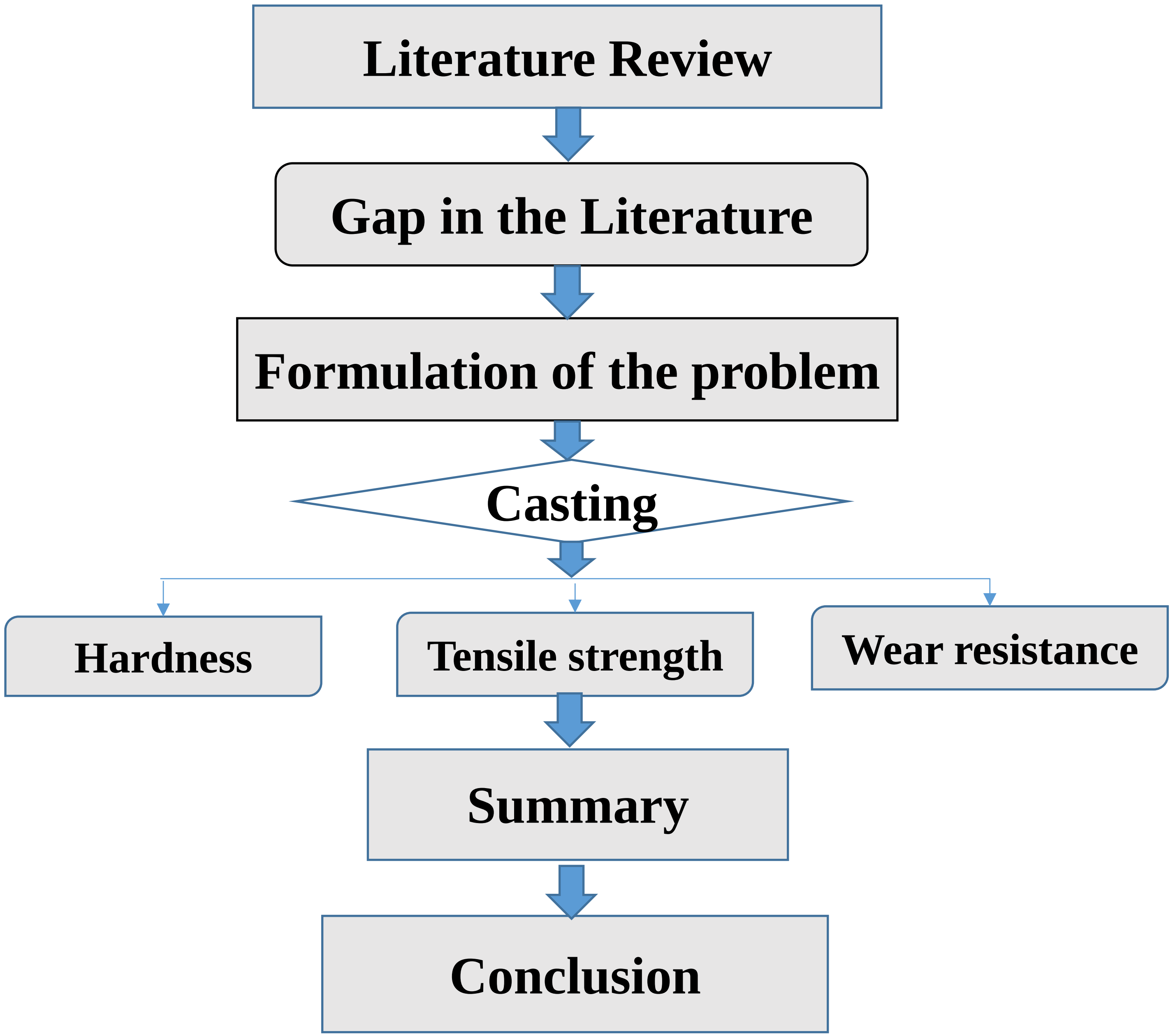
SL.NO.	TOPIC	EXPLANATION	DATE	AUTHOR
4.	Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite	The widespread adoption of particulate metal matrix composites for engineering applications has been hindered by the high cost of producing components. Although several technical challenges exist with casting technology yet it can be used to overcome this problem. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which affects directly on the properties and quality of composite material.	04, july 2009	Manoj Singla, D. Deepak Dwivedi , Lakhvir Singh, Vikas Chawla

SL.NO.	TOPIC	EXPLANATION	DATE	AUTHOR
5.	Preparation and Characterization of Aluminium-Silica Metal Matrix Composite	The excellent properties of these materials and relatively low production cost make them a very attractive for a variety of applications. In this present work, Al alloy LM13-SiO2 composites were produced by stir casting method. The reinforcement SiO2 particle size used for preparation of composites are 106µm, 150µm, 250µm and 355µm with varying amount of 3 to 12 wt% in steps of 3. The prepared composite specimens were machined as per test standards. Effects of weight percentage of SiO2 particles on wear, tensile strength of Al alloy LM13-SiO2 composites have been investigated.	01 ,May 2018	G B Mallikarjuna, E 1asavaraj

Objectives

- To synthesize aluminum metal matrix composite
- To do mechanical and metallurgical aluminum metal matrix composite

Methodology



Applications

Most of the engineering applications such as aviation, defense, marine and automotive requires components with light weight and along with favorable,

Mechanical properties;

This demand perhaps satisfied by metal matrix composites (MMCs) of aluminium by virtue of its distinguished achievement.

EXPERIMENTAL DETAILS

Matrix Material

Aluminium Alloy (AA) 5083 was chosen as the base matrix material with magnesium as the primary alloying element as demonstrated in Table 1. The mechanical and physical characteristics of AA5083 matrix material is delineated in Table 2. Alloys in this series avail excellent welding characteristics and high resistance to corrosion in marine atmosphere. AA5083 aluminum alloy has highest strength of the non-heat treatable alloy, one of the major drawback of the AA5083 that it is not reusable and cannot be used above 650°C temperature.

Table 1: Chemical composition (wt%) of 5083 aluminium alloy

<table>
<tr><th>Element</th><th>Mn</th><th>Fe</th><th>Cu</th><th>Mg</th><th>Si</th><th>Zn</th><th>Cr</th><th>Ti</th><th>Al</th></tr>
<tr><th>Min</th><td>0.4</td><td rowspan="2">0.4</td><td rowspan="2">0.1</td><td>4</td><td rowspan="2">0.4</td><td rowspan="2">0.25</td><td>0.05</td><td rowspan="2">0.15</td><td rowspan="2">Balance</td></tr>
<tr><th>Max</th><td>1.0</td><td>4.9</td><td>0.25</td></tr>
</table>

Table- 2: Physical and Mechanical Properties of AA5083 aluminium alloy

S.No	Properties	Units	Values
1	Density	g/cm3	2.80
2	Melting Point	°C	635
3	UTS	MPa	317
4	YS	MPa	229
5	Shear Strength	MPa	190
6	% Elongation	-	16
7	Poisson’s Ratio	-	0.33
8	Crystal Structure	-	FCC

Particulate Material

One of the important functions of reinforcement in a composite material is to improve the mechanical property. In this work we are using recycled fuse carrier ceramic material, is an inorganic, non-metallic oxide, nitride, or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension.

Fig. 1. Before Recycling Fuse Carrier Ceramic materials

Fabrication Process

Owing to its cost effectiveness and simplicity, Conventional stir casting method was preferred to develop the aluminium MMCs. The AA5083 alloy as exposed in the Figure 2 were blended inside the crucible with its melting temperature inside the stir casting furnace as demonstrated in the Figure 4. Fuse Carrier Ceramic of 99.5% purity with particle size less than 20µm was preheated before mixing with aluminium melt. Legitimate stirring is obligatory to accomplish orderly distribution of reinforcement in the matrix material. The melt is stirred with the guidance of mechanical stirrer in order to develop a vortex. Meanwhile, Fuse Carrier Ceramic particulates with 4, 8 & 12 wt% were preheated and fed in to the aluminium melt at constant feed rate.

Fig.2. Pure AA5083(O)

Fig.3. Recycled Fuse Carrier Ceramic Particles

The various process parameters used to contrive the aluminium metal matrix composite material is displayed in Table 3. After continuous stirring of the molten mixture, it was discharged in to the preheated permanent mould at room temperature, which is previously adopted for required dimensions for accomplishing specimens. After cooling, the samples were taken out from the mould and the required specimens were cut using Wire Cut EDM machine for further testing and analysis.

Fig.5. Stir Casting Process

Fig.6. Moulding

Table.3. Testing Specification for Stir Casting

S.No	Process Parameters	Value
1	Stirring Time	5 mins
2	Stirring Speed	200 rpm
3	Melting Temperature	600°C
4	Crucible Size	4 (Bell Crucible)
5	Furnace	Electric muffle furnace
6	Preheating Temperature	500°C
7	Maximum Temperature of furnace	1100°C

Composition of Specimens

In this experiment, the fabrication is done by Stir casting. For fabrication matrix material is taken as aluminium alloy AA5083(O) and reinforcement as recycled fuse carrier ceramic. These materials are taken in different composition which are listed below table 4

Table.4. Compositions of each specimens

Elements	Specimen 1		Specimen 2		Specimen 3	
	In gms	In (%)	In gms	In (%)	In gms	In (%)
AA5083	960	96	920	92	880	88
Reinforcement (Fuse carrier ceramic particulates)	40	4	80	8	120	12

Specimen 1

Specimen 2

Specimen 3

Specimens

Fig. 7. Specimens

Mechanical Characteristics of Composites

The mechanical properties specifically microhardness of the cast specimens and Ultimate Tensile Strength (UTS) were explored. Tensile test was implemented out to assess the mechanical behaviour of developed AA5083/Ceramic aluminium metal matrix composite material. Figure 8 shows the tensile specimen in consonance with ASTM E8M04 standard. Tensile strength was regulated by employing digitalized universal testing machine alongside maximum load about 50 kN.

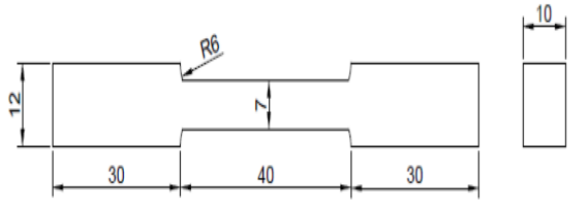


Fig. 8. ASTM E8 Standard Tensile Strength

The microhardness was retrieved using Vickers microhardness tester according to ASTM E92 standard specimen as shown in Figure 9. Each sample is polished using emery papers before micro-hardness test is conducted. 15 N load was enforced at the same time as the indentation for every test with an interminable dwell time of 5 seconds. At 10 disparate spots the microhardness of the advanced composite material was resolved to furnish repeatability of the secured results.

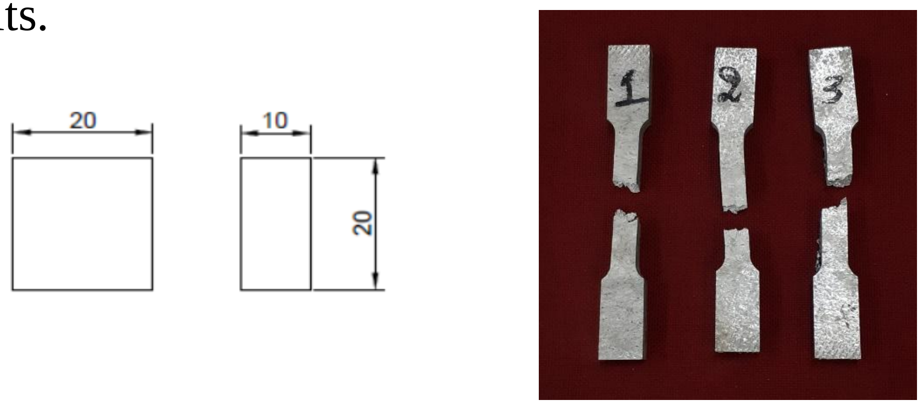


Fig.9. ASTM E92 Standard hardness specimen

Wear Behaviour of Composites

A computer unified pin on disc machine (DUCOM – TR 20-LE) as shown in the Figure 10 was employed for the investigation of wear rate at room temperature. The machine consists of a fixed arm with pulley at one end and a stationary pin at other end. Before each attempt, the specimens were gleamed using recognizable SiC emery sheets to persuade homogeneous surface roughness (Ra value of 0.03 μm). In line with typical ASTM G99 30 mm height & 8 mm diameter wear samples were flourished over wire EDM method and the surface was gleamed metallographically. Every analysis was bolstered 3 times & a balance data was depicted. Experiment was conducted at loading condition of 15 N at a sliding distance of 2000 m, 1 m/s and track diameter of 80 mm.

Fig. 10. Pin on Disc Machine (DUCOM – TR 20-LE)

RESULTS AND DISCUSSION

Tensile Strength

Tensile tests were conducted to estimate the yield strength, ultimate tensile strength and various properties. The empirical testing authorized the stress-strain curves for AA5083 augmented 4, 8 and 12 wt% Ceramic particulates. It is observed that the yield strength decreases with upturn in wt% of reinforcement in the composite material. It is not necessary that the graph between percentages of reinforcement versus yield strength should have to be a linear one. Figure 11 depends on the elastic nature of the composite under consideration, and the stress at which the material begins to deform plastically

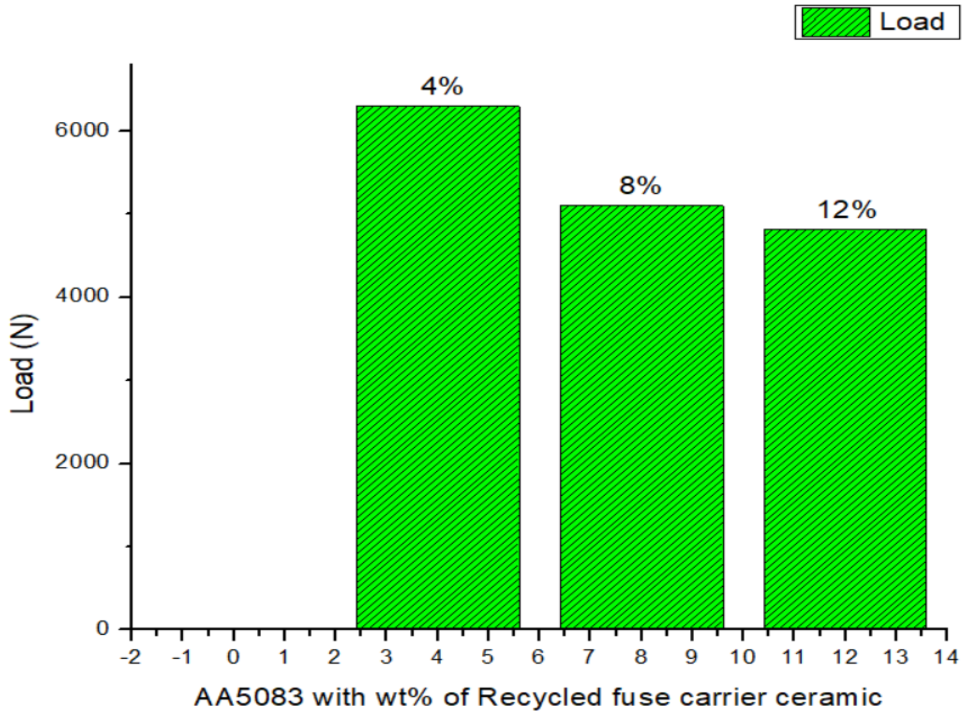


Fig.11. Load vs AA5083 with wt% of Recycled fuse carrier ceramic

Microhardness

From Table 5, it can be analysed that the hardness increases marginally with raise in weight percentage of ceramic. This steady increase in hardness can partially prove the dispersion of Recycled fuse carrier ceramic particulates in AA5083 metal matrix. The superior value of hardness of composites illustrates that the continuation of ceramic particulates in the matrix. The presence of ceramic reinforcement starts to the increase in deprive to plastic deformation of the matrix during the hardness test. From Figure 12, the appreciable hardness difference between samples can be studied.

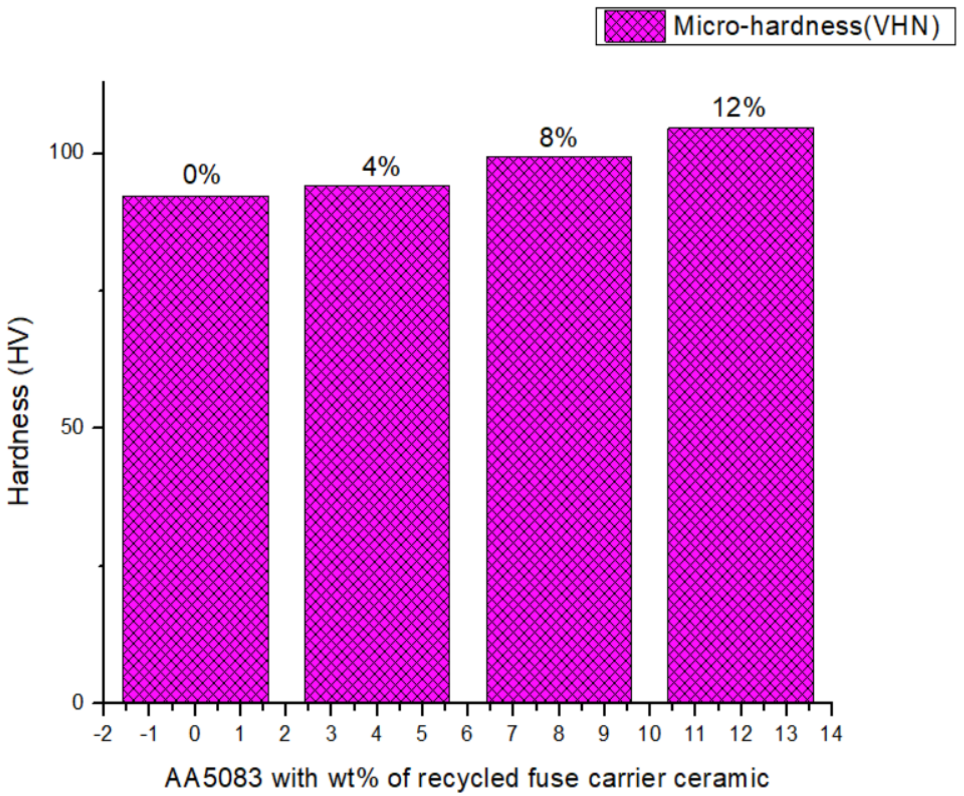


Fig.12. Hardness of AA5083/Ceramic particulates with respect to wt% of reinforcement

Table.5. Microhardness with varying wt% of ceramic

S.No	wt% of Recycled fuse carrier ceramic	Microhardness(VHN)
1	0	92.3
2	4	94.0
3	8	99.5
4	12	104.6

Wear characteristics

Tribological observations were implemented to understand the wear behaviour of AA5083(O)/Ceramic composite employing a pin-on-disk wear tester. Wear experiments were supervised adopting a ‘pin-on-disc wear tester’ for 4, 8 & 12 wt% Ceramic. The experimental wear data’s achieved from verifying 4 specimens is delineated in Table 6.

Table.6. Experimental Wear Results

S.No	Time (sec)	Wear of AA5083(O)	Wear in µm when Ceramic is 4%	Wear in µm when Ceramic is 8%	Wear in µm when Ceramic is 12%
1	0.98	0	0	0	0
2	150.902	53.65	19.28	112.63	20.07
3	300.872	88.99	20.8	115.56	19.31
4	450.848	101.18	32.66	111.81	27.37
5	600.814	127.41	32.27	116.43	31.11
6	750.778	164.18	39.81	103.37	34.12
7	900.74	166.09	49.08	109.31	34.3
8	1050.702	172.06	58.33	110.86	33.54
9	1200.665	183.31	58.14	120.8	36.18
10	1350.63	194.24	58.17	116.43	36.21
11	1500.594	183.88	58.72	125.68	38.62

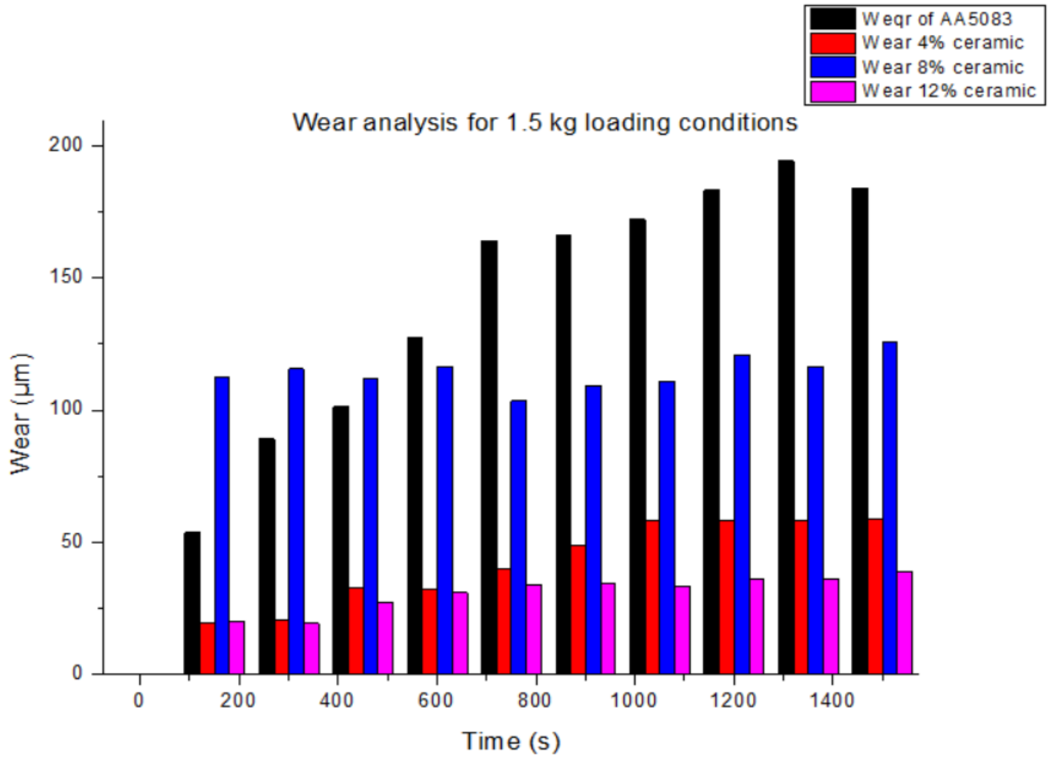


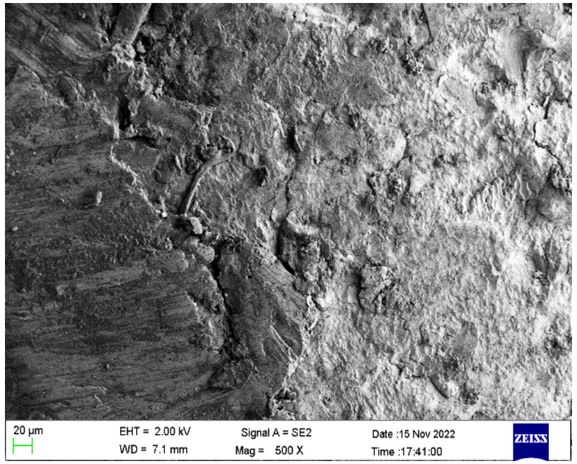
Fig.13. Wear with respect to time (1.5 Kg loading condition)

The Figure 13 represents wear of the samples with respect to time. From the Figure 4.3 it can be analysed that the sample with higher Ceramic content has lesser wear rate that all other samples with lesser percentages of Ceramic. The wear rate for the samples with 4 & 12 wt% ceramic has very low difference in wear comparing with 8 wt% of Ceramic at 1350 seconds. The test reveals that the sample with 8 wt. % Ceramic has a wear of 109.31 µm which is significantly higher than the base metal sample with 58.17 µm. The samples with 4 and 12 weight percentage of Ceramic also show substantial reduction in wear compared to the base metal alloy.

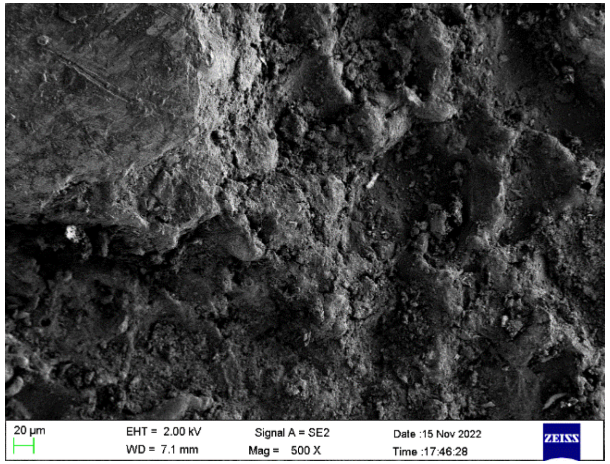
Surface Morphology

The scanning electron microscope (SEM) is a sort of electron magnifying instrument that pictures the example surface by examining it with high-energy beams of electron emission in a raster sweep design

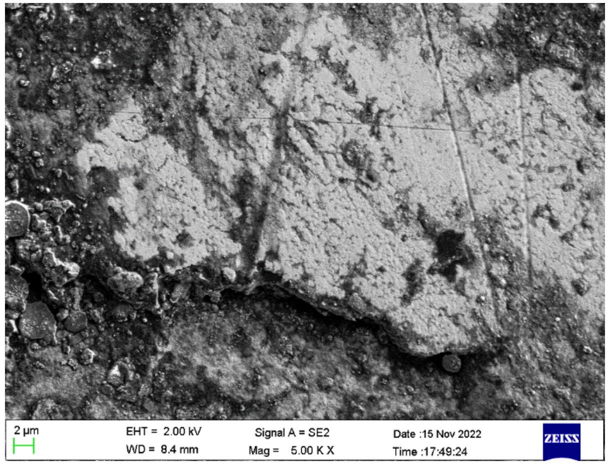
Fig.14 Before SEM analysis of wear and fractured specimens



Specimen 1



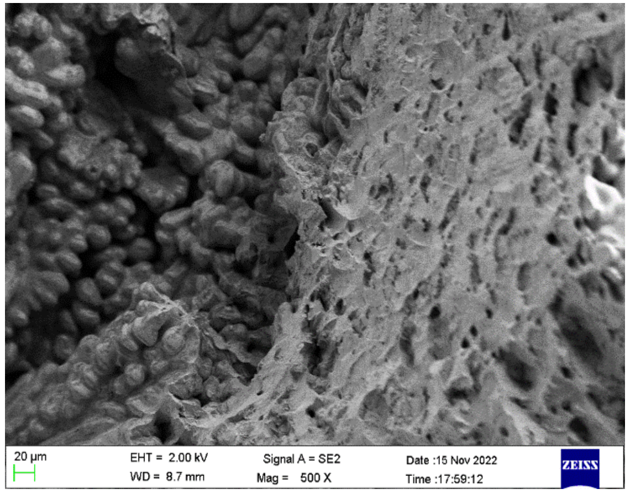
Specimen 2



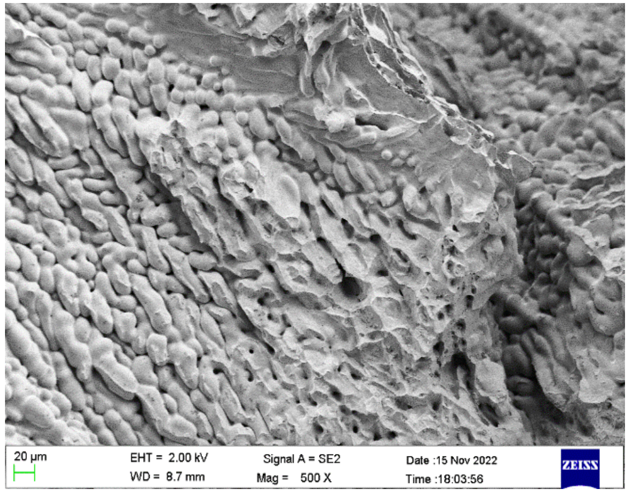
Specimen 3

Fig.15. SEM of wear specimens

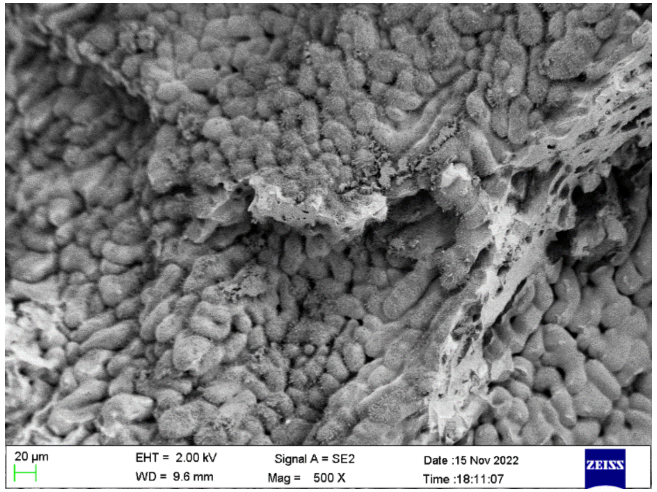
After wear testing surface of the samples see through Scanning Electron Microscopy (SEM) in SITRA Meditech, Coimbatore. Fig clearly shows the wear surface of the particulate filled AA5083 composites.



Specimen 1



Specimen 2



Specimen 3

Fig.16. SEM of fractured specimens

After tensile testing fractured of the samples see through Scanning Electron Microscopy (SEM) in SITRA Meditech, Coimbatore. Fig clearly shows the fractured area of the particulate filled AA5083 composites.

Figures clearly shows the homogeneous distribution of reinforcement particles. SEM images also reveal that no agglomeration of particles in the composite.

CONCLUSION

- In this work, AA5083(O) alloy was successfully reinforced with varying weight percentage reinforcement of recycled by in-situ stir casting process.
- From the micro hardness test it was recognized that the surface hardness of the material surge with upturn in reinforcement, a trend which could be associated to the increase in presence of magnesium which increases the surface hardness of the composite and improves the wettability of ceramic in the matrix.
- The wear test conclusions further prove that wear resistance of the samples further escalates unquestionably as the percentage of reinforcement increases. This is due to the evolution of a thin ceramic layer which brings about self-lubricity to the material. This thin ceramic layer formation was realised at the interfaces.
- From the tensile testing outcomes, it was discovered that the tensile strength of the material reduces with increment in reinforcements by a factor of approximately 14% for every 2% addition of Ceramic and the material seemed to fail in a more ductile manner with increase in reinforcements which may be attributed to the decrease in the base material.

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THANK YOU