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Characterization of Al 5052 Based Metal Matrix Composites Reinforced with SiC and Al_2O_3

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Abstract: When compared to traditional aluminium alloys, composites made of aluminium display several material characteristics, including enhanced stiffness, wear resistance, specific strength, vibration dampening, and a lower coefficient of thermal expansion. Non-metallic reinforcement aluminium matrix composites, which have advantages over the base material typically include and preferred SiC& Al_2O_3 as reinforcements to enhance the desired mechanical qualities. Vertex stir processing (VSP) is a novel technique used to produce hybrid composite to improve mechanical properties and microstructure refinement. In this investigation work the fabrication of all Al5052 aluminium hybrid composite was done by VSP method. An effort has been made to look at the impact of SiC& Al_2O_3 reinforcing elements in an Al5052 matrix. Three combinations of composites had been prepared with different % wt of reinforcements. The microstructural alterations were examined using scanning electron microscopy (SEM).Using a Brinell hardness tester, the microhardness of samples was evaluated. A composite with the following reinforcementsAl5052/ 6%wtSiC/ 6%wt $Al_2O_3$was found to exhibit superior mechanical properties.

Keywords: *Metal matrix composites, Vertex stir casting, Aluminum 5052, Silicon carbide, Al_2O_3 composites.*

1. Introduction

Composite materials are made by combining two or more distinct materials in order to create a new material with properties that are different from those of the individual materials. Aluminium-based metal matrix composites (Al-MMC) are a type of composite material in which an aluminium matrix is reinforced with a second material, typically ceramic particles, fibres, or whiskers. The resulting material has improved mechanical properties, such as increased strength and stiffness, making it useful for a variety of applications.The choice of strengthening material or materials depends on the desired properties of the composite. For example, ceramic particles can be added to increase the stiffness and wear resistance, while fibres or whiskers can improve the strength and toughness. The reinforcement material is typically added to the aluminium matrix by various process, which involves mixing the reinforcement and then consolidating them through a series of steps such as casting and cooling.Al 5052 alloy is primarily α-Al phase & magnesium in the solid solution and have several advantages over conventional aluminium alloys, including higher specific strength, stiffness, and wear resistance. They are employed in numerous applications, such as aerospace, automotive, and electronic industries. The quality and effectiveness of casting, as well as the mechanical property, are improved by grain refinement because it tends to create an equiaxed grain structure [1, 2]. Due to a decrease in surface tension caused by the presence of magnesium in the aluminium alloy, the aluminium melt is more wettable with the nucleating sites [3]. Refinement can improve an aluminium alloy's mechanical properties by providing reinforcement. SiC and Al_2O_3 are the most popular ceramic reinforcements because they ensure a small growth in strength to weight ratio, wear property and modulus [4–8]. In this exertion, an attempt has been made by means of a stir-casting route to explore the mechanical property like Strength, and hardness. Enrichment of Al5052 alloy is done by adding Al_2O_3 and SiC reinforcements, in a proportion of 2wt.%, 4wt.% & 6%wt. added proportions to Al 5052, retains matrix (Al5052) lightweight properties while becoming hard and powerful in its alloyed state. Due to its extensive property, it is employed where lightweight and resistance to corrosion are the main purpose for the construction [9]. Al 5052 aluminium is also found and application d in fields with a lot of vibration, since magnesium is a key alloying element with a high fatigue strength. Due to its superior corrosion resistance, this alloy is used in boats, marine components, gasoline, and oil tubes [10]. The Al5052 aluminium alloy is advantageous for high-end applications since each element present has unique properties. Magnesium slows down the alloy's ability to be formed, & zinc aids in increasing castability as well as strength. Iron raises the temperature at which recrystallization occurs, whereas silicon boosts fluidity, copper reduces the pitting effect, chromium and manganese improve strength and boost corrosion resistance respectively [11,12].

Purpose of the study. To analyze the structure of composite material and evaluate the effectiveness of the Mechanical Characteristic for automotive usage.

2. Material and methods

In this work, Al 5052 has been taken as a matrix (Brought by a local foundry) and Al_2O_3 (purchased from Materion Global Headquarters, Mayfield Heights, Ohio, United States,) and SiC (Purchased from M/s Parshwamani Metals, Bhuleshwar, Mumbai) mixture as reinforcing materials respectively. The Technical specification of composite materials is listed in Tables 1,2 and 3 respectively. The stir-casting method was employed in an open environment to createthe composite. Al_2O_3 and SiC with different weights per cent (2% wt., 4% wt.& 6% wt.) havebeen mixed in the matrix.

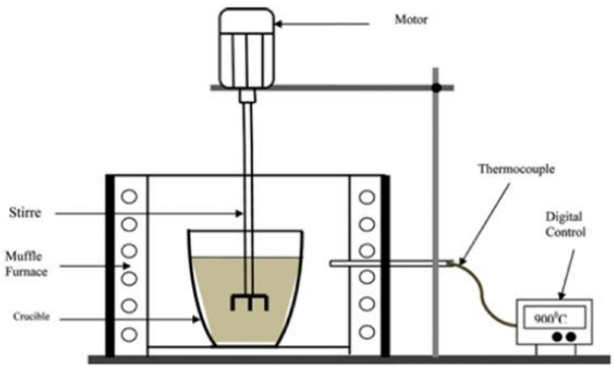

Figure 1. Stir casting setup [6]

Fig. 1 depicts the stir-casting experimental setup. In order to create vertices inside the molten matrix, aluminium billets were first melted at 600°C and constantly agitated for three minutes at 300 to 350 rpm. After the confirmation of vertex formation, a mixture of Al_2O_3 and SiC was put into the matrix, which received continuous stirring for 5 to 7 min at 500 to 550 rpm. Different classes of composites, with a variation of % of Particulates, are listed in Table 4.

Table 1.Properties of Al5052.

Name	Specification
Magnesium	2.2%-2.8% by wt
Chromium	0.15% -0.35% (maximum)
Copper	0.1% (maximum)
Iron	0.4% (maximum)
Manganese	0.1% (maximum)
Silicon	0.25% (maximum)
Zinc	0.1% (maximum)
Al	96.7%-95.9%

Table 2. Properties of Al2O3

Name	Specification
Chemical formulation	Al_2O_3
Molar mass	101.960 g·mol−1
Density	3.987 g/cm3
Melting point	2,345 K
Boiling point	3,250 K
Solubility in water	immiscible
Solubility	not dissolvable in any solvents
Thermal conductivity	30 W·m−1·K−1

Table 3.Properties of SiC.

Name	Specification
Chemical formulation	CSi
Molar mass	40.096 g·mol−1
Density	3.16 g.cm−3 (hex.)
Melting point	2,830 °C (5,130 °F; 3,100 K) (decomposes)
Solubility	Insoluble in water, soluble in molten alkalis and molten iron

3. Characterization

Sample Preparation

A sample of Specimens was prepared as per the ASTM Specification and 5 test samples were made and the average readings are reported the in the subsequent test results. Sample compositions and designation are listed in Table 4.

Table 4.The composite designations and descriptions of sample.

Sample Number	Composition
SM1	Al 5052
SM2	Al5052/SiC 2%wt.
SM3	Al5052/SiC 4%wt.
SM4	Al5052/SiC 6%wt.
SM5	Al5052/Al_2O_3 2%wt.
SM6	Al5052/Al_2O_3 4%wt.
SM7	Al5052/Al_2O_3 6%wt.
SM8	Al5052/Al_2O_3 2%wt /SiC 2%wt.
SM9	Al5052/Al_2O_3 4%wt /SiC 4%wt.
SM10	Al5056/Al_2O_3 6%wt /SiC 6%wt.

Density Measurement

The composite's density was calculated using the densities of each component of the SiC& Al_2O_3 reinforcements. The density of the sample materials based on Archimedes's principle was calculated by using Eq. (1)[13].

$$\rho_{comp} = \frac{M}{M-M_1} \times \rho_{water} \quad (1)$$

M1 is the mass of the composite in distilled water, and M is the mass of the composite in air. The findings of the density of composite samples made under various conditions are displayed in Table.5.

Table 5.The Theoretical and measured density values of the composites.

Sample Number	Sample Composition	Theoretical density (g/ cm3)	Measured density (g/ cm3)	voids volume (%)
SM1	Al 5052	2.715	2.715	0.000
SM2	Al5052/SiC 2%wt	3.205	3.123	0.082
SM3	Al5052/SiC 4%wt	3.229	3.103	0.126
SM4	Al5052/SiC 6%wt	3.303	3.203	0.100
SM5	Al5052/Al_2O_3 2%wt	3.910	3.810	0.100
SM6	Al5052/Al_2O_3 4%wt	3.991	3.871	0.120
SM7	Al5052/Al_2O_3 6%wt	4.203	4.103	0.100

SM8	Al5052/$Al_2O_3$2%wt/SiC2%wt	5.204	5.112	0.092
SM9	Al5052/$Al_2O_3$4%wt/SiC4%wt	5.407	5.305	0.102
SM10	Al5056/$Al_2O_3$6%wt/SiC6%wt	5.993	5.899	0.094

Hardness

Brinelll hardness testing equipment was used to measure the hardness of composite materials in accordance with ASTM E10 standards. In order to get the average value of hardness, three separate locations on the samples were tested for hardness at room temperature (27C). Fig. 5 illustrates how SiC& Al_2O_3 affect hardness based on various compositions. According to Fig. 3, the inclusion of SiC and Al_2O_3 content increases in the hardness of samples SM8 to SM10 compared to other composite samples. Dislocations are typically avoided by hard-ceramic particles, which improves the results of hardness [14]. Similar results were seen by other researchers [15]. Based on the findings, it may be deduced that the silicon carbide particles generate barriers that impede the movement of the dislocations. Composites' hardness increases as a result of this. This result is consistent with those of similar work. Who found that one of the primary causes of an increase in hardness values was "the sustenance of a bulk of dislocations at the matrix interface during the solidification process due to the low thermal expansion coefficient, of reinforcing particulates like SiC and Al_2O_3 compared to Al5052 [16].

4. Result and Discussion

Tensile properties

The ASTM E8 standards were followed for conducting the tensile tests on the MMCs utilizing the Universal Tensile Testing Machine (UTM). It is clear from Table 3 that the composite materials have higher tensile strengths than the as-cast Al alloy. The tensile strength of MMC rises as the amount of particles %wt increases because the reinforcing particles prevent the matrix from deforming plastically which is shown in Fig 2.

Compressive properties

Using the Universal Tensile Testing Machine (UTM), compression strength tests were conducted to examine the mechanical behaviour of MMCs in accordance with ASTM standards. It is clear from Fig. 5 that when compared to the as-cast Al alloy, the compressive strength of the composites (SM 8 to SM 10) is higher. Because the addition of the reinforcing particles prevents the matrix from deforming plastically, the compressive strength of MMC increases as %wt. of the particle content does as shown in Fig.3

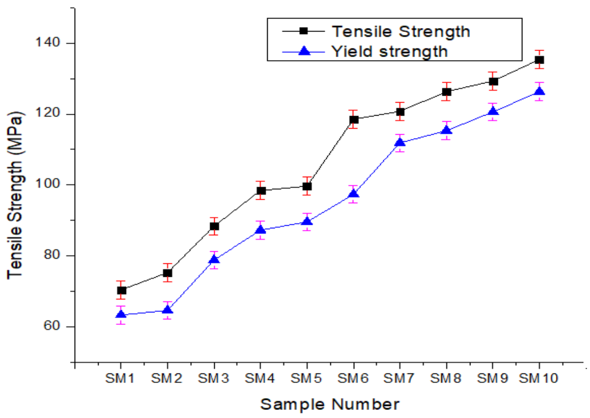

Figure 2. Tensile strength Vs. varying % wt of composite samples.

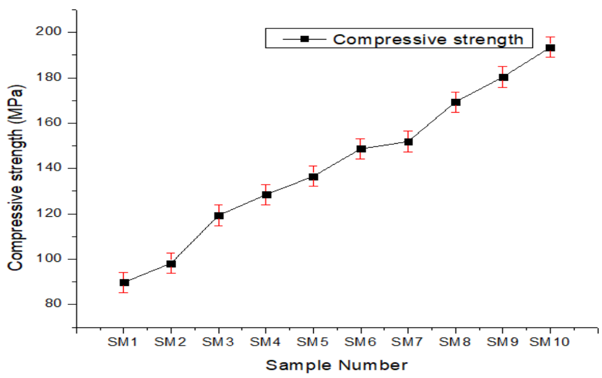

Figure3. Compressive strength Vs. varying % wt of composite samples.

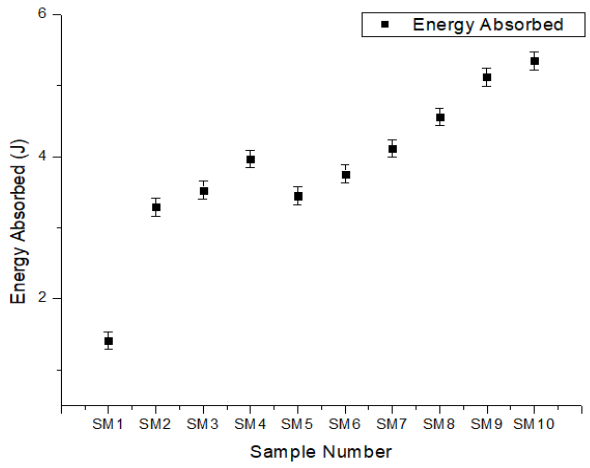

Figure 4. Impact strength Vs. varying % wt. of composite samples

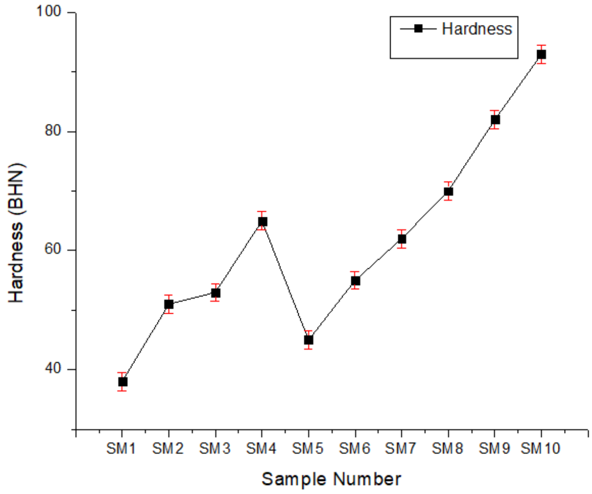

Figure5. Hardness value of sample with different wt.% of SiC and Al2O3

According to IS 1757 requirements, the Charpy test was used to conduct the impact testing on the samples. According to the results of the impact tests, which are shown in Fig. 4, it is obvious that the sample made up of 6%wt SiC and 6%wt Al_2O_3 absorbs more energy than other samples.

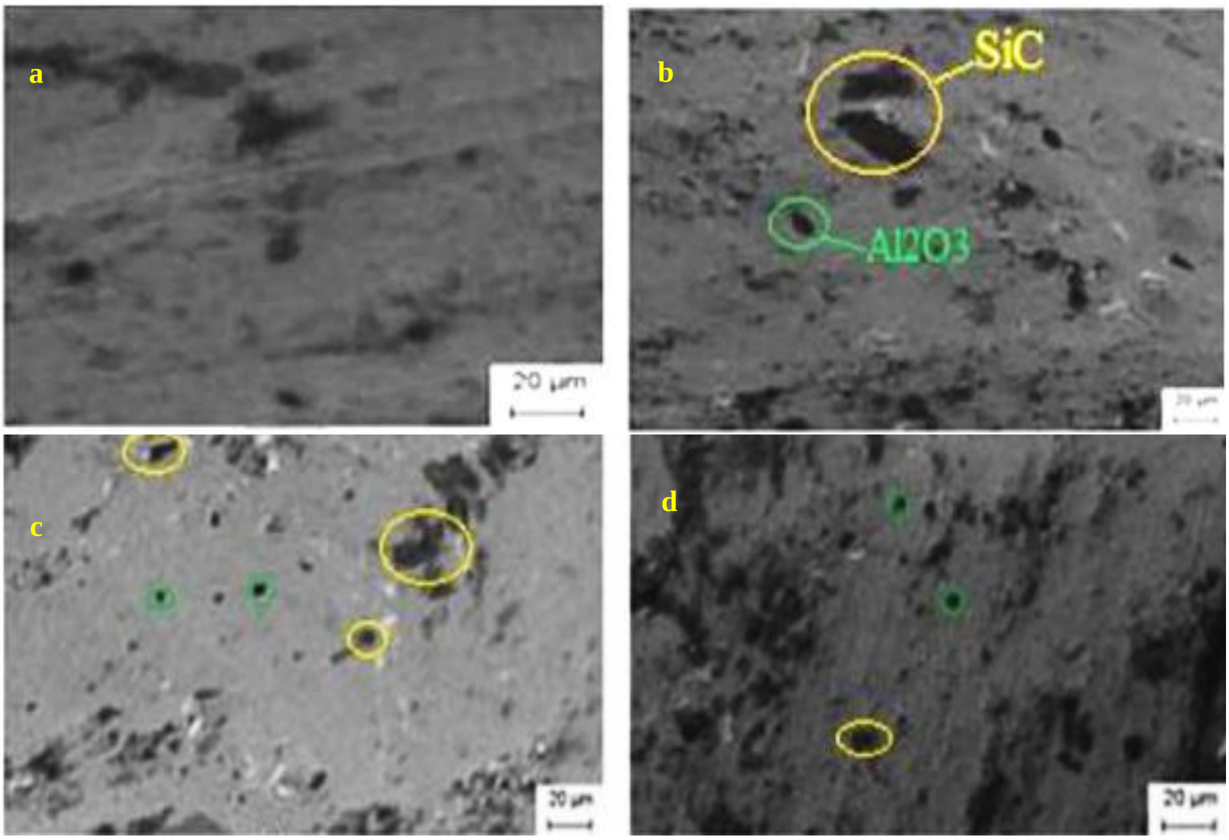

Figure 6 SEM Images of particles distribution (a) as-cast Al5052, (b)Al5052/ 2%wt SiC/2%wt Al_2O_3, (c) Al5052/4% wtSiC/4%wt Al_2O_3, and (d) Al5052/6%wt SiC/6%wt Al_2O_3.

The Al5052/SiC/Al_2O_3 with different wt % particulate composite microstructure, depicted in Fig. 6, confirms the reinforcement's homogeneous distribution. As the SiC and Al_2O_3 elements are absorbed in the melt during the blending process, a whirl of molten material is created by the stirrer's spin. Due to the SiC&Al_2O_3 by Al composite's poor wettability, less force is required to stir the melted material when using a stirrer. WhenSiC&Al_2O_3 particles have been introduced into the molten aluminium, specific flow transitions significantly impact the dissemination. Elating of SiC/Al_2O_3 particles results due to the momentum transfer as well as the outspread flow of melt, which also averts particles from acclimatization in the matrix. Regional hydrodynamic forces are meanwhile induced on the SiC/Al_2O_3 particle packing. These forces can disperse the SiC/Al_2O_3 particle clumping, resulting in a homogeneous microstructure throughout the whole cast segment. The transfer of weight from the matrix to the reinforcement is aided by a solid, uniform microstructure between the two. As a result, rather than along the interface, the break occurs in the composite through the reinforcement. Despite not being a load-bearing component, SiC/Al_2O_3 particles are able to genuinely embed themselves in the matrix with the aid of a solid particle or matrix interface, increasing the crack resistance. According to reports, the interfacial connection between the Al5052 matrix and SiC& Al_2O_3 partials is strengthened during solidification. The SiC/Al_2O_3 particles even distribution ensures the strong bonding in the Al matrix.

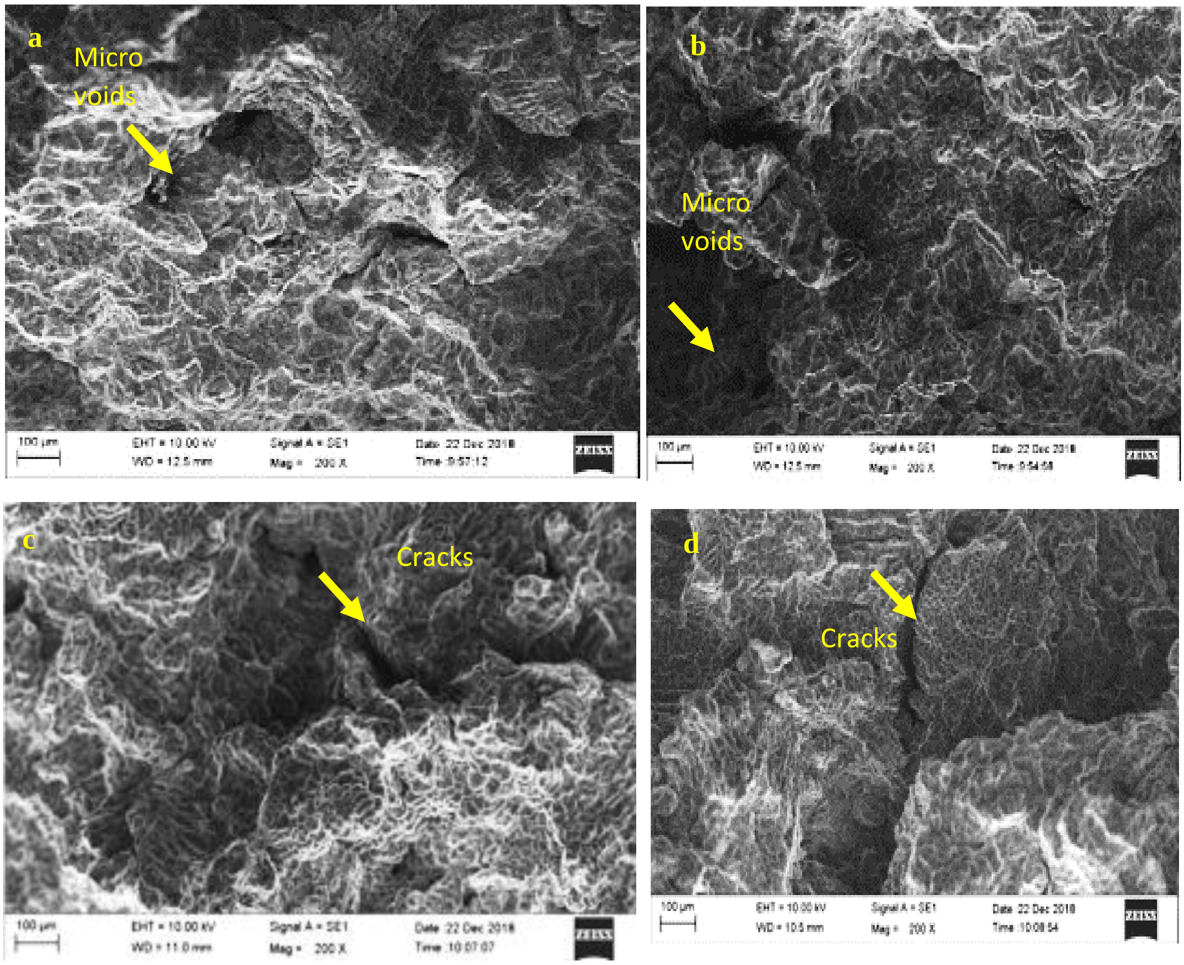

Figure7: SEM shows the Tensile Fractured surface of samples: (a) as-cast Al5052, (b)Al5052/2%wt.SiC/2%wt. Al_2O_3, (c) Al5052/4%wt.SiC/4%wt Al_2O_3, and (d)Al5052/6%wt.SiC/6%wt. Al_2O_3

To investigate the fracture location and, to find areas of microcrack initiation, early crack growth, and overloaded areas, as well as to classify the satisfactory scale fracture features, a scientific study of these fracture surface structures had to be carried out with SEM at high magnification (see fig. 8). The depression size in the SM 8 specimen fractured surface is smaller when compared to the SM 9 composite sample. Similarly, SM 9 show smaller size depressions compared to SM 10 specimen. Fig 8 shows the surface failure generally; the size of the depression is in a directly proportional relationship with the composite strength. The large and smaller depression is associated with the particulates, and ductile fracture of the matrix respectively. In often the fracture surfaces revile the smooth surfaces pointing which has fractured rather than decoherer, which is by means of high interfacial strengths that dominate in these composites. Other than these composites are also failed through particulate fracture and matrix ligament rupture can be observed in Fig 7 similar observations were also reported in other research work [15].

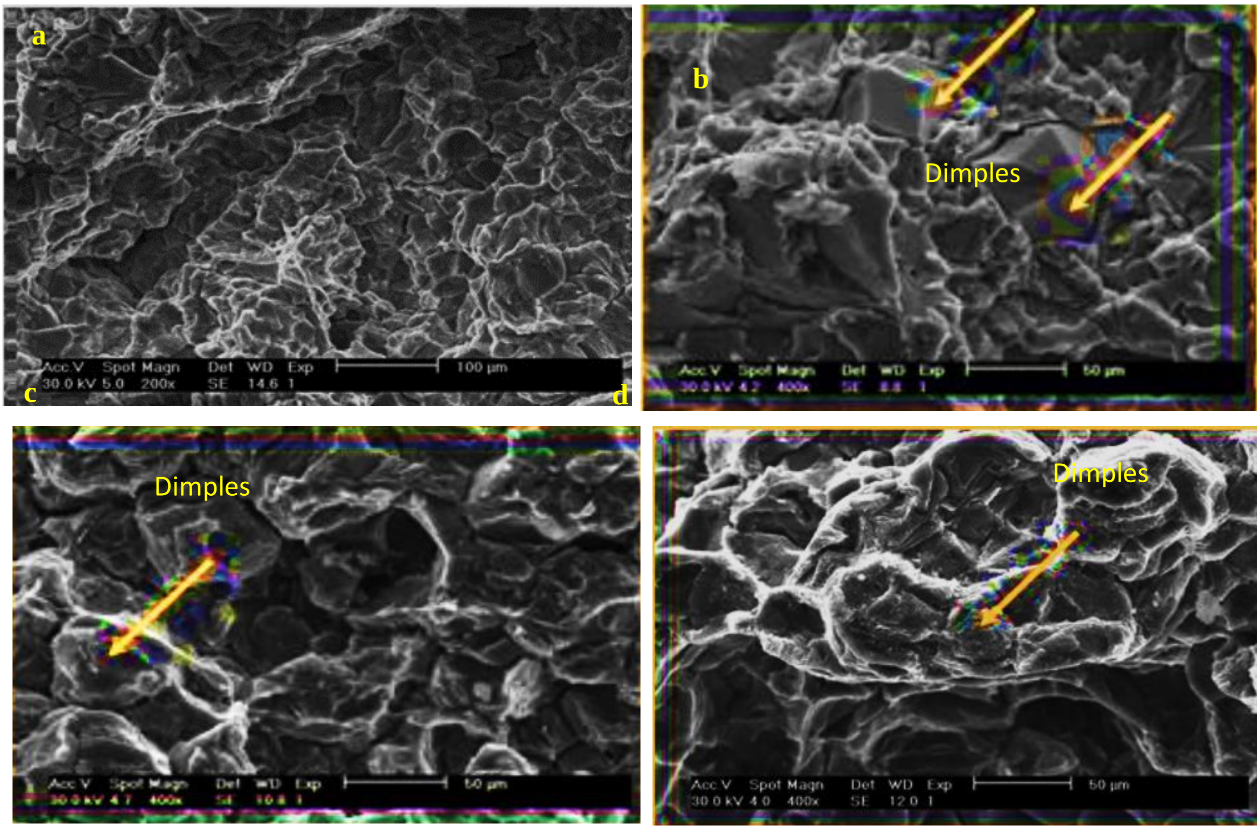

Figure 8: SEM shows the Impact fractured surface of samples: (a) as-cast Al5052, (b)Al5052/ 2%wt SiC/2%wt Al_2O_3, (c) Al5052/4%wt SiC/4%wt Al2O3, and (d)Al5052/6%wt SiC/6%wt Al_2O_3.

4. Conclusions

The investigation's findings about the mechanical Characterization performances of the as-cast led to the following conclusions Al 5052 properties increase with the addition of SiC and Al_2O_3 Particles. It also noticed that the mechanical properties of SM 8, SM 9 and SM10 composites increased with the incremental addition of alloying weight percentage. SM 8, SM 9 and SM10 show excellent properties when compared to SM 2 to AM 7. It has been noticed that Al 5052 attains special properties with the addition of a smaller quantity of SiC& Al_2O_3 both together. Further, SEM studies revealed uniform particle circulation in the matrix system with little porosity and also reveals the propagation and development of cracks in the fracture failure and influence of particle distribution in the hybrid composites.It is noticed the presence of both Particulate SiC and Al_2O_3 increases the hardness by 40.86% 46.41% of Compressive strength, 51.93% Tensile strength and 26.36% Impact Energy Absorption. In compression with the as-cast Al-5052. It is also observed that 66.39% Compressive strength, 72.68% of Tensile strength and 74.21% Impact strength increases in compression with Al-5052+SiC composite samples

5. References

[1] CarleD, BlountG.The suitability of aluminium as an alternative material for car bodies, Mater Des1999;20:267-72

[2] MurtyBS, KoriSA, Chakraborty M, Grain refinement of aluminium and its alloys by heterogeneous nucleation and alloying.Int Mater Rev2002;47:3–29.

[3] Cibula A, Mechanism of grain refinement of sand castings in aluminium alloys, InstMetals J1949; 76:321–60.

[4] BirchMEJ, FisherP. Mechanism offade in grain refining of aluminium with titanium boron aluminium, Solidification processing.London:TheInstituteofMetals;1987.p.500– 2.

[5] Pollock. T.M, , Weight Loss with Magnesium Alloys, Science, 328 (5981), 2010, 986-987. [6]. Lloyd D.J, Particle reinforced aluminium and magnesium matrix composites, Int. Mater. Rev.39, 1994, 1-23.

[6] Ibrahim.L.A, Mohamed.F.A, Lavernia. E.J, particulate reinforced metal matrix composites: a review, Matter. Sci. 26,1991, 1137-1156.

[7] S.K.Sahoo, J. Majhi, S.C. Patnaik, AjitBehera, J.K. Sahoo and BhabaniP.Sahoo, Characterisation of AlSi-TiB2In-situ Composite Synthesised by Stir Casting Method, S.K.Sahooet al./Elixir Materials Science113(2017) 49066-49069

[8] AbhijeetBhowmik, DilipMishra , A Compressive Study of an Aluminum Alloy AL-5052, Advance Physics Letter, ISSN (Print) : 2349-1094, ISSN (Online) : 2349-1108, Vol_3, Issue_1, 2016

[9] Metals Handbook Vol.2 -Properties and Selection: Nonferrous Alloys and Special-Purpose Materials.ASM International.

[10] Narayanaswamy, R. (2009). A Crystallographic texture perspective formability investigation of aluminium 5052 alloy sheets at various annealling temperatures. Materials and Design, 1804-1817.

[11] Ravindran, R. (2009). An analysis of void coalescence in AL-5052 alloy sheets annealed at different temperatures formed under different stress conditions. Materials Science and Engineering, 252–267.

[12] Dora Siva Prasada, ChintadaShobab, NalluRamanaiah, Investigations on mechanical properties of aluminum hybrid composites, j mater restechnol ;3(1):79–85, 2014

[13] Mehdi, R., Nader, P. and Naser, E. (2010). Investigation of particle size and amount of alumina on microstructure and mechanical properties of Al matrix composite made by powder metallurgy. Materials Science and Engineering, A527, pp. 1031–1038.

[14] Rajesh, K. B. and Sudhir, K. (2011). Influence of SiC particles distribution and their weight percentage on 7075 Al alloy. Journal of Materials Engineering and Performance, 20(2), pp. 317-323. DOI: 10.1007/s11665-010-9681-6.

[15] Yogesh, K. S., Rahul, C., Hitesh, B. and Anil, K. (2015). Wear behavior of aluminum alloy 6061-based composites reinforced with SiC, Al2O3, and red mud: a comparative study. The Minerals, Metals & Materials Society, 67(9), pp. 2160-2169.