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Analysis of Mechanical Properties of Aluminium Based Metal Matrix Composites Reinforced with Alumina and Sic

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Abstract- **In the present work, Al356 alloy is taken as base material and then it is reinforced with alumina(Al_2o_3) and siliconcarbide(sic). The prepared aluminium metal matrix composite samples are in the ratio of Al356:Al_2O_3=9:1 and Al356:Sic=9:1. The fabrication method used for sample preparation is Stir Casting Process. After Preparation of suitable samples certain tests are performed to analyse various mechanical properties like Tensile strength, Compressive strength, Shear strength, Impact strength and Hardness. After that microstructure of the samples is also observed under microscope. At last, a comparison is made between the mechanical properties of base aluminium alloy and the prepared aluminium metal matrix composites.**

Keywords- Al356 alloy, Stir Casting, Al356/Al_2O_3 aluminium metal matrix composite, Al356/Sic aluminium metal matrix composite.

I. Introduction

A composite material can be defined as a combination of a matrix and a reinforcement, which when combined gives properties superior to the properties of the individual components. The matrix, normally a form of resin, keeps the reinforcement in the desired orientation. It protects the reinforcement from chemical and environmental attack, and it bonds the reinforcement so that applied loads can be effectively transferred.[1-5]. Composite materials have unique place in manufacturing industry because of their properties such as high strength and stiffness, wear resistance, thermal and mechanical fatigue and creep resistance. Till date a large number of composites have been invented & successfully found their use for different applications. Metal matrix composite (MMCs) is a advancement in production of composites[6]. Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high module[7]. Here, in MMC matrix of metal or alloy & some reinforcement material is used to produce composite. Matrix is the base material in the composite. Among the various matrix materials available, aluminium and its alloys are widely used in the production of metal matrix composites. Different aluminium based composites with various reinforcement material have been reported by researchers. Reinforcement of aluminium alloy by hard and soft reinforcements such as SiC, MgO, graphite, Si-rice husk, and many more is continue in research industry and in production in many cases. Wide range of applications and requirement of metal matrix composites in industry for different applications put many researchers in finding a cost effective production methods for these composites[8]. There are different methods for fabrication of composites, depending upon type of material involved and also on type of composite to be produced. Casting is commonly used method in production of MMC. Powder metallurgy is other widely used method for production of MMC. One of the obstacles in wide use of MMC in various applications is its plastic counterparts. But MMCs are preferred in many cases due to High strength; fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts[9].Stir casting technique is mainly used for the fabrication of the composite. Stir casting set-up mainly consists a furnace and a stirring assembly. In general, the solidification synthesis of metal matrix composite involves a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. [10-15].

II. Materials and Method

Al356 alloy which acts as a matrix is taken as the basic material. The detail of composition and properties of the material are as:

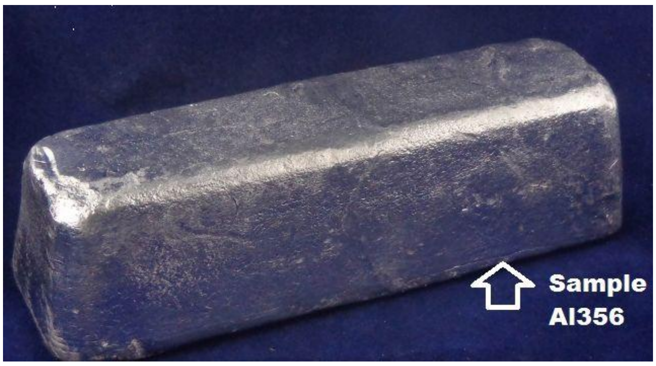

Figure 2.1 Aluminum Alloy Al356 sample.

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2.1 Chemical composition of Al356 alloy

Element	Wt%
Cu	0.20
Mg	0.20 to 0.45
Mn	0.10
Si	6.5 to 7.5
Fe	0.20
Zn	0.10
Ti	0.20
Al	Balance

Table 2.1 Chemical composition of Al356 alloy

2.2 Mechanical and Thermal properties of Al356 alloy

Tensile Strength(MPA)	230
Hardness(HRC)	55
Toughness(joule)	6
Fatique Strength(1×10^7 MPA)	120
Endurance Limit	56
Modulus of Elasticity	71
Shear Strength	120
Latent Heat of Fusion	389kj/kg
Specific heat	963j/kg
Liquidus temperature	615°c
Solidus temperature	555°c

Table 2.2 Mechanical and Thermal properties of Al356 alloy

2.3 Reinforcement Selection

Many materials can be used as reinforcements with Aluminum alloys which provide strength, hardness, very high resistance to crack propagation, high fracture toughness to the design structure. But it is decided to take Silicon Carbide (SiC) and Aluminum oxide (Al_2O_3) in powdered form as reinforcement for AMMC. The properties of reinforcement are as:

Figure 2.2 Aluminium oxide powder (Alumina Powder, Al_2O_3)

Figure-2.3 Silicon Carbide (SiC)

2.3.1 Properties of Alumina

Denisty	3.96g/cc
Colour	Ivory
Elastic Modulus	370GPa
Poisson's Ratio	0.22
Vickers Hardness	1365Hv
Thermal Conductivity	30 W/m-K
Specific Heat	880 J/kg-K
Melting Point	2072 ^{0}C
Mean Diameter Size	40µm

Table 2.3 Properties of Alumina.

2.3.2 Properties of Silicon Carbide

Melting point	2200 to 2700
Hardness	2800(kg/mm^2)
Denisty	3.1(g/cm^3)
Cofficient of Thermal Expansion	4.1(µm/m/°C)
Fracture thoughness	4.6(MPa-m$^{1/2}$)
Poisson's ratio	0.14
Colour	Black

Table 2.4 Properties of Silicon Carbide.

2.4 Fabrication Methods:

Stir casting method was used to prepare AMMC of aluminium (Al 356) alloy and reinforcement particles. Reinforcement material (alumina) was first preheated at a temperature of 250^{0}C for 5minutes to improve wettability with matrix forming alloy.The Furnace temperature was set to about maximum 700-750°C in order to minimize the chemical reaction between the substances. Melting of Al356 ingots were performed at a temperature of 750°c and the liquid alloy was then allowed to cool in the furnace to a semi solid state at a temperature of about 600^{0}C. Reinforcement particles (pre-heated) were added to the molten alloy and stirring performed speed of 350 rpm for 10 minutes to reach mushy state. The composite slurry was then superheated to 720^{0}C and a second stirring performed to ensure uniform distribution of alumina particles using a mechanical stirrer was done.

2.5 Chemical composition of Al356/Al_2O_3 AMMC

Al356/Al_2O_3 AMMC	Weight of Al356	Weight of Sic	Melting Temp. (Al356) (60mins)	Stirrer Speed (RPM)
10wt% Al_2O_3	900 grams	100 grams	740-750 ^{0}C	350

Table 2.5 Chemical composition of Al356/Al_2O_3 AMMC

2.6 Chemical composition of Al356/Sic AMMC

Al356/Sic AMMC	Weight of Al356	Weight of Sic	Melting Temp. (Al356) (60mins)	Stirrer Speed (RPM)
10wt% Sic	900 grams	100 grams	740-750 ^{0}C	350

Table 2.6 Chemical composition of Al356/Sic AMMC

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Seven samples are prepared for both Al356/Al_2O_3 and Al356/SiC AMMC. Similar samples of base Al356 alloy is also prepared.

Figure 2.4 Al356/Al_2O_3 and Al356/SiC AMMC.

III. EXPERIMENTAL PROCEDURE

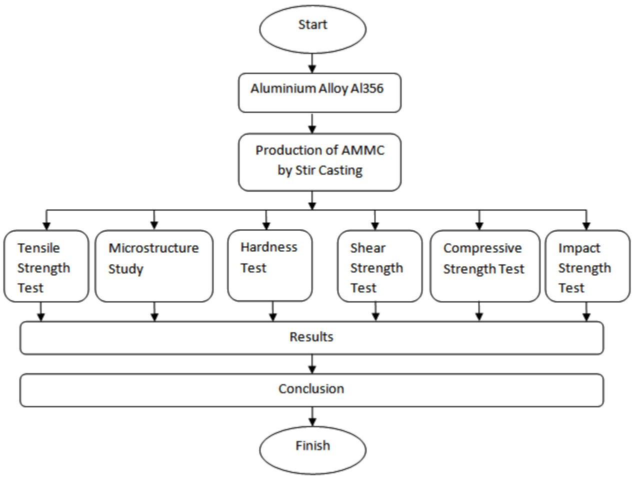

Figure 3.1 Flow chart of Experimental followed.

3.1 Tensile Strength Test

Tension strength tests were performed on samples machined from the Al 356 alloy composites with dimensions of 6 mm diameter and 36 mm gauge length. Tests were performed by universal testing machine (UTM) linked with computer to facilitate analysis with the help of software. All specimens were test at room temperature.

3.2 Hardness Test

A Rockwell hardness tester machine used for the hardness measurement. The surface being tested generally requires a metallographic finish and it was done with the help of 100, 220, 400, 600 and 1000 grit size emery paper. Load used on Rockwell's hardness tester was 250 grams at dwell time 25 seconds for each sample. For hardness testing samples were prepared as per specification required for Brinell hardness Test (i.e. 10mm × 10mm × 25 mm).

3.3 Toughness Test

Toughness of MMC was carried out on Charpy Impact Testing Machine. Four samples with different percentage of reinforcement were prepared. Samples with square cross-section of size (10 × 10 × 55) with single V-notches were prepared.

3.4 Microstructure

Metallurgical Microscope integrated with software operation was used for microstructure examination. As per requirement samples were cut in desired size and prepared for testing using Diamond polishing machine. A series of emery papers of grit sizes ranging from 400µm – 1500µm were used to prepare sample surface for examination.

3.5 Compression Test

Compression tests were used to assess the mechanical behavior of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 19mm gauge length of 22 mm. Universal testing machine used for the Compressive Strength measurement.

3.6 Shear Test

Shear tests were used to assess the mechanical behavior of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 19mm. Universal testing machine used for the Shear Strength measurement.

IV. RESULTS AND DISCUSSIONS

4.1 Tensile Test and Yield Strength

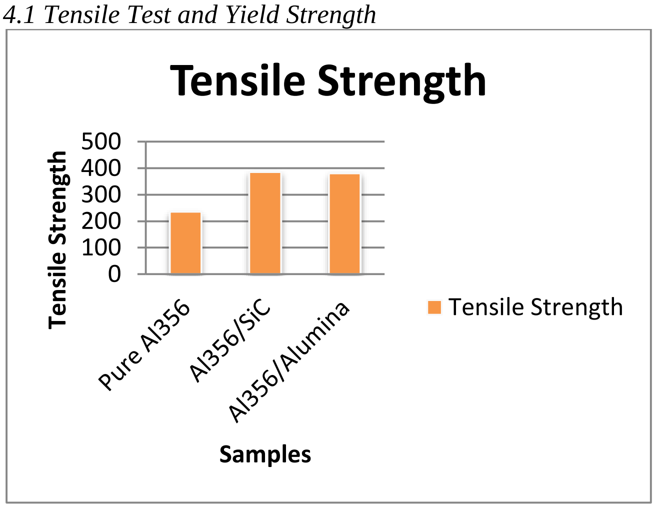

Figure 4.1 Comparison the Tensile Strength of Al356 With Al356/10wt%Sic & Al356/10wt% Al_2O_3

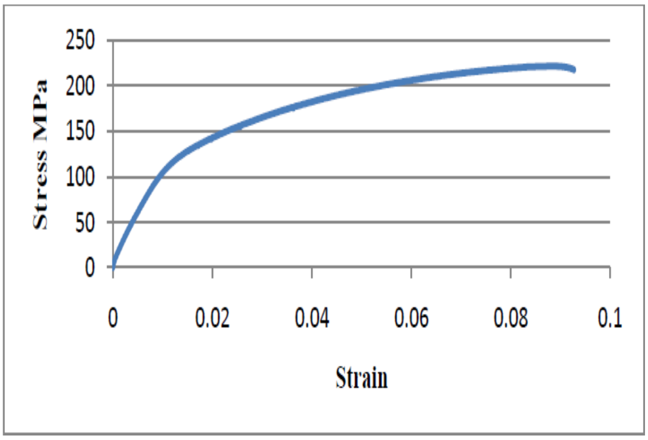

Figure 4.2 Stress vs. Strain Curves for Al 356 with 10% SiC

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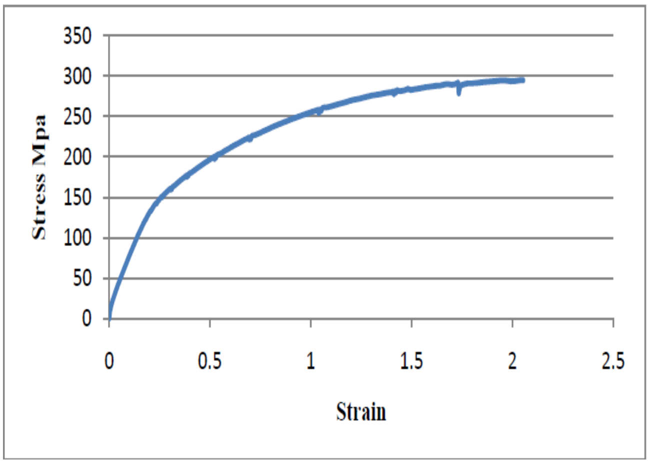

Figure 4.3 Stress vs. Strain Curves for Al356 with 10% Al_2O_3

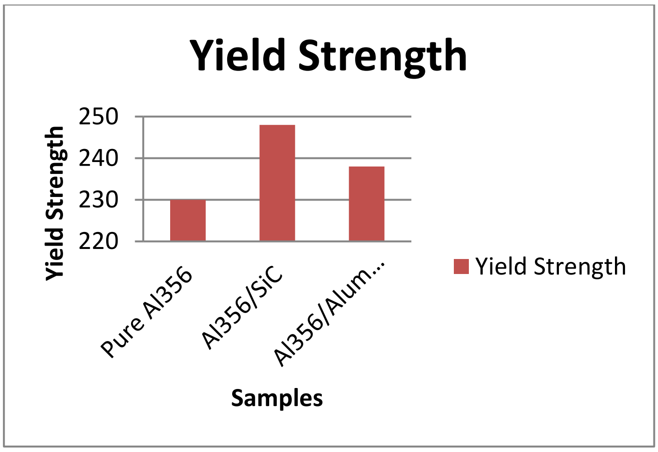

Figure 4.4 Comparison the Yield Strength of Al356 With Al356/10wt%Sic & Al356/10wt% Al_2O_3

Serial No.	Composite	Yield Strength (N/mm^2)	UTS (N/mm^2)	Elongation (%)
1	Al 356	230	236	9
2	10% SiC	248	385	1.98
3	10 % Al_2O_3	238	380	2.7

Table 4.1 Experimental value of UTS, yield Strength and Percentahe Elongation.

As shown in Chart Figure number 4.1 results predict that as the reinforcement wt.% UTS is also increases. This happens may be due to dispersion of SiC & Alumina which create hinderance to dislocation motion. This may results increase in tensile strength of Al356 alloy.

As shown in Figure number 4.4 results predict that as the reinforcement wt.% Yield Strength is increases. This happens may be due to dispersion of SiC & Alumina which create hinderance to dislocation motion. To move this defect (plastically deforming or yielding the material), a larger stress must be applied. This may results increase in tensile strength of reinforced AMMCs.

4.2 HARDNESS TEST

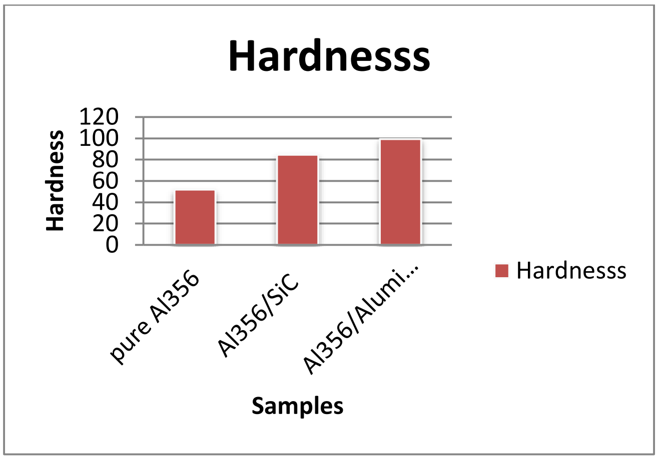

Figure 4.5 Comparison the Hardness of Al356 , Al356/10wt%Sic & Al356/10wt% Al_2O_3

Serial no.	Composites	Trail 1	2	3	Total Hardness	Average Hardness (HRC)
1	Al356					52
2	10% SiC	84	85	85	254	84.6
3	10% Al_2O_3	99	99	100	298	99.3

Table 4.2 Experimental value of Hardness.

In Figure number 4.5 results predict that uniform increase in hardness is also seen. This is due to increase in resistance to deformation by adding SiC and Alumina as reinforcement in Al356.

4.3 IMPACT TEST

Serial No	Composites	Trial 1	2	3	Total force(Nm)	Average Force(Nm)
1	Al356					6.3
2	10% SiC	8.1	9.4	8.5	26	8.6
3	10 % Al_2O_3	7	7.8	6.1	20.9	6.9

Table 4.3 Experimental value of Toughness.

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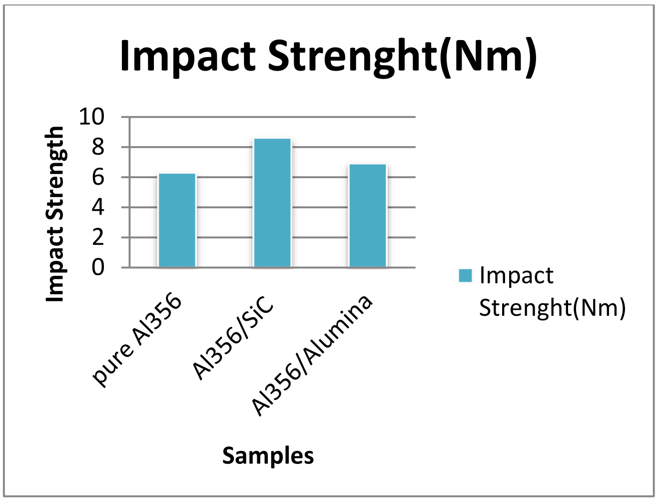

Figure 4.6: Comparison of Impact Strength of Al356 with Al356/10wt%Sic & Al356/10wt% Al_2O_3

Figure 4.6 shows that with the increase in SiC & Al_2O_3 constituent Impact strength is increases w.r.t base metal. This is due to proper dispersion of SiC & Al_2O_3 into the matrix or strong interfacial bonding in between the Al alloy and SiC& Alumina interfaces.

4.4 COMPRESSION TEST

Serial No	Composites	Trial 1	Trial 2	Trial 3	Total	Average Compressive Strength(Mpa)
1	Al356					399
2	10% SiC	423.62	424.16	422.45	1270.23	423
3	10 % Al2O3	439.4	441.12	438.75	1319.27	440

Table 4.4 Experimental value of compressive strength.

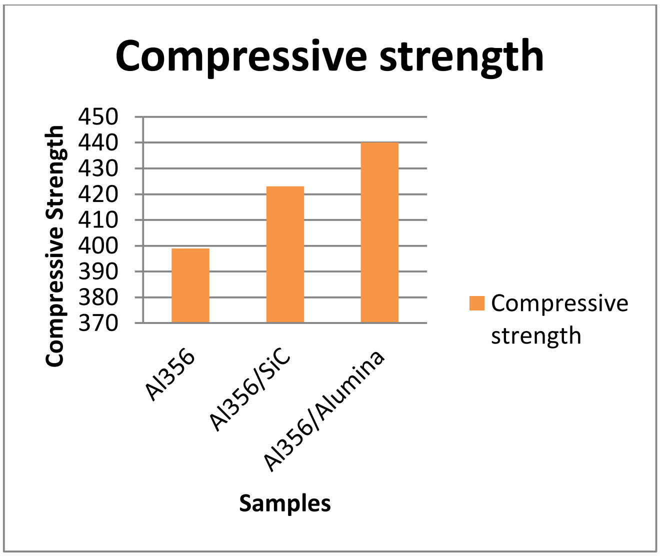

Figure 4.7 Comparison of Compressive Strength of Al356 with, Al356/10wt%Sic & Al356/10wt% Al_2O_3

Figure4.7 shows that with the increase in SiC & Al_2O_3 constituent Impact strength is increases w.r.t base metal. This is due to proper dispersion of SiC & Al_2O_3 into the matrix or strong interfacial bonding in between the Al alloy and SiC& Alumina interfaces.

4.5 SHEAR TEST

Serial No	Composites	Trial 1	Trial 2	Trial 3	Total	Average Shear Strength
1	Al356					69 MPa
2	10% SiC	132.19	133.95	132.13	398.27	133 MPa
3	10 % Al_2O_3	126.42	123.67	122.85	372.94	124 MPa

Table 4.5 Experimental value of Shear Strength.

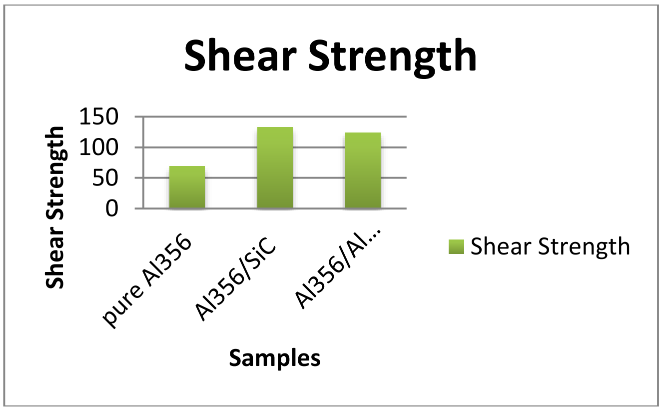

Figure 4.8 Comparison of Shear Strength of Al356 with, Al356/10wt%Sic & Al356/10wt% Al_2O_3

As shown in Figure number 4.8 results predict that as the reinforcement wt.% Shear Strength is increases. This happens may be due to dispersion of SiC & Alumina into the matrix.

4.6 MICROSRUTURE

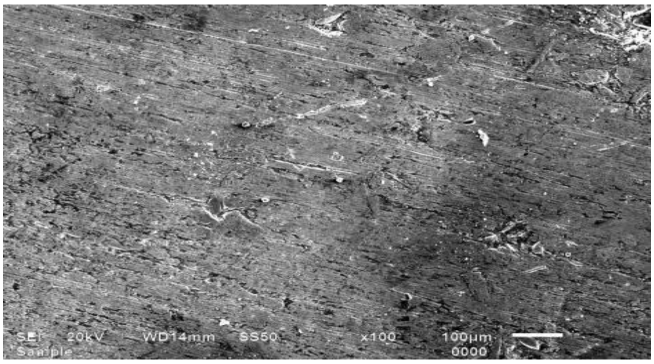

Figure 4.9 Microscopic View of 10 % SiC Reinforced in Al356.

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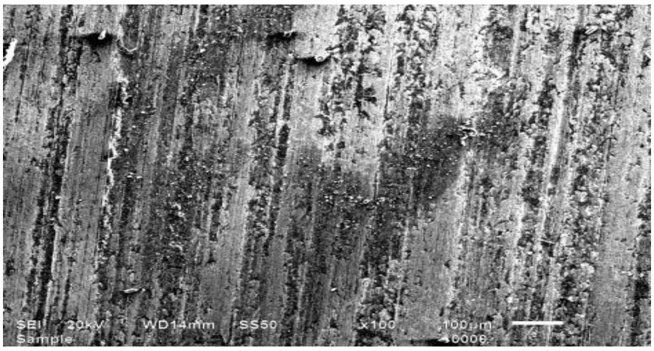

Figure 4.10 Microscopic View of 10 % Alumina Reinforced in Al356

Figures 4.9, 4.10 are presented with the microphotographs of Cast Al356-SiC and Alumina composites respectively. Pictures taken under 100x. From figures it can be observed that, the distributions of reinforcements in the respective matrix are fairly uniform. Further these figures reveal the homogeneity of the cast composites. The microphotograph also clearly revels the increased filler contents in the composites, cracks are also seen in the microstructure

V. CONCLUSIONS

From all above characterizations following conclusions have been drawn:

1. Tensile Strength increases in both AMMCs as compared to base Al356, but it is more in case of Al356/SiC AMMC .
2. Yield Strength also increases in both AMMCs as compared to base Al356, but it is more in case of Al356/SiC AMMC.
3. Hardness also increases in both AMMCs as compared to base Al356, but it is more in case of Al356/Al_2O_3 AMMC.

4. Impact Strength also increases in both AMMCs as compared to base Al356, but it is more in case of Al356/SiC AMMC .
6. Compressive Strength also increases in both AMMCs as compared to base Al356, but it is more in case of Al356/Al_2O_3 AMMC.

7. Shear Strength increases in both AMMCs as compared to base Al356, but it is more in case of Al356/SiC AMMC.

8. From the microstructure pictures it can be observed that, the distributions of reinforcements in the respective matrix are fairly uniform. The microphotograph also clearly revels that with increase in filler contents in the composites, cracks are also seen in the microstructure.

Thus SiC and alumina as reinforcement for Al356 to form AMMCs, can be utilize in many technologically important applications.

VI. SCOPE OF FUTURE WORK

1. Further reinforcement type, grain size of particles etc can be undertaken for further study with
 same setup.
2. By change in base metal and stirring rpm new observations can be obtain.
3. Percentage reinforcement % change can also done to obtain the new results.

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