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INFLUENCE OF REINFORCED PARTICLES ON MECHANICAL PROPERTIES OF FABRICATED Al/(SiC/Gr)-METAL MATRIX COMPOSITE

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Abstract*- A composite is made from two or more different materials together. The materials that make up a composite do not dissolve in each other, they remain separate. Aluminium alloy (AA) 7075 is soft and light material mostly used metal matrix composite as it has high stiffness, low density and easy fabricate. AA-7075 is mostly used in aerospace applications due to its flexibility and light weight. It is also used in mold tool manufacture, biomedicals etc. AA-7075 is used as matrix material whereas graphite and silicon carbide are used as the reinforcement materials. Stir casting technique is used for the fabrication of composites in the present work. The factorial design is used to decide the number of samples to be fabricated by stir casting. The weight percent (wt.%) of graphite and silicon is decided based on the review literature. Scanning Electron Microscopy (SEM) analysis is used to characterize the AA-7075 metal matrix composite. Energy Dispersive Spectroscopy (EDS) is used to analyze the composition of the specimen fabricated. The mechanical behaviour is determined by hardness test, compression test and tensile test. The results obtained from experiments are analyzed by using ANOVA in design expert.The maximum hardness is obtained 99 HV at 4 wt.% of SiC, similarly maximum tensile strength is recorded as 245 MPa at 4 wt.% of SiC. The maximum compressive strength of composite is recorded as 488 MPa at 4 wt.% of Gr with 4 wt.% of SiC.

Keywords*- Metal matrix composites, Surface finish, Stir casting, Scanning electron microscopy, Energy dispersive spectroscopy

I. INTRODUCTION

Aluminium is the most suitable material as an alternate for steel due to its light weight. Aluminium being soft and ductile has become favourable among researchers and is most widely used metal for metal matrix composite. Metal matrix composite (MMC) has high strength to weight ratio and high wear resistance. These properties of metal matrix composite leads to its use in biomedical, aerospace and automobile industry [1]. Due to low density and easy fabrication of aluminium it is widely used metal for metal matrix composite. There are many grades of aluminium available in the market like Al-6061, Al-6065, Al-7075 etc. Among the different grades of aluminium, Al-6061 and Al-7075 are most widely used. Al-6061 widely used in marine field, construction and automobile sector, having moderate strength and exhibit property of high resistance to corrosion whereas Al-7075 mostly used in aerospace, mold tool manufacture, biomedicals etc.[2]. Fig.1 shows the stir casting setup used for the casting process.

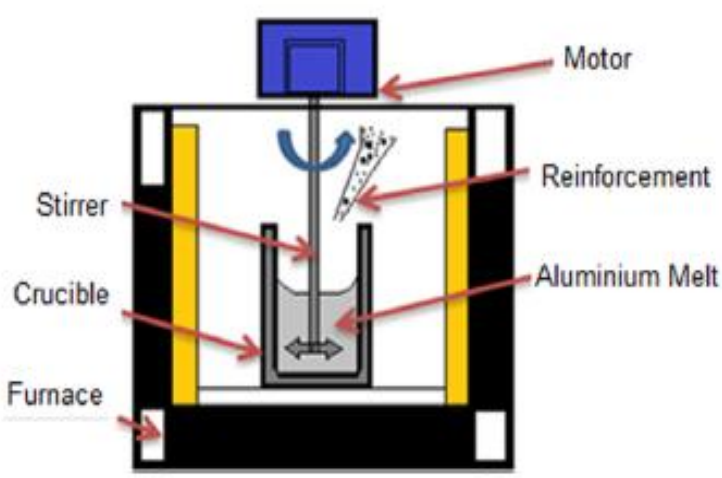


Fig.1 Stir casting setup [3]

Kumar et al. [4] studied the impact of nano reinforced particles on MMC. It has been observed that the tensile strength of composite increased on addition of graphene content. Authors further concluded that the hardness of composite increased by adding 3 wt.% nano graphene compared to adding of 1 wt.% or 5 wt.% nano graphene. Priyadarshi and Sharma [5] studied the effect of various variables on cutting force and average roughness by process parameters during machining of Gr/SiC/AA-6061 hybrid composite. Experimental results show that depth of cut (DOC) and feed rate having major impact on to the machining force. Raghavendra and Ramamurthy [6] studied the tribological characteristics of composite fabricated through stir casting technique. Alumina and SiC were used as the reinforcement materials. It has been observed that on addition of SiC, friction coefficient was reduced due to which reduction in vibration and noise was obtained. Verma and Vettivel [7] studied the mechanical characteristics of B_4C and Rice Husk Ash (RHA) were used as reinforcement materials. SEM was used for analysis of microstructure. It has been observed that maximum tensile strength was obtained 260 MPa at 5 wt.% of B_4C whereas maximum compressive strength was obtained at 5 wt.% RHA + 5 wt.% B_4C. Hayajneh et al. [8] studied the influence of graphite particulates on the surface quality of machined 4 wt.% Magnesium/Aluminium alloy. Authors concluded that surface quality of composite decreased on addition of graphite particulates because it can be easily sheared during machining. Singh and Sharma [9] analysed the influence of SiC reinforcement on Aluminium metal matrix composite. Stir casting technique was used for the fabrication of hybrid composite. Authors concluded that hardness and tensile strength of the composite increased on addition of wt.% of SiC reinforced particles. Rajkumar and Rajan [10] studied the effect of B_4C and Gr on machining parameters of hybrid composite. It has been observed that hardness of the composite icreased on addition of B_4C. Authors concluded that hardness of the composite reduces by adding graphite. Kang and Chan [11] studied effect of Al_2O_3 nano reinforcement on tensile properties of aluminium composite. The mechanical properties improve by increasing the wt.% of reinforcement. Beyond 4% of nano reinforcement the strengthening effect decreases due to clustering of reinforcement particulates. Doel and Bowen [12] studied the impact of reinforcement on tensile properties of metal matrix composite. The SiC reinforcement were used into three different sizes of 5, 13 and 60 µm. The reinforcement size of 5 µm and 13 µm of SiC increases tensile strength and yield stress compared to 60 µm. The composite having 5 µm reinforcement size being more ductile. It has been observed that tensile strength and proof stress of the composite having size 13 µm was greater than 5 µm reinforced particle size.

II. MATERIAL AND EXPERIMENTAL PROCEDURE

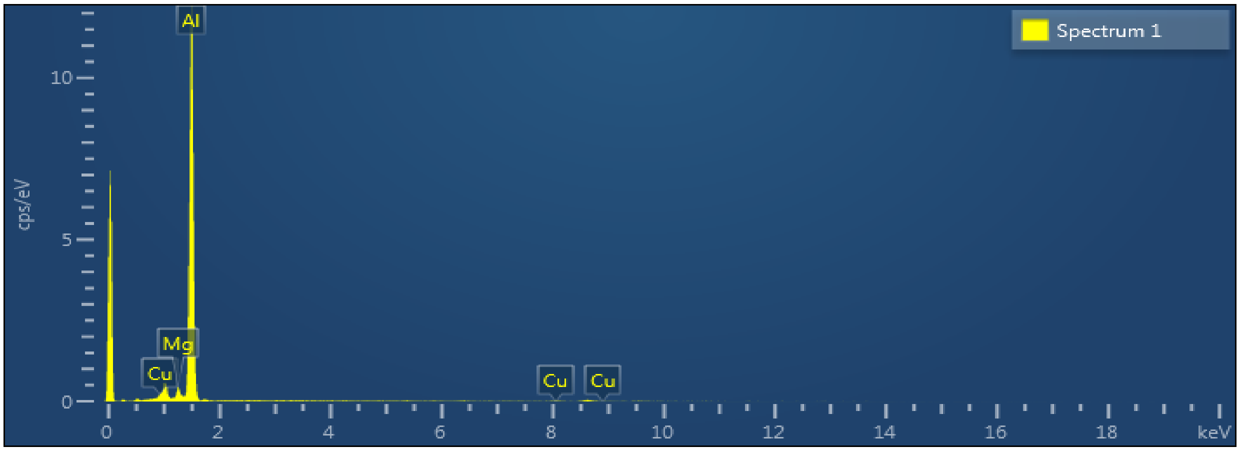
2.1 Raw material

The hybrid metal matrix composite be composed of matrix and reinforcement material. The AA7075 is used as material whereas Graphite and SiC are used as reinforcement materials.

2.1.1 Matrix material

In the present study AA-7075 was used as the matrix material. AA-7075 is strong with a strength comparable to many steels. It has superior stress corrosion resistance compared to other aluminium alloys. It was acquired from M/s Ozair Tradelink Gujarat, India in the form of raw material as shown in fig.2(a). Zinc acts as primary alloying element in AA-7075. The various alloying elements in AA-7075 were verified by Energy Dispersive Spectroscopy (EDS) are presented in Fig.2(b). The EDS test conforms that the acquired material was AA-7075. The various alloying elements identified are Al, Zn, Mg and Cu.

Fig. 2(a)AA-7075 before casting



Spectrum 1				
Element	**Line Type**	**Weight %**	**Weight % Sigma**	**Atomic %**
Al	K series	92.11	0.60	94.88
Zn	K series	4.54	0.52	1.93
Mg	K series	2.45	0.17	2.80
Cu	K series	0.90	0.31	0.39
Total		100.00		100.00

Fig. 2(b) EDS of AA-7075 before casting

2.1.2 Selection of reinforcement material

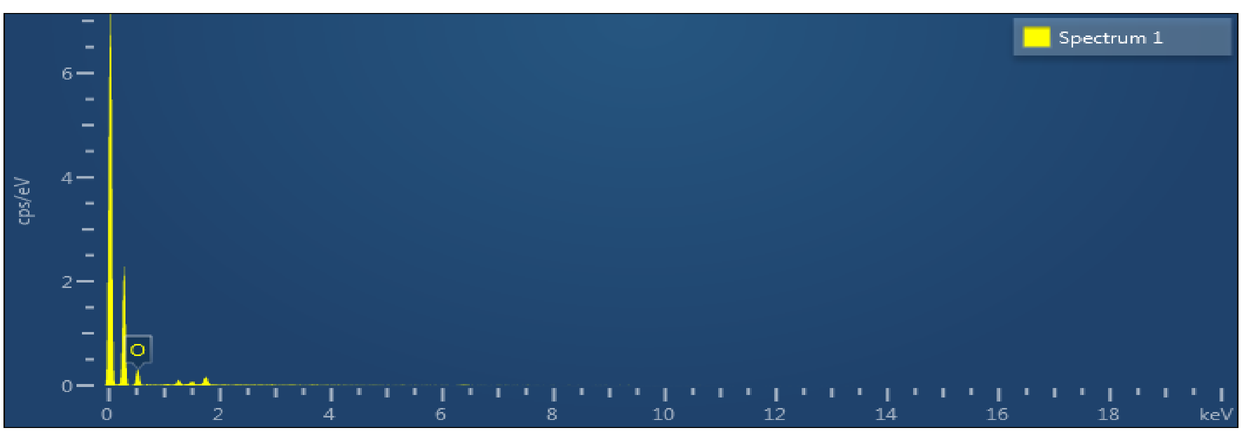
The Graphite and Silicon carbide (SiC) were selected as the reinforcement materials as per the work reported in available literature. Graphite is a crystalline allotrope of carbon. The graphite was purchased from SV Ispat Private limited, Pune, Maharashtra, India. The Silicon carbide is a semiconductor containing carbon and silicon. The Silicon carbide was purchased from Vidhi Abrasives Products GIDC Chhatral, Ahmedabad, Gujarat, India.

2.1.2.1 Graphite

Graphite is a mineral composed exclusively of the element carbon. The coarse particles of Graphite having size 35μm is used as reinforcement material. The detail of graphite which was used as reinforcement is shown below:

Fig. 3(a) Image of graphite powder

Fig.3(b) SEM of graphite powder



Spectrum 1				
Element	**Line Type**	**Weight %**	**Weight % Sigma**	**Atomic %**
C	K series	72.29	1.14	77.65
O	K series	27.71	1.14	22.35
Total		100.00		100.00

Fig.3(c) EDS of graphite powder

Fig.3 Details of graphite powder

Fig.3(a) shows the image of graphite powder of particle size of 35µm. Fig.3(b) shows the SEM of graphite powder. Fig.3(c) shows the EDS of graphite powder which confimed that the reinforcement was graphite.

2.1.2.2 Silicon carbide

The silicon carbide behaves almost like a diamond. The silicon carbide with particle size 50µm is used as the reinforcement material. The detail of silicon carbide which was used as reinforcement is shown below:

Fig.4(a) Image of silicon carbide

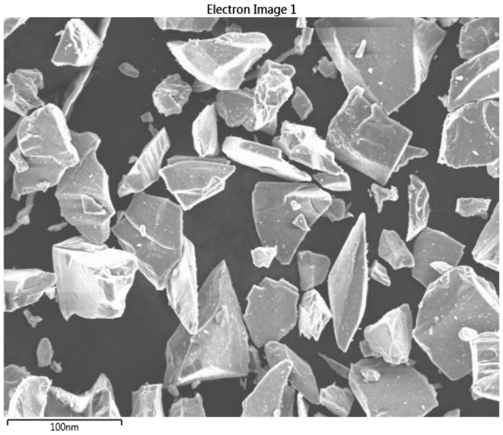


Fig.4(b) SEM of silicon carbide

Spectrum 1				
Element	**Line Type**	**Weight %**	**Weight % Sigma**	**Atomic %**
Si	K series	26.04	4.33	13.08
C	K series	73.96	4.33	86.92
Total		100.00		100.00

Fig.4(c) EDS of silicon carbide

Fig.4 Details of silicon carbide

Fig.4(a) shows the image of silicon carbide powder. Fig.4(b) shows the SEM image of silicon carbide having particle size 50µm. Fig.4(c) shows the EDS image silicon carbide powder which confirmed that the purchased reinforcement was silicon carbide.

2.2 Preparation of casted samples

The stir casting technique is considered as the best technique for fabrication of Aluminium (MMC). Stir casting machine supplied by M/s Swamiequip to PEC University, Chandigarh and used in the present work to cast the samples.

2.2.1 Stir Casting

Stir casting technique appears a promising technique for fabrication of metal matrix composite. In stir casting we use the stirrer to agitate the molten metal matrix. The stirrer is generally made up of material which can withstand a higher melting temperature than matrix temperature. Generally graphite stirrer is used in stir casting. The distribution of particle in molten metal is also affected by the velocity of stirrer, angle of stirrer, vortices cone. The process parameters for stir casting route are as under:

(1) Stirring speed
(2) Stirring time
(3) Stirring temperature
(4) Reinforcement pre-heat temperature
(5) Pouring temperature

The detail of stir casting machine is shown in Fig.5. Fig.5(a) shows the parts of stir casting machine i.e. measuring and control unit, crucible, reinforcement pre-heat furnace, melting furnace and stirrer. The measuring and control unit displays all the parameters that are used during fabrication process. It shows melting temperature, stirrer speed, mould temperature etc. The matrix material is poured through crucible into the melting furnace. The reinforcement particles are poured through reinforcing furnace into the melting furnace. The melting furnace is heated upto the melting temperature of matrix material. The stirrer is used to stir the mixture of matrix material and reinforcement particles. The permanent mould is placed below the bottom pouring unit. The permanent mould is used to obtain the samples of various dimensions for experimentation. Fig.5(b) shows the melting of AA-7075 in the melting furnace. The matrix material is heated upto the melting point of matrix material. Fig.5(c) shows the permanent mould used in the present work. The mould was heated upto the temperature of 450^0C in order to avoid the temperature gradient between mould and molten metal. The casted samples removed from the mould after gradual cooling of mould. Fig.5(d) shows the muffle furnace which was used for pre-heating of reinforced particles. The reinforcement particles were preheated at 250^0C in the muffle furnace in order to remove the moisture content from reinforced particles.

Fig. 5(a) Stir casting machine

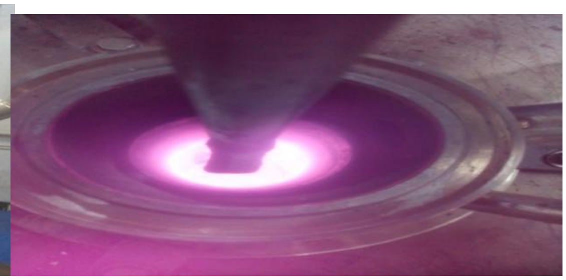


Fig. 5(b) Melting of metal in melting furnace

Fig. 5(c) Permanent mould

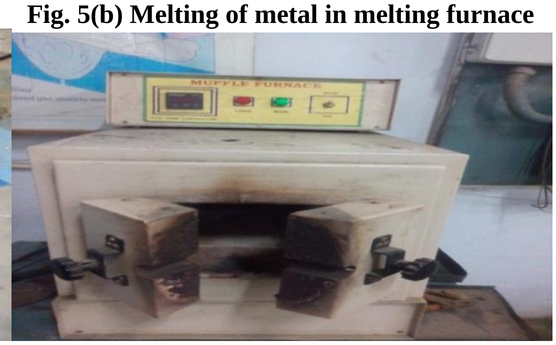


Fig. 5(d) Muffle furnace

Fig.5 Details of stir casting machine in PEC University, Chandigarh

2.2.2 Details of casted samples

The samples were obtained from the permanent mould after gradual cooling of mould. The samples obtained are of different sizes. The first cavity having diameter of 26 mm and length of 280 mm. The second cavity having diameter of 18 mm and length of 280 mm. The third cavity having dimensions (length=280 mm, width= 10mm and depth= 10 mm). Fig.6 shows the detail of casted samples.

Fig. 6: Detail of casted samples

TABLE.1 Shows the wt. % of different reinforcements

Samples	AA-7075(wt.%)	Gr (wt.%)	SiC (wt.%)
1	100	0	0
2	96	4	0
3	96	0	4
4	92	4	4

2.3 Characterization and mechanical behaviour

Optical was used for microstructure analysis, EDS was used for composition of samples. The mechanical behaviour was determined by hardness test. Brief description of the test performed is discussed in the following subsections:

2.**3.1 Hardness Test**

The hardness of the samples was measured by using Mitutoyo HM 100 series microhardness tester as shown in Fig.7.The hardness test was performed at NITTTR Chandigarh. The Vickers hardness tester was used for measuring the hardness of fabricated samples. A load of 0.5 kg was applied for 10 seconds and after that indenter was removed.

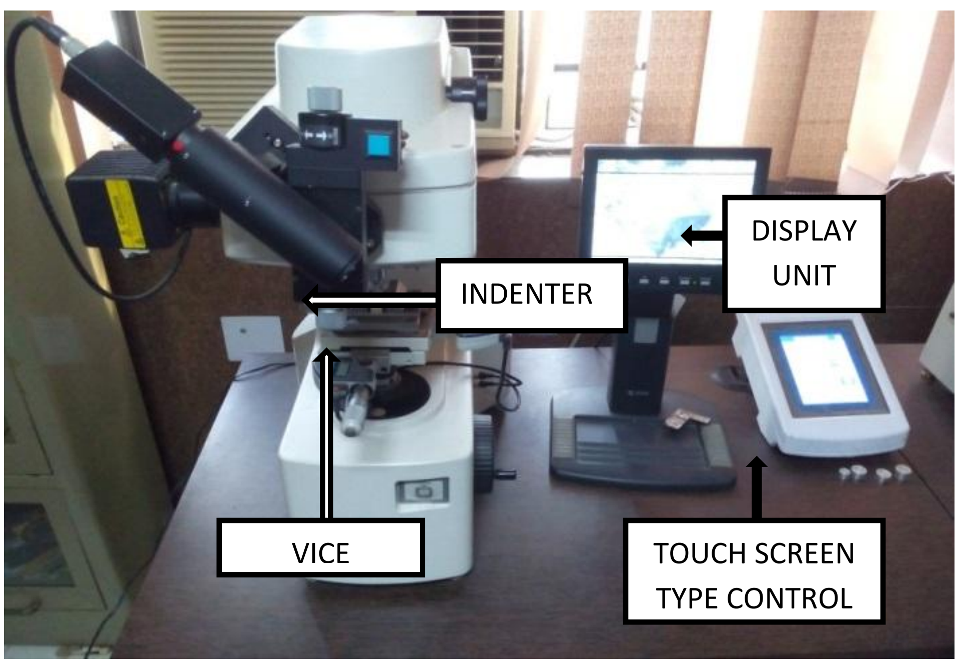


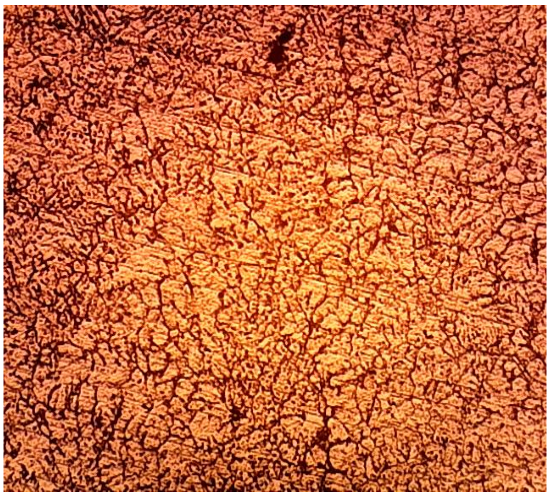
Fig.7 Hardness Tester

Fig. 8 Samples used for hardness test

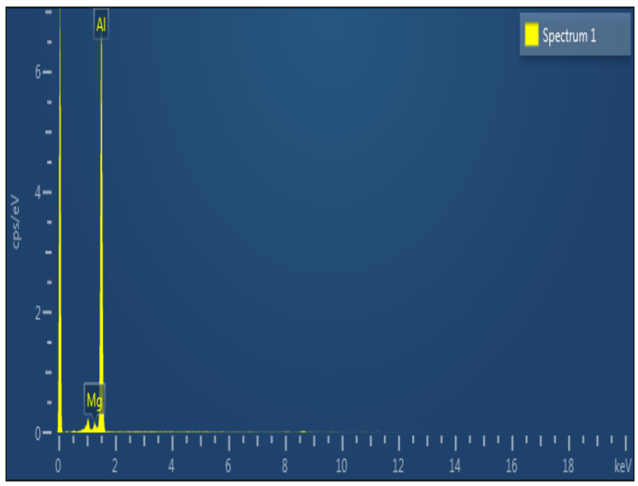
III. RESULT AND DISCUSSION

3.1Characterization of casted samples

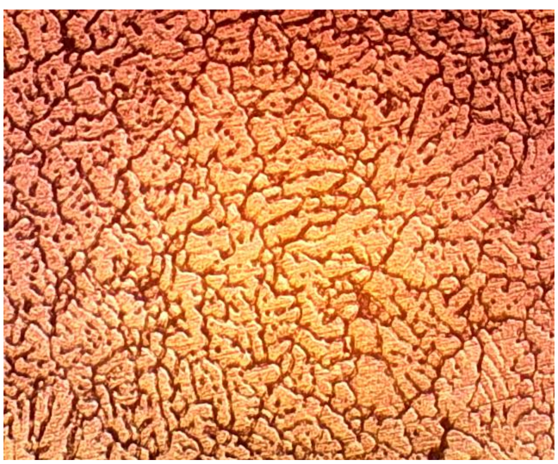
The microstructure and EDS of hybrid composite is shown in fig.9. Fig. 9 shows the proper dispersion of matrix and reinforcement material.



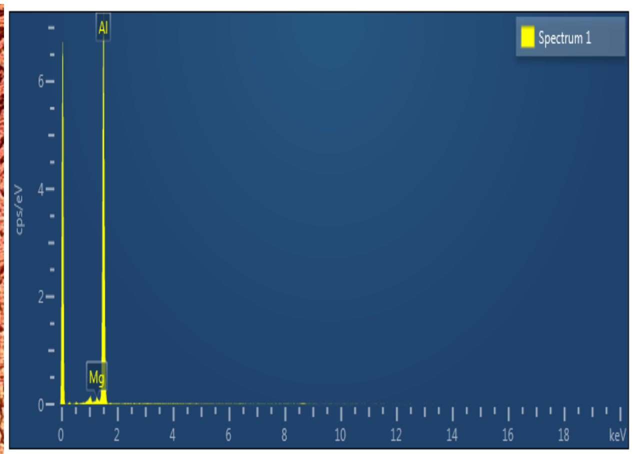
(a)



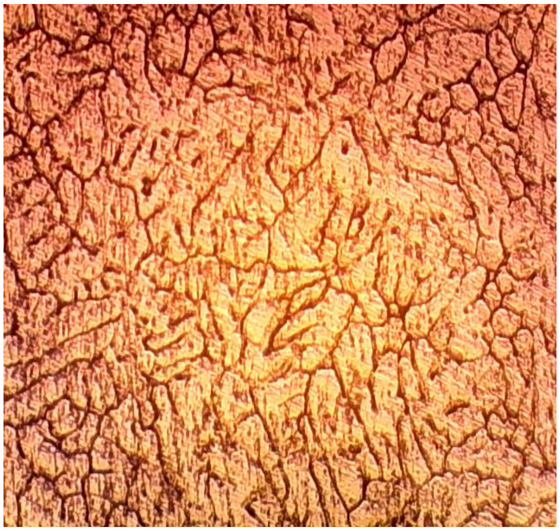
(b)

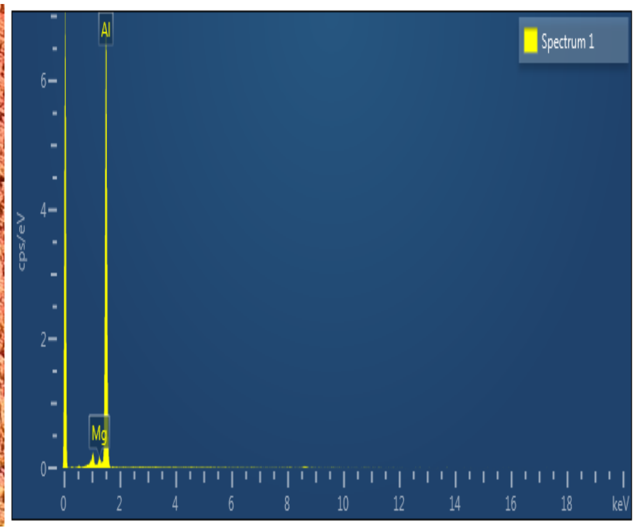


(c)

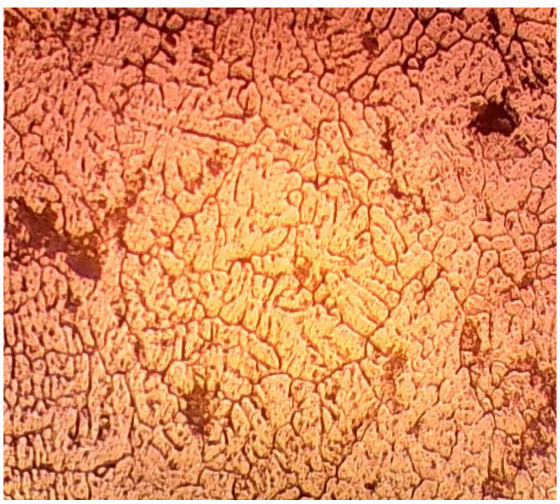


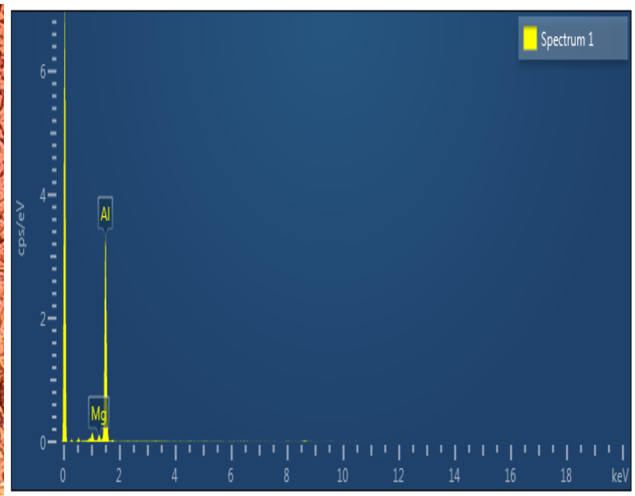
(d)





(e) **(f)**





(g) **(h)**

Fig.9 Microstructure and EDS analysis of casted samples

Fig. 9(a) shows the microstructure of pure AA7075. The grain structure of pure AA7075 shows boundaries are closer. Fig. 9(b) shows EDS image of pure AA-7075 which confirms the major alloying elements viz. Zn, Mg, Cu etc.

Fig. 9(c) shows the microstructure of AA7075+ 4% Gr hybrid composite. The grain structure of AA7075+4%Gr shows boundaries are not closer compared to pure AA7075. Fig. 9(d) shows the EDS image which confirms the elements like carbon, zinc, magnesium etc. The presence of carbon indicates graphite content into the composite.

Fig. 9(e) shows the microstructure of AA7075+ 4% SiC hybrid composite. The grain structure of AA7075 +4 % SiC shows that on adding SiC to Al the structure changes and the grains are nicely oriented without any voids. Fig. 9(f) shows EDS image which confirms the elements like Zn, Mg, Si, C. The presence of silicon and carbon indicates silicon carbide into the composite.

Fig. 9(g) shows the microstructure of AA7075+4%Gr+4%SiC hybrid composite. The presence of voids might have affected the properties obtained. Fig. 9(h) shows EDS image which confirms the presence of graphite and silicon carbide into the composite.

3.2 Effect on hardness

The hardness of AA-7075 was found to be 96 HV. It has been observed that by increasing the wt.% of Graphite (4%) the hardness of composite decreased to 94 HV.

Table 3.1 Hardness values for casted samples

Sample No.	Wt.% of AA-7075	Wt.% of Gr (percentage)	Wt.% of SiC (percentage)	Hardness (HV)
1	100	0	0	96
2	96	4	0	94
3	96	0	4	99
4	92	4	4	97

The hardness of composite increased on addition of wt.% (4%) silicon carbide and reached to 99 HV, at wt.% of (4%) Graphite + (4%) SiC the hardness value was found to be 97 HV. The results indicate that by increasing the wt.% of SiC the hardness of composite increased. The grain structure shows in different figures for pure Al, addition of Gr, addition of SiC and addition of both Gr+SiC throw light on the hardness observed in the samples. It can be seen that the grain structure of pure Al shows the boundaries closer than the Al+Gr, whereas on adding SiC to Al the structure changes and the grains are nicely oriented without any voids. In case of Al+Gr+SiC the presence of voids might have affected the properties obtained.

IV. CONCLUSION

The following conclusions are drawn on the basis of experimental work and analysis of results on AA7075/Gr/SiC hybrid composite.

- SEM and EDS results shows proper mixing of matrix and reinforcement material.
- The grain structure shows that boundaries of pure Aluminium are closer than Al+Gr.
- The maximum hardness is obtained 99 HV at 4 wt.% of SiC..
- It has been observed that on increasing the wt.% of silicon carbide the hardness of composite increased, whereas on addition of graphite reinforced particulates the hardness of composite decreased.

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