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Impact behavior of Nano SiC reinforced AA7075 metal matrix composites by FE simulation tests

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Abstract: *The aluminum alloy is having one of the superior material properties which is used in different industrial sectors like aerospace, automobile and general engineering industries because of their favorable microstructure and mechanical behavior. Research shows that The MMC's of Al alloy reinforced with SiC reinforcement have shown considerable increase in Strength, toughness, hardness etc. In this work, Composites of AA7075 and SiC(50nm) as reinforcement were fabricated by using stir casting techniques. Addition of Silicon carbide was made in weight percentage in the range of 0 to 8% respectively. Charpy Impact test was carried out for the MMC specimens. Results showed increase in energy and Toughness for the increased SiC content in the Specimens. FEM Analysis was carried out using Johnson cook material model for the MMC's, and Experimental and FEM results were compared in this work.*
Keywords:*50nmSiC, AA7075, MMC's Fabrication, Charpy Impact test with FEA by using ABAQUS software, Johnson Cook Material constants*

1. INTRODUCTION:

Metal matrix composites are popular choice when it comes to selection of materials for structure design of Aircraft and marine, automobile applications. Lot of research has undergone and has been undergoing in the field of MMC's. The experiments and results of the researchers have shown improved and enhanced Mechanical and wear properties for the reinforced MMC's. These metal matrix composites have been classified into fiber reinforced, particle reinforced and whisker reinforced composites. Particle reinforced metal matrix (PAMC) are popular choice for the researchers because of ease of the fabrication of samples. Reinforcements like Silicon carbide (SiC), alumina (Al2O3) are most commonly used reinforcements with aluminum alloys available in the series like 2K, 3K, 6K & 7K series etc. Aluminum alloys are first choice in the field of Aircraft fuselage design due to their Light weight and higher strength. When these aluminum alloys are reinforced with particles it has been observed from the research that they shown better mechanical properties. Compared to as cast alloys. AA7075 is aluminum zinc alloy which is used in the landing gear struts, wing attachments, engine mountings, and also used for the Bulkheads which carry concentrated masses in the aircraft. Two common methods are used for

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the making MMC's at Mass production, powder metallurgy (solid state technique) & casting (liquid state). the most commonly liquid state processing methods are used to produce MMC's. These are stir casting, pressure in filtration, squeeze casting &pressure less infiltration Unlu et al. [18] has conducted Experiment, and in his work, the AMMC's prepared by stir casting method have gained better mechanical properties compared to the Solid state (PM) method.

2. EXPERIMENTAL WORK

2.1 MATERIALS

In the present work, AA7075 ingots were used as a matrix and Silicon carbide particles (500nm) are chosen as reinforcement. Research and literature reveals that improved mechanical and tribological properties have been obtained by using nano particles. AA7075 which is also known as Aluminum Zinc alloy which comes from the aluminum 7000 series is a selected matrix material as it provides good strength, toughness and highly corrosive resistance. It is widely used in aircraft and marine structural applications. Specimens were made by adding the silicon carbide with weight in percentage, in the range of 0% to 8%. Major alloying components of AA7075 are shown in below table 1.

TABLE 1. COMPOSITION OF AA7075

Alloying agent	Weight.%	Alloying agent	Weight%
Cu	1.6	Zn	5.5
Mg	2.5	Cr	0.15
Si	0.4	Ti	0.2
FE	0.5	aluminum	Balance
Mn	0.3	-	-

3. FABRICATION OF MMC's

The particle reinforced composite, AA7075 as a matrix and Silicon Carbide (SiC 500nm) as a reinforcing material with 0, 2,4,6,8 wt% was fabricated by stir casting technique. About 750 grams of AA7075 ingots were taken in to electrical furnace and the matrix metal was melted at 800oC.the stir casting assembly is shown in fig.1.The magnesium ribbons were added at higher temperature to increase the wettability.Then 15 grams of the SiC powder (500nm) was taken (2% wt. of the base metal) and combined with heated liquid state metal. the mixture was preheated up to 300oC to avoid the moisture content in the liquefied metal. the molten mixture was stirred at a constant speed of 300rpm with a mechanical stirrer.

Finally the molten mixture was poured in to the 15mmX150mm sized moulds and allowed to cool.the cast samples are shown in fig.2.The same procedure was carried out to get the samples with 0%, 4%, 6% and 8%.

Fig.1 Stir casting set up

Fig.2.Stir cast samples

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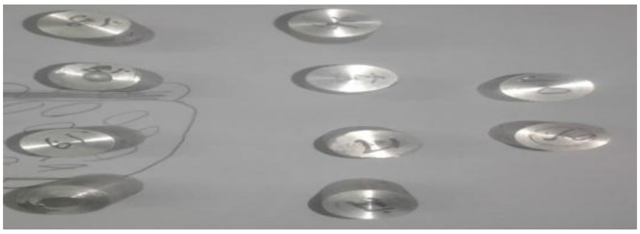

Fig.3 specimens for XRD

4. X-RAY DIFFERACTION

Stir cast samples were machined & made into different specimens as per ASTM standards to carryout mechanical tests. Before conduction of the tests the samples were tested using X-ray diffraction (XRD) peak intensities and peak positions were obtained for the 0%, 2%, 4%, 6%, 8% samples respectively from the X-ray Diffractometer. XRD Patterns list and peak intensities, positions were obtained from Diffract meter system=XPERT-3.for the MMC samples. XRD tests confirmed the crystallite size of the SiC and its cubic structure. The figure 3. Shows XRD samples and fig.4 shows XRD patterns of all the prepared samples.

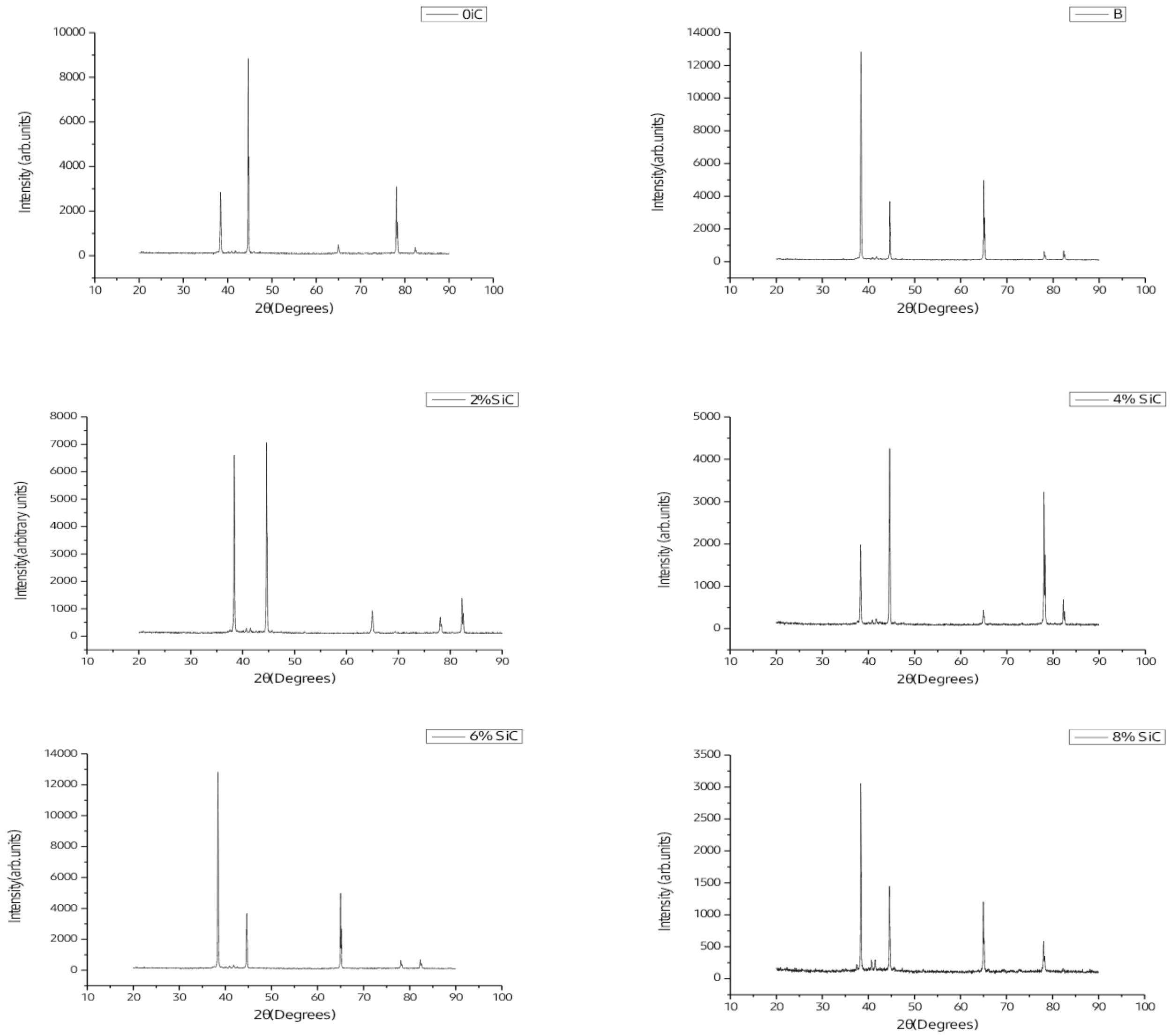

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Fig.4.XRD Peaks of (0% to 8% SiC) MMC samples

5. CHARPY IMPACT TEST

Charpy impact test was carried out to enhance the impact energy and impact strength of the fabricated samples the experiment was conducted and impact specimens were prepared as per the ASTM E23 – 18 standards. Impact tests were conducted using a fully instrumented test machine. Which gives the impact energy in the range of from 0·2 J to 360 J. 22·7 kg of hammer was used with striking velocity in the range of 0·1 m/s to 5·1 m/s. Three samples were fabricated for each weight percentage. And all the specimens were tested at a constant striking velocity of 2·5 m/sec, the specimen details and impact test machine are shown in Fig.5,6 and 7 respectively. variation of absorbed energy with time.was observed and the absorbed energy was recorded. Charpy impact tests were conducted on both unreinforced and reinforced MMC specimens. Test specimens measured 55 × 10 × 10 mm. The notch had a depth of 2 mm and a notch tip radius of 0·02 mm

Fig.5.Impact test specimens

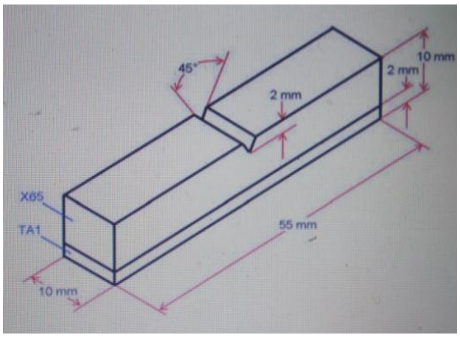

Fig.6.Charpy Impact test specimen size

Fig.7 Impact testing machine

6. VOLUME, MASSFRACTIONESTIMATION

Before doing the FEM analysis for the impact test, mechanical properties like Density, volume fractions, Mass fractions & Young's modulus needs to be estimated estimated. Therefore by using rule of mixture empirical relations following values were used for the FEM analysis.
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Density of the composites is given by equation

$$\rho_c = f_m \rho_m + f_r \rho_r \qquad \text{(1)}$$

The following equations were used to measure the mass fraction of matrix and reinforcement also volume fractions of SiC finally young's modulus is estimated by kerner equation.

$$f_m = \frac{M_m}{(M_m + R_m)} \qquad \text{(2)}$$

Similarly mass fraction of reinforcement is calculated using below relation.

$$f_r = \frac{R_m}{(M_m + R_m)} \qquad \text{(3)}$$

Volume fractions of reinforcement are determined by using below expressions.

$$V_{sic} = \frac{\frac{m_{sic}}{\rho_{sic}}}{\left[\frac{m_c - m_{sic}}{\rho_{Al}}\right] + \frac{m_{sic}}{\rho_{sic}}} \quad \ldots (4)$$

And young's module of all specimens is estimated by below equation.

$$E_c = E_m\left[1 + \frac{v_p}{1-v_p} \times \frac{15(1-m_m)}{8-10m_m}\right] \quad \ldots (5)$$

Using above empirical relations, the young's modules of all the specimens were calculated as shown in the table below.

S.No	MMC Samples	Young's Modulus (GPa)
1	$E_{as\ cast}$	71.7
2	$E_{2\%SiC}$	74.5
3	$E_{4\%SiC}$	77.3
4	$E_{6\%SiC}$	80.3
5	$E_{8\%SiC}$	83.4

TABLE 2. YOUNG'S MODULUS VALUES ESTIMATED BY RULE OF MIXTURE METHOD

These results shows that young's modulus of the MMC increases as the weight percentage of reinforcement (Silicon carbide) increases research also reveals that young's modulus linearly increases with addition of particle, whiskers, and fiber reinforcements.

7. JOHNSON COOK MATERIAL CONSTANTS

To carryout FEM analysis for impact test, flow stress and fracture stress are required using Johnson cook material model all the material constants were obtained. The flow stress is defined as

$$\sigma = (A + B\varepsilon^n)(1 + C * ln\varepsilon^*)(1 - T^m) \quad \ldots (6)$$

Where

A=Yield Strength of the MMC

B= constant

n=Strain hardening Co-efficient

Ɛ=Strain

C= coefficient of strain rate

Ɛ*=Strain rate

T=Temperature and M=Thermal softening coefficient

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At first the value of Yield stresses were obtained from tensile tests. And the constants B and n were obtained by plotting the graph $\ln(\sigma - A)$ *and* $\ln\varepsilon$ the slopes and intercept values gives the values of n and B.

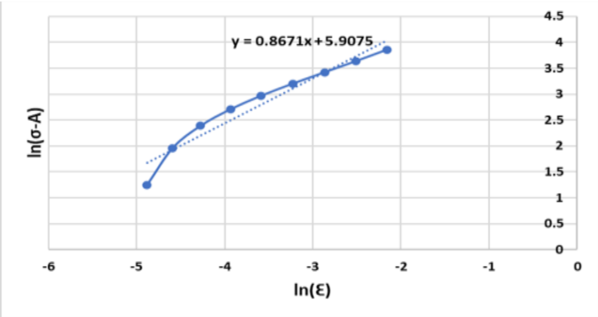


Fig.8 Values of constants n and B

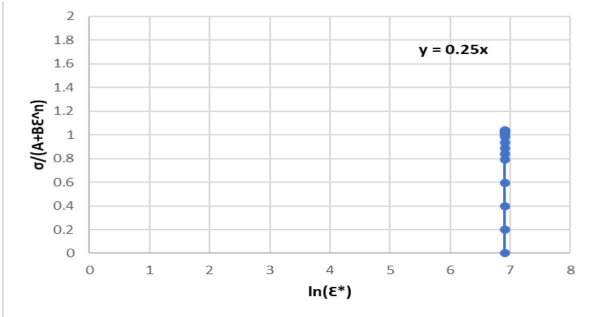


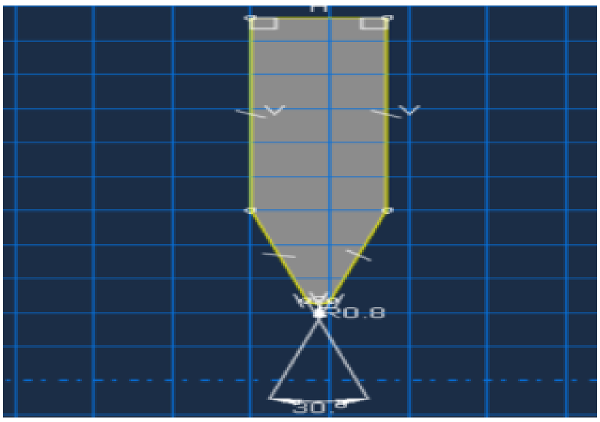
Fig.9 Value of constant C

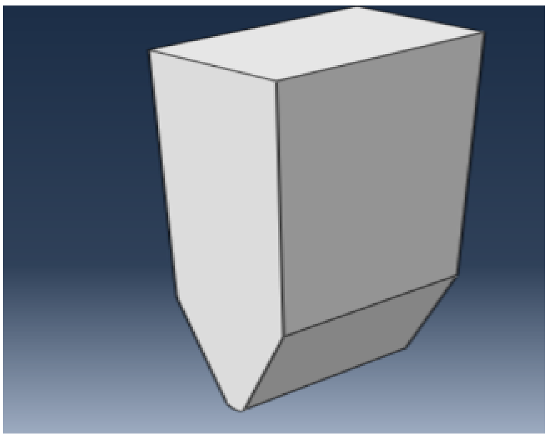
%SiC	A	B	n	C
0%	199.74	367.7855413	0.867	0.25
2%	233.79	22879.58	1.9571	0.0625
4%	252.8	32338.05535	2.0343	0.0625
6%	274.14	63006.93	2.1366	0.0625
8%	319.36	116308.3345	2.2168	0.0001

TABLE.3 JOHNSON COOK MATERIAL CONSTANTS

8. FEM ANALYSIS

Charpy impact test was carried out with Johnson cook material conststants by using ABAQUS Impactor and the specimen model were created as per the ASTM standards and estimated young's modulus, Johnson cook material constants used to study the impact behavior. Fine Meshing was made near the Impactor Zone Hexagonal 8 Node (C3D8R) Brick elements used to mesh the model 60166 nodes were created and Total 65723 nodes were created all the details of FEM analysis shown in the below figures.





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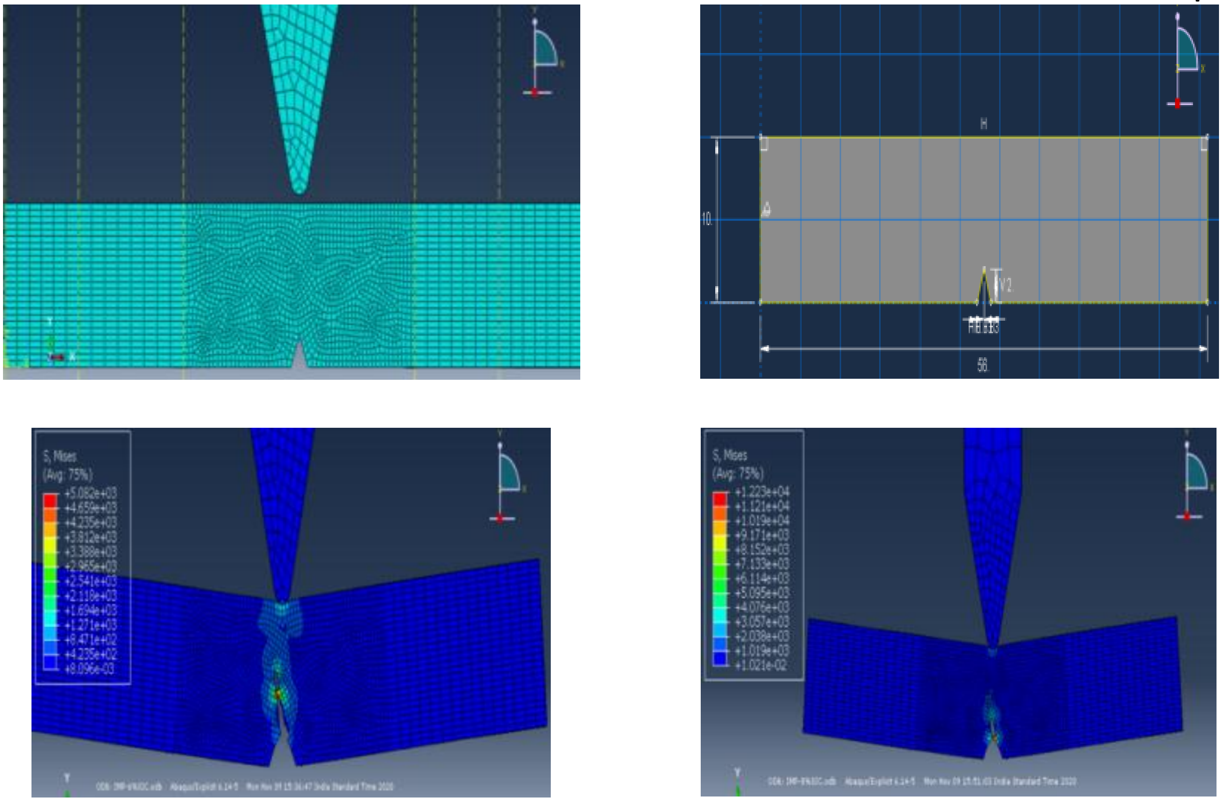

Fig.10 Meshed Model Boundary conditions FEM

9. RESULTS AND DISCUSSIONS

Von mises stresses were obtained from the FEM results and the deformations, internal energy were also obtained whichare given below.

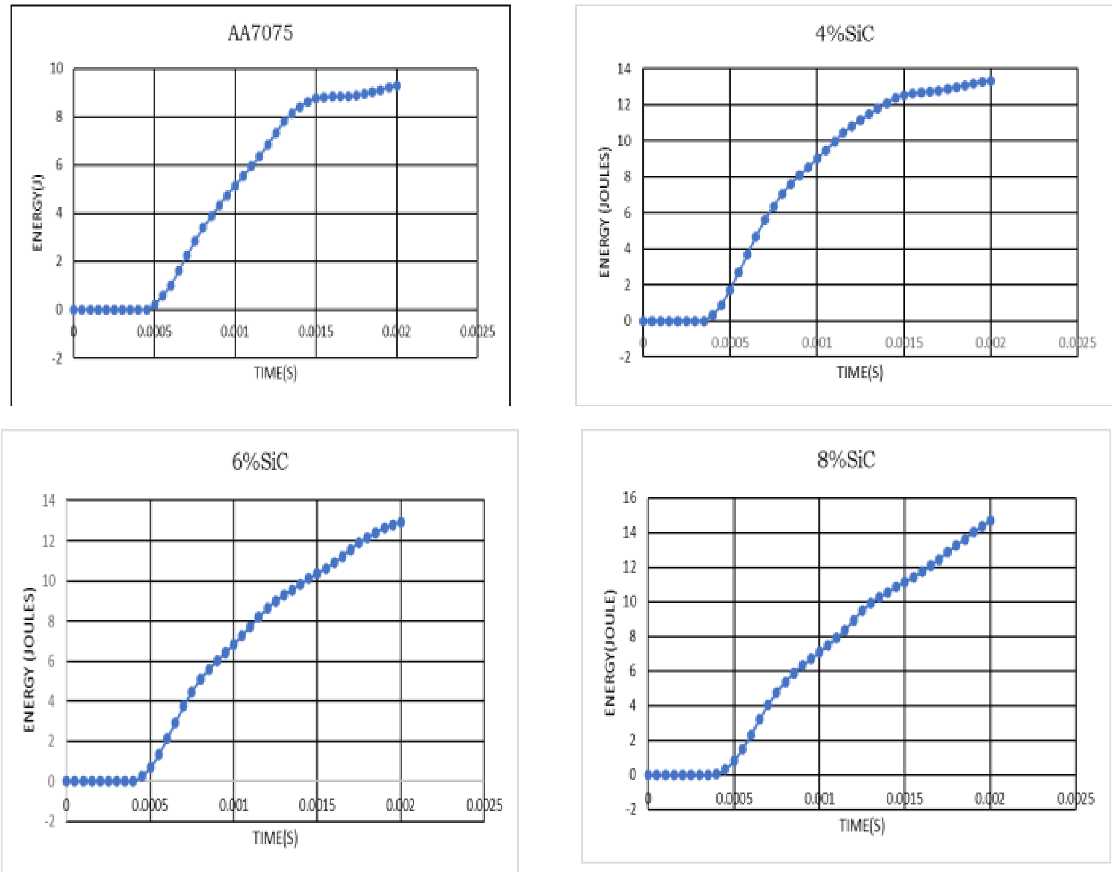

Fig 11. Comparisons of FEM Results with Experiment results

COMPOSITION	ENERGY(JOULE)-EXP	ENERGY(JOULE)-FEM
AA7075 as Cast	9J	9.29563
2%SIC	10J	11.0119
4%SIC	13J	13.3207
6%SIC	13J	12.9597
8%SIC	14J	14.6748

TABLE.4 RESULT COMPARISON

10. CONCLUSION

In this work Stir cast Samples of nano SiC reinforced AA7075 metal matrix composites were fabricated and XRD peak positions, intensities confirmed the presence, crystal structure and crystal size of the silicon carbide. Impact test experiments showed the increase in the energy for increase in weight percent of reinforcements.

Young's modulus was linearly increased with the addition of SiC and the FEM analysis was carried out using Johnson cook material constants and the impact behavior of MMCs with FEM was almost same as compared to the experimental results

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