Static and Dynamic analysis of LM6/Silicon nitride metal matrix composite using Ansys software

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Abstract— Behavior of aluminum matrix (LM6) /Silicon nitride composite is investigated by analytical and finite element analysis. Tests are performed to find out the static(deformation) and dynamic(natural frequency) behavior for 0%,6%,and 10% volume fraction of silicon nitride/LM6 composite.Static analysis(deformation) modal analysis (natural frequency) are simulated using the finite element analysis software ANSYS.

Keywords— Metal matrix composite, LM6, Silicon nitride, static analysis, dynamic analysis

I. INTRODUCTION

LM6 is Light metal which belongs to the 4^{th} series of Aluminium.Its property of resistance to cracking, corrosion resistance makes wide application in automobile and aerospace industry[1].Applications of Aluminum-based MMCs have increased in recent years as engineering materials. The introduction of a ceramic material in the powder form into a metal matrix produces a composite material that results in an attractive combination of physio mechanical properties which cannot be obtained with monolithic alloys[3] [4].

In Metal Matric composite coste plays a vital role for application in automobile and aerospace sector. although the potential benefits in weight saving, increased component life, and improved recyclability should be taken into account. Today, even in those terms, MMCs are still significantly more expensive than their competitors[7]. By using simple fabrication technique and mass production method ,use of inexpensive reinenforcement will bring down the manufacturing cost of Metal Matrix Composites.

In the past, several studies have been carried out on metal matrix composites. SiC, TiC and TaC reinforment. material for metals such as aluminium or iron [5]. While the study of Silicon nitride reinforcement in LM6 alloy are rare. Silicon nitride is easily available cheaper reinforcement hence it will decrease the production cost of Metal Matrix Composite [6].

Work starts with Study of previous researches on composite materials and Material synthesis for various percentage of silicon nitride. The study is to analyze the effect of static loading, and vibration of the material in the metal matrix composite of LM6 and Silicon nitride.

II. MATERIAL PROPERTY CALCULATION

The chemical composition and mechanical properties of LM6 aluminium alloy and Silicon nitride are given below. By using rule of mixture calculation,Young's modulus and Poissons ratio of LM6 and silicon nitride metal matrix composite is obtained for varying volume fraction of Silicon nitride(0%,6% and 10%). These material properties obtained are used for analysis.

Rule of Mixture formula:

For young's modulus:

$$E = (E_m V_m) + (E_R V_R)$$

For density:

$$\rho = (\rho_m V_m) + (\rho_R V_R)$$

where,

E_m → Young's modulus of Base metal

V_m → Volume fraction of Base metal

E_R → Young's modulus of reinforcement

V_R → Volume fraction of reinforcement

ρ_m → Density of Base metal

ρ_R → Density of reinforcement

TABLE2.1: CHEMICAL COMPOSITION OF LM6[2].

Chemical composition	Percentage
Copper	0.1 max
Magnesium	0.10 max
Silicon	10.0-13.0
Iron	0.6 max
Manganese	0.5 max
Nickel	0.1 max
Zinc	0.1 max
Lead	0.1 max
Tin	0.05 max
Titanium	0.2 max
Aluminum	Remainder

TABLE2.2: ENGINEERING PROPERTIES OF LM6[18].

Density,(ρ)	2.68g/CC
Poisson's ratio,(μ)	0.3
Young's modulus,(E)	71 Gpa

TABLE 2.3: ENGINEERING PROPERTIES OF SILICON NITRIDE[18].

Density,ρ	3.44g/CC
Poisson's ratio, μ	0.3
Youngs modulus,E	310 a

TABLE 2.4: ENGINEERING PROPERTIES OF LM6/ Si_3N_4 COMPOSITE MATERIAL OBTAINED FROM RULE MIXTURE CALCULATION.

Property	Unit	0% of Si3N4	6% of Si3N4	10% of Si3N4
Density	g/cc	2.68	2.785	2.842
Modulus Of Elasticity	GPa	71	85.34	94.9
Poisson's Ratio	_	0.3	0.3	0.3

III. RESULTS AND DISCUSSIONS

The prepared CAD models are imported to ANSYS workbench and are meshed. Engineering properties of material like young's modulus, poisson's ratio and density are fed into ansys software as given in Table 4. Static analysis and dynamic analysis(modal analysis) is performed to determine total deformation and natural frequency of the composites of 0%,6%,and 10% volume fraction of Si_3N_4.Natural frequencies were extracted for the first six modes. The deformations for each of the mode are recorded. Fig. 3.1 shows the meshed model of the component.

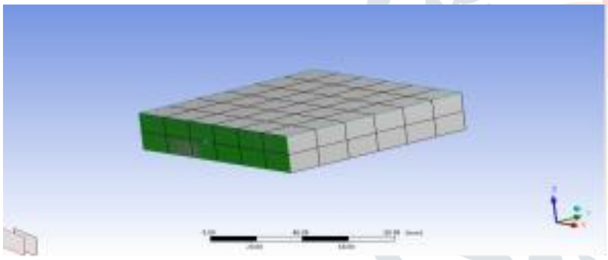


Fig 3.1 Meshed model of LM6/ silicon nitride

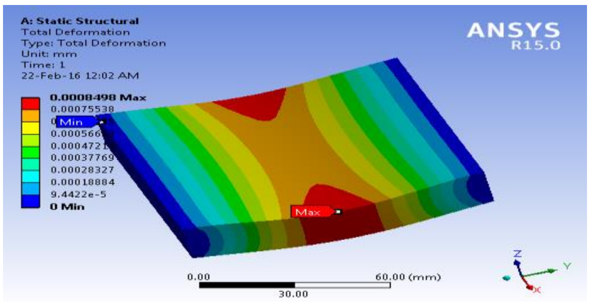


Fig 3. 2 Total deformation for the specimen with 0% Vol of Si_3N_4

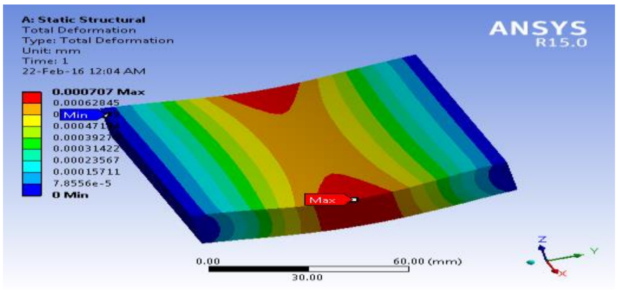


Fig 3. 3 Total deformation for the specimen with 6% Vol of Si_3N_4

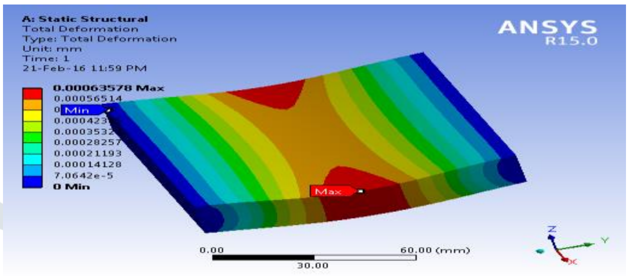
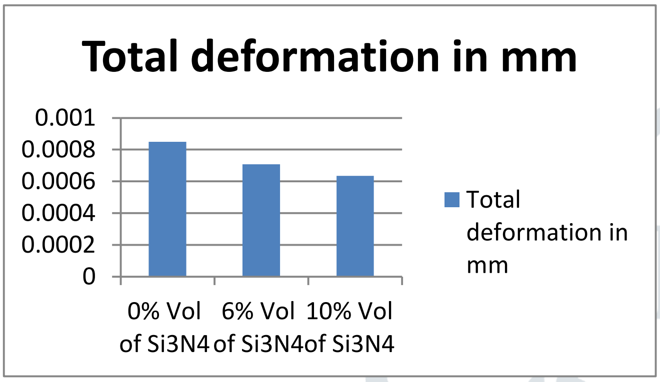


Fig 3. 4 Total deformation for the specimen with 10% Vol of Si_3N_4

Fig. 3.2, 3.3 and 3.4 shows total deformation for the composite with 0%,6% and 10% Vol of Si3N4 respectively.The displacement boundary conditions are that the opposite faces are fixed and load is applied on the top face of the component. Total deformation values for the composites with 0%,6% and 10% Vol of Si3N4 is shown in below table 3.1

Table 3.1:Total deformation of components with different volume percentage of Si3N4

components with different volume percentage of Si3N4	0% Vol of Si3N4	6% Vol of Si3N4	10% Vol of Si3N4
Total deformation in mm	0.0008498	0.000707	0.00063578



GRAPH 3.1 Total deformation of components with different volume percentage of Si3N4,

In graph 3.1 we can observe that as we increase percentage volume of silicon nitride in LM6 deformation of the material decreases, this shows increase of bending strength in the material.

Then Modal analysis is performed to determine the natural frequencies of the composites. Natural frequencies were determined for the first six modes. The deformations at each mode are recorded for different volume fraction of silicon nitride(0%,6%,10%).

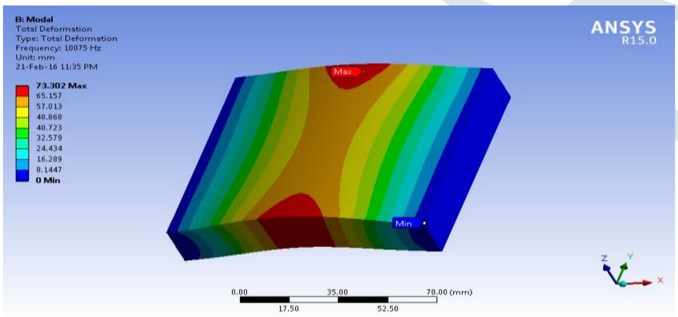


Fig 3.2.1 Mode 1

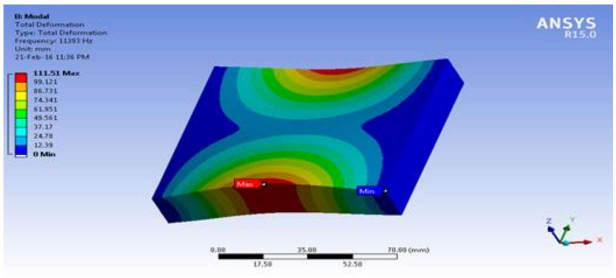


Fig 3. 2.2 Mode 2

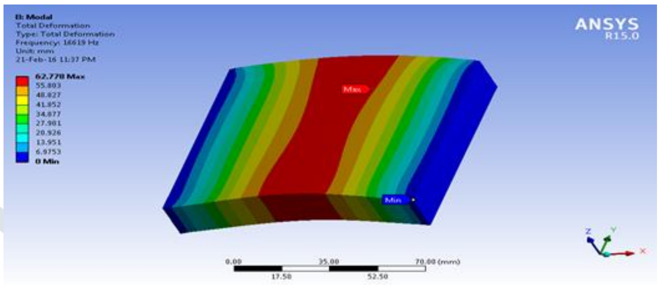


Fig 3. 2.3 Mode 3

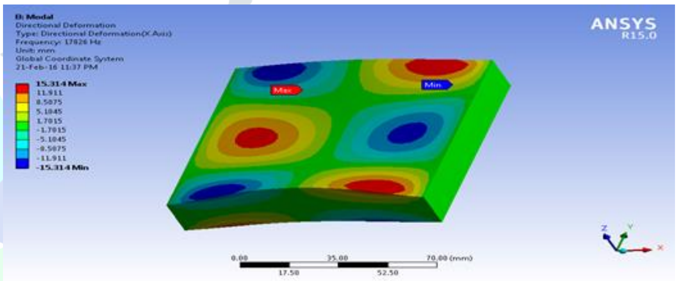


Fig 3. 2.4 Mode 4

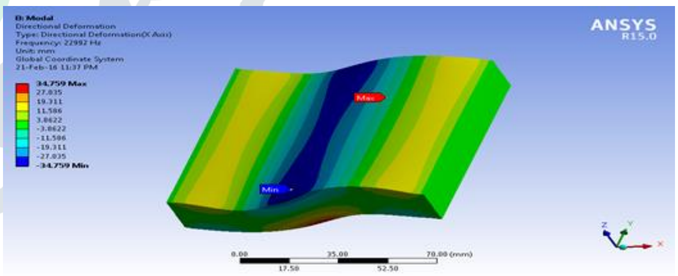


Fig 3. 2.5 Mode 5

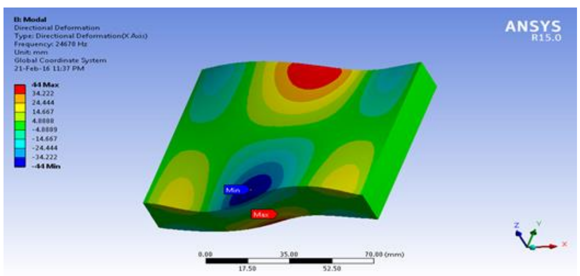


Fig 3. 2.6 Mode 6

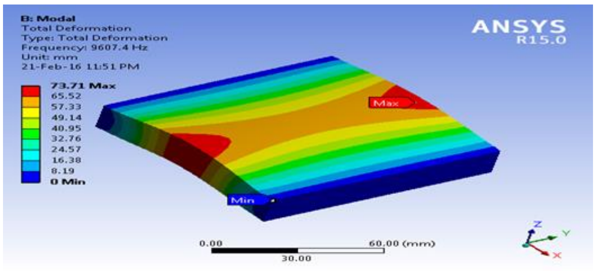


Fig. 3 Mode shapes for the block with 0% Vol of Si3N4

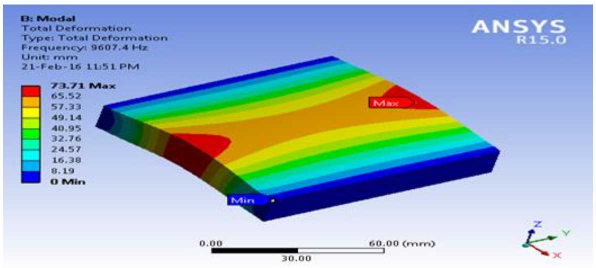


Fig. 3.3.1 Mode 1

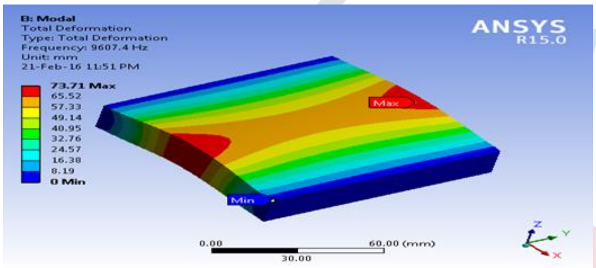


Fig. 3.3.2 Mode 2

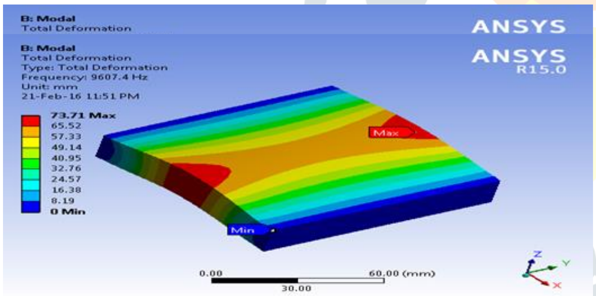


Fig. 3.3.3 Mode 3

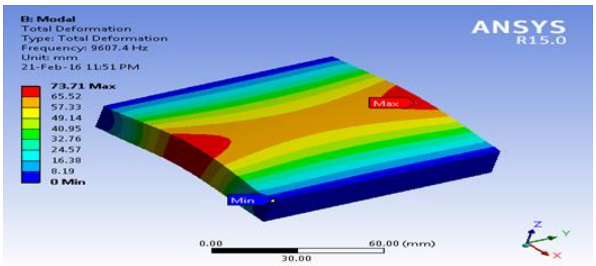


Fig. 3.3.4 Mode 4

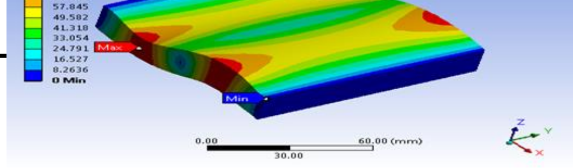


Fig.3.3..5 Mode 5

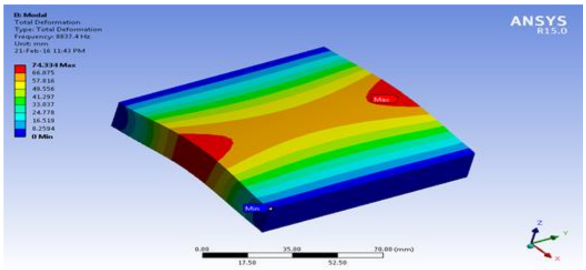


Fig. 3.3.6 Mode shapes for the block with 6% Vol of Si3N4

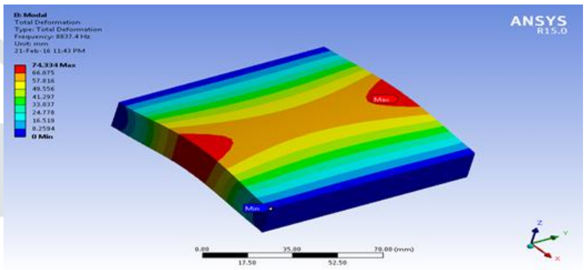


Fig. 3.4.1 Mode 1

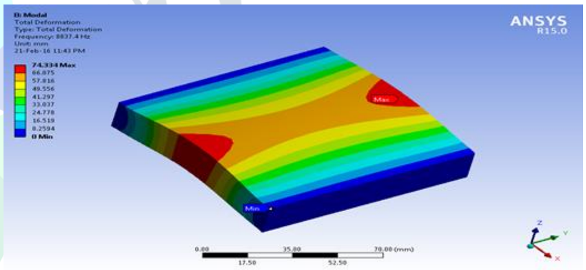


Fig. 3.4.2 Mode 2

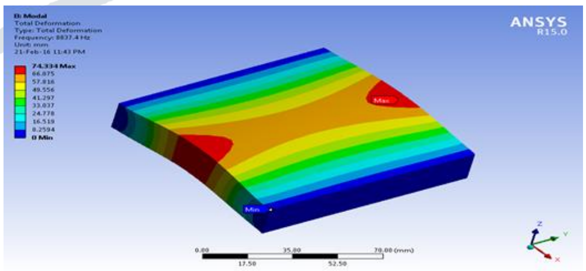


Fig. 3.4.3. Mode 3

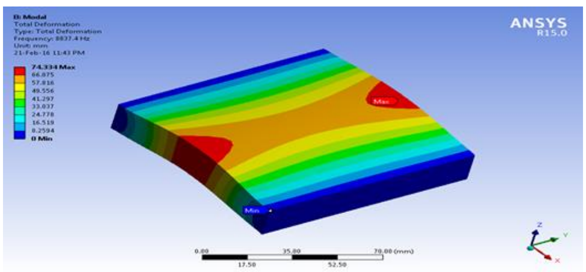


Fig. 3.4.4. Mode 4

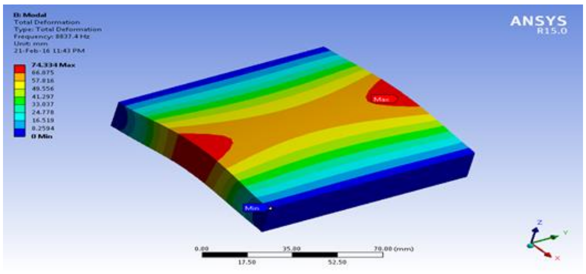


Fig. 3.4.5. Mode 5

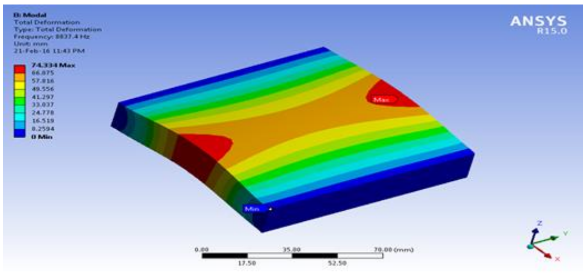


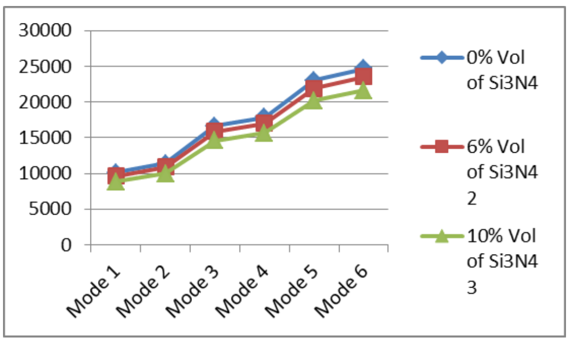
Fig. 3.4.6. Mode 6

Fig. 3.2 ,3.3,3.4 shows natural frequency of first six modes(six degrees of freedom) for 0%,6%and 10% Vol of Si_3N_4 respectively . The displacement boundary conditions are one end is fixed and other end is left free.

Table 6 shows the natural frequency of the components at different modes.

Table 3.2: Natural frequencies of components with different volume fraction of Si_3N_4

Frequency in Hz			
components with different volume percentage of Si3N4	***0% Vol of Si_3N_4***	***6% Vol of Si3N4***	***10% Vol of Si3N4***
Mode1	10075	9607.4	8837.4
Mode2	11393	10864	9993.6
Mode3	16619	15848	14577
Mode4	17826	16998	15636
Mode5	22992	21924	20167
Mode6	24670	23525	21639



Graph 2: Natural frequency of components with different volume fraction of Si_3N_4

In graph 2 it can be observed that silicon nitride has an effect on vibrational property generated in LM6 metal matrix composites as percentage of silicon nitride is increased in metal matrix there is reduction in natural frequency, hence there is reduction in vibration

CONCLUSIONS

1. Component subjected to static force analysis to evaluate the strength of the components, the above analysis shows that by increasing the percentage of silicon nitride reduces the deformation in the components.

2. Components subjected to free vibration test to evaluate the damping behavior and natural frequency of the composites. It is shown that silicon nitride has an effect on vibrational property generated in LM6 metal matrix composites. For 6% and 10 % by Vol addition of silicon nitride, there is reduction in natural frequency. This shows that increasing the silicon nitride content reduces the vibration in the material.

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