International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 11 (2019) pp. 2630-2635

Comparative Analysis of AMMC and Al alloy produced by Plunger Technique for Buckling of column using FEM

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Abstract

Aluminium metal matrix composite (AMMC) is considered as a new structural material. In the present investigation Al-3%Mg alloy and Al-3%Mg-10%SiC particulate composite are prepared by the plunger technique for the comparative study. Plunger technique is a modified stir casting method for production in laboratory scale which can be scaled up for production to be used in structural applications. It is required to develop general design guidelines to prevent buckling in column like structure. So buckling analysis of the structures using finite element method (FEM) is considered with increasing axial load to get the modal frequency with corresponding deflection. In the present work energy method is used to attain the maximum deflection with respect to axial load in the buckling analysis. A FEM model of cylindrical cross-section column like structure is presented. The column bottom end is fixed and top end is free. The axial load is applied at the free end and perpendicular to the cross-section. From the FEM model the conclusion is drawn that on increasing the axial load deflection increases but stiffness increases in case of AMMC as compared to alloy.

Keyword: Aluminium metal matrix composite, Alloy, buckling, finite element, deflection

INTRODUCTION

Aluminium Metal Matrix Composites (AMMCs) have been developed and used in the ever expanding fields of automobiles and aerospace industries and construction applications. AMMCs offer a variety of properties that are much superior to the matrix alloy. AMMCs have been reported to have improved strength-to-weight ratio, higher specific modulus and better wear properties [1,4,5]. In recent past, Aluminum-based composites have potentially grown in engineering and structural applications starting from automobile and construction industries to marine and aerospace industries[1-3]. Aluminum has a very unique combination of physical and mechanical properties as well as good corrosion resistance which can be used in variety of structural applications. Aluminum is light weight, has high strength-to-weight ratio, good thermal and electrical conductivity and thermal coefficient of expansion. Addition of alloying elements like magnesium is made in order to further improve its properties. Thus, aluminium and its alloys with magnesium reinforced with ceramics, have become the most suitable candidates for structural applications. The aluminium-magnesium-silicon carbide (SiC) composites are very light weight, have high strength-to-weight ratio, high specific strength, high specific rigidity therefore it shows improved buckling behaviour. Moreover, as these MMCs are extensively used in construction applications, they are subjected to different adverse conditions which result in buckling. Thus it becomes very vital to study the buckling behaviour of these composites. So Finite Element Method (FEM) was used to analyse the fixed free column structure on matrix alloy and MMC[6-7]. The aim of the present investigation was to investigate the deflection of column type structure made of Al-3%Mg alloy and (Al+3%Mg+10%SiC) AMMC under compressive load using finite element approach.

FINITE ELEMENT ANALYSIS PROCEDURES

The materials (Al-3%Mg alloy and Al-3%Mg-10%SiC) for present investigation are produced by plunger technique, mentioned elsewhere [4,5] and their microstructures are shown in fig i&2 as well as mechanic and physical properties are tabulated in Table-1.

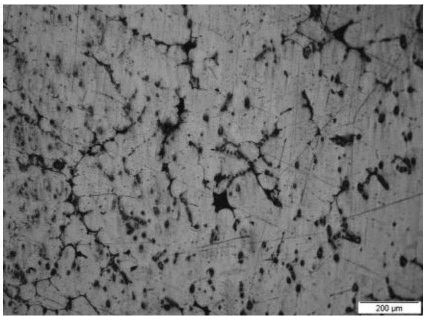


Fig.1 Microstructure of Al-3% Mg alloy

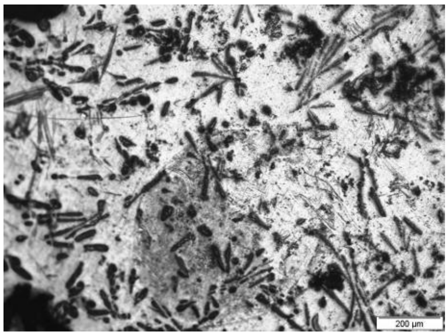


Fig.2 Microstructure of Al-3% Mg-10%SiC MMC

Table 1. Mechanical property of alloy and composite

Material	Yield Strength (MPa)	Tensile Strength (MPa)	Elastic Modulus (GPa)	% of Elongation	Poisson's ratio	Density Kg/m^3
Alloy	91	224	62	21.25	0.32	2668
Composite	136	293	77	6.7	0.29	2699

A solid column of height (L) and diameter (D) shown in (Fig.1) is considered for Finite Element analysis made of Al-3%Mg alloy and Al-3%Mg-10%SiC composite.

A geometrical model of column as shown in Fig.1 with diameter (D) = 11.2 mm and height (L) = 250 mm were considered for buckling analysis [104] using ANSYS R 14.0 software. . The steps involved in this procedure are given in flow chart (Fig.2).

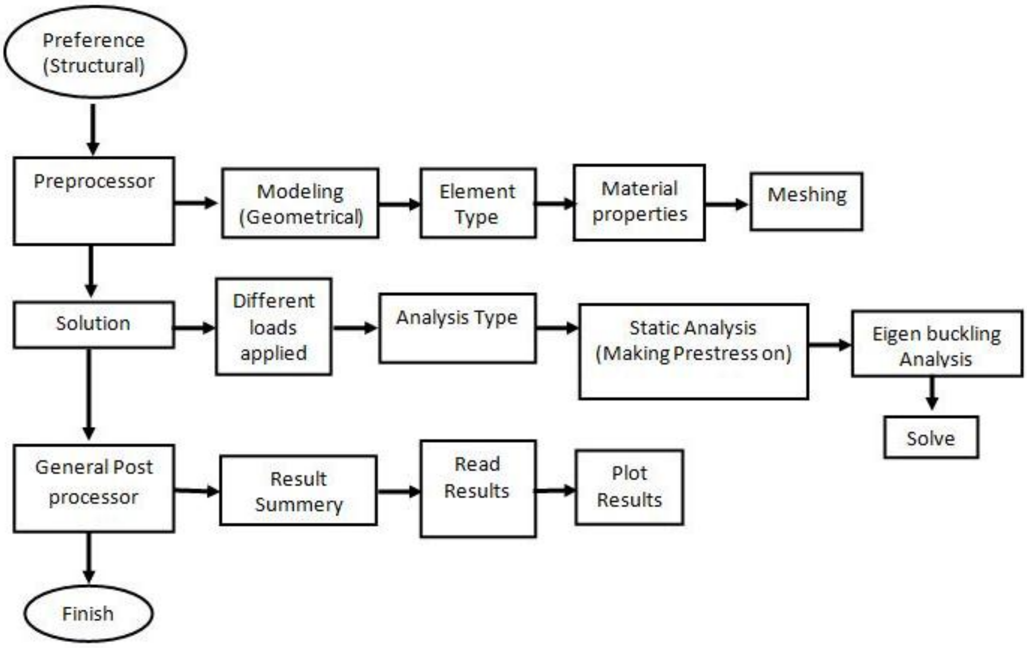


Fig.4 Finite element process flow chart

Using the above path, the first three mode shape of deformation for buckling of columns had been investigated considering three different loads and the results were compared through figures and graphs.

Buckling analysis using FEM

Euler's buckling load for fixed-free column is $P=\frac{n^2\pi^2EI}{4l^2}$ [104]. Columns made of base alloy (Al-3%Mg) and MMC (Al-3%Mg-10%SiC) was considered for FEM analysis.

Using Table-1 data the buckling loads for first mode of deflection i.e. n=1 was calculated as $(P)_{Alloy}$=1.89KN and $(P)_{Composite}$=2.34KN .The buckling analysis was done for the load which was below the critical load.

RESULT AND DISCUSSION

The deflection distribution zones and deflections along the length of the column for different loads i.e. 0.5KN, 1KN, 1.5KN were shown in the following figures.

Case: 1 Deflection zones under the axial Load 0.5KN

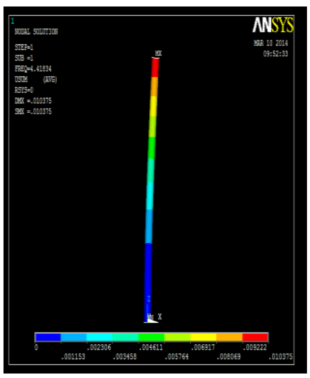


Fig. 5 (a): Buckling deflection for first Mode shape of alloy with load 0.5KN

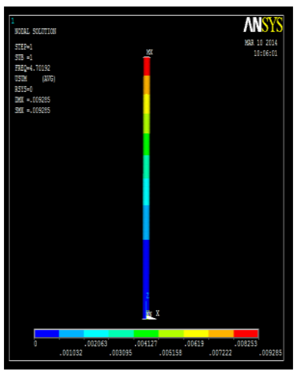


Fig. 5 (b): Buckling deflection for first Mode shape of MMC with load 0.5KN

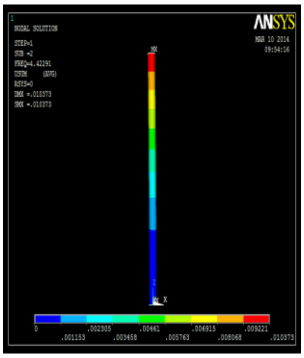


Fig. 6 (a): Buckling deflection for second Mode shape of alloy with load 0.5KN

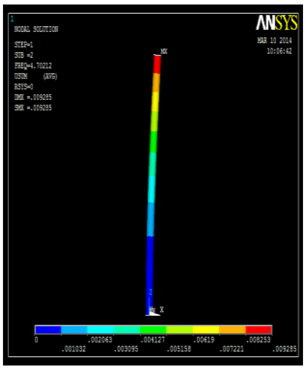


Fig. 6 (b): Buckling deflection for second Mode shape of MMC with load 0.5KN

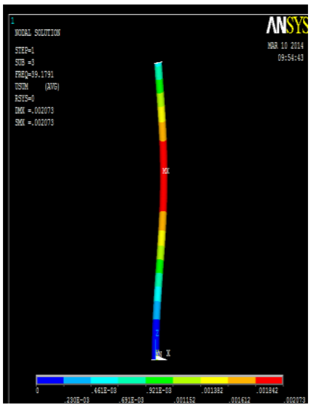


Fig. 7 (a): Buckling deflection for Third Mode shape of alloy with load 0.5KN

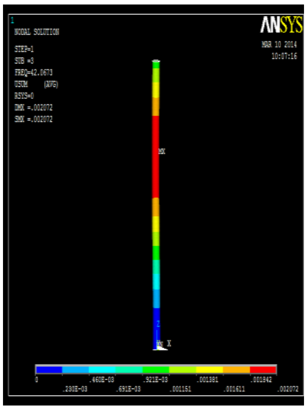


Fig. 7 (b): Buckling deflection for Third Mode shape of MMC with load 0.5KN

Case: 2 Deflection zones under the axial Load 1.0 KN

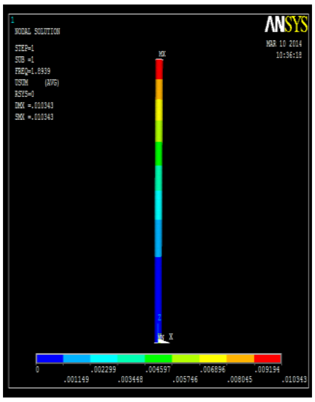


Fig. 8 (a): Buckling deflection for first Mode shape of alloy with load 1KN

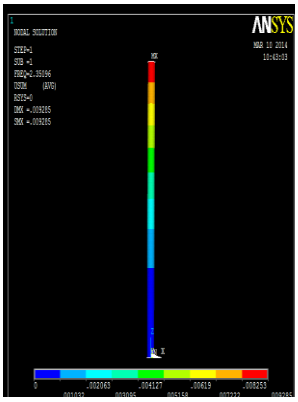


Fig. 8 (b): Buckling deflection for first Mode shape of MMC with load 1KN

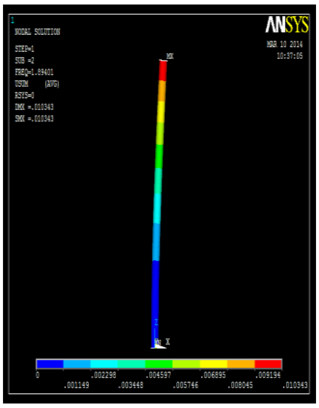


Fig. 9 (a): Buckling deflection for second Mode shape of alloy with load 1KN

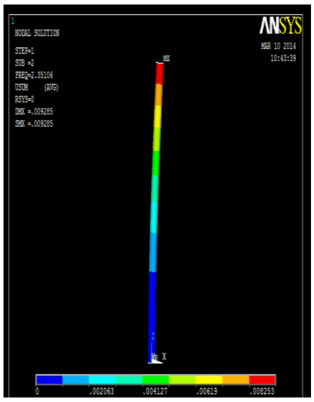


Fig. 9 (b): Buckling deflection for second Mode shape of MMC with load 1KN

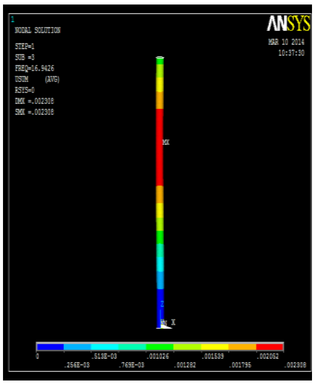


Fig. 10 (a): Buckling deflection for Third Mode shape of alloy with load 1KN

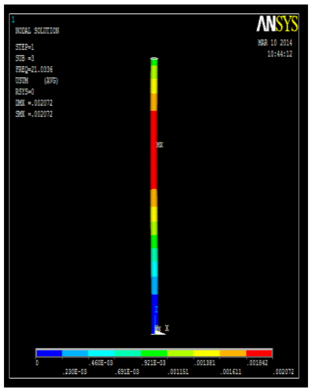


Fig. 10 (b): Buckling deflection for Third Mode shape of MMC with load 1KN

Case: 3 Deflection zones under the axial Load 1.5KN

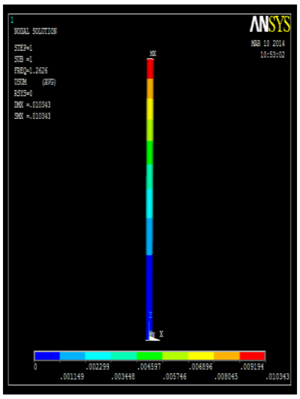


Fig. 11 (a): Buckling deflection for first Mode shape of alloy with load 1.5KN

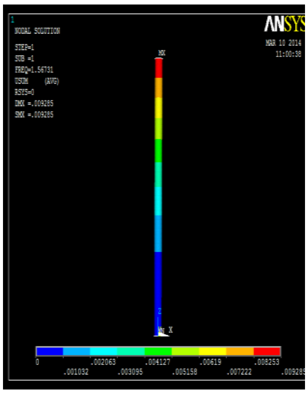


Fig. 11 (b): Buckling deflection for first Mode shape of MMC with load 1.5KN

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 11 (2019) pp. 2630-2635

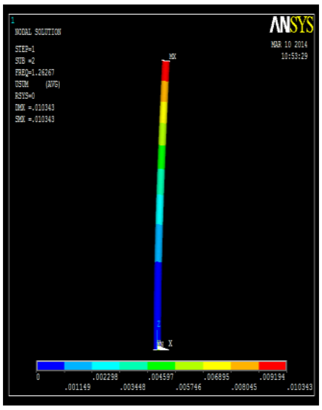


Fig. 12 (a): Buckling deflection for second Mode shape of alloy with load 1.5KN

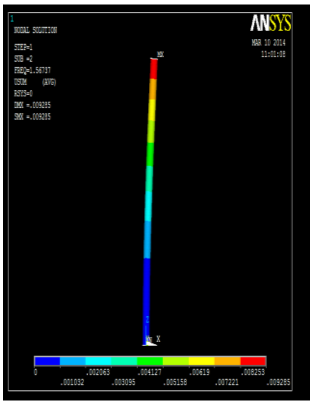


Fig. 12 (b): Buckling deflection for second Mode shape of MMC with load 1.5KN

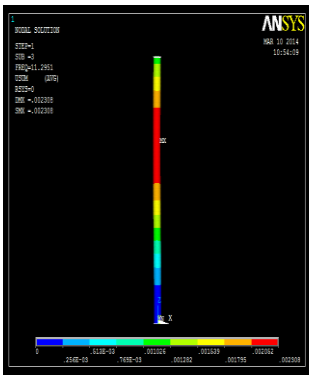


Fig. 13 (a): Buckling deflection for Third Mode shape of alloy with load 1.5KN

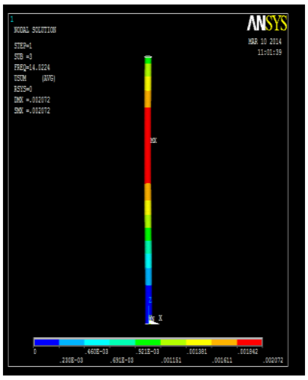
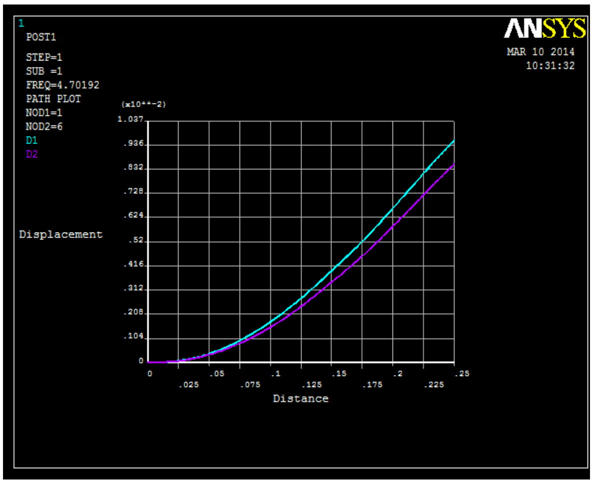


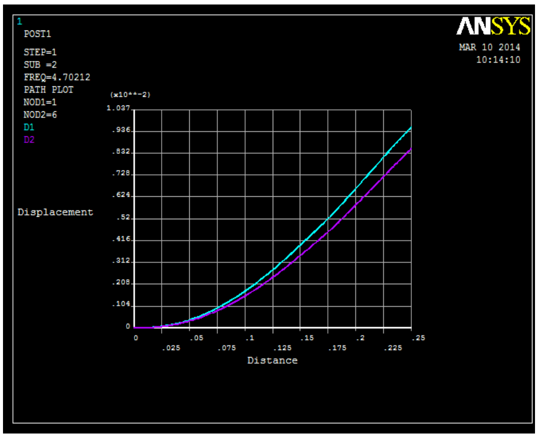
Fig. 13 (b): Buckling deflection for Third Mode shape of MMC with load 1.5KN

Case: 1 Deflection curves under the axial Load 0.5KN



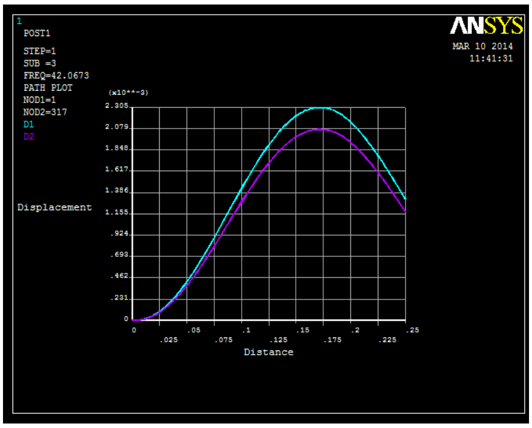
D1 —— **Alloy D2** —— **composite**

Fig. 14 (a) First mode deflection vs. distance with 0.5KN load



D1 —— **Alloy D2** —— **composite**

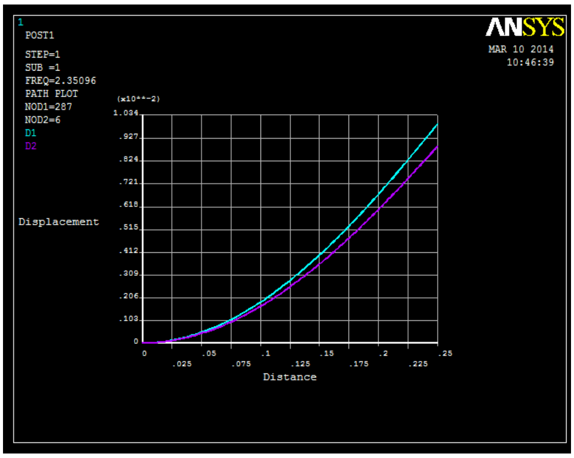
Fig. 14 (b) Second mode deflection vs. distance with 0.5KN load



D1 —— **Alloy D2** —— **composite**

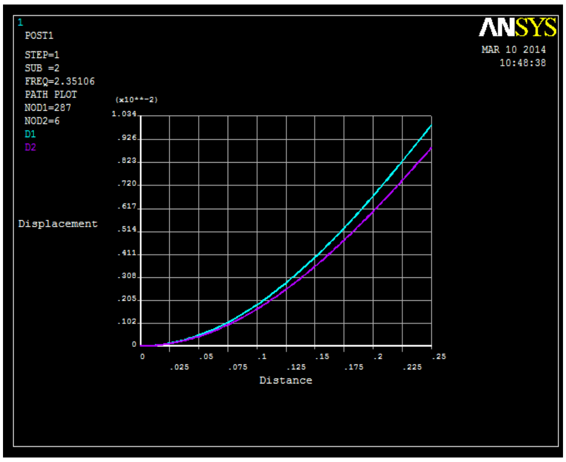
Fig. 14 (c) Third mode deflection vs. distance with 0.5KN load

Case: 2 Deflection curves under the axial Load 1.0KN



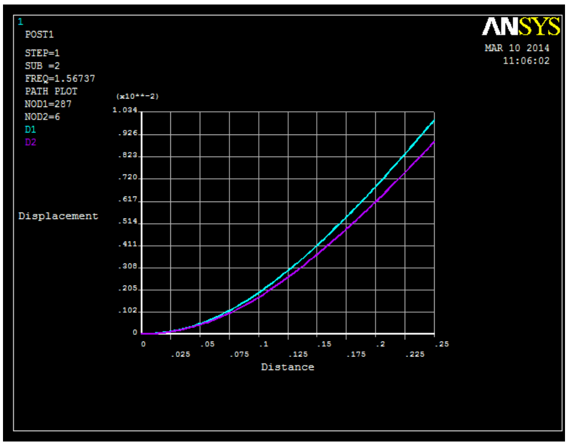
D1 —— **Alloy D2** —— **composite**

Fig. 15 (a) First mode deflection vs. distance with 1KN load



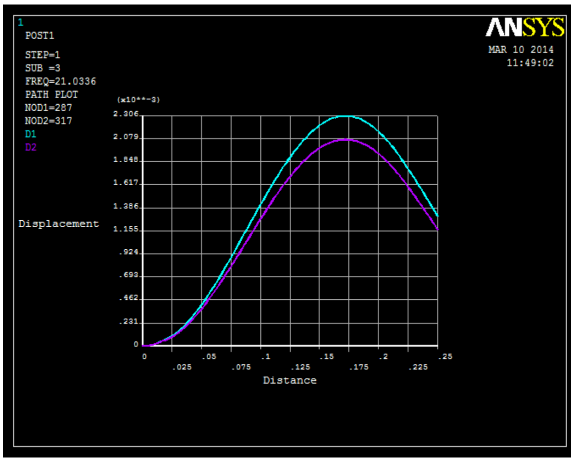
D1 ___ **Alloy D2** ___ **composite**

Fig. 15 (b) Second mode deflection vs. distance with 1KN load



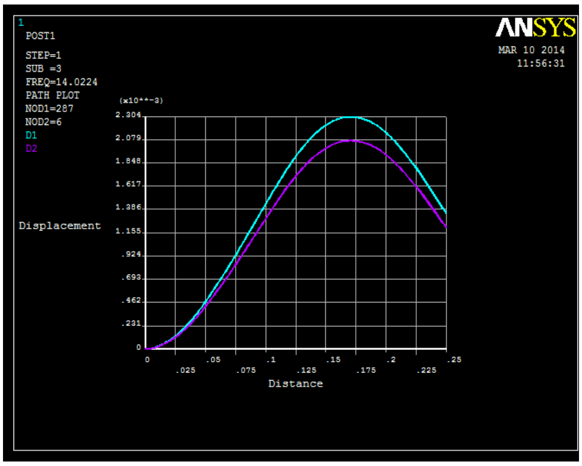
D1 ___ **Alloy D2** ___ **composite**

Fig. 16 (b) Second mode deflection vs. distance with 1.5KN load



D1 ___ **Alloy D2** ___ **composite**

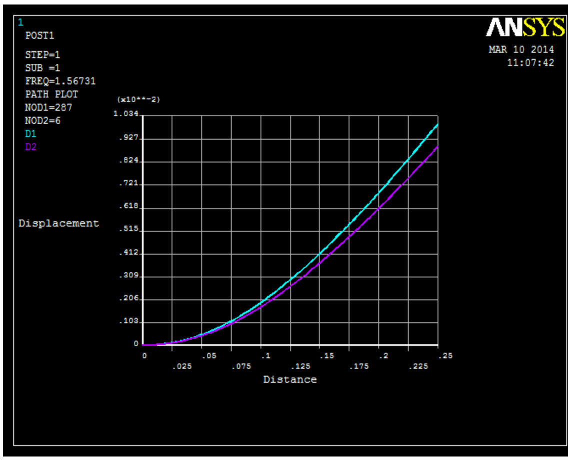
Fig. 15 (c) Third mode deflection vs. distance with 1KN load



D1 ___ **Alloy D2** ___ **composite**

Fig. 16 (c) Third mode *deflection vs. distance with 1.5KN load*

Case: 3 Deflection curves under the axial Load 1.5KN



D1 ___ **Alloy D2** ___ **composite**

Fig. 16 (a) First mode deflection vs. distance with 1.5KN load

CONCLUSIONS

For structural applications higher buckling stiffness is required. On comparing the alloy (Al-3%Mg) deflection at different loads [Fig. 5 (a)-13 (a)] with the deflection of composite (Al-3%Mg-10%SiC) at the same loads [Fig. 5 (b)-13 (b)]; it was observed that higher buckling stiffness was achieved in case of AMMC as compared to matrix alloy at different loads. The same result was reflected in deflection vs. distance curve [Fig. 14 (a) to 16 (c)] with different loads within Euler's buckling load.

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