ISSN 2395-1621

Study on Effect of Natural Frequency on Tapered Cantilever Beam

[1]Nilesh D Chopade, [2]Prof. K. K.Chaudhari

[1]ndchopade122@gmail.com

[1]PG Student,
[2]Assistant Professor,

J.T.Mahajan College of Engineering, Faizpur.

ABSTRACT

Beams are very common types of structural components and it can be classified according to their geometric configuration as uniform or taper and slender or thick. If practically analyzed, the non-uniform beams provide a better distribution of mass and strength than uniform beams and can meet special functional requirements in architecture, aeronautics, robotics, and other innovative engineering applications. Design of such structures is important to resist dynamic forces, such as wind and earthquakes. It requires the basic knowledge of natural frequencies and mode shapes of those structures. In this work we consider Aluminium and Fiber Reinforced Polymer (FRP) beams with fixed free (cantilever). The study uses ANSYS work bench to derive finite element model of the beam. The numerical results are presented to show mode shapes and natural frequency of Aluminium and Fiber Reinforced Polymer beams. Experimentation was also conducted in order to verify numerical results. The effects of taper ratio are also investigated.

***Keywords:* - Natural frequency, Beam, ANSYS.**

ARTICLE INFO

Article History

Received: 29th June 2016

Received in revised form : 29th June 2016

Accepted: 1st July 2016

Published online : 1st July 2016

I. INTRODUCTION

Beams are structural members that have smaller dimensions of cross sections compared to its length (its axis) and are subjected to loads perpendicular to its axis; i.e. they are subjected to transverse loads. The whole beam deforms in the plane containing the axis and the transverse loads. We say that the beam bends. The beams are usually supported at both ends and they are termed differently depending on the support conditions. For this work we use the Aluminium and Fiber Reinforced Polymer (FRP) with different boundary condition Beams and Boundary Condition. As shown in following Fig. 1 when one end of a beam is fixed, and the other free, it is called a Cantilever beam, or simply a Cantilever.

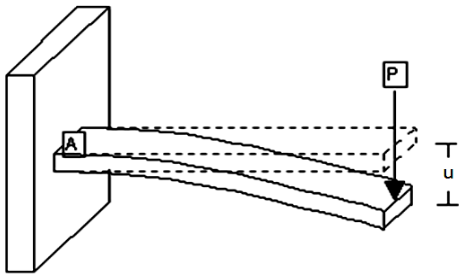

Fig.1 Cantilever beam under load

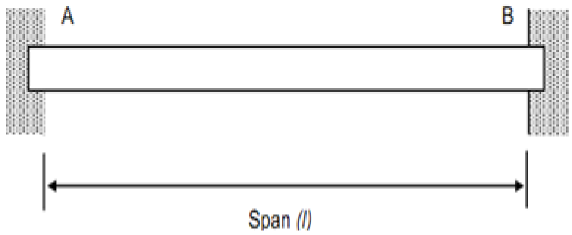

Fig.2 Fixed Beam

When both end-supports are simple, the beam is called a Simply Supported Beam. If both ends of a beam are fixed, it is a Fixed-Fixed Beam or simply a Fixed Beam as shown in Fig. 2. The diving board on a swimming pool, the slab on a porch, wall mounted structures, overhanging booms of cranes, etc can be modelled as cantilever. These physical systems can be idealized with loss of some accuracy and generalization but ability and simplicity of analysis. For the vibration analysis Euler beam theory is used. The Euler-Bernoulli beam theory also known as Engineer's beam theory or classical beam theory is a simplification of the linear theory of elasticity which provides a means of calculating the load-carring and deflection characteristics of beams. Also the study uses

ANSYS work bench to derive finite element model of the beam. The numerical results are presented to show mode shapes and mode natural frequency of Aluminium and Fiber Reinforced Polymer beams.

II. PROBLEM DEFINITION

Historically beams were square timbers but are also metal, stone, or combination of wood and metal. such as aluminium, fiber reinforced polymer (FRP), mild steel etc. Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads due to an earthquakes or wind. The loads carried by a beam are transferred to columns, walls or girders, which then transfer the force to adjacent structural compression member. Generally composite materials are increasingly being preferred in the construction of aerospace structures such as aircraft wings and helicopter blades. These materials have favourable engineering properties such as high strength, stiffness to weight ratio and excellent fatigue behaviour. Another advantage of such structure is its ability to be controlled of the structural properties such as elastic and structural couplings through the use of specific lay-up and fiber orientations. Due to their practical importance and potential benefits mentioned above, the vibration analysis of beam has been an important research area in recent years.

III. MATHEMATICAL MODELLING

3.1 Linearly Tapered beam element

The beam element is assumed to be associated with two degrees of freedom, one rotation and one translation at each node. The location and positive direction of this displacement in a typical linearly tapered beam element are shown in Fig.3. Also the plan and elevation view of cantilever tapered beam with linearly varying width and depth is shown in Fig.4.The depth of the cross section at ends are represented by a_1 (at free end) and a_0 (at fixed end) similarly the width of the both end are represented by b_1 (at free end) and b0 (at fixed end) respectively. The length of element is l.

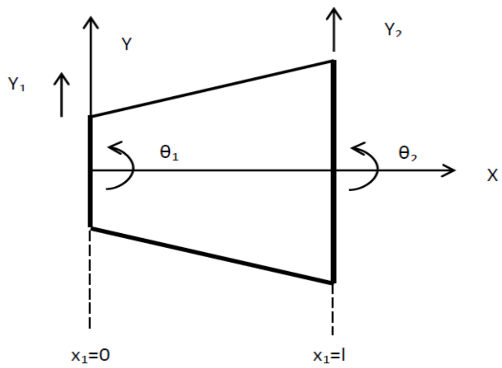

Fig.3 A Typical Linearly Tapered Beam Element

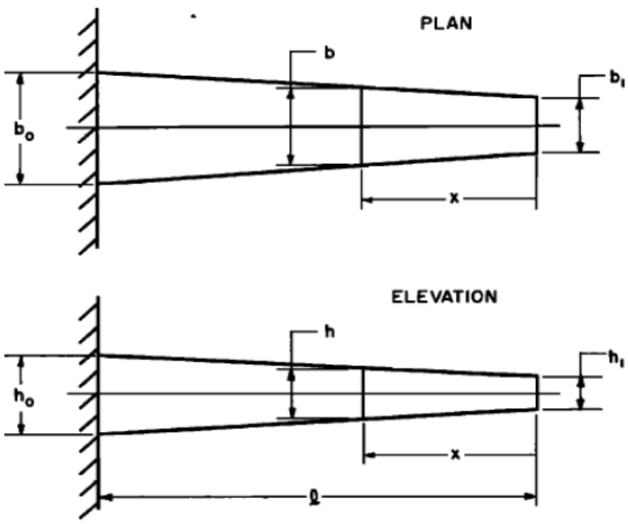

Fig.4 Plan and Elevation view of cantilever tapered beam with linearly varying width and depth

IV. FINITE ELEMENT ANALYSIS

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and in industries. In more and more engineering situations today, we find that it is necessary to obtain approximate numerical solutions to problems rather than exact closed form solution.

It is not possible to obtain analytical mathematical solutions for many engineering problems. An analytical solution is a mathematical expression that gives the values of the desired unknown quantity at any location in a body, and as a consequence it valid for an infinite number of locations in the body. For problems involving complex material properties and boundary conditions, the engineer resorts to numerical methods that provide approximate, but acceptable, solutions. For this analysis prepare the model in CATIA software, then import it for meshing and lastly the simulation of taper beam done in ANSYS. For the analysis we consider cantilever and fixed such two types of boundary conditions

4.1 ANSYS results of Taper Beam for Cantilever Condition

4.1.1ANSYS result of Aluminium Beam for different taper ratio

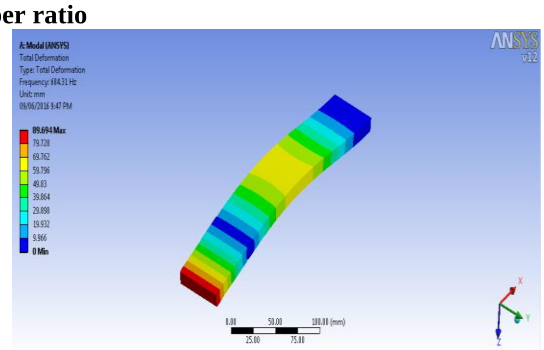

Fig.5 Frequency of Mode 2 for (β=1, α=1)

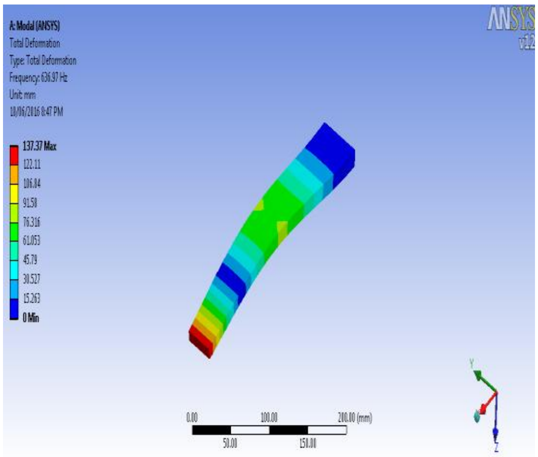

Fig.6 Frequency of Mode 2 for (β=1.5, α=1.5)

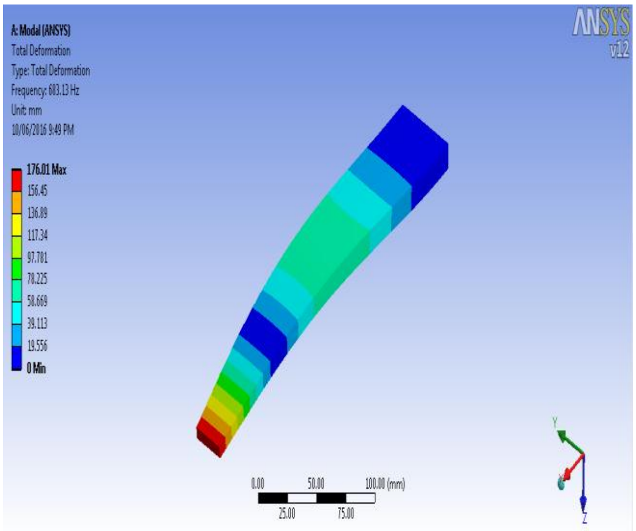

Fig.7 Frequency of Mode 2 for (β=2, α=2)

4.1.1ANSYS result of Fiber Reinforced Polymer Beam for different taper ratio

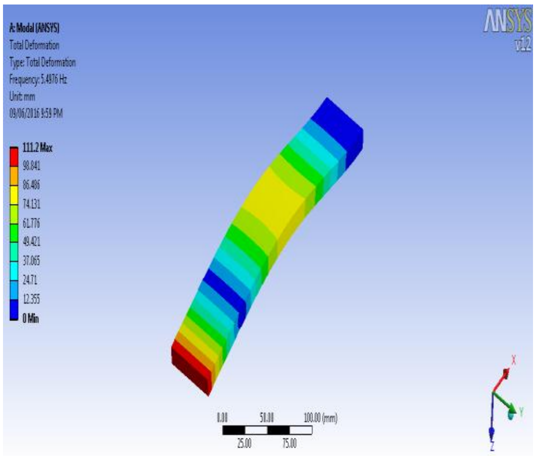

Fig.8 Frequency of Mode 2 for (β=1, α=1)

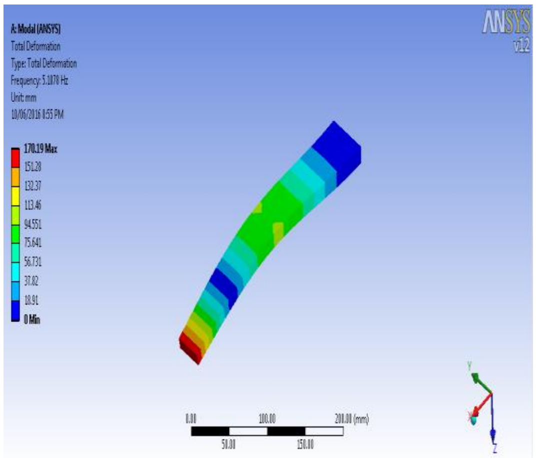

Fig.9 Frequency of Mode 2 for (β=1.5, α=1.5)

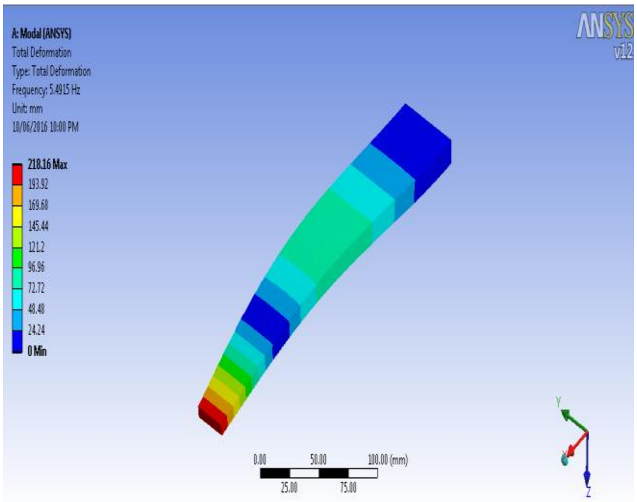

Fig.10 Frequency of Mode 2 for (β=2, α=2)

V. EXPERIMENTAL SETUP

5.1 Experimental Procedure

Common method of characterizing the vibrations of a structure is by imparting a known force and measuring the response of the structure. By measuring both the input to the structure and the response, the frequency response of the structure can be calculated. Calculating the frequency response over multiple locations, either simultaneously or individually, will yield data that can be used to estimate the dynamic response of the structure. The scale of a modal test can vary greatly. Test structures can be as small as silicon wafers used in electronics, and as large as multistory industrial sifters used at rock quarries. The size and geometry of the test structure will play a role is choosing how to excite it. The two most common methods are impact testing using a modal hammer and shaker testing.

After collection, the data can be processed using LabView. The result of the measurements and processing would be an animated model of the operating deflection shapes (ODS) that clearly illustrates the movement of the structure. Most commonly, these models are analyzed to identify modal frequencies. At these frequencies the structure vibrates with minimal input energy. Exciting the structure at these frequencies can easily cause damage to the system. Characterizing the response of the structure mean that the design can be changed to reduce the response, or the operating conditions can be adjusted to avoid failures.

Impact Hammer Modal Testing

A typical impact test will use an impact modal hammer and a response accelerometer. It is important to consider the scale of the test structure when selecting these sensors. The impact hammer imparts an impulse force into the system and is intended to excite a broad bandwidth. The Impact hammers range in size, sensitivity, and hardness depending on the scale of the system they need to excite and the bandwidth of interest. Similarly, the response accelerometer needs to be sensitive enough to detect the ringing of the structure without saturating. The output of the impact hammer and accelerometer are used to calculate the frequency response functions (FRFs) across the structure.

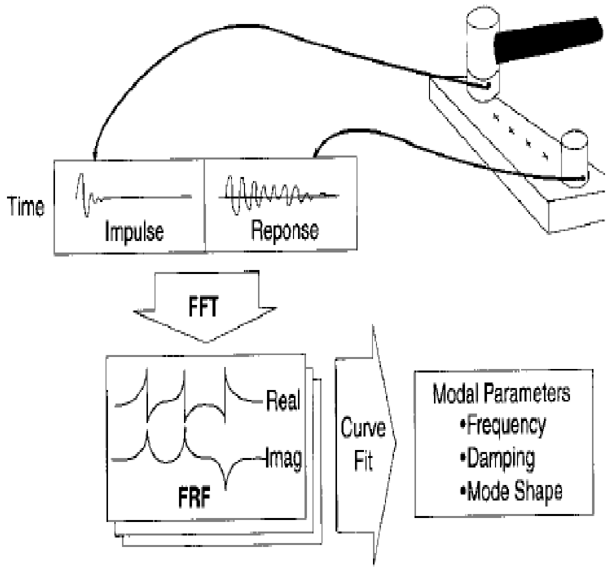

Fig.11 Typical Impact Hammer Modal test

VI. RESULTS

The Comparative results of ANSYS and Experimental of Aluminium and FRP Cantilever beam are as follows.

Aluminium Cantilever										
Sr. No.			Natural Frequency (Hz)							
			1st mode		2nd mode		3rd mode		4th mode	
			ANSYS	Experimental	ANSYS	Experimental	ANSYS	Experimental	ANSYS	Experimental
1	β=1	α=1	110.05	111.76	684.31	686.59	1896	1899.28	3661.8	3668.15
2		α=1.5	115.32	117.18	611.01	613.11	1618.9	1623.23	3101.1	3108.63
3		α=2	119.46	120.87	570.71	572.89	1466	1469.89	2786.7	2793.60
4	β=1.5	α=1	124.19	125.21	710.16	712.42	1918.8	1923.46	3678.8	3686.26
5		α=1.5	129.96	131.56	636.97	639.22	1649.7	1654.14	3139.7	3146.55
6		α=2	133.6	134.80	591.98	594.11	1486.1	1490.98	2802.4	2810.18
7	β=2	α=1	134.79	136.11	729.17	732.01	1937.1	1940.31	3694.5	3701.85
8		α=1.5	144.97	146.62	698.58	701.54	1773.1	1777.01	3341.7	3347.58
9		α=2	153.08	154.89	683.13	685.73	1679.8	1682.99	3135.2	3140.54

Table.1 ANSYS and Experimental results of Aluminium Cantilever Beam

FRP Cantilever										
Sr. No.			Natural Frequency (Hz)							
			1st mode		2nd mode		3rd mode		4th mode	
			ANSYS	Experimental	ANSYS	Experimental	ANSYS	Experimental	ANSYS	Experimental
1	β=1	α=1	0.883	1.26	5.4975	6.90	15.232	17.97	29.414	33.49
2		α=1.5	0.926	1.37	4.9088	6.47	13.001	15.44	24.892	28.60
3		α=2	0.9602	1.20	4.5854	6.55	11.771	14.11	22.361	25.53
4	β=1.5	α=1	0.9976	1.11	5.7071	7.17	15.424	18.03	29.577	33.25
5		α=1.5	1.0426	1.33	5.1078	6.57	13.226	15.78	25.166	29.50
6		α=2	1.0743	1.20	4.7582	6.35	11.941	14.29	22.51	26.24
7	β=2	α=1	1.083	1.49	5.8608	7.62	15.575	18.16	29.716	33.25
8		α=1.5	1.164	1.43	5.615	7.13	14.254	17.00	26.861	30.21
9		α=2	1.229	1.65	5.4915	6.66	13.504	16.11	25.199	29.35

Table.2 ANSYS and Experimental results of FRP Cantilever Beam

VII. CONCLUSION

On the basis of a comparison between the results, the reliability and accuracy of the present work have been proved. The obtained results shows that with increasing the taper angle, the natural frequency is also increased. The proposed procedure is verified by the previously produced results and method calculated for the beam using the Finite Element Method, which requires less computational effort due to availability of computer program.

REFERENCES

1. Dawid Cekus, "Free Vibration Of A Cantilever Tapered Timoshenko Beam", Scientific Research of the Institute of Mathematics and Computer Science,2012,Vol 11 Issue 4: 11-17
2. Dewey H. Hodges, Jimmy C. Ho and Wenbin Yu, "The Effect of Taper On Selection Constants For In-Plane Deformation Of An Isotropic Strip." Journal of Mechanics of Materials and Structures, Vol 3, No.3 March-2008
3. Dongil Shin, Soomin Choi, Gang-Won Jang, Yoon Young Kim, " Finite element beam analysis of tapered thin-walled box beams" Thin-Walled Structures 102 (2016) 205-214
4. D. Zhou, K.Cheung ''Vibrations of Tapered Timoshenko Beams in Terms of Static Timoshenko Beam Functions" Journal of Applied Mechanics, ASME, Vol.68 July 2001
5. Farid Chalah, Salah Eddine Djellab, Lila Chalah-Rezgui,Kamel Falek and Abderrahim Bali, ''Tapered Beam Axial Vibration Frequency: Linear Cross-Area Vibration Case" APCBEE Procedia 9 (2014) 323-327
6. Foudil Mohri, Sid Ahmed Meftah, Noureddin Damil, "A large torsion beam finite element model for tapered thin walled-opened cross section beams" Engineering Structures 99 (2015) 132-148
7. Gokhan Bulut, "Effect of taper ratio on parametric stability of a rotating tapered beam" European Journal Of Mechanics A/Solids 37 (2013) 344-350
8. Jung Woo Lee, Jung Youn Lee, "Free vibration analysis using the transfer-matrix method on a tapered beam.'' ELSEVIRE, Computers and Structures 164 (2016) 75-82
9. Le Wang, Ning Guo, Zhichun Yang, "Boundary condition identification of tapered beam with flexible supports using static flexibility measurements'' Mechanical Systems Signal Processing 75 (2016) 138-154
10. Ling Li, Dingguo Zhang, " Dynamic analysis of rotating axially FG tapered beams based on a new rigid – flexible coupled dynamic model using the B-spline Method " Composite Structures 124 (2015) 357-367
11. M.O. Kaya, O. Ozdemir Ozgumus,"Flexural–torsional-coupled vibration analysis of axially loaded closed-section composite Timoshenko beam by using DTM", Journal of Sound and Vibration 306 (2007) 495–506