Structural and Modal analysis of Air craft wing

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Abstract: **This paper presents modal analysis of aircraft wing. Aircraft wing used for investigation is A300 (wing structure consist of NACA64A215). A cad model of a aircraft wing has been developed using modeling software CATIA V5 and modal analysis was carried out by using ANSYS WORKBENCH14.0.modal analysis has been carried out by fixing one end (root chord) of aircraft wing while other end(tip chord) is free. The interest is to find the 6 modes of vibration with its respective natural frequency and mode shapes. To validate a project experimental modal analysis of cantilever beam was performed. The result of EMA was compared with numerical modal analysis as well as analytical frequency of cantilever beam. This paper only represent numerical modal analysis of aircraft wing and is validated by considering aircraft wing as a cantilever beam.**

Keywords: **ANSYS WORKBENCH14.0, CATIA V5**

NUMERICAL MODEL ANALYSIS

I. INTRODUCTION

The modal analysis deals with the dynamics behavior of mechanical structures under the dynamics excitation. The modal analysis is used to determine the dynamic characteristics of a system such as natural frequency, mode shapes etc. The modal analysis helps to reduce the noise emitted from the system to the environment. It helps to point out the reasons of vibrations that cause damage of the integrity of system components. Using it, we can improve the overall performance of the system in certain operating conditions. We know two basic methods of the modal analysis, namely the numerical modal analysis and the experimental modal analysis. The experimental modal analysis deals with measurements input data from which a mathematical model is derived. This paper is mainly concerned about numerical modal analysis. Wing construction is similar in most modern aircraft. In its simplest form, the wing is a framework made up of spars and ribs and covered with metal which is shown in Fig.1.1. Spars are attached to fuselage and the tip chord is free, hence aircraft wing is considered as a simple cantilever beam.
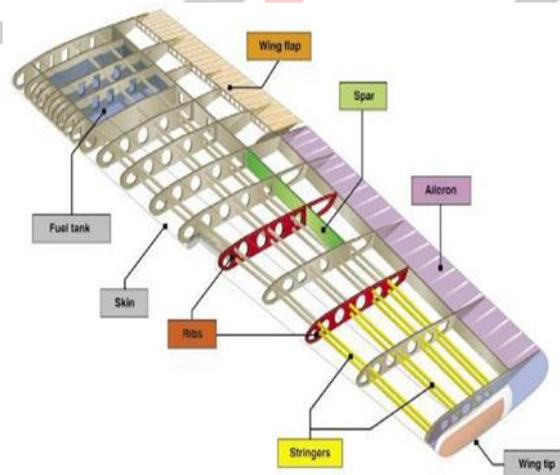
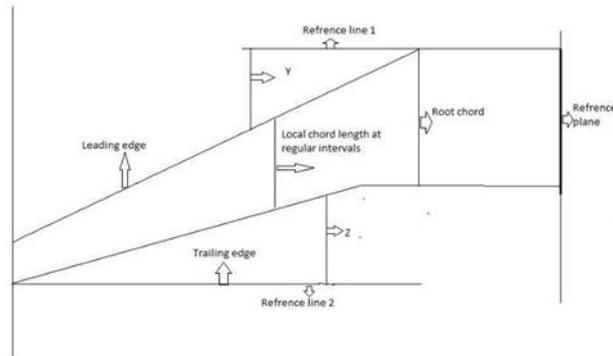

Fig. 1.1 simple aircraft wing structure

Fig.1.2 conceptual sketch of aircraft wing

The main aim of paper is to determine the dynamic characteristics of aircraft wing such as natural frequency and mode shapes and its objective are as mentioned below

1)   Study about the wing design and its dimension
2)   To create a model of aircraft wing using CATIA V5 software package.
3)   Importing a cad model to ANSYS WORKBENCH14.0
4)   Solving problem in ANSYS WORKBENCH14.0
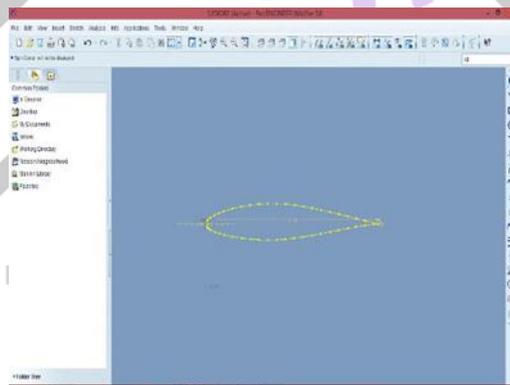5)   Interpreting the results and conclusion

II. WING DESIGN PARAMETERS

Fig. 2.1 NACA64A215 airfoil shape

The co-ordinates (X,Y,Z) of airfoil are obtained from the uiuc airfoil site.there are two table one of upper curve and other is of lower curve.The data has to be copied for both curve in a notepad wth Z dimension zero.The notepad file is to be saved with "filename.pts"otherwise it will be read as text document.In CATIA V5 create a coordinate system, draw a straight line equal to chord length.then with the help of spline curve draw the random curve for lower or upper curve.right click on the spline curve drawn various list of option available click modify. As the pts file have been saved select cordinate system and open the pts file. The curve now will consist of the cordinate of the airofoil.repeat the procedure for the lower curve which will complete the one section of aircraft wing and extrude it with thickness equal to that of rib.

Aircraft type model	A300-600R
Wing area (m^2)	260
Wing span (m)	44.84
MAC (m)	6.44
Aspect ratio	7.73
Taper ratio	0.3
Average thickness (t/c %)	10.5
¼ chord sweep angle (°)	28

Table. 2.1 Specification of aircraft wing

Z = b.tan (20.1035)

c = 11.54 + 2.75 - Y- Z

Local taper ratio=local chord length/root chord length Y= distance of a point on leading edge whose co-ordinates is (0, 0) from the reference line 1.

Z= distance of trailing edge point whose co-ordinate is (0, 0) from the reference line 2

All the above values are found with the help of geometry (conceptual sketch Fig .1.2) and trigonometric relation.

Airfoil	NACA64A215
Material	Aluminum
Modulus of elasticity	70×10^9 Pa
Poisson's ratio	0.35
Rib Thickness	100 mm
Density	2700kg/m^3

Table. 2.2 material properties

III. CAD MODEL OF AIRCRAFT WING IN CATIA V5
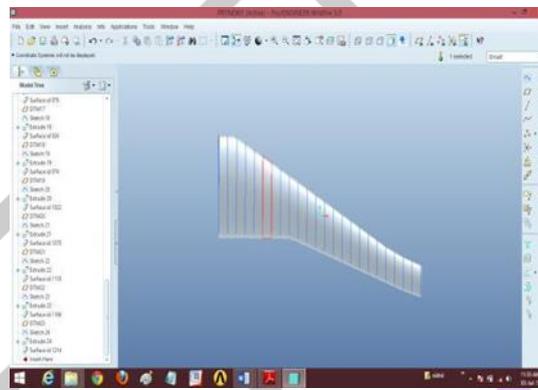
Fig. 3.1 Aircraft wing cad model in CATIA V5

The aircraft wing model is created according to the data available and value found from the geometry and trigonometric relation. There are 24 sections of airfoil which are being projected at regular interval from the reference plane. Each section is padded 50 mm mirror extended so that the airfoil section is converted into the rib section with a thickness of 100 mm, Wing tip is also called as tip chord. The aircraft wing is hollow structure with spars passing through the ribs and attached to the fuselage which holds the aircraft wing hence it is considered as a cantilever beam. Root chord end and tip chord end are packed by the surface protrusion. The skin of aircraft wing is covered by a small layer with the help of surface protrusion. The aircraft wing cad model is save as STEP file. This STEP file is imported to the ansys workbench.

IV. NUMERICAL MODAL ANALYSIS

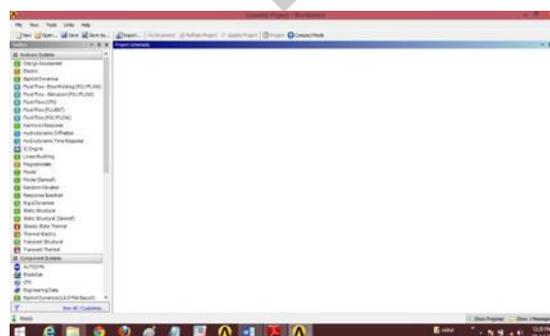Here the software package used for numerical modal analysis is ansys 14.0 software package.

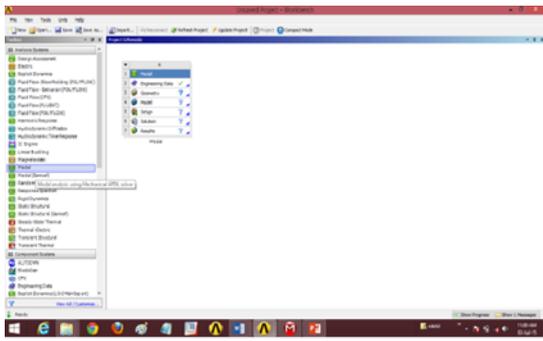Fig. 4.1 Graphical environment of ansys14.0 software package [workbench]
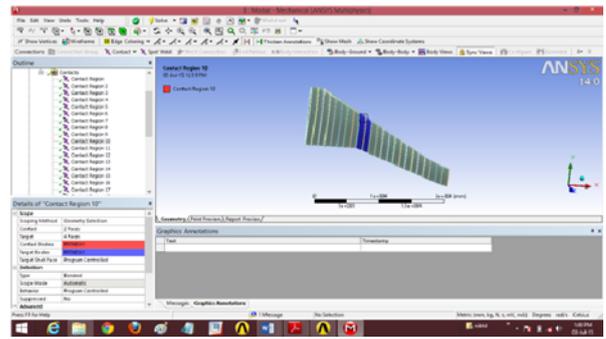
Fig.4.3 modal analysis in outline
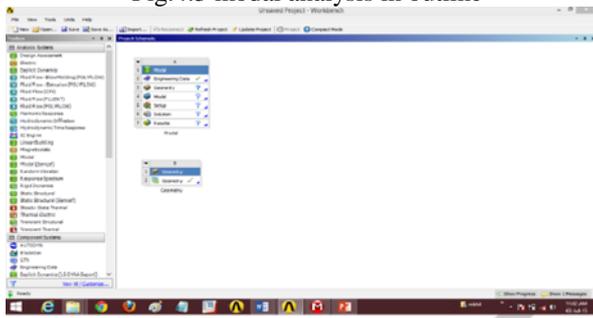

Fig 4.8 bonded contacts

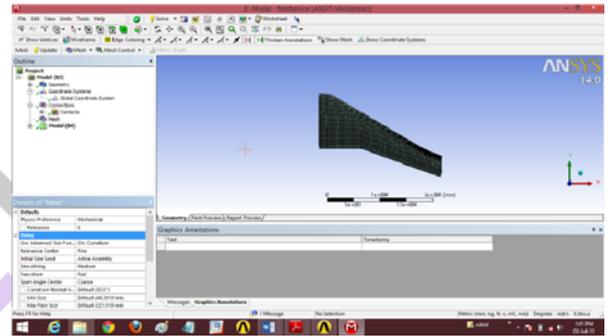Fig. 4.4 importing cad model to ansys workbench

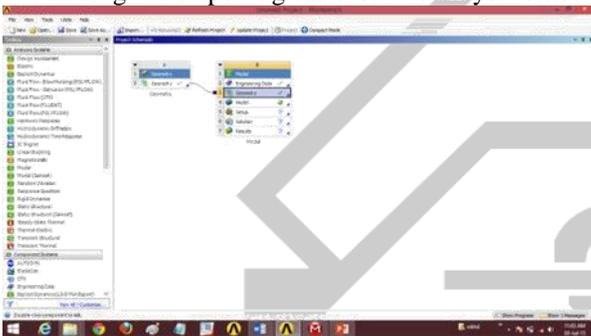
Fig 4.9 meshing (fine mesh)

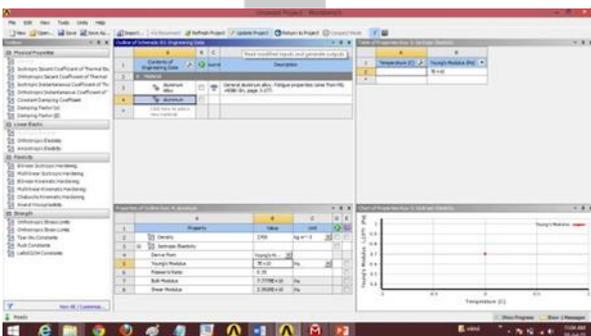
Fig. 4.5 attaching cad geometry to modal geometry

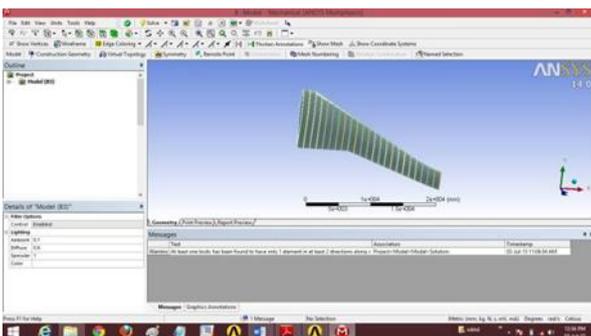Fig 4.6 specifying the material and its properties

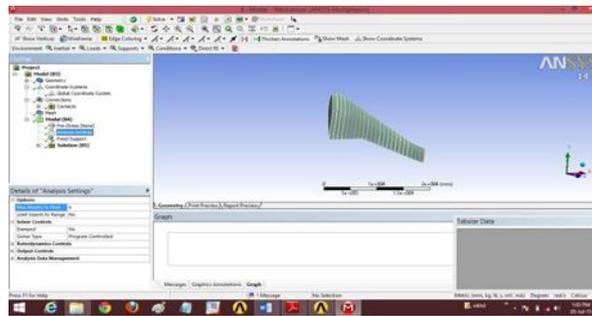Fig 4.7 geometry in modal design modeler
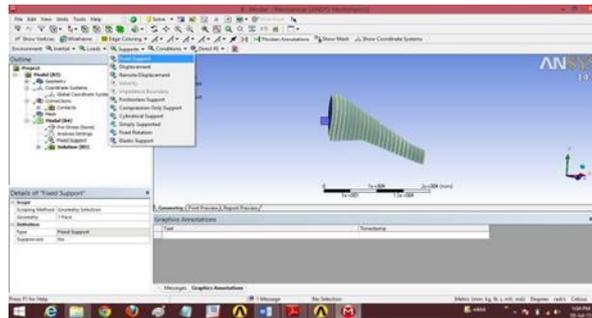
Fig. 4.10 selection of no. of modes

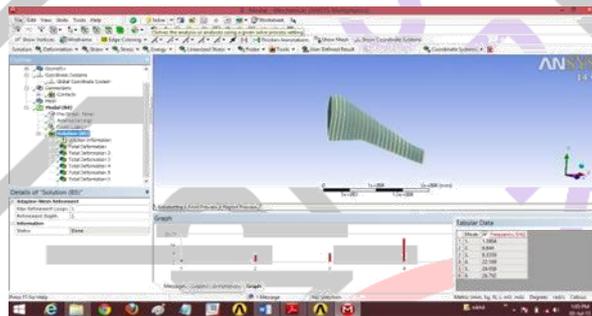Fig. 4.11 fixed support at root chord

Fig 4.12 solution obtained

V. NUMERICAL MODAL ANALYSIS of Cantilever Beam

The difference between aircraft wing and cantilever beam is in its structures. Aircraft wing can be considered as a cantilever beam since its root chord is fixed into fuselage with the aid of spars and other end which is also called as tip chord is free. Aircraft wing model is difficult to be fabricated due to lack of manufacturing resources as well as cost of such model fabricated is very high. To validate a project experimental modal analysis of cantilever beam was performed at welan technologies office, pune to find out experimental natural frequency which has been compared with numerically [ansys workbench14.0] obtained natural frequency and theoretically obtained natural frequency of cantilever beam. For every problem the material used is aluminum. The following table 5.1 and 5.2shows the material properties and dimension of cantilever beam respectively.

Material	**Aluminum**
Modulus of elasticity	70×10^{9}Pa
Poisson's ratio	0.35
Density	2700kg/m^{3}

Table. 5.1 material properties

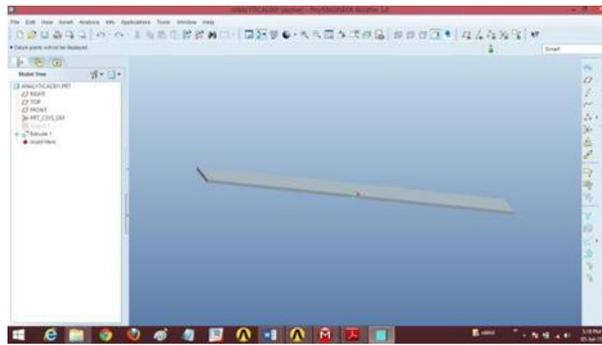| Length	0.5m
Width	0.045m
Height	0.005m
Moment of inertia	4.6875×10^{-10}m^{4}

Table. 5.2 cantilever beam dimensions
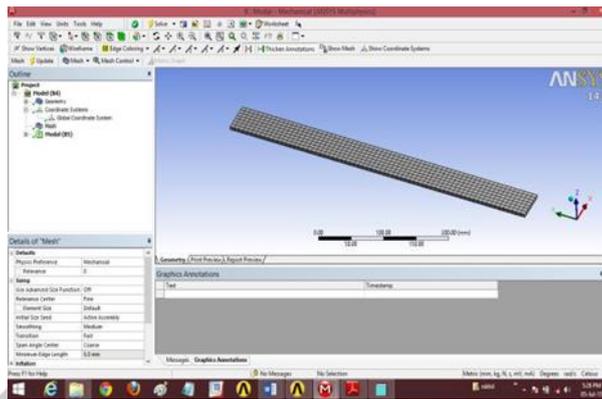
Fig. 5.1 cad model of cantilever beam in PROE5.0

Fig. 5.2 meshing of cantilever beam
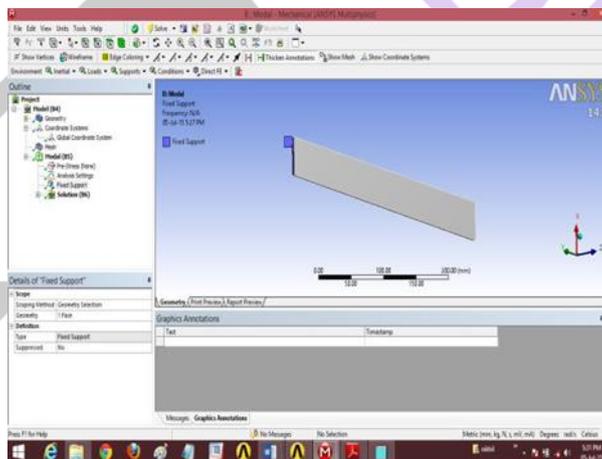
Fig. 5.3 fixed support

	Mode	✔ Frequency [Hz]
1	1.	16.608
2	2.	104.01
3	3.	147.42
4	4.	291.24
5	5.	338.99
6	6.	570.97
7	7.	890.54
8	8.	944.47

Table. 5.3 cantilever beam natural frequency

Mode no. 3, no 5, no. 7 are torsional bending mode. These modes are not calculated. Theoretical approach is limited to transverse vibration of cantilever beam, hence these values are neglected.

VI. THEORETICAL APPROACH METHOD

The following given equations have the frequencies of the modes and their shapes and have been deduced from Euler-Bernoulli Beam Theory.

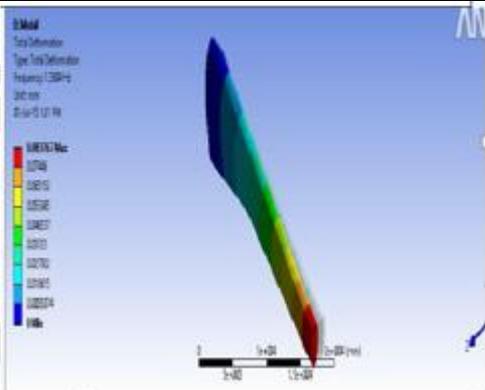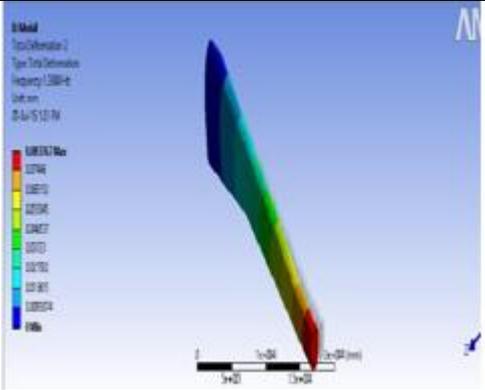| Mode	Frequency[Hz]
1	16.45
2	103.06
3	288.52
4	565.52
5	934.85

Table. 6.1 theoretically obtained frequency

VII. RESULTS

Result obtained for numerical modal analysis of aircraft wing [NACA64A215] are shown in Table 7.1 and 7.2. Result obtained for numerical and theoretical approach method are shown in Table 5.3 and 6.1 respectively.

	Mode	✔ Frequency [Hz]
1	1.	1.3804
2	2.	6.644
3	3.	8.3359
4	4.	22.169
5	5.	26.056
6	6.	26.792

Table.7.1 Tabular data of aircraft wing frequency

MODE No.	NUMERICAL FREQUENCY IN HZ	MODESHAPES
1	1.3804	
2	6.644	
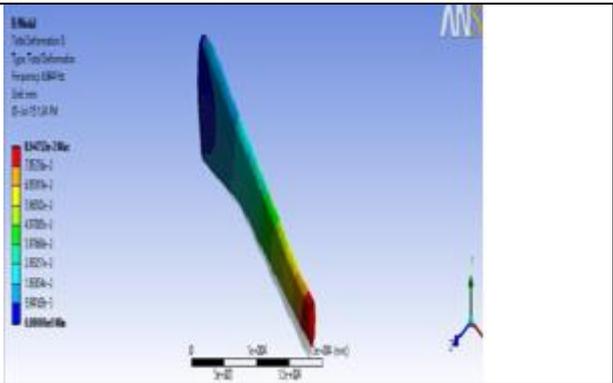
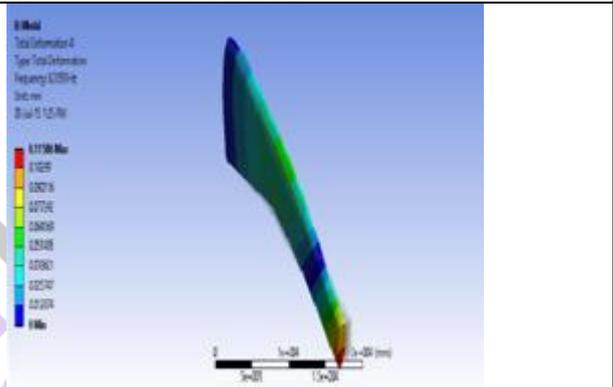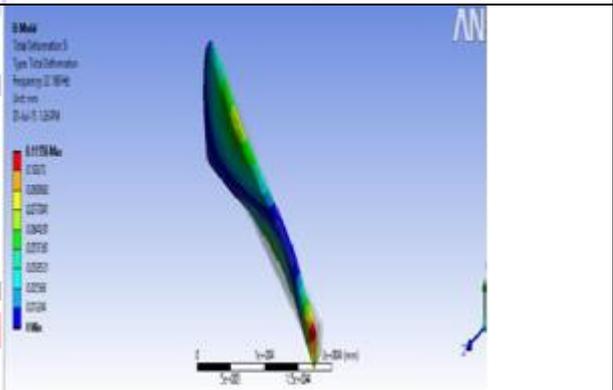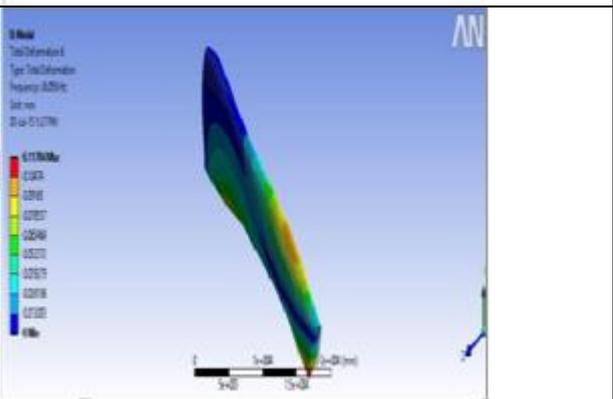|		
3	8.3359	
4	22.169	
5	26.056	
6	26.792	

Table. 7.2 aircraft wing natural frequency with its respective mode shapes

Mode	Theoretical Frequency [Hz]	Numerical Frequency[Hz]	Error [Hz]
1	16.45	16.60	0.15
2	103.06	104.01	0.95
3	288.52	291.24	2.72
4	565.52	570.97	5.45
5	934.85	944.47	9.62

Table. 7.3 Comparative table of cantilever beam frequency

Mode no.	Numerical Frequency [Hz]	Mode shapes
1	16.63	
2	104.01	
3	291.24	
4	570.97	
5	944.47	

Table. 7.4 Cantilever beam numerical frequency with its respective mode shapes

VIII.   DISCUSSION & CONCLUSIONS

The discussion and conclusion on The basis of result is presented in this section. The aircraft wing model is simulated in ansys14.0 under modal analysis system. Proper meshing and boundary conditions are applied on the model. The result obtained are shown in table 7.2. Theoretical approach method is not suitable for aircraft wing due to rigorous mathematical equation. The result of numerical modal analysis and theoretical approach method of cantilever beam were compared as shown in table 7.3.

This investigation revealed that natural frequency obtained from numerical and theoretical approach are in close agreement, which validated FE model of the cantilever beam for modal analysis. The valid modal analysis results of cantilever beam proves that the procedure opted for numerical modal analysis of aircraft wing and its result are correct.

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