iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** IV **Month of publication:** April 2017

DOI: http://doi.org/10.22214/ijraset.2017.4100

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Optimization and Vibration Analysis of Compressor Blade with Different Blade Angle

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Abstract: The effective uses of a Compressor blade are limited at its maximum operational junction frequency. The study was conducted by using the Finite element method. The compressor blades are used with flow of with rotation such as power houses and industrial applications. The major study was done on compressor blade by using different materials with different blade angle profile of 5.5, 8.5, 12.5 and 16.5. A natural frequency was analyzed and harmonic analysis is performed for validation. In our analysis, ANSYS was used and the model was developed on CATIAV 5.0. In order to verify the present ANSYS model, the Natural frequency with their modes by using four types of materials are compared with the available experimental results present in the literature. And the design of compressor blade with different angles of 5.5, 8.5, 12.5 and 16.5. In this study, the simulations of different profile blade angles and three types of materials i.e. structural steel, Carbon fiber reinforced plastic and Titanium alloys, was analyzed for natural frequency and the configurations of blade design are proposed. The results show that increasing blade angle and material like carbon fibre reinforced plastic of compressor blade increases the frequency with increase min a number of modes simultaneously. The natural frequency of the compressor blade is compared by using three types of materials and is predicted that at 12.5, 16.5 blade angle profile a carbon fibre reinforced plastic gives better frequencies in different modes.
Keywords: Compressor Blade, Blade angle, Stainless steel, Titanium alloys, Natural Frequency

I. INTRODUCTION

A compressor is a mechanical device that converts from high pressure dry air by rotating motion, and conserves a high pressure air. It has mostly replaced the reciprocating piston engine because of its greater air efficiency and high power-to-weight ratio. Because the compressor operates in rotating motion, the compressor is a form of heat engine that derives much of its improvement in its high power rotating efficiency through the use of variable stages in the high pressure, which results in a closer approach to the ideal reversible process.

Compressor blade between two convex shoulder contact with contact stiffness between the direct impact on the blade response of the resonance frequency and damping effect is good or bad, contact stiffness of accurate or not directly affect the nonlinear response calculation to the accuracy of the results . Currently speaking, contact stiffness mostly according to experimental methods or experience to a given, and this is limited to some special situation, can't use, and gave to solve nonlinear response brought a lot of inconvenience .This paper puts forward a kind of make use of the finite element method to solve contact stiffness method, can reduce the use of test method determine the tangential contact stiffness need a lot of time and money [1-3].

II. TYPES

Compressors are created in a different variety of models ranging from small <1 hp (<0.75 kW) units rarely used as mechanical moving components for pumps, compressors and other shaft power driven equipment, to 2,000,000 hp (1,500,000 kW) compressors used to generate pneumatic power. There are many classifications for modern compressors.

Axial Flow Compressor
Radial Flow Compressor
Vane Blower Compressor
Roots Blower Compressor

III. MATERIALS USED

Generally there are three kinds of materials used for compressor blades they are Structural steel, Titanium alloys and carbon fiber reinforced plastic. The thermal conductivity of Carbon fiber reinforced plastic is 6.7 W/mK the melting and boiling point of structural steel are 1084˚ and 2595˚ and that of Titanium alloy are 658˚ and 2057˚ [4].

www.ijraset.com
IC Value: 45.98
Volume 5 Issue IV, April 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

A. Material Property

Material Properties	Stainless Steel	Titanium alloys	Carbon Fibre Reinforced Plastic
Young's Modulus	1.9e11 pa	0.0163 pa	1.12e11 pa
Poisson's Ratio	0.275	0.34	0.354 pa
Density	8000 kg/m3	1630 kg/m3	1800 kg/m3
Thermal Conductivity	14 w/mK	6.7 w/mK	24.3 w/mK
Specific Heat	490J/kgK	565 J/kgK	795.5 J/kgK

Table 1: Material property

B. Objective of the Work

The main objective of the current work is

1) To predict natural frequency, and harmonic effects for different blade angle (5.5, 8.5, 12.5, 16.5 Degrees) on the compressor blade.
2) To simulate the compressor blade of the different material having different blade angles for variable modes.
3) Parameter sensitivity study of Compressor blade.
4) To define natural frequency effects, harmonic effects for the compressor blade of the different blade angle profile and different material and constant acceleration of 9.81m/s^2.
5) To predict frequency distribution along the compressor blade.

IV. FINITE ELEMENT METHOD

The finite element method (FEM) (its practical application often known as finite element analysis (FEA)) is a numerical technique for finding approximate solution of partial differential equation (PDE) as well as integral equation. The solution approach is based either on eliminating the differential equation completely (steady state problem), or rendering the PDE into an approximation system of ordinary differential equation, which are then numerically integrated using standard technique such as Euler's method , Rungekutta, etc. In solving partial differential equations, the primary challenge is to create an equation that approximates the equation to be studied , but is numerically stable , meaning that error in the input and intermediate calculation do not accumulate and cause the resulting output to be meaningless. There are many ways of doing this, all with advantages and disadvantage. The finite element method is a good choice for solving partial differential equation over complicated domain (like cars and oil pipelines), when domain changes (as during a solid state reaction with a moving boundary), when the desired precision varies over the entire domain, when the solution lacks smoothness.

A. Finite Element Analysis

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structures utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to

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ISSN: 2321-9653
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fracture.

B. Finite Element Analysis Work

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress [5-6].

V. MODELING

A. The procedure for solving the problem is

1) Create the geometry.

2) Mesh the domain.

3) Set the material properties and boundary conditions.

4) Obtaining the solution

Analysis Type- Modal and Harmonic analysis (Coupled field)

B. Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

1) CAD Model:

Base width	26
Blade height from base	65
Blade height	180
Blade angle	5.5^0,12.5^0
Blade thickness	15

Table 2: Dimension of Compressor blade (All Dimension in mm & Degrees)

CATIA Model of Compressor blade with different angle.

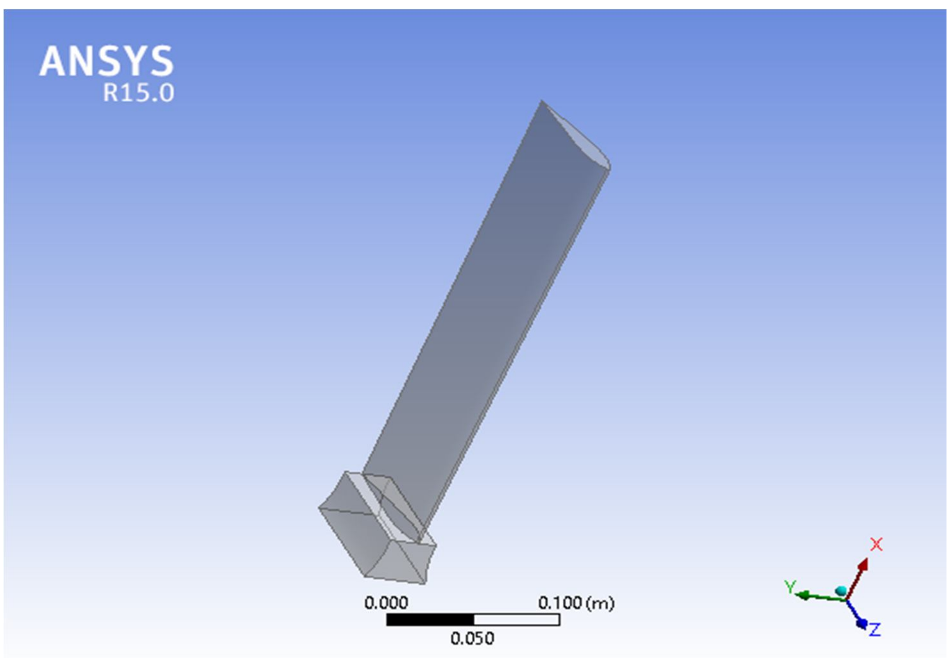

Figure 5.1 CAD Model of Compressor blade with 5.5^0 angle

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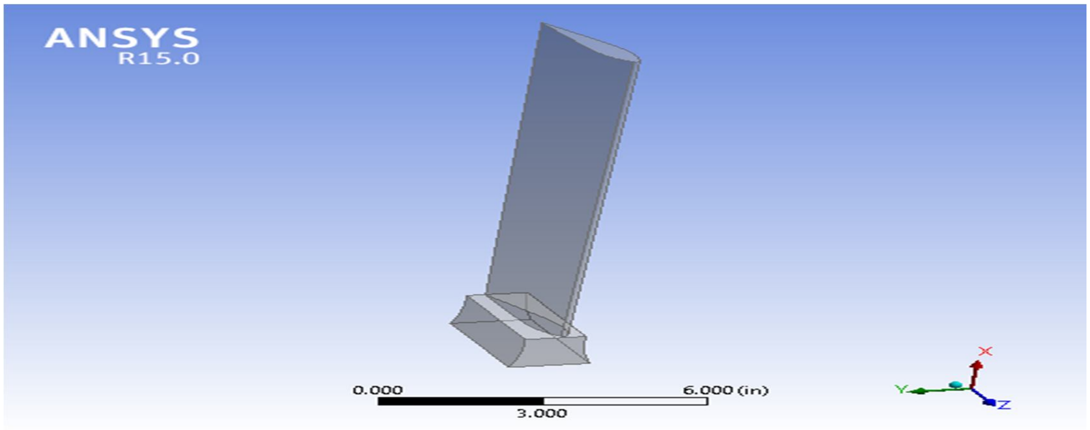

Figure 5.2 CAD Model of Compressor blade with 8.5^0 angle

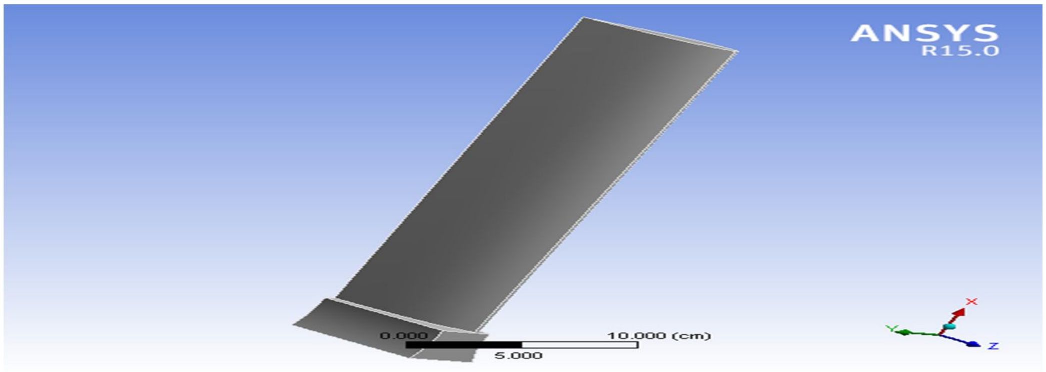

Figure 5.3 CAD Model of Compressor blade with 12.5^0 angle

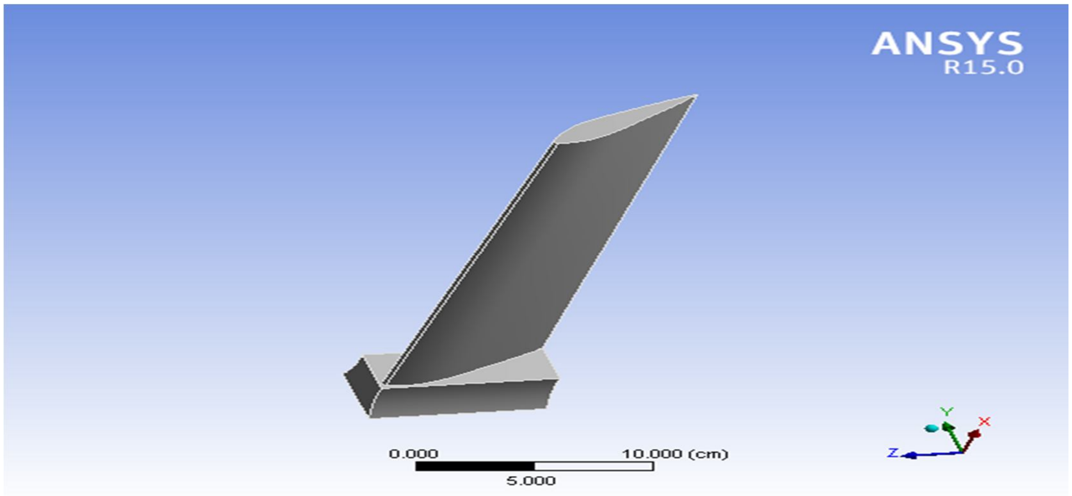

Figure 5.4 CAD Model of Compressor blade with 16.5^0 angle

VI. ANALYTICAL RESULT

Frequency along the Compressor blade with Different Blade angles and Materials Modal - Harmonic analysis was carried out on three types of materials of structural steel, Titanium alloys and Carbon fiber reinforced plastic with different blade angles to determine the frequency distribution along the compressor blade of the different angle. Frequency distribution contours in case of blade angle of 5.5,12.5 for the two different profiles are shown in Figures, and the effect of different blade profiles on the frequency and modes distribution for various blade angles and materials are represented in the Figures.

Modes	Experimental Results	Simulation Results
3	628	569
4	616	857.63
5	602	1534.4
6	585	2550.7
7	579	2678.5
8	570	2904.4

Table 3: Validation Result of Compressor blade with Different Modes and Frequency.

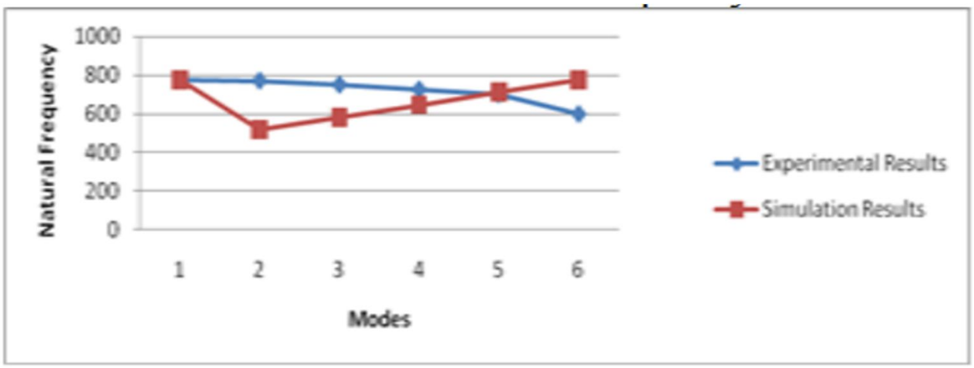

Figure 6.1 Frequency and modes Distributions along the Compressor blade

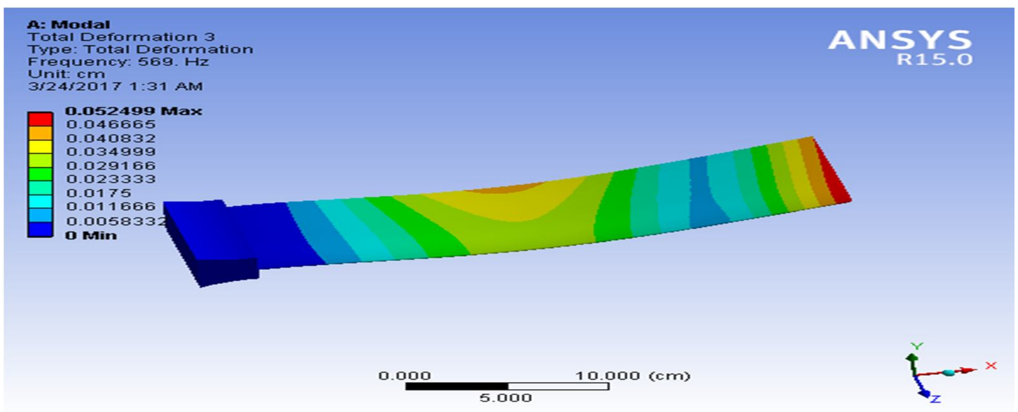

Figure 6.2 Third mode Frequency of Compressor blade of Stainless Steel.

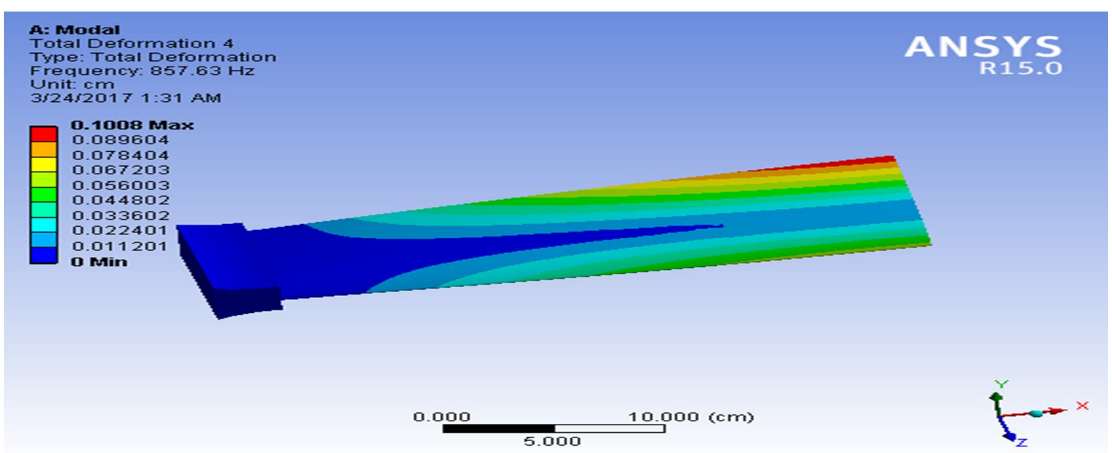

Figure 6.3 Fourth mode Frequency of Compressor blade of Stainless Steel.

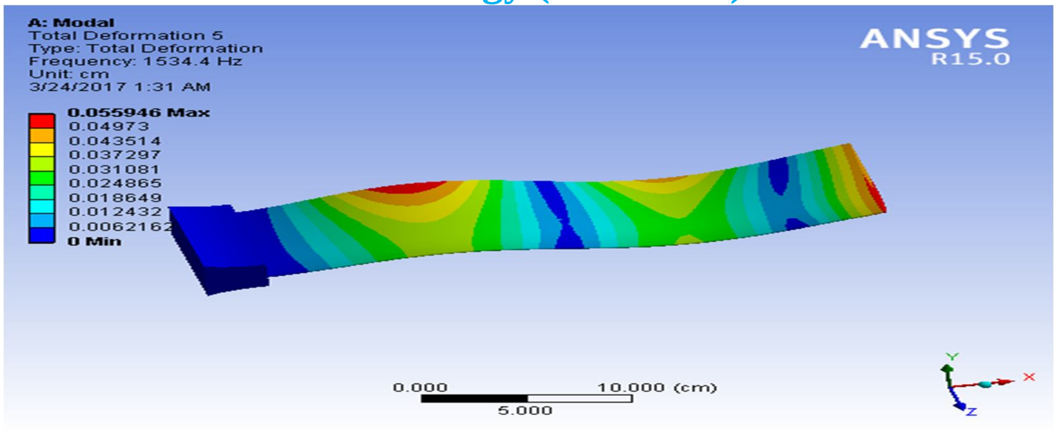

Figure 6.4 Fifth mode Frequency of Compressor blade of Stainless Steel.

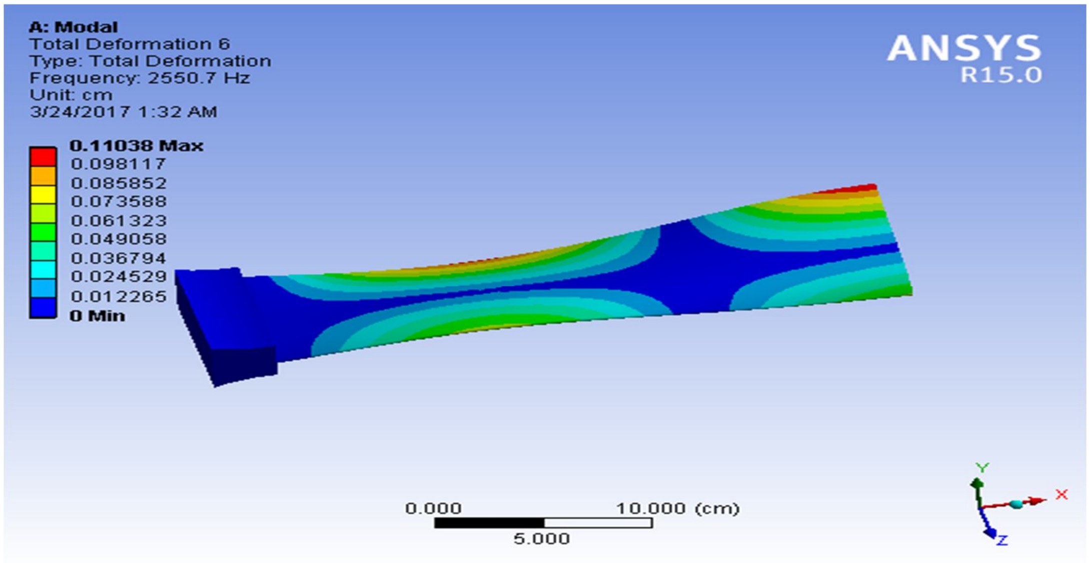

Figure 6.5 Sixth mode Frequency of Compressor blade of Stainless Steel.

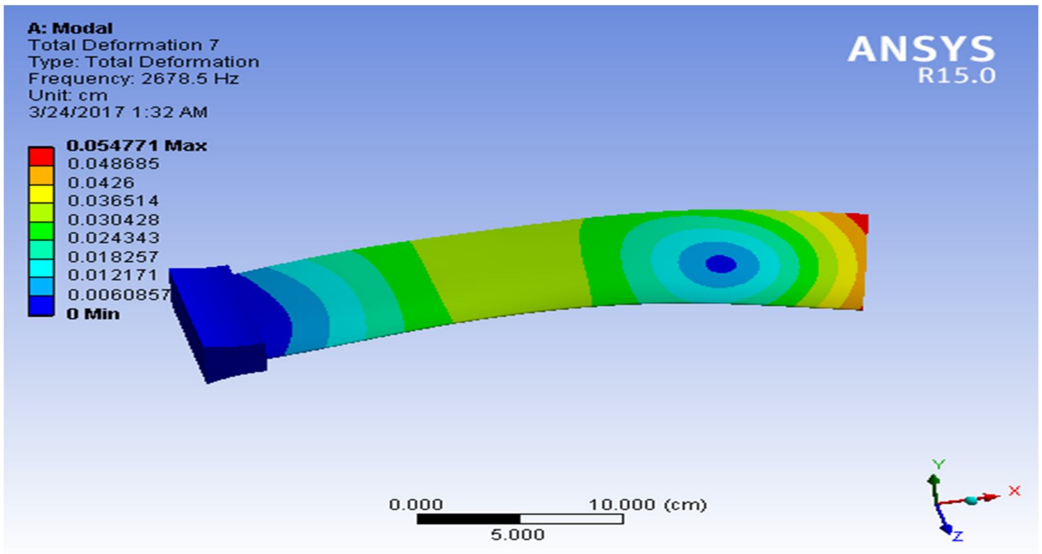

Figure 6.6 Seventh mode Frequency of Compressor blade of Stainless Steel.

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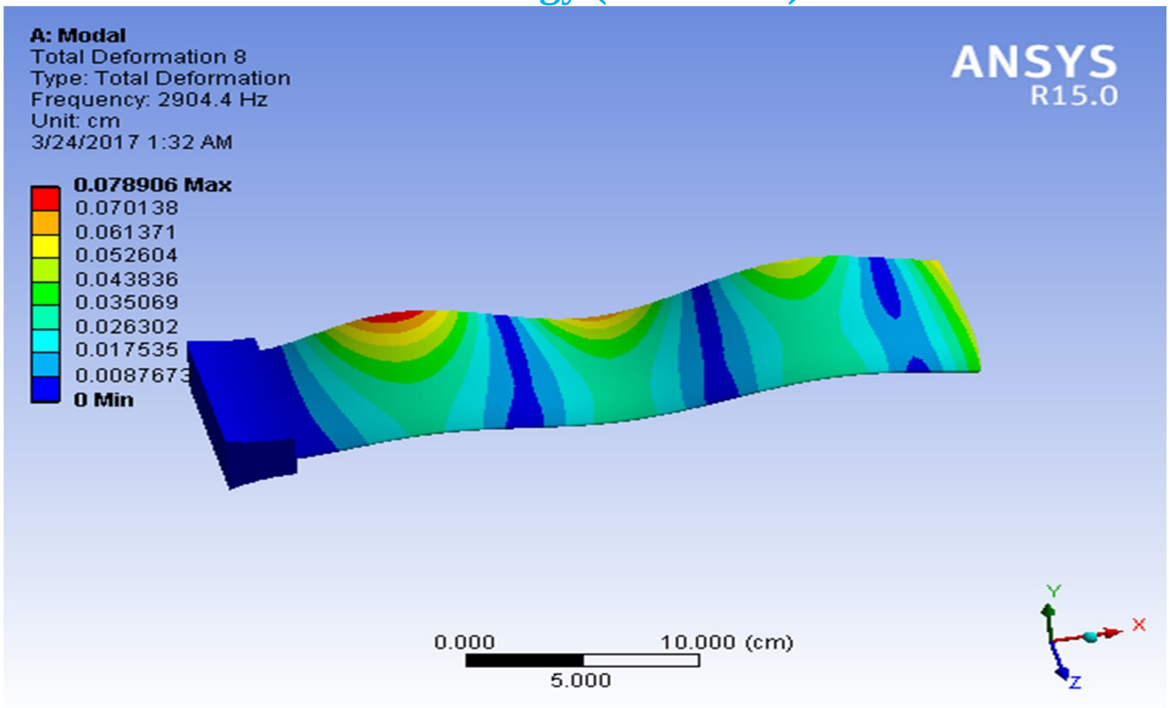

Figure 6.7 Eighth mode Frequency of Compressor blade of Stainless Steel.

Comparison of frequency with different material

Mode	Natural Frequency (Hz)					
	Stainless steel		Titanium alloys		Carbon fiber reinforced plastic	
	5.5^0 angle	12.5^0 angle	5.5^0 angle	12.5^0 angle	5.5^0 angle	12.5^0 angle
1	90.92	85.34	4.99	3.34	171.2	158.3
2	487.7	491.5	26.73	29.12	915.31	922.4
3	569	579	31.21	50.56	1068.8	1096
4	857.6	883	45.88	79.35	1562.7	1690
5	1534	1680	84.01	123.5	2875.4	2987
6	2550	2768	136.6	178.3	4655.6	4893
7	2678	2987	146.1	198.4	4996.3	5389
8	2904	3087	158.4	234.2	5420.5	6567

Table 4: Natural Frequency of Compressor blade with Different blade angles and materials.

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Mode	Natural Frequency (Hz)					
	Stainless steel		Titanium alloys		Carbon fiber reinforced plastic	
	8.5^0 angle	16.5^0 angle	8.5^0 angle	16.5^0 angle	8.5^0 angle	16.5^0 angle
1	98.46	128.3	0.0007	4.57	185.3	198.3
2	485.5	578.3	0.0008	6.34	911.18	982.4
3	615.5	784.4	0.006	13.46	1154.4	1296
4	928.7	1034	0.0015	43.35	1691.8	1790
5	1658	1856	0.0028	63.5	3109.6	3287.3
6	2666	2856	0.0046	78.3	4975.3	4393.3
7	2770	3098	0.0046	98.45	5054.7	5889.4
8	3146	3234	0.0054	124.2	5877.4	6865.2

Table 5: Natural Frequency of Compressor blade with Different blade angles and materials.

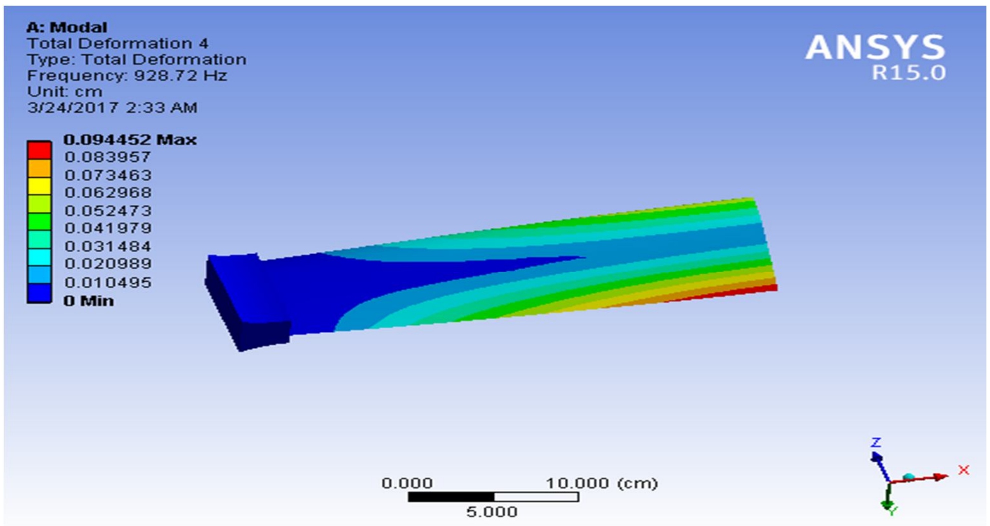

Figure 6.8 Fourth mode Frequency of Compressor blade of 8 Degree Blade angle of stainless steel.

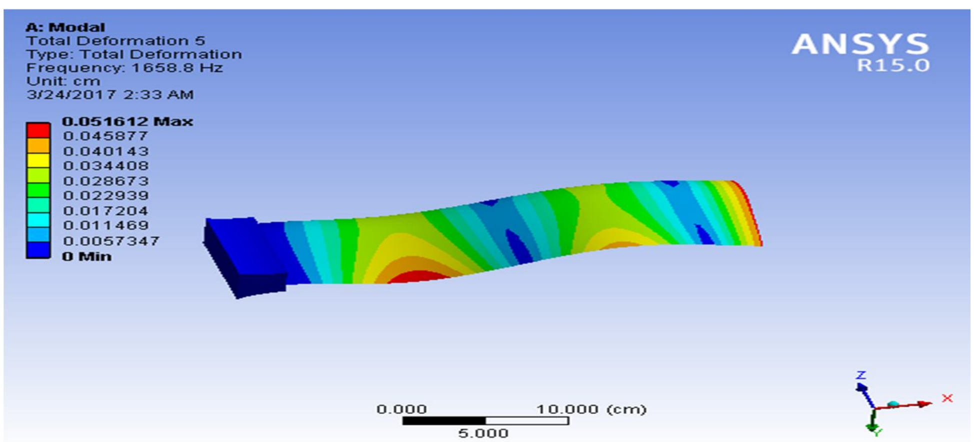

Figure 6.9 Fifth mode Frequency of Compressor blade of 8 Degree Blade angle of stainless steel.

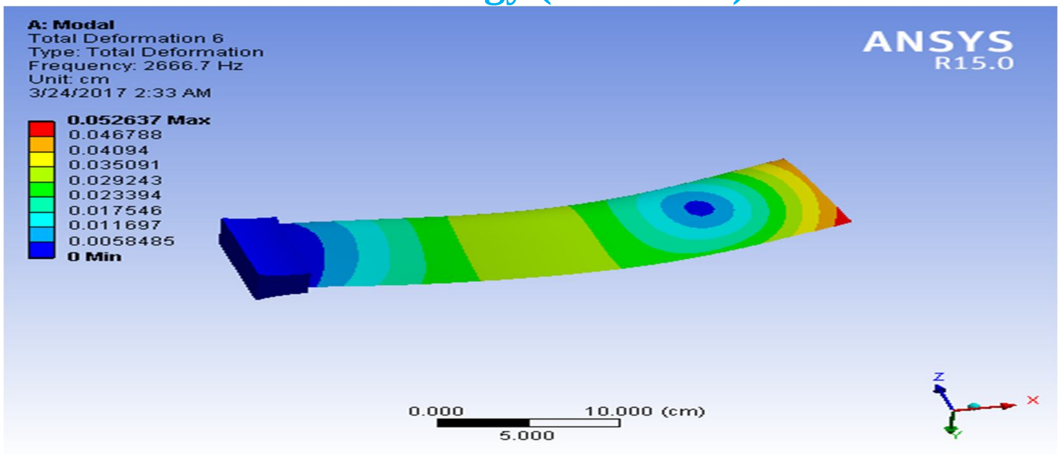

Figure 6.10 Sixth mode Frequency of Compressor blade of 8 Degree Blade angle of stainless steel.

VII. GRAPHICAL COMPARISION

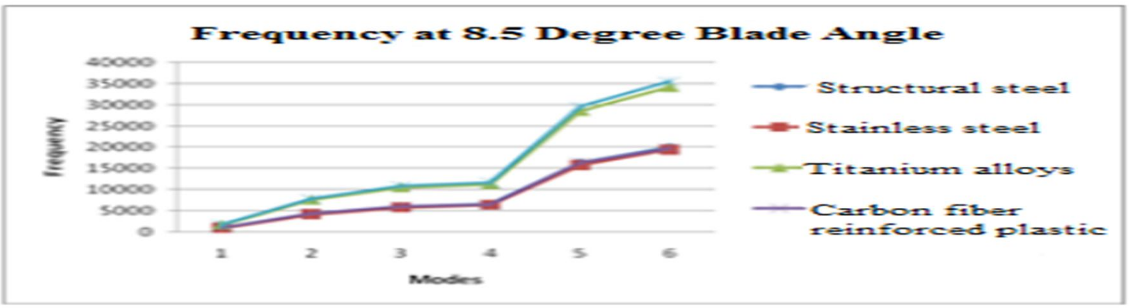

Figure 7.11 Comparison of Natural Frequency and modes Distributions along the Compressor blade of with Different Material

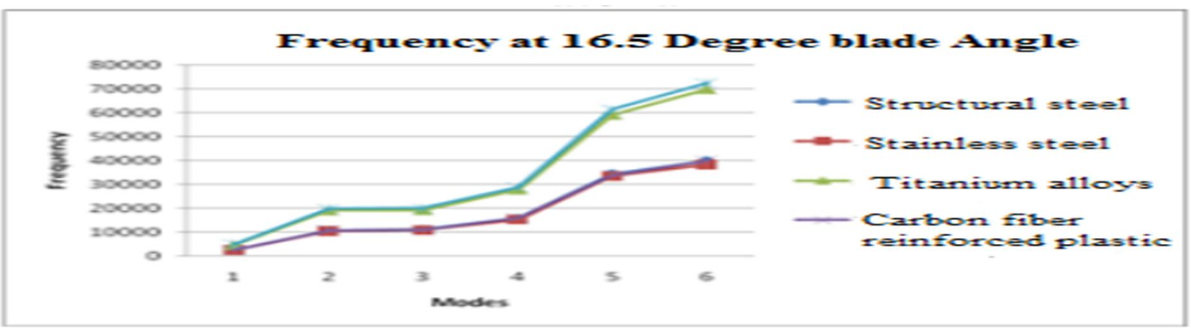

Figure 7.12 Comparison of Natural Frequency and modes Distributions along the Compressor blade of with Different Material

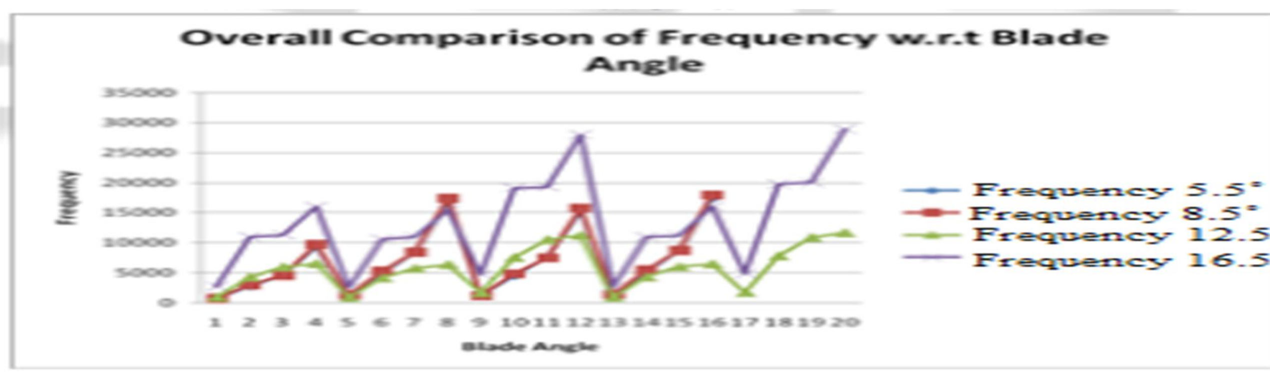

Figure 7.13 Comparison of Natural Frequency and modes Distributions along the Compressor blade of with Different Material

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VIII. RESULT AND CONCLUSION

The current analysis has presented a study of natural frequency characteristics of a compressor blade of different profiles. Coupled-field analysis was carried out on structural steel, carbon fiber reinforced plastic and titanium alloys system. The effect of blade angle profiles of the compressor blade with angle 5.5^0 ,8^0 ,12.5^0 ,16.5^0 on the natural frequency and modes of different materials effects distribution along the compressor blade was studied. From the analysis of the results, following conclusions can be drawn.

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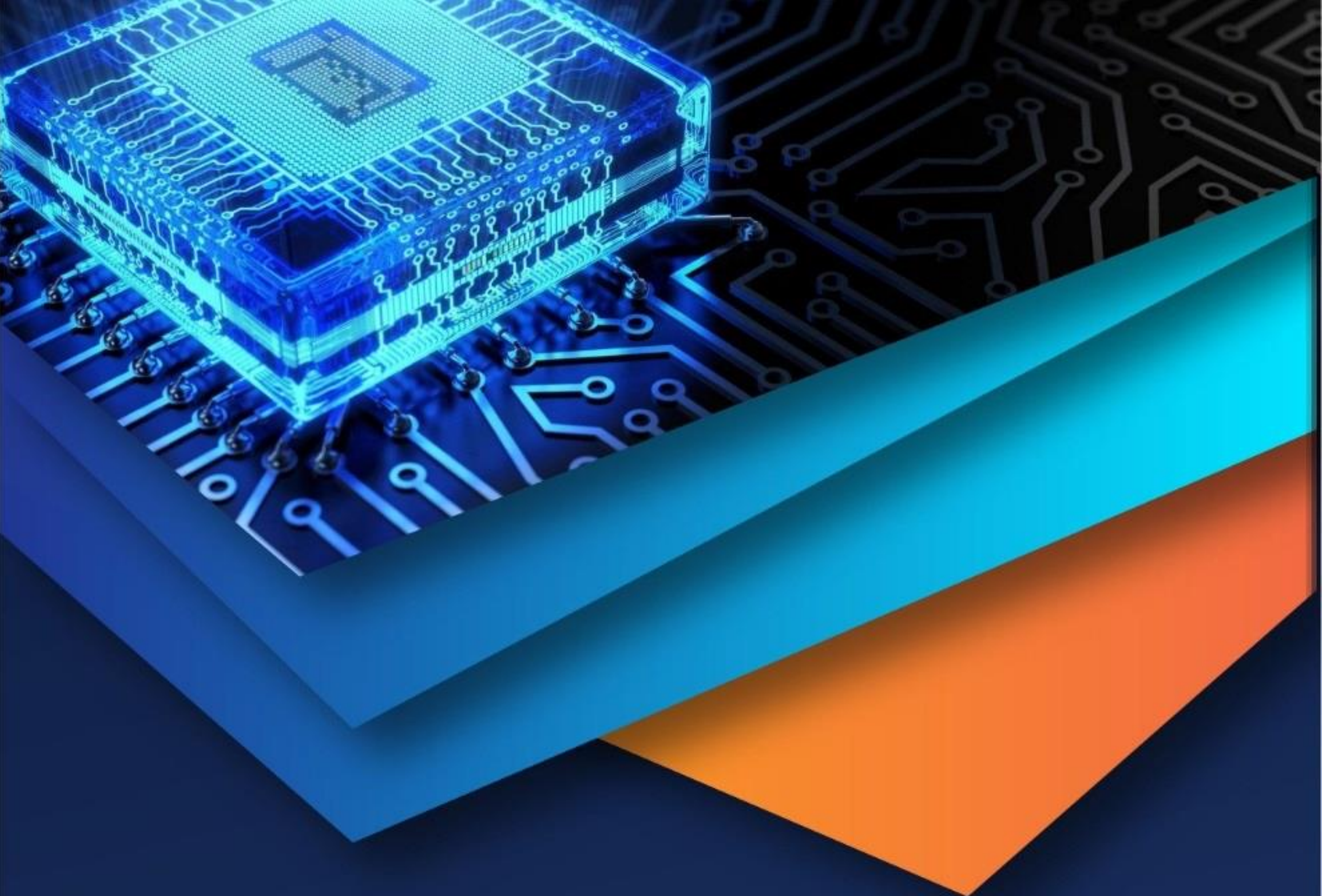

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