# Vibration Analysis of Fiber Reinforced Plastic Fan Blade

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**Abstract-** ***AbstractStructural vibration problems causes a major hazard and design limitations for a very wide range of engineering products. The Aim of this paper is to analytically extract the natural frequencies of cooling tower fan blades of different sizes. So that, Designer can ensure that natural frequencies will not be close to the frequency of the main excitation forces in order to avoid resonance. Three dimensional models of blades have been developed in Unigraphics NX 5 and modal analysis is carried out by ANSYS 15. Also, an experimental study carried out for FRP composite blades. Concurrence between ANSYS results and Experimental results has been found for the frequency range of interest.***

***Key Words:****Vibration analysis, Cooling Tower Fan Blade, Ansys, FFT Analyzer.*

## 1. INTRODUCTION

Cooling tower fan blades are exposed to severe conditions of excitation and vibration during their service life. Thus it may have a negative effect on their dynamic behaviour and this may lead to structural damage that is the collapse of cooling tower. Consequently, it is necessary to undertake vibration analysis, so that the excitation of the blade to their natural frequencies and therefore the resonance phenomenon can be avoided. Under these circumstances, the blade structure must be designed strong enough to operate under the range of frequency interest, withstand the severe conditions and survive the maximum resistance to fatigue. To achieve these requirements, glass fiber-reinforced composites are frequently used in such structural applications, Because of their excellent formability, their mass saving advantage, their high stiffness-to-density and strength-to-density ratios and the greater freedom to use these properties in the desired orientation and position. Furthermore, these lightweight structural materials have some precise objectives, which cannot be reached with some other conventional materials. These attractive advantages have positively led to integrate such materials in the construction of cooling tower fan blades. In order to minimize vibration problems a vibration analysis is carried out on blades made of different dimensions and use for various applications. A lot of research is done on vibration analysis of different types of blades by different methods. The frequencies at which vibration naturally occurs, and the modal shapes, which the vibrating system assumes, are properties of the system, and can be determined by doing Modal Analysis using ANSYS.Detailed modal analysis determines the fundamental vibration mode shapes and corresponding frequencies. Now, for a particular problem it is needed to find an analytical solution to determine natural frequency of non-uniform, tapered FRP composite blades of various dimensions and also to develop a program to predict the natural frequency of FRP fan blades. A vibration analysis of non-uniform, tapered, composite blade has been carried out by analytical method, and experimental method.

### 1.1 Problem Definition

The objective of this paper is to,

1) Find natural frequency of FRP fan blade by performing model analysis in Ansys.
2) Measurement of natural frequency by using FFT analyzer.
3) To set the natural frequency series for 24 ft, 26 ft, 30 ft Fan blades.

### 1.2 Methodology

A vibration analysis of non-uniform, tapered, composite blade has been carried out by model analysis and experimental method. A FRP composite blade can be considered as a stepped, taper, continuous cantilever beam. The circular section of FRP blade has been fixed. Ansys simulation has been done by doing modal analysis using commercial software ANSYS Workbench. A three dimensional model of blades has been generated in UNIGRAPHICS (NX5). A modal analysis in Ansys is carried out. In modal analysis, first refresh the material and geometry then do meshing, further in an analysis system select number of modes required, Apply fixed support at circular section of the blade then, Find the solution. The Solution gave natural frequencies and corresponding mode shapes and Total deformation. An Experimental method to find natural frequency of FRP composite blades required experimental setup consist of a composite blade considered as a cantilever beam, Circular end of the blade was fixed. The Accelerometer was put on the tip on blade, accelerometer connected to FFT analyzer. After initial disturbance by hammering on tip of blade analyzer display indicates values of the natural frequency of FRP composite blades. A comparison has been made between ANSYS results and Experimental results.

## 2. SPECIFICATION OF BLADE

**Table -1:** Design Data for24ft, 26ft, 30ft Blade

| Blade design data for 24ft, 26ft, 30ft blades. (STD. Chord, Distance are in mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sr. No. | Twist Angle | STD. Chord 24' | Distance | | Twist Angle | STD. Chord 26' | Distance | | Twist Angle | 30 STD' Chord | Distance |
| 00 | 18.50 | 550 | 285 | | 24.00 | 603 | 305 | | 18.50 | 630 | 285 |
| 01 | 17.50 | 537 | 182 | | 22.50 | 585 | 200 | | 17.50 | 610 | 230 |
| 02 | 14.50 | 511 | 182 | | 21.00 | 562 | 195 | | 14.50 | 585 | 230 |
| 03 | 12.50 | 492 | 182 | | 19.50 | 542 | 195 | | 12.50 | 564 | 230 |
| 04 | 10.50 | 473 | 182 | | 8.00 | 520 | 195 | | 10.50 | 542 | 230 |
| 05 | 8.00 | 453 | 182 | | 16.50 | 499 | 195 | | 8.00 | 520 | 230 |
| 06 | 6.50 | 434 | 182 | | 15.00 | 478 | 195 | | 6.50 | 498 | 230 |
| 07 | 5.00 | 414 | 182 | | 13.50 | 456 | 195 | | 5.00 | 475 | 230 |
| 08 | 4.00 | 395 | 182 | | 12.50 | 435 | 195 | | 4.00 | 453 | 230 |
| 09 | 3.25 | 376 | 182 | | 10.50 | 413 | 195 | | 3.25 | 430 | 230 |
| 10 | 2.75 | 356 | 182 | | 9.00 | 391 | 195 | | 2.75 | 407 | 230 |
| 11 | 2.25 | 337 | 182 | | 7.50 | 370 | 195 | | 2.25 | 385 | 230 |
| 12 | 1.25 | 318 | 182 | | 6.00 | 348 | 195 | | 1.25 | 363 | 230 |
| 13 | 1.00 | 298 | 182 | | 4.50 | 326 | 195 | | 1.00 | 340 | 230 |
| 14 | 0.60 | 279 | 182 | | 3.00 | 305 | 195 | | 0.60 | 318 | 230 |
| 15 | 0.30 | 259 | 182 | | 1.50 | 283 | 195 | | 0.30 | 295 | 230 |
| 16 | 0.00 | 240 | 182 | | 0.00 | 262 | 195 | | 0.00 | 272 | 230 |

**Table -2:** Material Properties of Frp Composite

| FRP Material | Young's Modulus (E) ($N/mm^2$) | Poisson's ratio ($\mu$) | Density ($\rho$) ($Kg/mm^3$) |
|---|---|---|---|
| **Glass fiber epoxy** | **13425** | **0.265** | **$1.76*10^{(-6)}$** |

## 3. ANSYS SIMULATION FOR CALCULATION OF NATURAL FREQUENCY

### 3.1 Following Steps are carried out in Modal Analysis by ANSYS Workbench.

1) Build the model-: A three dimensional model of blades has been generated in UNIGRAPHICS (NX5.) and saved as a STEP file or IGES format.
2) Choose analysis type in Ansys Workbench-: Modal analysis has been selected
3) Import Model-: A 3-D model of FRP blade whose analysis was to be done has been imported in Ansys Workbench in STEP File or IGES format.
4) Input Material Properties-: Frp composite material was unavailable, the FRP material of required material properties has been generated.
5) Refresh the material and Geometry-: In modal analysis refreshed material and geometry.
6) Meshing-: Element type has been defined and did meshing.
7) Boundary conditions-: In an analysis system numbers of modes required were selected. In order to apply constraints, a fixed support was applied at root of blade i.e. at circular section of FRP blade. External loads Ignored since free vibrations has been assumed.
8) Solution-: Total deformation and modal parameters has been found.

### 3.2 Results of ANSYS Simulation

In this section modal analysis has been done by use of Ansys software. It involves study of different modal parameters of system. Ansys simulation has been used to analyze the modal parameters of various FRP blades. Thus avoiding the need for carrying out several experiments which is time consuming and costly.
The results presented ahead are the List of natural frequencies, Mode shapes and Total deformation for 24ft, 26ft, 30ft FRP blades.

#### 3.2.1Natural frequencies for 24FT FRP fan blade.

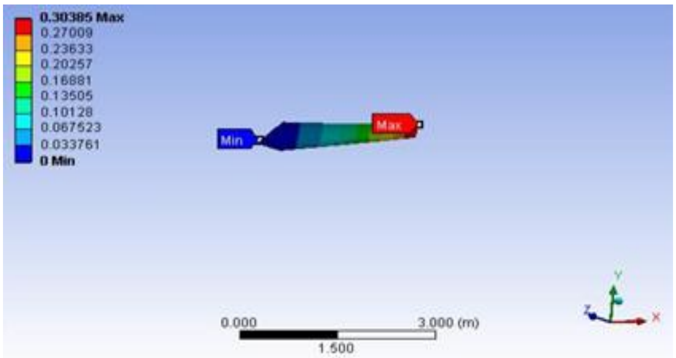


**Fig -1:**Total Deformation plots- mode 01 of 24 ft. blade corresponding to Frequency 6.08 Hz.

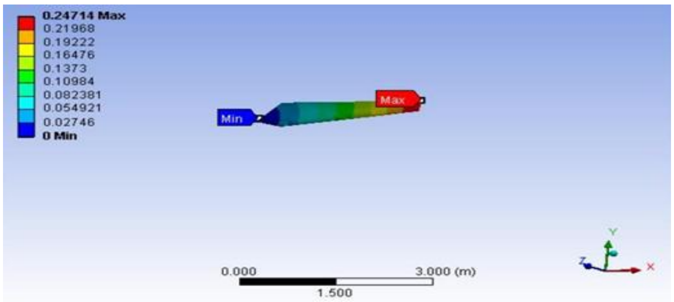


**Fig –2:** Total Deformation plots-mode 02 of 24 ft. blade corresponding to Frequency 10.81 Hz.

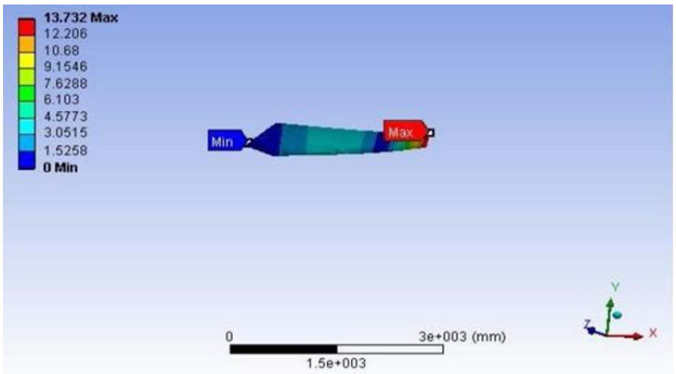


**Fig -3:** Total Deformation plots- mode 03 of 24 ft. blade corresponding to Frequency 22.32 Hz.

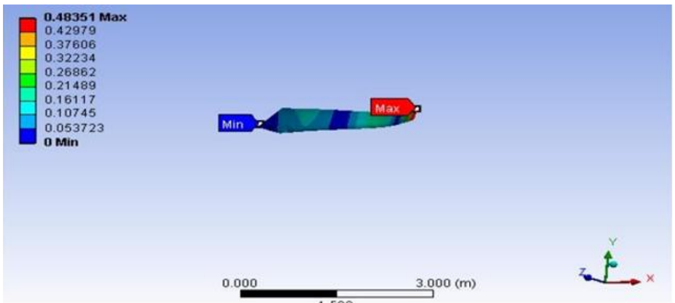


**Fig-4:** Total Deformation plots-mode 04 of 24 ft blade corresponding to Frequency 54.42 Hz.

**Table-3:**Natural Frequency of 1,2,3,4Modes for 24FT Blade.

| Mode | Frequency [Hz] |
|---|---|
| 1. | 6.0882 |
| 2. | 10.814 |
| 3. | 22.584 |
| 4. | 54.427 |

### 3.2.2 Natural frequencies, for 26ft FRP fan blade.

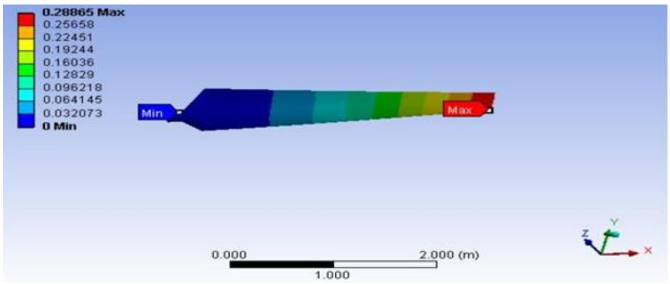


**Fig -5:**Total Deformation plots -mode 01 of 26 ft. blade corresponding to Frequency 4.39 Hz.

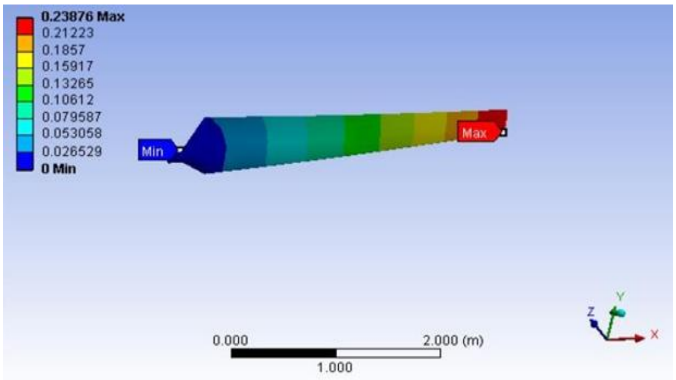


**Fig -6:** Total Deformation plots-mode 02 of 26 ft. blade corresponding to Frequency 10.97 Hz.

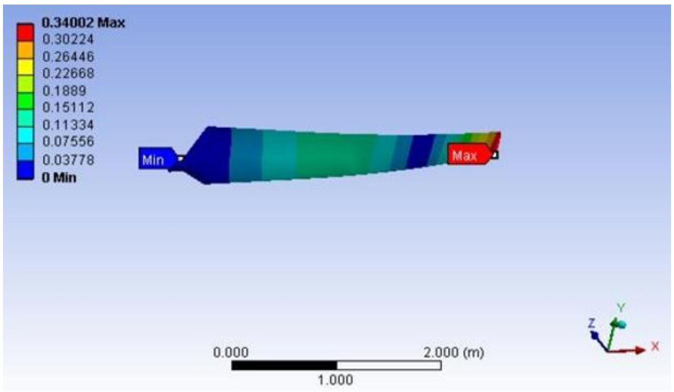


**Fig –7:**Total Deformation plots- mode 03 of 26 ft. blade corresponding to Frequency 17.82 Hz.

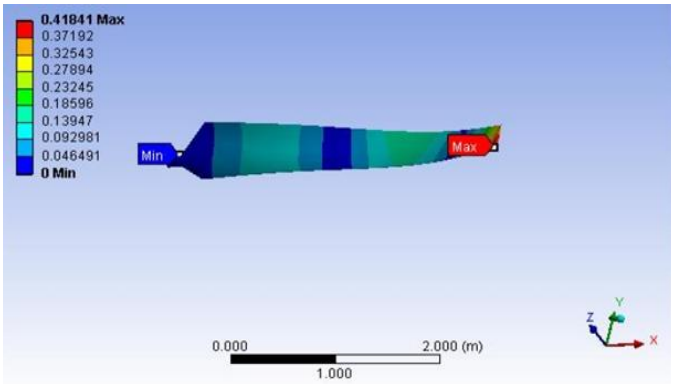


**Fig –8:**Total Deformation plots- mode 04 of 26 ft. blade corresponding to Frequency 44.98 Hz.

**Table –4:** Natural Frequency of 1,2,3,4 Modes for 26ft Blade.

| Mode | Frequency [Hz] |
|---|---|
| 1. | 4.3947 |
| 2. | 10.977 |
| 3. | 17.823 |
| 4. | 44.981 |

### 3.2.3 Natural frequencies for 30ft FRP fan blade

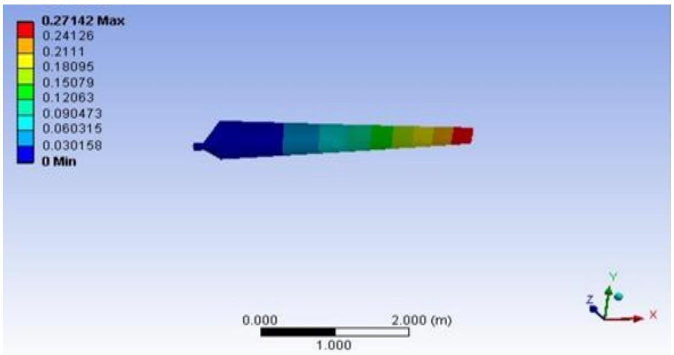


**Fig – 9:** Total Deformation plots- mode 01 of 30 ft. blade corresponding to Frequency 3.21 Hz.

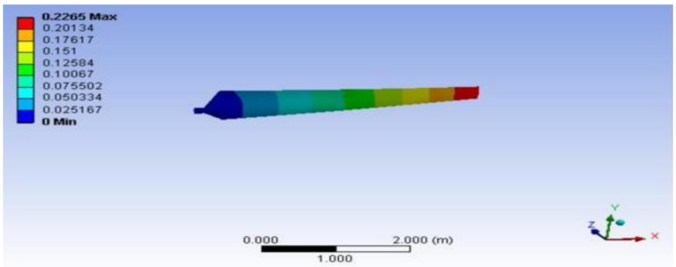


**Fig – 10:** Total Deformation plots- mode 02 of 30 ft. blade corresponding to Frequency 8.80 Hz.

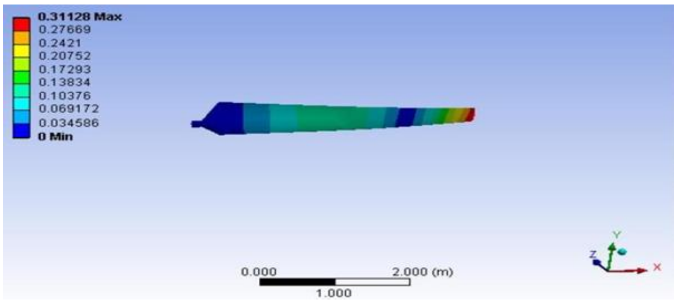


**Fig -11:** Total Deformation plots mode 03 of 30 ft. blade corresponding to Frequency 13.25 Hz.

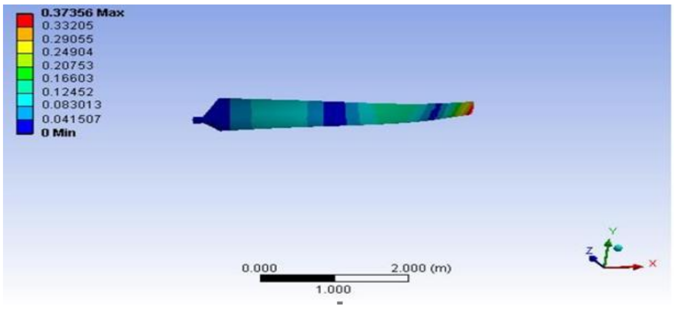


**Fig -12:** Total Deformation plots mode 04 of 30 ft. blade corresponding to Frequency 33.49 Hz.

**Table– 5:** Natural Frequency of 1,2,3,4 Modes for 30ft Blade.

| Mode | Frequency [Hz] |
|---|---|
| 1. | 3.2145 |
| 2. | 8.8072 |
| 3. | 13.259 |
| 4. | 33.49 |

## 4. EXPERIMENTAL WORK TO FIND NATURAL FREQUENCY OF FRP BLADES

### 4.1 Set up and instrumentation used

The tests were carried out on FRP composite blade. The block diagram of the experimental setup is shown in Fig. 13. Experimental setup consist of FRP composite blade hold as a cantilever beam as shown in Fig. 13.The accelerometer has been put on tip of blade and connected to FFT Analyzer. An accelerometer is used to sense amplitude of vibration. The analysis has been done with the help of FFT analyzer. The following instruments were used for measuring, recording and analyzing the natural frequency of FRP blades.
Accelerometer – make by – ADASH.
CF-0106 Connecting Cable – make by – ADASH.
Vibration analyzer- handheld FFT analyzer- ADASH.

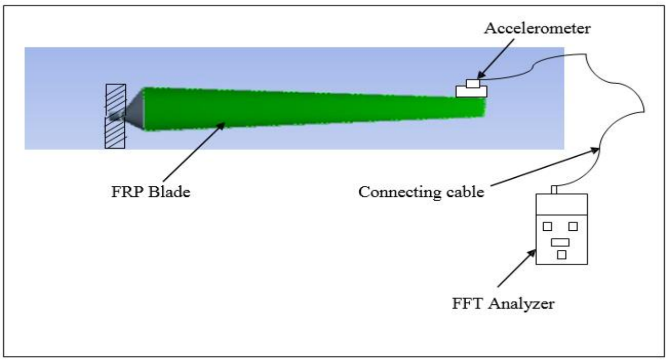


**Fig -13:**Block diagram of the experimental Set-up.

### 4.2 Measurement and analysis

The experimental set up as described in the earlier section has been used for measurement of natural frequency of FRP blades. This section gives details of experimental work carried out on FRP composite blades. The experimental results obtained have been compared with the Ansys results. For the determination of natural frequency a small disturbance given or hammered on tip of blade so, that the blade subjected to free vibration. Display of FFT analyzer displayed frequency plots. List of frequencies have been recorded for 24ft, 26ft, & 30ft FRP blades. Table -6 shows the experimentally obtained natural frequency for various FRP blades. The results are compared with the theoretically obtained results. From Result table it can be observed that there are good agreements between ANSYS results and Experimental Results. The Result table showing natural frequencies of FRP composite blades has been found by Experimental method.

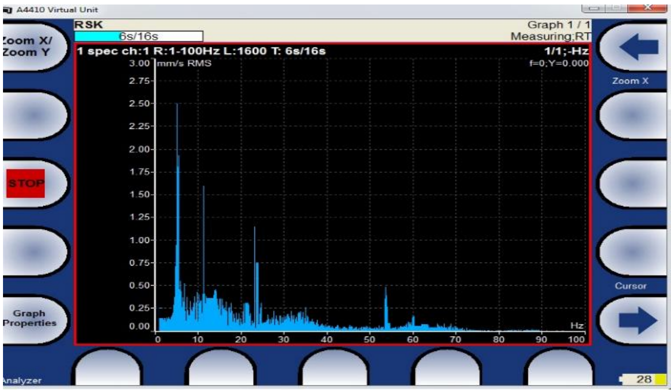


**Fig - 14:** Frequency Response for 24 ft Blade.

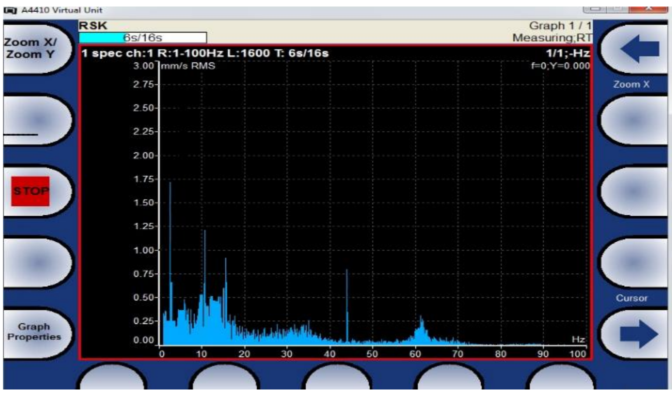


**Fig -15:** Frequency Response for 26 ft Blade.

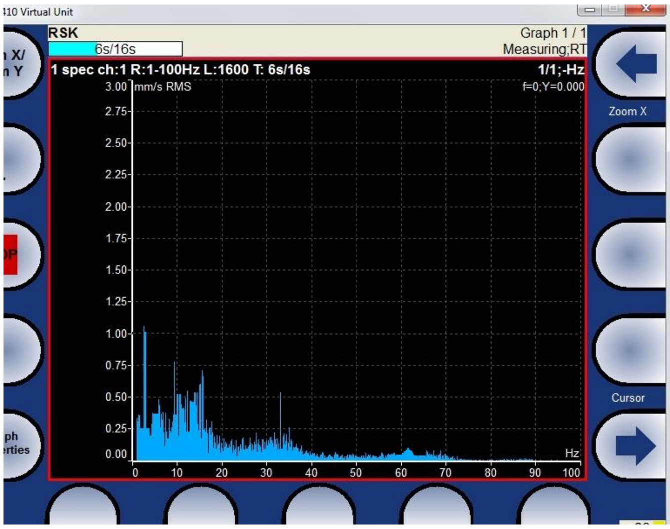


**Fig -16:** Frequency Response for 30 ft Blade.

**Table - 6:** Result table showing natural frequencies by Experimental method.

| Blade Size | Mode 1 | Mode 2 | Mode 3 | Mode 4 |
|---|---|---|---|---|
| 24 ft | 7 | 9 | 24 | 52 |
| 26 ft | 5 | 10 | 18 | 46 |
| 30 ft | 4 | 9 | 14 | 33 |

### 5. COMPARISON OF ANSYS AND EXPERIMENTAL RESULT

**Table-7:** Comparison between Ansys Result and Experimental Results

| Blade Size | Ansys | | | | Experimental | | | |
|---|---|---|---|---|---|---|---|---|
| | Model | Mode 2 | Mode 3 | Mode 4 | Model | Mode 2 | Mode 3 | Mode 4 |
| 24 ft | 6.0882 | 10.814 | 22.58 | 54.42 | 7 | 9 | 24 | 52 |
| 26 ft | 4.394 | 10.977 | 17.823 | 44.981 | 5 | 10 | 18 | 46 |
| 30 ft | 3.214 | 8.807 | 13.259 | 33.49 | 4 | 9 | 14 | 33 |

### 6. CONCLUSIONS

As compared ANSYS results, with Experimental results, it is being observed that Good agreement between ANSYS results and experimental results has been found in the frequency range of interest for a FRP Composite blades. Ansys results are close to the experimental results. Therefore the above obtained natural frequencies can be considered while designing the FRP fan blades.

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