

# Investigation of Wind Mill Yaw Bearing Using E-Glass Material

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**ABSTRACT:** Wind-turbine yaw drive endures to display a high rate of rapid failure in meanness of use of the best in current design performs. Subsequently yaw bearing is one of the priciest components of a yaw drive in wind turbine, higher-than-expected failure tariffs growth cost of energy. Supreme of the difficulties in wind-turbine yaw drive appear to discharge from bearings. Yaw bearing is located between the Tower and Nacelle portion of the Wind Turbine and slews shadow the wind way. The modelling of yaw bearing is done using Pro-E and fatigue life and static loading capacity are investigated by ANSYS. There is a gear positioned on the outer ring of the bearing and the Yaw Drive Motor is mated with this gear. The gear controls the angle control relative to the direction of the wind. This bearing gathering consists of an Outer ring, Inner ring, balls, and seal. Surviving yaw bearing made up of Carbon and Low Alloyed steels, High Alloyed Steels and Super Alloys. In this yaw bearing constitutes fairly accurate 25 tons of weight. So we categorical to diminish the weight of yaw bearings using composite materials.

**KEYWORDS:** Yaw Bearing, Composite Material, Ansys, Fatigue Life, Yaw Drive, Static Load.

## I. INTRODUCTION

In 2002, worldwide electricity production was about 31,000MW. This is a 27 increase over the previous year. In the past few years, the wind turbine generating system, which emits no carbon dioxide, has gained widespread acceptance as the cleanest and most environmentally friendly energy [1]. The technical trend for wind turbines is to increase reliability and efficiency while reducing the cost of operation. The bearings, which are one of the most important components for wind turbines, require designs that optimize reliability and economic efficiency while considering the characteristics of these applications[3]. To reduce the weight of wind turbines and to make them aggressive to conventional power plants can be considered as the main goal of wind turbine optimization. The yaw bearing system is used to rotate the nacelle for wind direction along the tower axis[6]. Therefore, the modal analysis of sliding yaw bearing can provide the basis of the dynamic characteristics analysis and optimization design of sliding yaw bearing[12]. Meanwhile, the modal analysis can be considered as the reference to avoid yaw bearing resonance during wind turbine working.

## II. LITERATURE REVIEW

M-G Kim and P H Dalho [2] stated that looking at the up scaling of the rotor diameter not only the loss in power production but the aerodynamic loads arising from yaw misalignment will have an increasing impact on the yaw system design in future wind turbines. This paper presents an overview of yaw systems used in current wind turbines and a review of patents with regards to the yaw system. The current state of the art of yaw systems has been analyzed through a systematic literature review. Further a patent analysis has been done through the European Patent Office. Today's design and strength requirements as per IEC and GL standards will be reviewed and alternative design calculations will be discussed.

Patents for the yaw bearing are incorporating the reduction of loads through the usage of friction bearings or different bearing arrangement approaches. The paper shows that the conventional yaw system designs are still trying to meet the high requirements regarding the lifetime of a wind turbine and turbulent wind loads. New designs for yaw systems in general are hard to find. Many patents concentrate on control algorithms that depend on additional instruments and incorporate electromechanical systems.

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Liu Yanping and Shang Lilong, Yu Yi [4] proposed that sliding yaw bearing works in the complex environment with large load range, so its dynamic analysis is very important. The modal analysis of sliding yaw bearing is not only an effective method for analyzing sliding yaw bearing's dynamic characteristics, but also the basis of the dynamic respond analysis. This paper used the parameter design function of UG code to build the 3-D model of sliding yaw bearing and imported the model to ANSYS code to build finite element model. Then the finite element modal analysis was applied after meshing the model. Finally, the low-order natural frequency and the vibration mode were obtained.

KristianOpsahlBredesen [5] said that NOWITECH (Norwegian Research Centre for Offshore Technology) are developing a 10 MW offshore reference wind turbine to encourage increased production of renewable energy. This thesis presents a mechanical design and dimensioning of a transition piece between the yaw bearing (part of the nacelle) and the tower in this reference turbine. A fatigue analysis to verify the lifetime of 20 years for the main shaft, bed plate and transition piece has also been performed.

The final design has shape like a cone, which distributes the loads from the yaw bearing to the whole section of each tower leg. An extreme load case with 50 year occurrence period has been used for the Ultimate Limit State analysis. The material EN-GJS-400-18 is suggested for the transition piece, bed plate and main shaft. It has yield strength of 240 MPa and a tensile strength of 370 MPa. The mass of the transition piece is 49.6 tones and a peak stress of 262 MPa in a single node was found.

## III. YAW BEARING

Yaw bearings are indispensable to the protected and capable operation of wind turbines. They are classified as a large bearing and small bearing. Large bearing is suffer from much more numerous operational conditions compared to small bearings used for general industrial applications; in particular, they are subjected to superior peripheral forces in each direction, very thin lubrication film thickness during operation, and so on. Moreover, because they are installed on the wind turbine blade or a tower top of high altitude, it is costly and time consuming to repair or replace them in the field.

Therefore, a laboratory-scale test is required for ensuring the performance of the pitch and the yaw bearings before application in the field. A test rig is developed to verify the performance of the pitch and the yaw bearings, including their fatigue life and static loading capacity. The test rig can reproduce actual operational conditions such as 6 degree of freedom (DOF) dynamic loadings and rotation of bearings for both directions.

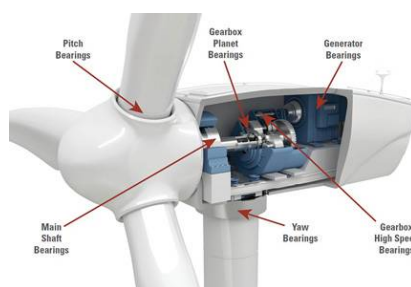


Fig. 1 Yaw Bearing Setup in Wind mill



Fig. 2 Yaw Bearing

The mounting interfaces of the test rig are also the same as those used in the original environment, and various sizes of bearings can be applied by using a changeable adaptor. This high reproducibility of actual loading, driving, and mounting conditions simultaneously as well as applicability to wide size ranges are distinctively advantageous characteristics compared to previous test rigs. The developed rigs for use in pitch and yaw bearings of 2.0–3.0 MW class wind turbine

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## 3.1 Component of Yaw Bearing

1. Outer Race Way
2. Inner Race Way
3. Balls
4. Cage or separators

## IV. CALCULATION FOR BEARING

### 4.1 Fatigue Life

#### 4.1.1 Lundberg-Palmgren method

The method for representative plenty life for ball bearings is to use mathematical models to estimate the minimum life. For ball bearings this typically is done using a model proposed by Lundberg and Palmgren. If the Lundberg and Palmgren theory is based on the ISO standard 281, ANSI/ABMA Standard 9 and Standard 11, and the stress life method.

The Lundberg-Palmgren theory and its derivative methods determine rolling contact fatigue life according to the statistical probability of the survival of a bearing; the probability of failure is the complement of probability of survival. Bearing life  $L$  is expressed in terms of millions of revolutions of the rotating raceway. The usual industry practice is to specify bearing life according to a 10% probability of failure, or  $L_{10}$ .  $L_{10}$  also can be expressed in hours of operation. The Lundberg-Palmgren model refers to the visible evidence of rolling contact fatigue of the raceway surfaces. Although rolling elements (i.e., balls, rollers) also could fail, the Lundberg-Palmgren theory does not accommodate that phenomenon. Derivative methods, based on Lundberg-Palmgren (e.g., Barnsby et al.), include the probability of rolling element failure.

#### 4.1.2 Applied loading

Thrust-type Ball bearings used for wind turbine yaw bearings. The principal load is an eccentrically applied thrust which results in an axial load and an overturning moment load. The distribution of the applied load to the individual balls is mainly one of thrust, where the number of loaded elements is greater than one-half. Ideally, the radial load is distributed over half (or fewer) of the rolling elements. Applied simultaneously with thrust and overturning moment loads, radial load affects the thrust type of load distribution but does not significantly alter it.

#### 4.1.3 Basic Dynamic Axial Load Rating

Basic dynamic axial load rating, or thrust basic dynamic capacity, is defined as the constant centric thrust load that a rolling bearing theoretically could endure for a rating life ( $L_{10}$ ) of 1 million revolutions. The load rating standards provide the following formula for a basic dynamic axial load rating for thrust ball bearings.

## V. MISCELLANEOUS DESIGN CONSIDERATIONS

A number of important non-rolling items can adversely affect yaw and pitch bearing service life if they are not properly satisfied. A partial list includes: External bolting, Cages or separators and Integral seals.

### 5.1 External Bolting

The proper operation of yaw bearings requires that the external mounting bolts have sufficient preload and strength to maintain the rings in contact with their mounting surfaces at all times. The maximum rolling element load ( $Q_{max}$ ) is used, with proper consideration of the number of elements and the number of bolts, to determine the maximum bolt load. See References, entries 14 through 18, for a brief bibliography of technical papers covering a bolted joint.

### 5.2 Cages or Separators

Most yaw bearings are supplied with plastic spacers between each rolling element. A four-point contact ball bearing has cylindrical spacers with hemispherical indented ends. The ball spacers for larger balls (50-mm diameter and larger) often have a steel-plate reinforcement cast into the plastic.

Use of segmented cages is very rare for yaw bearings. The opening that the cage requires between the raceways significantly reduces the available load-carrying ball path. The bearing manufacturer should be consulted about spacer design. The spacer material also must be compatible with the selected lubricant.

### 5.3 Integral Seals

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Wind turbine yaw bearings are usually supplied with integral rubbing lip seals. The bearing manufacturer should be consulted about materials, design, and placement of the integral seals. The seal material must be compatible with the selected lubricant.

## VI. DESIGN PARAMETERS

Yaw bearing consist of various elements like outer race way, inner race way, balls and cage. These parts are modelled by pro E wildfire 5.0 with 1.25 MW wind mill

### 6.1 Introduction About Pro-Engineer

Pro-Engineer is a powerful application. It is ideal for capturing the design intent of your models because at its foundation is a practical philosophy. Founder of this Pro-Engineer is Parametric Technology Corporation. After this version they are released Pro-E 2000i2, Pro-E 2001, Pro-e Wildfire, Pro-e Wildfire2.0... pro-e 5.0. In 2011, PTC rebranded Pro/Engineer as Creo Parametric. The current version of the software is 2.0. Pro/ENGINEER (Pro/E for short) is a commercial CAD/CAM package that is widely used in industry for CAD/CAM applications.

### 6.2 Yaw Bearing Dimensions

DESCRIPTIONS		DIMENSIONS (mm)
Outer race way	Outer dia	2390
	Inner dia	2128
	Height	120
	Holes	48 x Ø36 x Ø30
	Hole depth	90
Inner race way	Outer dia	2126
	Inner dia	1948
	Height	108
	Holes	48 x Ø33
Ball	Diameter	45
	No. of ball per row	75
External gear	Pitch circle dia	2340
	No. of teeth	130

Table 1 Yaw Bearing Dimensions

### 6.3 Modelling Images

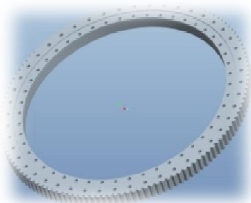


Fig 3 Outer Race Way

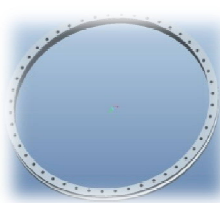


Fig 4 Inner Race Way

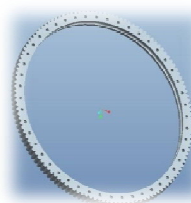


Fig 5 Cage

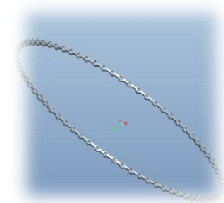


Fig 6 Yaw Bearing

## VII. SELECTION OF MATERIAL

A "composite" is when two or more different materials are combined together to create a superior and unique material. This is an extremely broad definition that holds true for all composites, however, more recently the term "composite" describes reinforced plastics. The composite material most commonly associated with the term "composite" is Fiber Reinforced Plastics. This type of composite is used extensively throughout our daily lives. Common everyday uses of fiber reinforced plastic composites include. Glass fiber reinforcement polymer (GFRP) material is used in this thesis. In GFRP material, E-glass fibre is used in this thesis.

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## 7.1 Existing Material Properties

Presently, alloy steels, stainless steels, carbon steels are used for making bearings. The material properties of the existing material are given in Table 2.

Properties	Carbon steels	Alloy steels	Stainless steels
Density( kg/m <sup>3</sup> )	7850	7850	7750-8100
Elastic Modulus (GPa)	190-210	190-210	190-210
Poisson's Ratio	0.27-0.3	0.27-0.3	0.27-0.3
Tensile Strength (MPa)	276-1882	758-1882	515-827
Yield Strength (MPa)	186-758	366-1793	207-552

Table 2 Material Properties of Existing Material

## 7.2 Proposed Material Properties

The use of E-Glass as the reinforcement material in polymer matrix composites is extremely common. Optimal strength properties are gained when straight, continuous fibers are aligned parallel in a single direction. To promote strength in other directions, laminate structures can be constructed, with continuous fibers aligned in other directions. E-Glass is a low alkali glass with a typical nominal composition of SiO<sub>2</sub> 54wt%, Al<sub>2</sub>O<sub>3</sub> 14wt%, CaO+MgO 22wt%, B<sub>2</sub>O<sub>3</sub> 10wt% and Na<sub>2</sub>O+K<sub>2</sub>O less than 2wt%. These involve melting the glass composition into a platinum crown which has small holes for the molten glass to flow. Continuous fibers can be drawn out through the holes and wound onto spindles, while short fibers may be produced by spinning the crown, which forces molten glass out through the holes centrifugally. Fibers are cut to length using mechanical means or air jets. The material properties of E-glass fibre are given in Table 3.

PROPERTIES	E- GLASS FIBER
Density(kg/m <sup>3</sup> )	2580
Young's Modulus (GPa)	72.3
Poisson's Ratio	0.22
Tensile Ultimate Strength (MPa)	3450
Compressive Strength (MPa)	1080

Table 3 Material Properties of Proposed Material

## VIII. RESULTS AND DISCUSSIONS

The finite element analysis of yaw bearing was done by using Ansys workbench. Static structural and modal analyses were done to find out the strength and vibration effect of the yaw bearing. The Ansys results were discussed below.

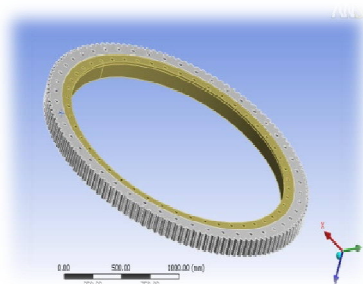


Fig 7 Imported Model of Yaw Bearing

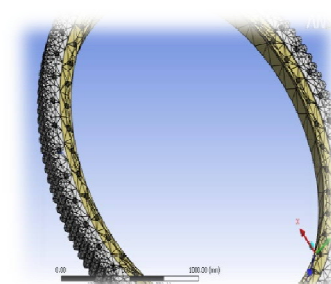


Fig8 Meshed model of yaw bearing



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## 8.1 Alloy Steel

### 8.1.1 Static Analysis of Yaw Bearing

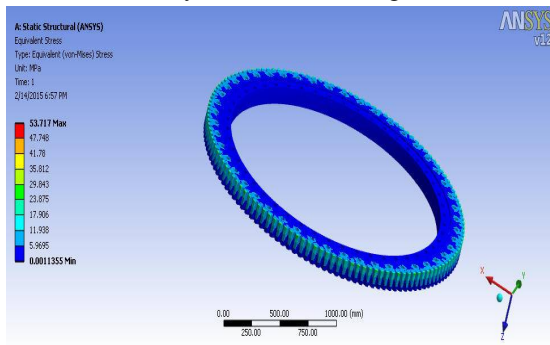


Fig 9 Stress obtained in yaw bearing

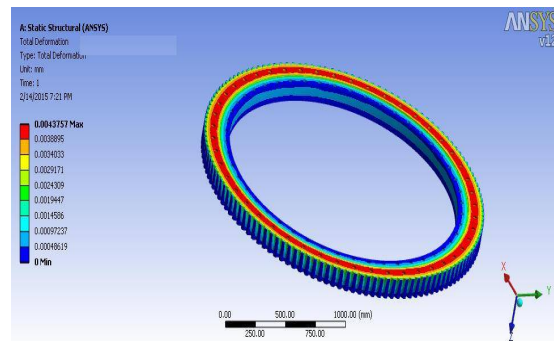


Fig 10 Deformation obtained in yaw bearing

### 8.1.2 Modal analysis of yaw bearing

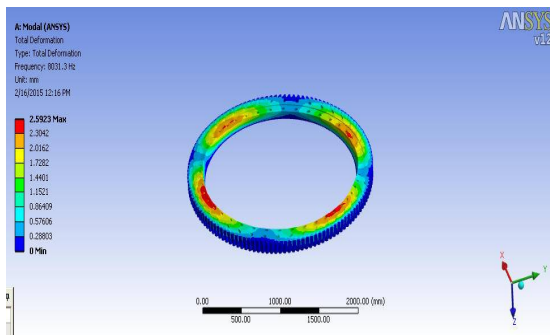


Fig 11 Frequency Obtained In Yaw Bearing

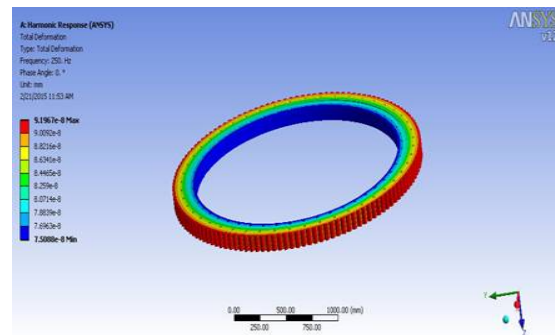


Fig 12 Deformation Obtained In Yaw Bearing

### 8.1.3 Harmonic analysis of yaw bearing

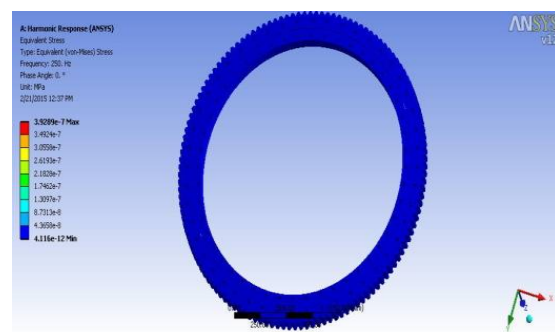


Fig 13 Frequency Response for Yaw Bearing

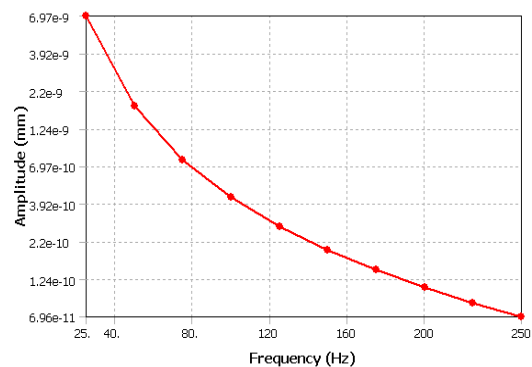


Fig 14 Stress obtained in yaw bearing

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## 8.2 E – Glass Fiber

### 8.2.1 Static Analysis of Yaw Bearing

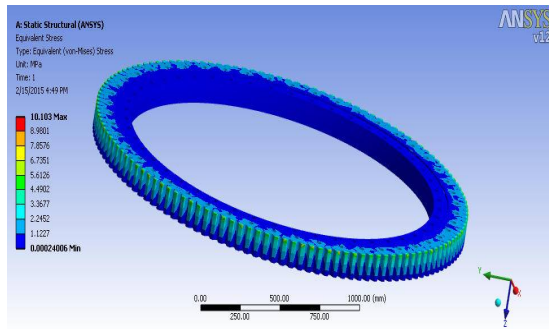


Fig15 Stress obtained in yaw bearing

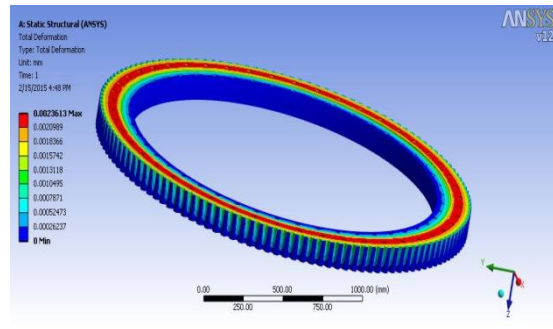


Fig 16 Deformation obtained in yaw bearing

### 8.2.1 Modal analysis of yaw bearing

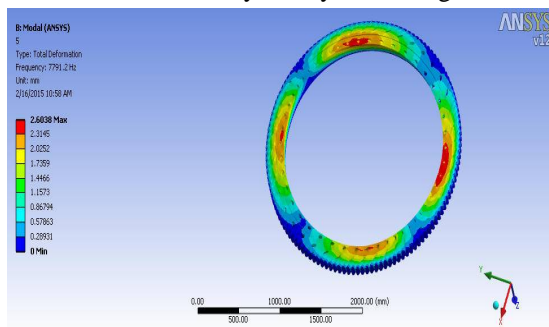


Fig 17 Frequency Obtained In Yaw Bearing

### 8.2.3 Harmonic analysis of yaw bearing

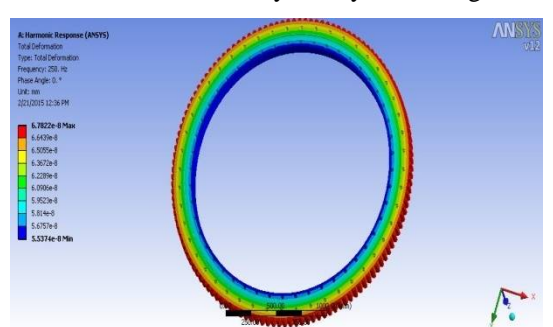


Fig 18 Deformation Obtained In Yaw Bearing

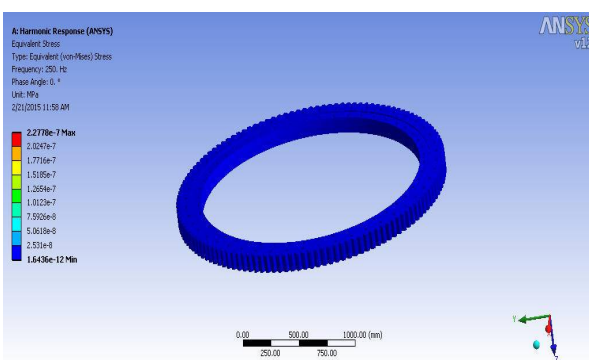


Fig 19 Stress obtained in yaw bearing

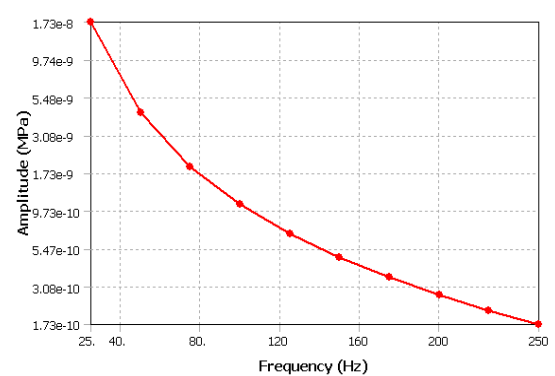


Fig 20 Frequency Response for Yaw Bearing

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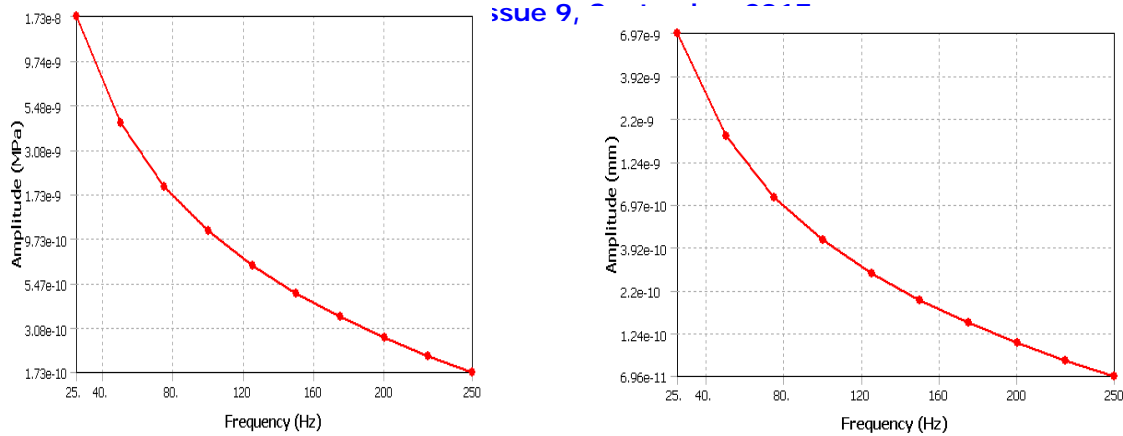


Fig 21 Frequency Response for Yaw Bearing

### 8.3 Result Comparison

S.NO	PROPERTIES	ALLOY STEEL	E-GLASS FIBER
1	Load	1.8 MPa	1.8 Mpa
2	Stress (MPa)	53.717	10.13
3	Deformation (mm)	0.0043757	0.002361
4	Total weight (Kg)	1347.5	481

Table 4 Result Comparison for Static Analysis

S.NO	PROPERTIES	ALLOY STEEL	E-GLASS FIBER
1	Frequency (Hz)	8031.3	7791.2

Table 5 Result Comparison for Modal Analysis

S.NO	PROPERTIES	ALLOY STEEL	E-GLASS FIBER
1	Deformation (mm)	9.196e <sup>-8</sup>	6.782e <sup>-8</sup>
2	Stress (MPa)	3.928e <sup>-8</sup>	2.278e <sup>-7</sup>

Table 6 Result Comparison for Harmonic Analysis

## IX. CONCLUSION

Yaw bearing is one of the critical components in the wind turbine. The replacement of conventional alloy steel material with composite material E-Glass fiber increases the strength and life of the yaw bearing. It also has very low fundamental bending natural frequency compared to alloy steel, so it has high resistant to vibration effect. The weight of the component is also drastically reduced by using composite material. From the analysing results, it is found that E-Glass fibre has better properties than Alloy steel. So it is better to use E-Glass fiber material for yaw bearing.

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