Structural Analysis of Fixture Carrying Turbine Wind Blade

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Abstract - *Renewable energy is energy that is collected from renewable resources, wind is one such Renewable resource from which the electricity can be produced. So most of the countries are producing the electricity by using wind power. The wind power is converted into electric power by using wind mills or wind turbines. The turbines are run by the wind fans or blades. The wind blades converts the wind energy into rotational energy. Most of the wind mills are installed at the hilly regions. The challenging task installing the wind mills is to carry the wind blades safely to the installation locations. During the transportation the blade is supported at the extreme points of the blade. The support/ Fixture at the region of the blade hub is very crucial and need to design based on the extreme pay loads that occur during road transportation. The current study is focused on the structural stability of the blade fixture for worst loads that occur during transportation.*

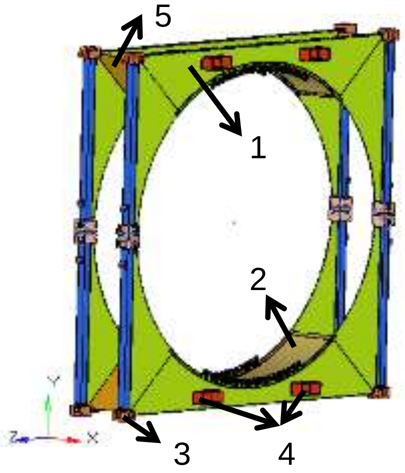
Key Words: **Fixture, Wind turbine blade, Transportation, Structural stability, FEM, Hyper-mesh.**

1. INTRODUCTION

The main function of the fixture is to hold, guide and supporting the device. The primary aim of the fixture design is to hold the device and prevent from breaking or worst loads during transportation. The specific fixture design depends upon many aspects like dimension, load and mode of transportation. The main goal here is towards design and analyze the superior fixture used to hold, support and guide the component body which is used in different applications. Solid works software is used for the modeling of all components also its assembly is done for fixtures. By means of ABAQUS the finite element analysis is conducted. The fixture design and manufacturing cost will be up to 10% - 20% of the total cost of the manufacturing system.

1.1 Purpose of fixture

The foremost purpose of the fixture in this is to locate the wind turbine blade fast and perfectly, by providing required supports to hold it safely. Another important objective is that the fixture design should be made in such way that the blade is secured from all the degrees of freedoms.



1. Supporting plate 2. Aligning plate 3. Mounting Lugs 4. Lifting slots 5. Cross member plate

1.2 CLASSIFICATION OF FIXTURES

Concerning to the some of the following features the fixture are classified as follows,

On the Basis of Application

- Work holding fixture
- Tool holding fixture
- Fit- up fixture
- Gauging fixture
- Holding fixture

On the Basis of Degree of Automation

- Hand operated
- Power operated
- Semi-automatic
- Automatic

2. LITERATURE SURVEY

The main purpose of this literature survey is to study the works carried out by different researchers, various methods concerned with the detailed study of the fixture design. To know the scope for any modern method of design, so that the design process is easier, strong and economical. The research methods previously discussed are analyzed in this literature survey to get high quality results in present work.

Price Shaun et al. [1] in this study, they generally discussed about the earlier automation and computer aided fixture designs (CAFD) projected firstly, then a brief overview about the fixture claims in manufacturing industry was proposed. After that the substantial exercise was carried out in the computer aided fixture design (CAFD) domain, together with their methodologies, necessities and operational principles were deliberated. They examined the methodologies, systems and applications of modern achievements in the field of computer aided fixture design. They concluded that a number of research aspects were promising and inspiring.

Mathijs Peeters et al. [2] they presented that wind turbine blade splitting up in to number of parts and transported separately to the installation website. For reducing the cost of energy (COE) there is a tendency towards increasing the length of wind turbine blades. This includes problems in manufacturing and transportation, so that the splitting up of wind turbine blade arises. They presented brief summary about possible implementations, bearing in mind the splitting position as well as orientation and also the type of joint used. Adhesive bonding is predictable towards structural and cost effective efficiency, but in the field of assemblage occurs a big problem.

Y. Zheng et al. [3] they focus mainly on study of fixture stiffness and they worked towards the experimental analysis of estimating the contact stiffness in normal and tangential directions. To know the different parameters like, effecting factors and normal contact stiffness the static method was applied. For the study of tangential contact stiffness the dynamic methods are established and it also estimates the contact stiffness in both normal and tangential directions. By obtaining the results of the static method in the documentation of normal contact stiffness, study is validated.

C.RadhaMadhavi et al. [4] they concerned about the studying of input data collected from customers like, part drawing and assembly drawing. By using Auto CAD and Solid works the machining and analysis of several parts in the fixture assembly is carried out, fixture design initiates by means of part modeling. In this a software package is used as COSMOS for analysis. From the customers brief project proposals studying in detailed then the actual designs activates, after that locating and calming ideas were decided. It also contains the availability, loading and unloading arrangement of parts. Material required for the fixture is carefully chosen. They designed fixture as per Industrial application standards. They concluded that fixture is as good as any dedicated fixture in manufacturing by examining the locating accuracy and machine part quality.

2.1 SUMMARY OF THE LITERATURE SURVEY

By conducting the literature survey some of the important concepts are comes to known like different methods of designing and methodologies and some of the scope or possibilities are identified as, the design optimization codes are further developed by means of addition of much more design variables and constraints, so that it is easy to find out real time results. Another parameter, by using flexible fixture systems (FFSs) it minimizes the cost related to fixture manufacturing in small to medium size. By doing virtual design simulation in a proposed project we can save a lot of time and speed of the design process. It also eliminates prototype testing of the fixture.

2.2 OBJECTIVES

To analyze the stress and displacement plots on the existing blade carrying fixture. To redesign the existing fixture to carry the new loads occurring from the new blade design. To analyze and check the factor of safety of new design so as to meet the new requirements.

3. METHODOLOGY

The dimensions of the wind turbine fixture is taken from the existing reference model, the existing reference model was designed for the turbine blade whose diameter was 2.7 meters and weight of 17 ton's. The reference model dimensions are modified to suit the current wind turbine blade whose diameter is 3.5 meters and the weight of 23 ton's. The appropriate stiffness and the lifting, mounting tubes are incorporated in the design as per the requirements of the logistic department. The 3-D CAD model is generated using the commercial CAD software like a solid edge. The CAD model is saved and exported in the form of neutral file format like IGS or para solid. The neutral files will help to import the model in any third party software. In a current project the third party software like, Hyper mesh and ABAQUS is used.

The CAD model is imported (neutral file) in to the pre-processing (HM) software for the discretization of the structure. The geometry clean-up process is carried out in a Hyper-mesh tool using a clean-up geometry commands like, removing of an unwanted holes, fillets and chamfers, which are not important from an analysis point of view. Geometry clean-up is followed by the mesh generation methods. The mesh generation methods/commands like, auto mesh, ruled, spin, drag, line drag are used to generate the mesh. In a current FE model first order 2-D elements like, quad, tria are used to represent the surfaces. 1-D elements like bar, beam and rigid links are used to represent nuts, bolts and connection mountings. In a current FE model the convergence is achieved by using H-method convergence. The average element size of 20 mm is maintained thought the structure. After the FE model creation the thickness properties and material properties are assigned as per the ABAQUS solver. The steel material properties with the following parameters are assigned to all the structural parts.

Density – 7.85 e^{-9} Ton's/mm^3
Young's modulus – 2.1 e^5 Mpa
Poisson's ratio - 0.3

Alloy steel with Yield strength – 650 Mpa is used
The loads and boundary conditions are assigned to the structure as shown in the figure 5.3, 5.12, 5.21 and 5.28. The appropriate ABAQUS commands are assigned to the FE model. The ABAQUS FE deck or (solver) file is exported in the (. INP) file. The (.INP file) ABAQUS INP file is submitted for the analysis in the ABAQUS solver.

The result from the ABAQUS solver is generated as a output data base file (.ODB). The ABAQUS result file is post-processed in the ABAQUS viewer and following contour plot are taken to conclude the analysis.

1. Stress plots
   - Von-Mises
   - Minimum principal
   - Maximum principal
   - Tresca's
2. Displacement plots

The maximum stresses obtained from the result file are compared with yield strength of the material to decide the factor of safety for the given loading conditions.

4. RESULTS AND DISCUSSION

To study the structural strength of the fixture which supports the wind turbine blade during the transportation. The fixture is analyzed under the 4 loading conditions like bumping, breaking, turning and lifting.

4.1 FE MODEL

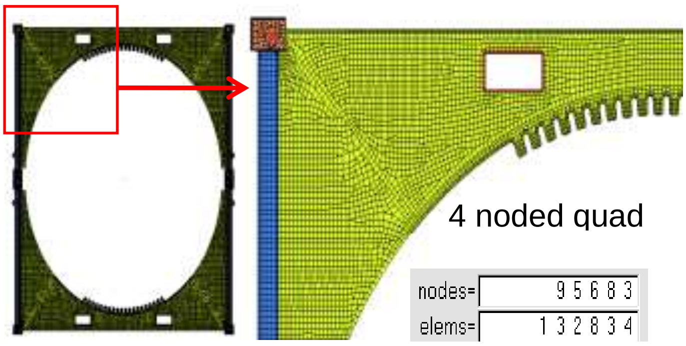


Fig-4.1 Finite element Model

The mesh is highlighted as shown in the image. The elements like 4 noded quad and 3 noded tria are used to mesh the full structure of the fixture. The number of nodes of FE model are 95683 and number of elements are 132834.

4.2 Load case 1: Bumping load in vertical direction

Mass of the blade: 23 tons, Mass of the fixture: 2.167tons, Total load: 25.167 tons. The bumping load acts on the structure when the vehicle move over the humps or road brakes or over small pits. During bumping the load on the structure will not be gradual, instead the load will be sudden and it causes the impact. The effect of impact is taken care by considering the G (acceleration) as 2 times.

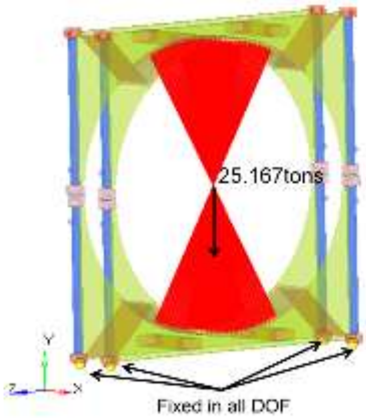


Fig-4.2 loads and boundary conditions for bumping

The Max Von Mises stress observed on the structure near the bolting location of the blade to the fixture is 280 Mpa.

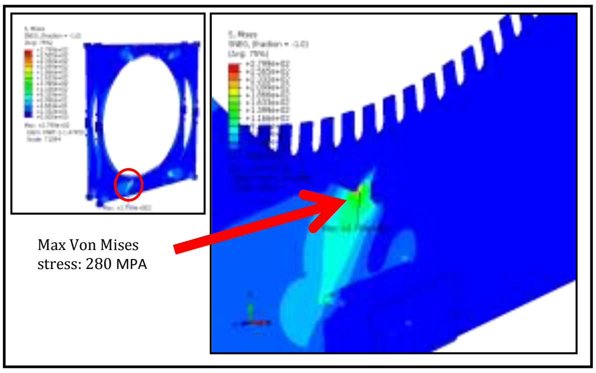


Fig-4.3 Max Von Mises stress in bumping load

The shear stress observed on the structure near the lifting lugs of the blade to the fixture is 285 Mpa.

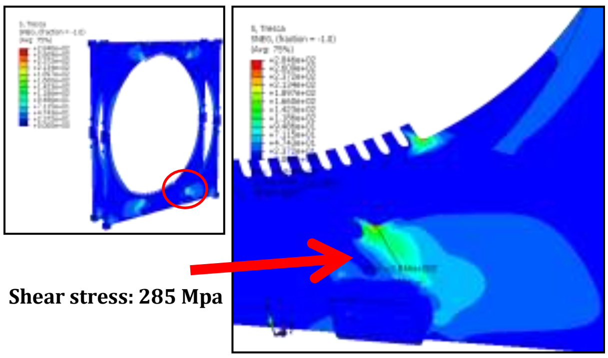


Fig-4.4 Shear stress in bumping load

4.3 Load case 2: Breaking load in axial direction

Mass of the blade: 23 tons, Mass of the fixture: 2.167tons, Total load: 25.167 tons. The breaking load acts on the structure when the vehicle decelerate to stop. During breaking the load on the structure will not be gradual, instead the load will be sudden and it causes the impact. The effect of impact is taken care by considering the G (acceleration) as 2 times.

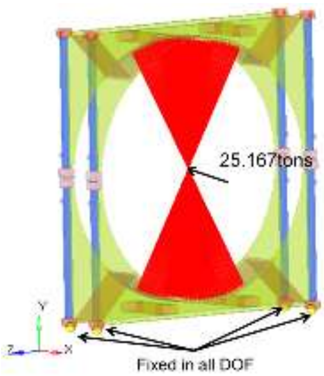


Fig-4.5 loads and boundary conditions for breaking

The Max Von Mises stress observed on the structure near the cross member plate of the blade to the fixture is 491 Mpa.

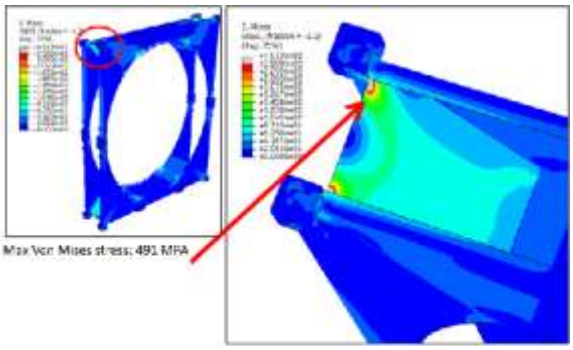


Fig-4.6 Max Von Mises stress in breaking load

The Shear stress observed on the structure near the cross member plate of the blade to the fixture is 565 Mpa.

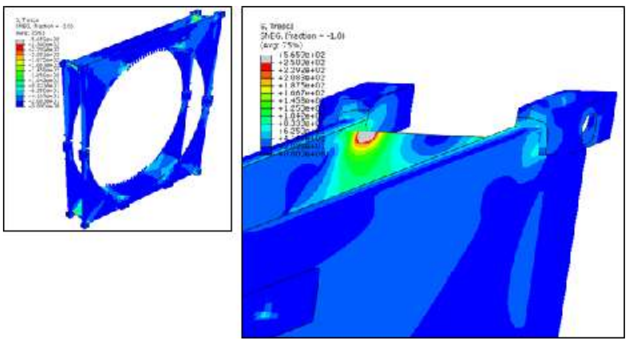


Fig-4.7 Shear stress in breaking load

4.4 Load case 3: Turning load in lateral direction

Mass of the blade: 23 tons, Mass of the fixture: 2.167 tons, Total load: 25.167 tons. The Turning load acts on the structure when the vehicle takes the sharp cut. During Turning the structure will not be gradual, instead the load will be sudden and it causes the impact. The effect of impact is taken care by considering the G (acceleration) as 1.5 times.

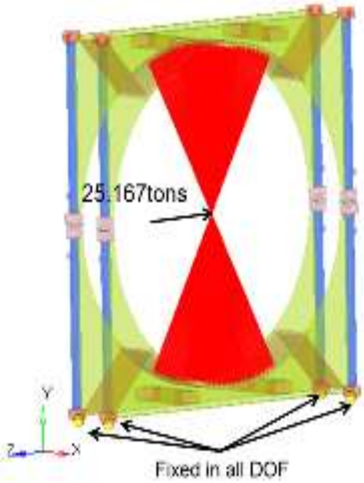


Fig-4.8 loads and boundary conditions for turning

The Max Von Mises stress observed on the structure at the supporting plate of the blade to the fixture is 57 Mpa.

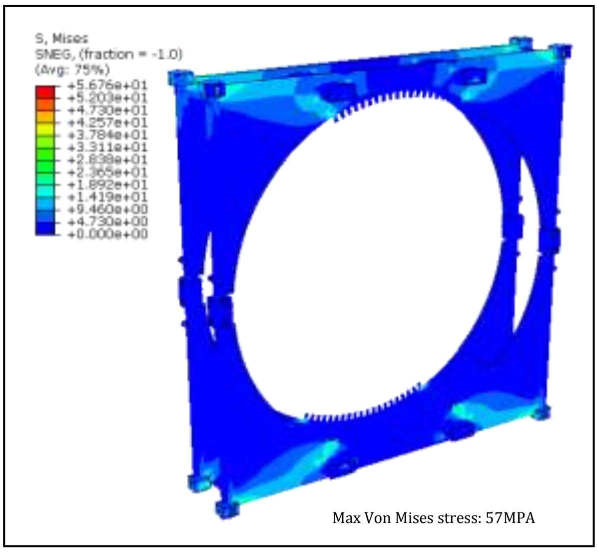


Fig-4.9 Maximum Von Mises stress in turning load

The Shear stress observed on the structure at the supporting plate of the blade to the fixture is 65 Mpa.

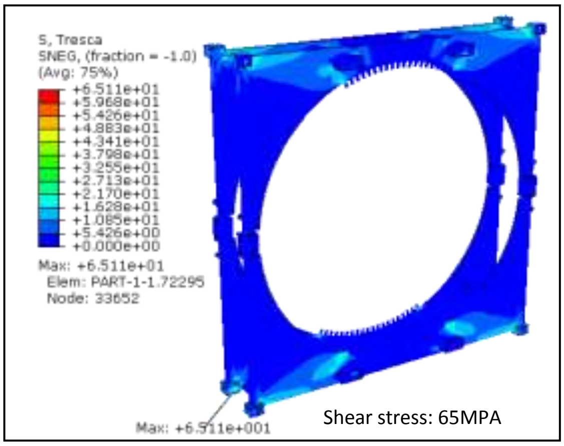


Fig-4.10 Shear stress in turning load

4.5 Load case 4: Lifting load in downward direction

Mass of the blade: 23 tons, Mass of the fixture: 2.167tons, Total load: 25.167 tons. The mounting boundary conditions will be different for the lifting conditions. The Lifting load acts on the structure when the turbine blade along with the fixture is lifted during shipping from road ways to waterways. During lifting the structure will not be gradual, instead the load will be sudden and it causes the impact due to jerk. The effect of impact is taken care by considering the G (acceleration) as 2 times.

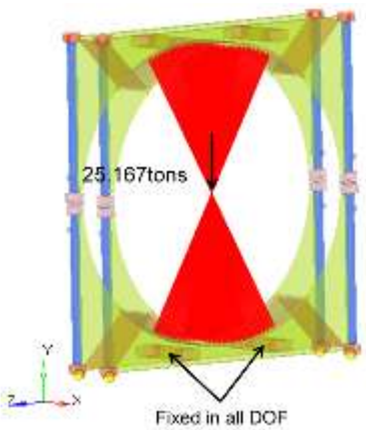


Fig-4.10 Lifting load acts in vertical directionThe Max Von Mises stress observed on the structure near the lifting lugs of the blade to the fixture is 95 Mpa.

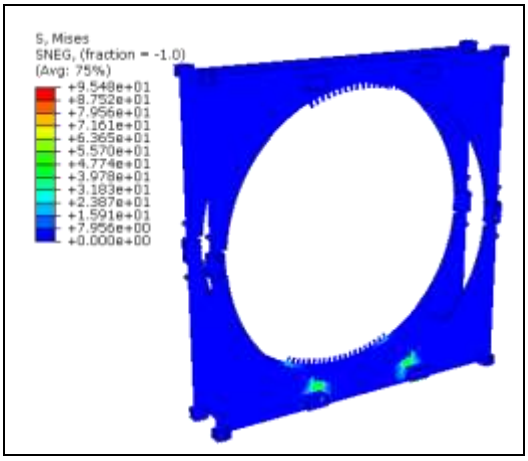


Fig-4.10 Maximum Von Mises stress in lifting load

The Shear stress observed on the structure near the lifting lugs of the blade to the fixture is 105 Mpa.

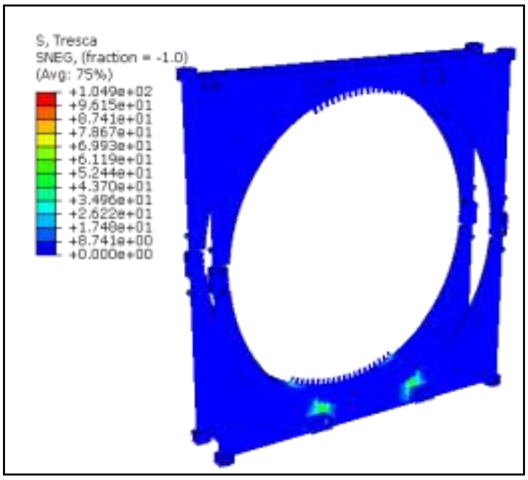


Fig-4.10 Shear stress in lifting load

4.6 RESULT SUMMARY

Table -1: Strength analysis report

Sl. No	Applied Loads on the structure (N)			Reaction force at fixed points (N)			YS(MPA)	Max Stress	FOS
	x	Y	z	X	y	z			
LC1	0	-493777	0	0	493777	0	650	285	2.28
LC2	**-493777**	**0**	**0**	**493777**	**0**	**0**	**650**	**565**	**1.15**
LC3	0	0	-370332	0	0	370332	650	65	10.00
LC4	0	-493777	0	0	493777	0	650	105	6.19

Table -2: Maximum stress analysis report

Sl. No	Stress (MPA)						FOS
	Von-mises	Max-Principal	Min-Principal	Shear	YS(MPA)	Max Stress	
LC1	280	198	284	285	650	285	2.28
LC2	**491**	**479**	**480**	**565**	**650**	**565**	**1.15**
LC3	57	52	52	65	650	65	10.00
LC4	95	37	105	105	650	105	6.19

5. CONCLUSIONS

From the above result summary the bending and breaking conditions are critical, the maximum stress observed is 565 Mpa in case of breaking condition. The maximum stress observed in the fixture assembly is on cross member plate which takes a maximum impact load, hence the design failure criteria has to be concluded based on the breaking condition. To conclude the results in the maximum stress on the cross member plate is maximum and also less than the yield strength of the material (650 Mpa). Therefore the factor of safety for the worst loading condition is 1.15. Hence the structure is safe and can be recommended for the manufacturing of a fixture.

5.1 FUTURE SCOPE

1. The only maximum stress of 565 Mpa is observed in the cross member plate and in rest of the parts the maximum stress is well below 350 Mpa, hence lower yield strength material grade can be verified to check the structural stability of the fixture for rest of the parts which will help to reduce the cost of the fixture. 2. Further scope can be designing a universal flexible fixture to support the blades of different geometry

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