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FEA BASED ANALYSIS OF SHACKLE FOR OFFSHORE APPLICATION

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Abstract— Nowadays Oil exploration in offshore area is responsible for increasingly greater percentage of production in the world. So mooring Systems play key role. Failure of a single component in a mooring line can produce incalculable damages. Due to environmental loading the mooring changes its position. Each component in the mooring are subjected to angular tensions from top and bottom. It produces strong non linearity in the components. Shackle is the critical part of this mooring system. Analysis of shackle is carried out by consideration of variation in angle from 1˚ to 5˚ in Plane and Out of Plane with ANSYS 12. An attempt has been made to analyze the effect of force angle on proof load. As the variation in angle increases from 1˚ to 5˚, proof load decreses. Validation of results are carried out by using horizontal UTM.

Keywords-*Proof Load, Break Load, Yield Strength, Ultimate Tensile Strength.*

I. INTRODUCTION

A mooring, in general terms is defined as a compliant structure that restrains a vessel against the action of wind, wave, and current forces. Mooring consist of number of components as like Floatation device, Wire, Chain, Shackle, Anchor etc

The purpose of a mooring is to safely hold a ship in a certain position to accomplish a specific mission. A key need is to safely hold the vessel to protect the ship, life, the public interest, and to preserve the capabilities of the vessel and surrounding facilities. Ship moorings are provided for Loading and unloading, Ship storage, Maintainance etc.[8]

General mooring system including only chain and anchor is shown in fig 1.1.

Due to environmental effects like waves, wind,current the ship and hence the entire mooring system undergo change into position.following are the degree of freedom of ship:

- Surge- In the X direction.
- Sway- In the Y direction.
- Heave- In the Z direction.

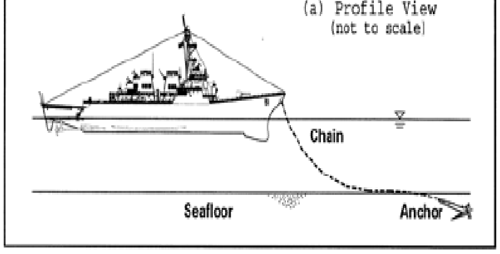


Fig 1.1 : General mooring system

- Roll- Angular about X axis.
- Pitch- Angular about Y axis.
- Yaw- Angular about Z axis.

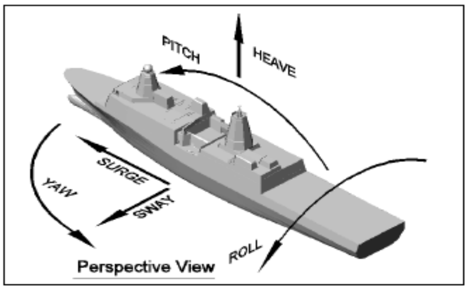


Fig 1.2 the degree of freedom of ship.

Due to the environmental conditions mooring is changing its position from one state to other state. Therefore each component of mooring is subjected to tension from above and below.. Shackle as shown in fig 1.3 is critical component of mooring system subjected to tensions. Number of shackle are connected in mooring but in this Paper the shackle which is connected to anchor is analyzed.

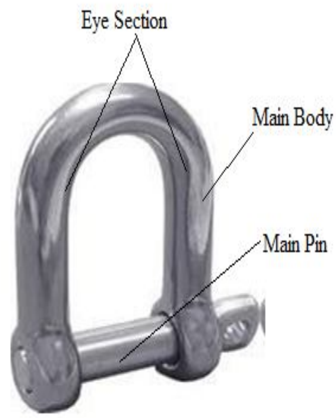


Fig. 1.3 Shackle

2. DESIGN AND ANALYSIS OF SHACKLE

Design of Shackle is carried out in CATIA V5 R18. For the analysis the model of Shackle is imported in ANSYS 12 Workbench.

A) Material Properties

Material Properties of Shackle are as follows:

- Material : Structural Steel DNV 203
- Mass : 471Kg
- Density : 7850 Kg/m^3
- Volume : 5.99e-2m^3
- Youngs Modulus : 2e11 Pa
- Poissons ratio : 0.3
- Yield strength : 2.5e8 Pa

B) Meshing of Shackle

For Meshing of model SOLID 185 element is used. The characteristics of meshing is as follows

Element type	Solid 185
Method of Mesh control	Hex Dominant
Size	13 mm
Statistics	
No. of Nodes	214875
No. of Elements	64228

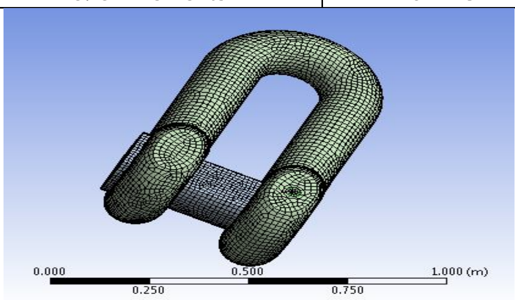
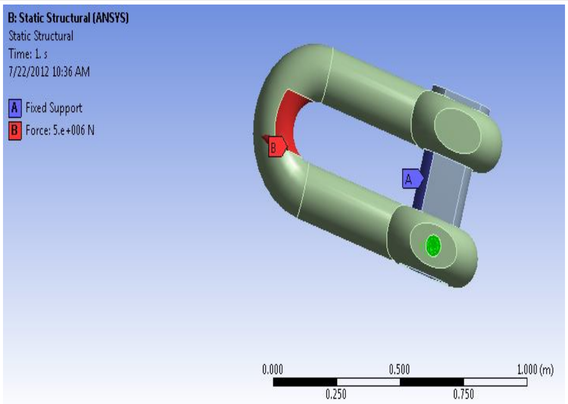


Fig. 2.1 Meshing of Shackle Assembly

C) Boundary Condition

Shackle is subjected to loading only on the inner face of the eye section of the main body as well as it is required to fix the inner face of Main pin because only this face comes in contact with Anchor. So that These faces can be selecting with the help of Imprint the faces option.

Proof Load : 5000 KN
Fixed Support: Inner face of Main Pin



3. RESULTS AND DISCUSSION

3.1 Analysis of shackle under consideration of axial load

3.1.1 Axial test of shackle under consideration of proof load

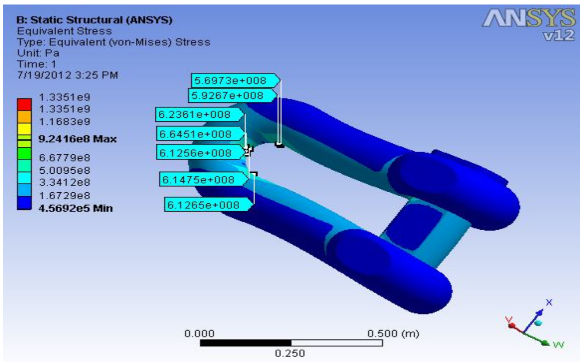


Fig. 3.1 Proof load 5000 KN

Due to contact of parts unavoidable stress concentration is formed hence probe values of stress as Max. Equivalent Stress (Von Mises Stress) are taken.

Max. Eq. Stress from result : 664.51MPa

Table 3.1: Stress for Proof load

Proof Load KN	Von mises Stress (MPa)(Probe)	Max. Deformation (mm)
5000	**664.51**	**1.0087**

Yield strength of shackle is just above the value of von mises stress. Hence Yield strength of shackle is 680MPa.

3.1.2 Axial test of shackle under consideration of break load and hence find out ultimate strength

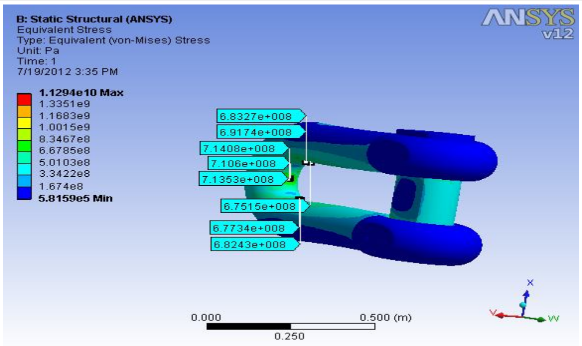


Fig 3.2 : Break load 9000 KN

Table 3.2 : Stress for Break Load

Break Load KN	Von Mises Stress (MPa)(Probe)	Max. Deformation (mm)
9000	**714.08**	**4.4418**

Hence value of ultimate strength just above the stress value.
Ultimate Strength : 730Mpa

3.2 Analysis of shackle when variation in plane

Material non linearity is solved in ANSYS 12 by giving Yield strength and Ultimate strength of Shackle.

- Yield Strength : 680 MPa
- Ultimate strength : 730 MPa
- Variation of angle : 1˚ to 5˚

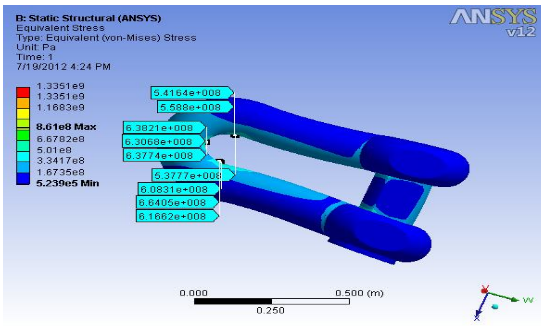


Fig 3.3 : Angle 1˚ and proof load 4800KN

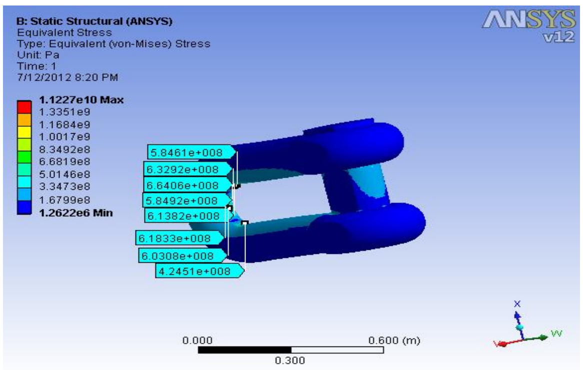


Fig 3.4 : Angle 2˚ and Proof load 4500KN

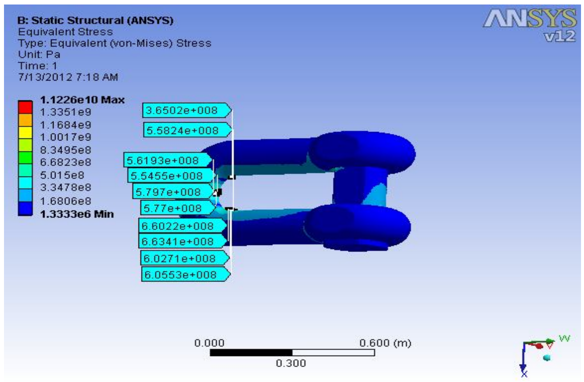


Fig 3.5 : Angle 3˚ and Proof load 4200 KN

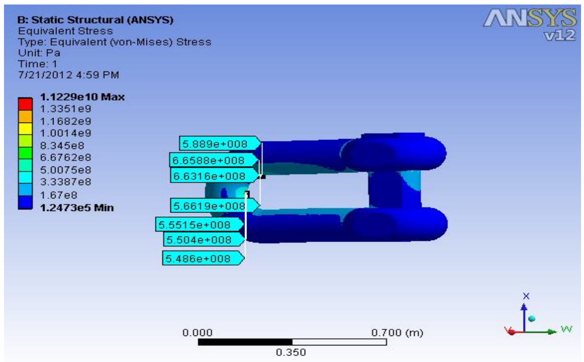


Fig 3.6: Angle 4˚ and Proof load 3990KN

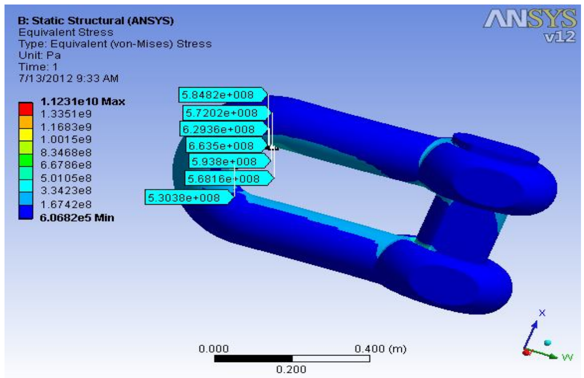


Fig 3.7 : Angle 5˚ and Proof load 3750KN

Table 5.3 : Effect of Angle on Proof Load

Angle	Proof load (KN)	Von Mises Stress (MPa)	Max. Deformation (mm)
1˚	**4800**	**664.05**	**1.1195**
2˚	**4500**	**664.06**	**1.1578**
3˚	**4200**	**663.41**	**1.1622**
4˚	**3990**	**665.88**	**1.2636**
5˚	**3750**	**662.39**	**1.3661**

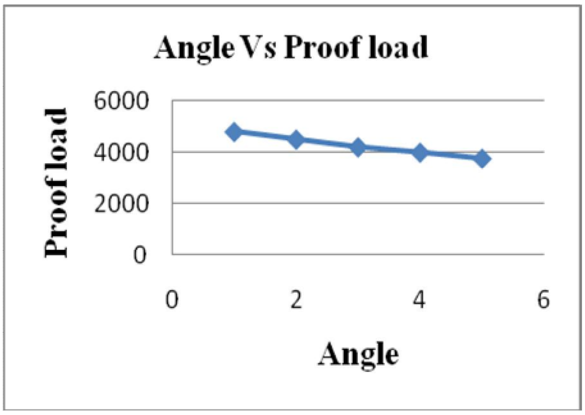


Fig 5.8: Graph of Angle Vs Proof load

As the angle goes on increasing from 1˚ to 5˚ In plane the proof load goes on decreasing from 4800 KN to 3750 KN as shown in fig. 5.8.

4. TESTING OF SHACKLE AND VALIDATION OF RESULT

Fig. 4.1 Horizontal UTM

Testing of shackle is carried out by using horizontal UTM shown in Fig 4.1. Eight specimens of Shackle as shown in fig 4.2 are tested.

Fig.4.2 Specimens of Shackle

Reading:

Specimen NO	Proof Load KN	Break Load KN	Max. Displacement(mm)
1	5000	8955	1.10
2	5000	8970	1.15
3	5000	8960	1.11
4	5000	8955	1.12
5	5000	8965	1.10
6	5000	8960	1.14
7	5000	8975	1.15
8	5000	8965	1.12

Proof load after testing is 5000 KN.
Break load of shackle when first visible crack observed is 9000 KN. From reading experimental value of displacement and FEA value of deformation are nearly same.

CONCLUSION

From the results obtained it is concluded that as the variation in angle on shackle increases from o˚ to 5˚ the proof load decreases from 5000KN to 3750KN. Hence Optimization of shackle is required to provide safety mooring system. Because if shackle fails and hence mooring system, the replacement cost of shackle is five times greater than overall cost including transportation.

FUTURE SCOPE

Present dissertation work covers the Shape optimization , but still it has a scope for material optimization. All mooring components are required corrosion protection. Corrosion control is needed for structural steel of offshore structures by considering :

- coatings and/or cathodic protection
- use of a corrosion allowance
- inspection/monitoring of corrosion
- control of humidity for internal zones (compartments)

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