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Design Analysis and Optimization of Parallel Motion Fender

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Abstract — *In this study collision analysis for the parallel motion fender system that designed to protection of collision between vessel and port was performed for the ABT 3200DWT GENARAL CARGO ship size, the impact forces and the impact energies were estimated by berthing energy calculations. Ship fenders often take large impact during berthing. This study presents a design and analysis of current parallel motion fender system and modified parallel motion fender system. In optimization maximum fatigue life, minimum shear stresses and min von-mises stresses are set as three objectives and the diameter of torque arm pin, torque arm pin distance and distance between two brackets are selected as three design variables. Non-linear FE analysis is first carried out to capture the impact response of force. Afterwards parametric studies are performed to investigate the influence of different variables on the design objectives. A taguchi method is used for design of experiments. ANSYS14.1 workbench is used for analysis. The optimum set is defined as the solution with the maximum fatigue life.*

Keywords- *Ship, Parallel Motion Fender, Torque tube, Torque arm pin, Optimization*

I. INTRODUCTION

Now a days marine transport has an important factor of many nation's economy, because it is a most inexpensive way of transporting heavy goods to the very long distances.

Today, navigation technology has vastly improved and has moved towards using bigger ships with deeper drafts. These ships include container cargo ships and LNG Tankers, whose displacements are in the order of thousands of dead weight tonnage (DWT).

Hence, ports and terminals need to be adequately designed for the berthing of these massive vessels without damage to the ship or the dock structure and often the ship channels must be dredged to accommodate these ships.

There are many types of fender system is used for berthing the vessels against jetty or another vessels. The type of fender that is most suitable for an application depends on many variables, including dimensions and displacement of the vessel, maximum allowable stand-off, berthing structure, tidal variations and other berth-specific conditions. The size of the fender unit is based on the berthing energy of the vessel which is related to the square of the berthing velocity.

Fenders are typically manufactured out of rubber, foam elastomer or plastic. Rubber fenders are either extruded or made in a mould.

II. Design Calculations

Dimension specifications of ABT 3200DWT GENARAL CARGO ship were taken out from PIPAVAV shipyard, The berthing energy of a ship was calculated by Kinetic energy method, which is most commonly used traditional method and time tested.

The energy absorbed by fender[8] :

$$E_{fender} = E_{ship} * C_e * C_m * C_s * C_c$$
$$= 5.0099 * 1.416$$
$$= 7.096 \text{ tonnes}$$

Where, E_{ship} = Kinetic energy of berthing ship
C_e = Eccentricity factor =
C_m, Virtual Mass factor =
C_s, Softness factor =
C_c, Berth configuration coefficient

III. Modeling and Analysis

3.1. Existing Parallel Motion Fender

The dimension specifications of the existing Parallel motion fender system were getting from PIPAVAV shipyard. Creo 2.0 was selected for making the model of PM-fender and Finite Element Method was selected for the analysis of the PM-fender system and simulations. Due to complicated loading and geometry problem non-linear static analysis was performed. This analysis was performed with ANSYS workbench, version 14.5.

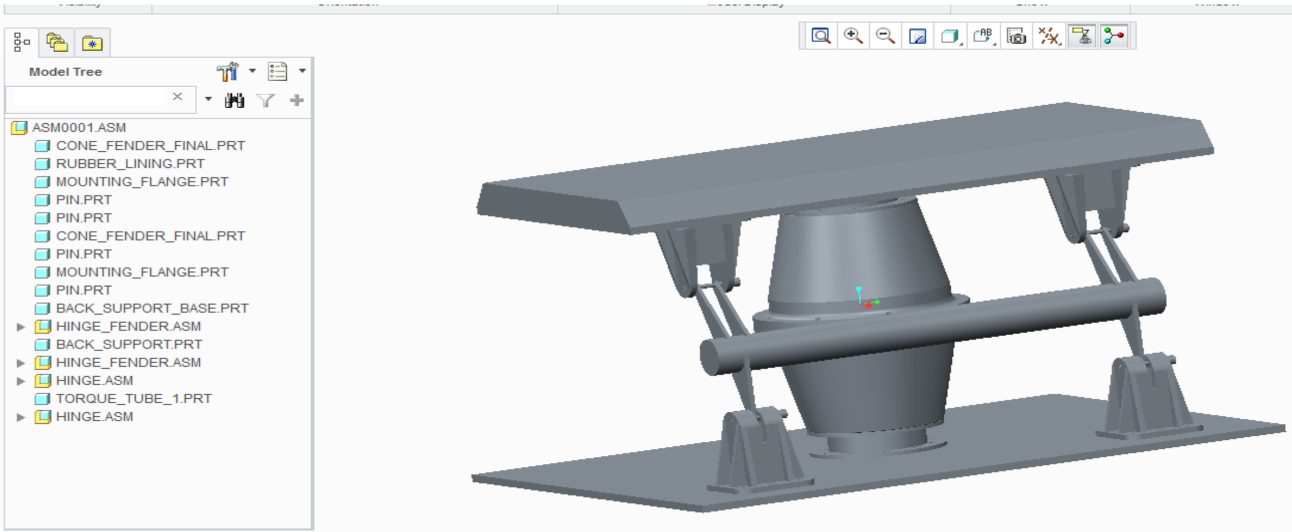

Figure 1. 3D solid model for existing PM-fender

To analyze the existing PM fender, we are using ANSYS 14.5 workbench. After analyzing evaluate and compare the results of maximum shear stress, Von-misses stress (Equivalent stress) and fatigue life for 90^0 striking angles.

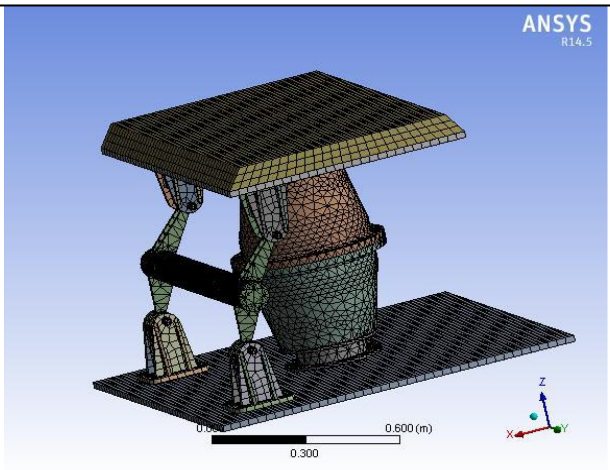

Figure 2. Meshing

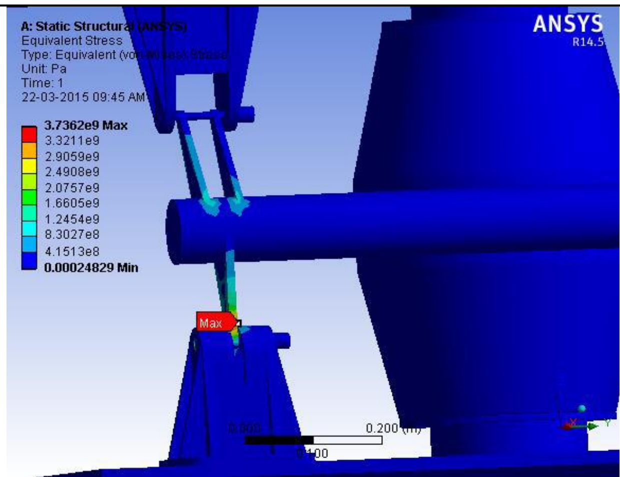

Figure 3. Von-mises stress at 90^0

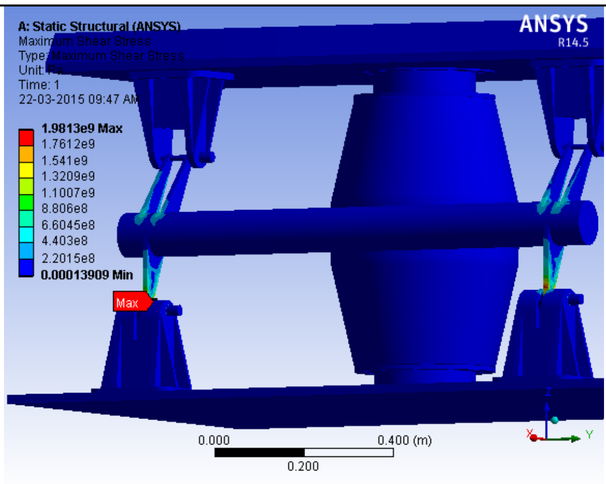

Figure 4. Maximum shear stress at 90^0

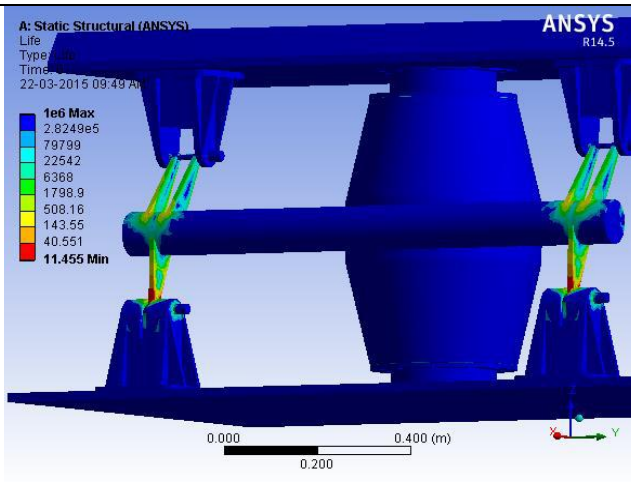

Figure 5. Maximum shear stress at 90^0

3.2. Modified Parallel Motion Fender

To overcome the most seen common structural failure of welded joint between torsion arm to torsion tube, we have added a box section at welded joint. After modeling we have analyze this model in ANSYS workbench, version 14.5 at 90^0 striking angle.

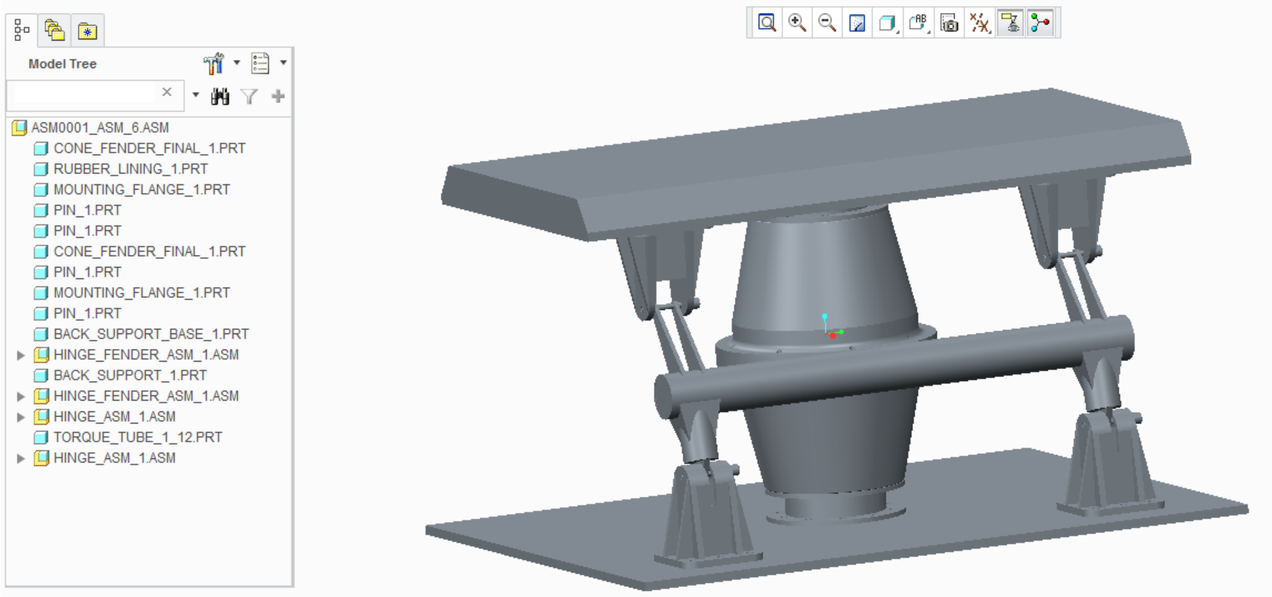

Figure 6. 3D solid model of modified PM-fender

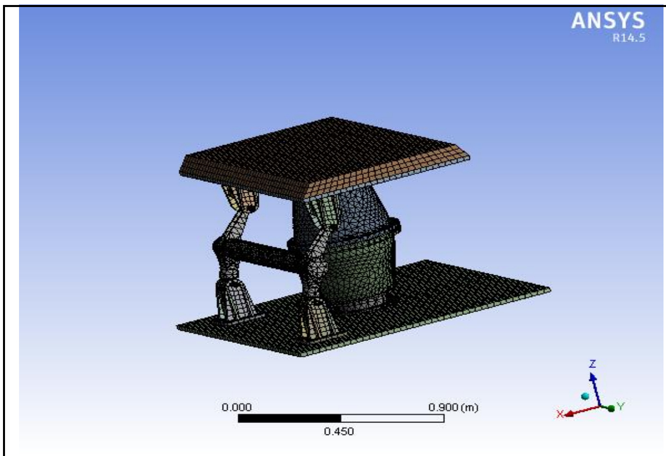

Figure 7. Meshing

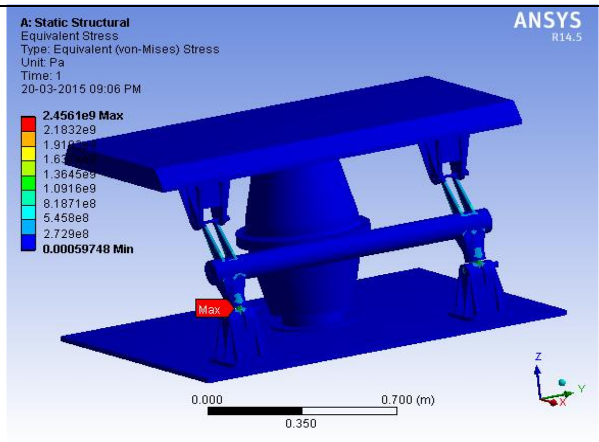

Figure 8. Von-mises stress at 90^0

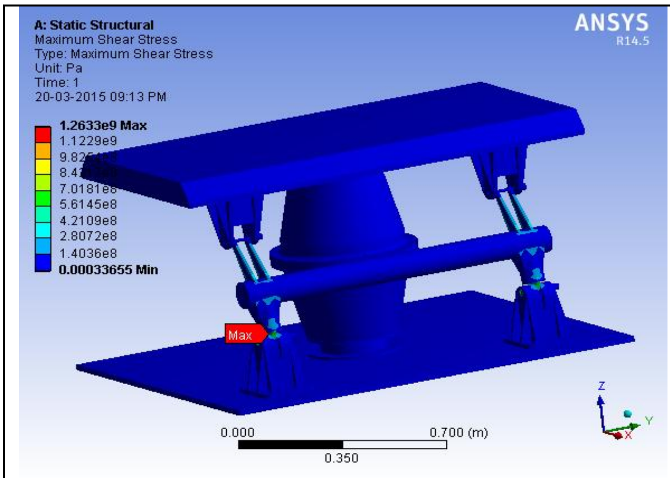

Figure 9. Maximum shear stress at 90^0

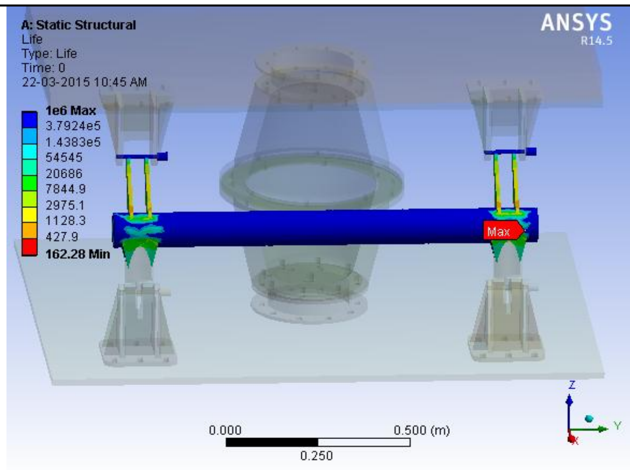

Figure 9. fatigue life at 90^0

Table 1. Comparision between existing model and modified model

	Force applied at 90^0	Von-mises stress	Maximum shear stress	Fatigue life
Existing PM – fender	49148 N	3.7362 X 10^9 Pa	1.9813 X 10^9 Pa	11.455 Cycles
Modified PM-fender	49148 N	2.4561 X 10^9 Pa	1.2663 X 10^9 Pa	162.28 Cycles

As per the above table, it can be show that maximum shear stress and Equivalent (Von-mises stress) are more at 900. So it is generate minimum fatigue life at torsion arm. After modified design of PM-fender, it shows that maximum shear stress and Equivalent (Von-mises stress) are much reduced. And also minimum fatigue life also improved by modified design.
Now, further work is to carry out on a parametric optimization for welded joint considering different parameters for that. And validating it with numerical analysis method.

IV. Optimization

Transcription of an optimization problem into a mathematical formulation is a critical step in the process of solving the problem. If the formulation of the problem as an optimization problem is improper, the solution for the problem is most likely going to be unacceptable.

- Design of Experiment

Design of experiment (DOE) is a method to identify the important factors in a process, identify and fix the problem in a process, and also identify the possibility of estimating interactions. There are various methods for optimization in which we have choose Taguchi method. For Torsion arm tube analysis there are three parameters with three level which is different torsion arm pin diameter (10mm, 12mm and 14mm), Torsion arm bracket diameter(75mm, 80mm and 85mm) and Torque tube thickness (5mm, 6mm and 7mm) was considered. After that find out the best combination of above three levels with MINITAB 16 software. From minitab-16 software, 3 factors and 3 levels were inserted in Taguchi design of DOE method and got the L9 (3*3) array.
Experiments were planned according to Taguchi's L9 orthogonal array, which has 9 rows corresponding to the number of testes with 3 columns at three levels as shown in table 5.3. The first column of table was assigned to Torsion arm pin diameter in mm, the second to Torsion arm bracket diameter in mm and the third column was assigned to Torque tube thickness. It means a total 9 model created and must be analyzed in ANSYS using the combination of levels for each independent factor. The analyzed results are then transferred in to a Signal to Noise (S/N) ratio. The category the higher-the better and smaller the better was used to calculate the S/N ratio for finding optimum set of parameters.

Table 2: Result table from DOE using L9 orthogonal array

Sr. no.	Torsion arm pin diameter (mm)	Torsion arm bracket diameter (mm)	Torque tube thickness (mm)	Von Misses Stresses (MPa)	Maximum Shear Stresses (MPa)	Fatigue Life (cycle)
1	10	75	5	390.44	223.18	2914
2	10	80	6	261.65	149.2	10046
3	10	85	7	239.62	135.33	13577
4	12	75	5	380.59	218.17	3153.5
5	12	80	6	271.63	153.69	9005.8
6	12	85	7	237.11	135.46	14076
7	14	75	5	379.54	216.65	3180.5
8	14	80	6	261.54	149.14	10060
9	14	85	7	233.04	131.51	14936

Using optimum set of parameters, which was achieved by Minitab software for Taguchi method of optimization was used for analysis of validation. The result was obtained by analysis is compared with predicated value of software for lowered value of Equivalent (Von Mises) stress and Maximum shear stress and maximum value of Fatigue life.
Analysis had done for optimum set of parameters arrived via Taguchi method, give result, Equivalent (Von Mises) stress is 225.634 MPa, Maximum shear stress is 132.356 MPa and Fatigue life is 14798 cycle. This analysed value is nearer our predicted value i. e. for Equivalent (Von Mises) stress is 229.688 Mpa, for Maximum shear stress is 130.087 and for

Fatigue life our predicted value is 14978.4 cycle (min.). From both the results of statistically analytical method and Ansys analysis investigation, Equivalent (Von Mises) stress, Maximum shear stress and Fatigue life are optimum at 14 mm torsion arm pin diameter, 85 mm torsion arm bracket diameter and 6 mm torque tube thickness.

IV. RESULT AND DISCUSSION

Here, we have performed three different analysis for existing model, modified model and optimized torsion tube model. For analysis ANSYS workbench, 14.5 was used and values of maximum von-mises stress, maximum shear stress and minimum fatigue life were evaluated. For boundary condition force should be apply at 900 striking angle. The magnitude of the force is 49148 N. Comparisons are shown in below table.

Sr. no	Model name	Von-mises stresses (Mpa)	Maximum shear stress (Mpa)	Fatigue life (Cycles)
1	Existing Parallel motion fender	373.62	198.13	11.455
2	Modified Parallel motion fender	245.61	126.63	162.28
3	Optimized torque tube model	225.634	132.35	14798

For Torsion arm tube analysis there are three parameters with three level which is different torsion arm pin diameter (10mm, 12mm and 14mm), Torsion arm bracket diameter(75mm, 80mm and 85mm) and Torque tube thickness (5mm, 6mm and 7mm) was considered. Final optimized value of this three parameters of torsion arm evaluated from Taguchi method is 14mm for torsion arm pin diameter, 85mm for torsion arm bracket diameter and 6mm for torque tube thickness.

For the analyses as increase the torsion arm pin diameter will increase the Fatigue life and reduce the von mises stress. Now for the Torque bracket diameter has been increase it will increase the Fatigue life and reduce the von-mises stress within certain limit beyond that limit it will increase the von-mises stress value. For best result has been carried out for changing the parameter values.

For analysis that combination of data has been selected according to Taguchi Method as shown in above Table.

As per the different data set in above table MINITAB simulation has been carried out that gives Torsion arm pin diameter is the most sensitive parameter for the analysis.

According to Minitab different parameter, Nonlinear Static analysis in ANSYS workbench has been carried out for analyze the fatigue life and von-Mises stress of the Parallel motion fender. Results shows that optimum results has been found for the 9th number data set.

V. CONCLUSION

In the present work Nonlinear Static analysis of Parallel Motion fender has been carried out in ANSYS work bench for Impact loading that shows Torsion arm pin is the most critical part for the Fender life. Analysis has been carried out for different parameter of Torsion arm Pin and optimize that parameter through Taguchi Method and ANSYS simulation.

Through Analysis it would be conclude that torsion arm pin diameter is the most create critical parameter for the Fender life and Optimize results shows that its life will increase then the existing and modified model of fender.

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