

The study of the lifting mechanism of the crane arm to a barge

C. Fratila (1), T. Axinte (1), R. C. Cojocaru(2) , C. Berescu(3) , I. C. Scurtu (4)

1 Center for Navy Scientific Research

2 Princess Cruises

3 CMA CGM

4 Naval Academy Mircea cel Batran Constanta

catalinmfratila@yahoo.com, tibi_axinte@yahoo.com, costi.cojo@yahoo.com,
cosmingrizzly@gmail.com, ionut.scurtu@anmb.ro

Abstract. During cargo loading and unloading, the vessels' lifting gear, even if anchored or moored, is affected by the pitch and roll movements, in addition to the usual stresses, a similar shore crane is subjected to. This paper aims at presenting an analysis of the lifting operations of a boom crane pertaining to a self-propelled barge. The analysis starts with the meshing with triangle elements, the stresses and the embedding using the finite elements method. The crane and the pertaining boom were modeled using CAD design, NX 10.0 from Siemens. The lifting equipment of the ships boom crane may be subject to dangerous defects occurring during the loading and unloading process. Subsequently, the research emphasizes the stresses occurred in the piston rod and in the eye of the lifting equipment, using the finite element method (FEM). After the stress analysis, several fatigue matters are studied: fatigue safety factor, fatigue life, strength safety factor and crack. The damaging or breaking of the eye or of the piston rod from the lifting equipment of the ships boom crane is leading to the blocking of the cylinder with the result of unfavorable events, such as deformation of the boom crane, damaging the loads and even the danger of sinking the barge. The results of this analysis provide ship-owner and maintenance engineers a useful tool to take appropriate decision during inspection of the lifting gear of the ship, prior commencement of the loading and unloading operations.

1. Introduction

The ship model considered in this paper is the crane barge. This type of barge is used for oil platforms, but may be also used at port facilities without harbor cranes, in order to load/unload weights up to 6.5 tons to and from other vessels. The lifting equipment of the boom crane is visually inspected to identify the status of the piston rod and eye of the mechanism, especially after bad weather conditions. Even more challenging is the observation of fatigue, which may not be visually apparent. For river operation, similar barges were constructed with flat bottom for greater stability .

Earlier designs of barges pushed by a pusher were only simple vessels used for transportation of cereals, ores, construction and wooden materials, etc.

The newer generations of barges are self-propelled barges having own propulsion and wheelhouses. The newer barges could also operate at sea (e.g. the Black Sea), but only at short distance from the shore for servicing offshore installations such as oil platforms. This type of barge may also be used in the military field because it can be used to load/ unload in optimal conditions various military equipment from military barges on shores without cranes, and reversely [1].

The lifting mechanism of the boom crane may be subject to structural failures during loading/unloading operations. On board incidents, may be avoided through preventive maintenance of components. Failures are dependent of factors including the ship's age, the damaged component, location, maintenance and repair. Fatigues represent one of the main concerns of several international organizations. The fatigue analysis can be evaluated the by using linear elastic fracture mechanics. There are authors that focused the research to a certain element such V-lock chain ring.

This paper aim at analyzing the stresses in the rod piston and in the eye of the lifting mechanism using the finite element method (FEM).

2. Crane barge

In order to explain the lifting mechanism of the crane, the authors designed the construction of the barge. This constituted the base, since the analysis of the main parts of the lifting and lowering cylinder in the boom crane of the barge could not be carried out without analyzing the construction.

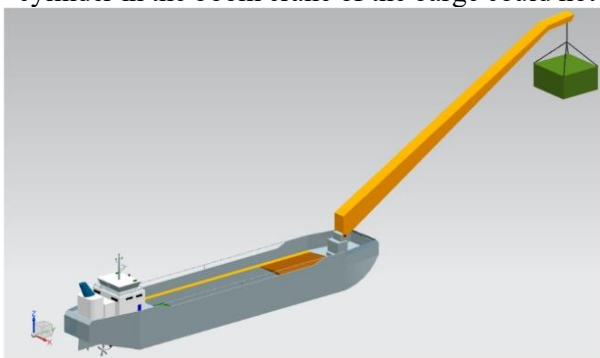


Figure 1. Crane barge during loading/unloading

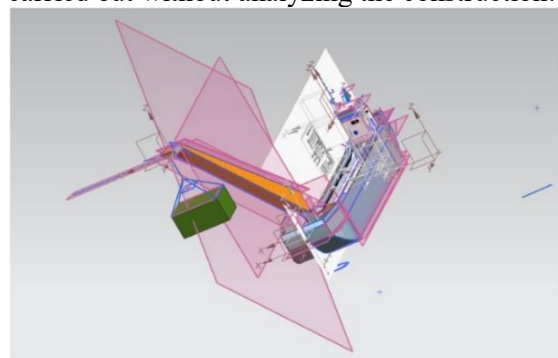


Figure 2. Original design of a crane barge

The first image presents the crane barge during the loading/unloading process, figure 1. The design has been obtained using several execution drawings, lines, circles, sketches etc. A total amount of 569 commands has been used as presented in the figure 3, Parts Navigator.

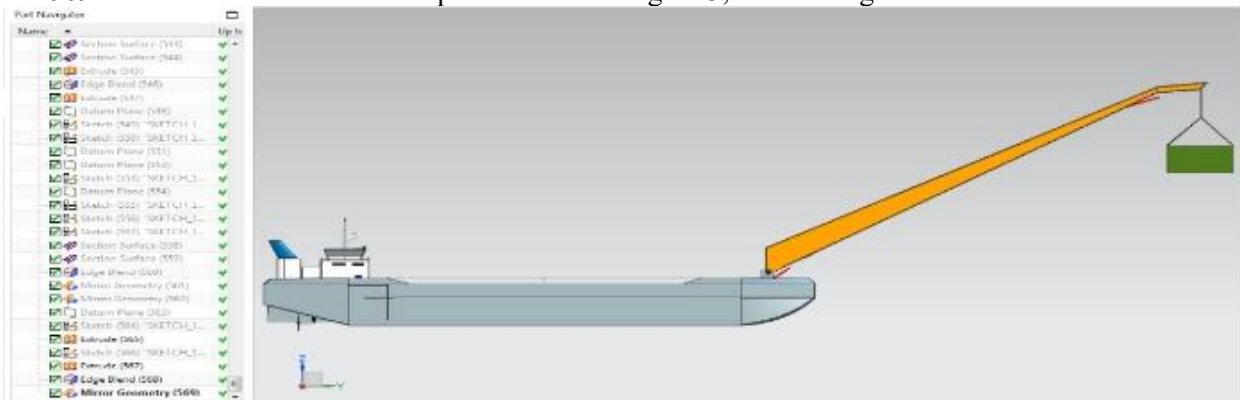


Figure 3. Last commands in Part Navigator

The crane barge's hull has been executed using an original Dutch drawing, figure 4, taking into account the mandatory dimensions in the field of shipbuilding:

- Length max = 62.40 m
- Breadth extreme = 11.40 m
- Depth = 4.40 m
- Dredging draught = 3.850 m
- Hopper volume = 1000 m³
- Class: GL + 100A5 RSA(20) Split Hopper Barge

The original drawings have been created through the command Raster Image from NX 10. Therefore, the final drawing has been adapted to the fluvial transport, figure 5.

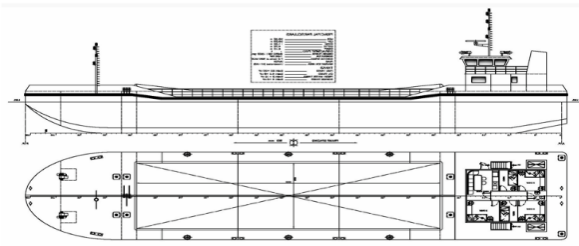


Figure 4. Original drawing

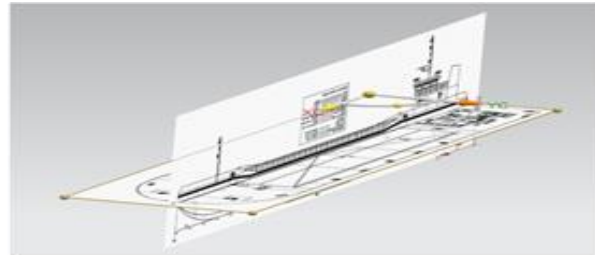


Figure 5. The command Raster Image

The loading/unloading process can be carried out only if the barge is anchored. During navigation, the barge should have the boom crane folded down and firmly fixed. The figure 6 presents the barge during navigation, in trimetric view.

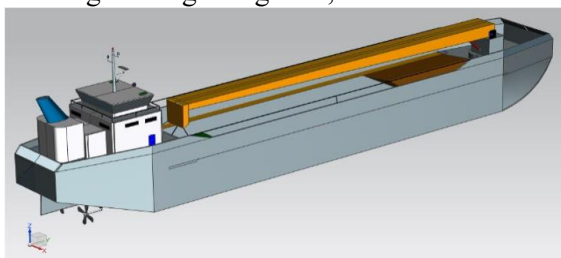


Figure 6. Longitudinal section

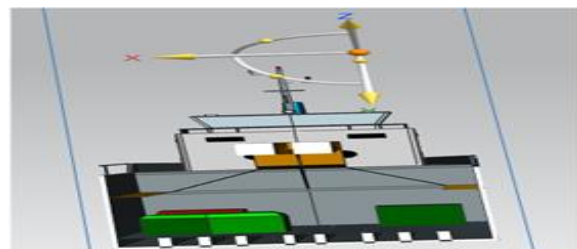


Figure 7. Transversal section

The interior of the barge has been designed as emphasized in the figures 6 and 7, with the double bottom, and the storerooms.

3. Presentation of the lifting mechanism

The lifting mechanism has been drawn by authors, considering the real dimensions of the mechanism, figure 8. The lifting mechanism of the boom crane is an important part of the crane. The crane cannot perform loading/unloading movements of the 6.5 tons weights:

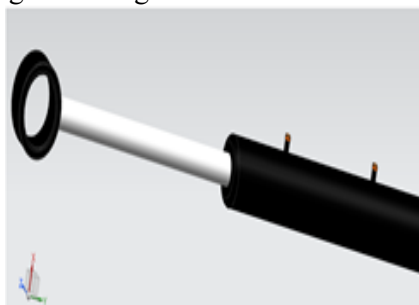


Figure 8. Lifting mechanism

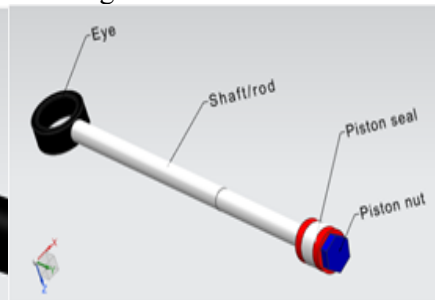


Figure 9. Original drawing

The piston of the lifting mechanism comprises of the following main components: the eye, the rod, the piston's seal and the piston's nut, as presented in the figure 9.

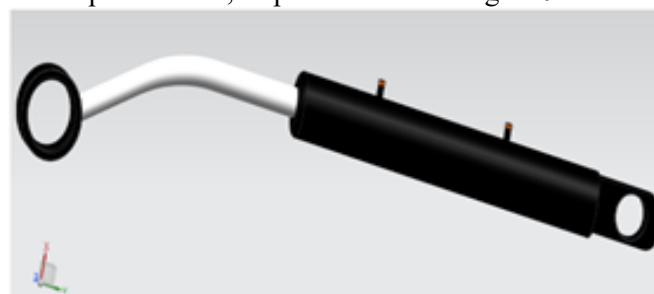


Figure 10. Piston subjected to bending

The shaft/rod of the piston is subjected mostly to bending processes, figure 10.

4. The analysis of the lifting mechanism of the boom crane

The analysis of the lifting mechanism has been subject to several scientific researches. Our analysis started with the meshing with triangle elements, the stresses and the embedding using the finite elements method, emphasized in the figure 11.

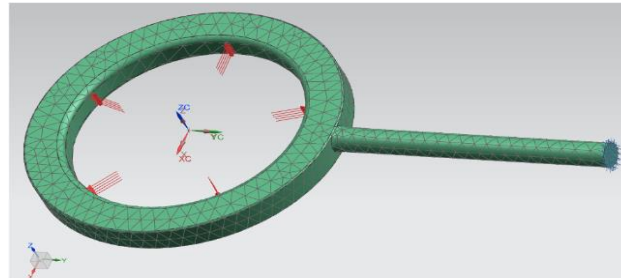


Figure 11. The pressures and embedding at the mechanism's eye

Using the finite elements analysis, the worst principal stress, figure 12, and the Von Mises stress, figure 14, have been determined. The extreme values are representing the values between the eye-piston contact is subjected to.

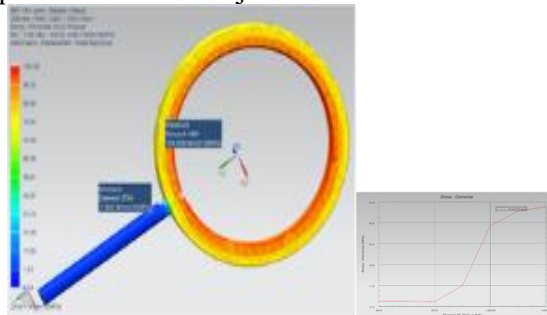


Figure 12. Worst principal stress with diagram

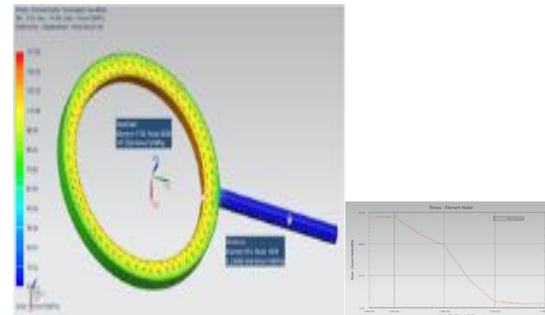


Figure 13. Von Mises stress with diagram

The extreme values of the mid principal stress, are being on the mechanism's eye, presented in the figure 14, [2].

During the lifting/lowering process of the boom crane of the barge, due to the fatigue of the material,

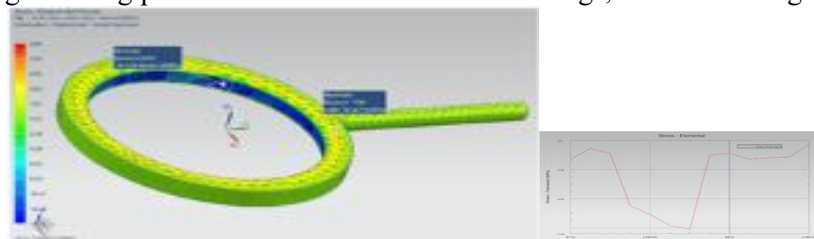


Figure 14. Mid principal stress with diagram

the part subjected to the most wearing is the piston's rod, fact which lead to the it's breakage, figure 17.

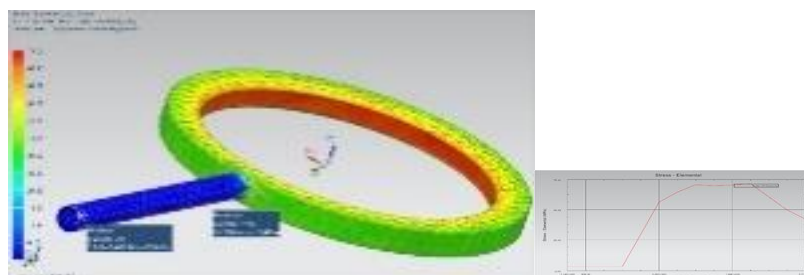


Figure 15. Max shear stress with diagram

The main parts of the lifting mechanism can be broken also due to cracks in the interior of the mechanism, as presented in the figure 22.

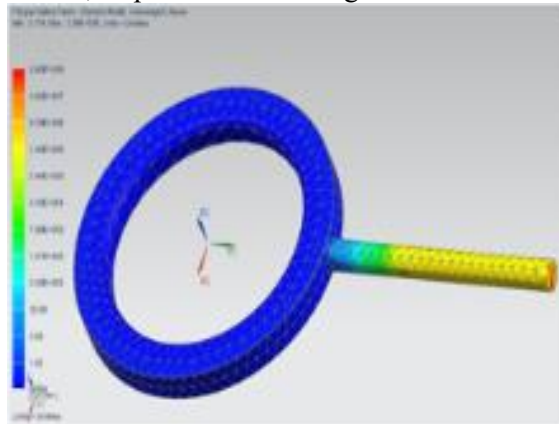


Figure 16. Fatigue safety factor at the mechanism's eye



Figure 17. Piston's breakage

The breakages of the mechanisms can be analyzed using specialized software. For the purpose of our study, the authors analyzed the breakage by the use of the software NX 12 from Siemens in 2D, figure 19.

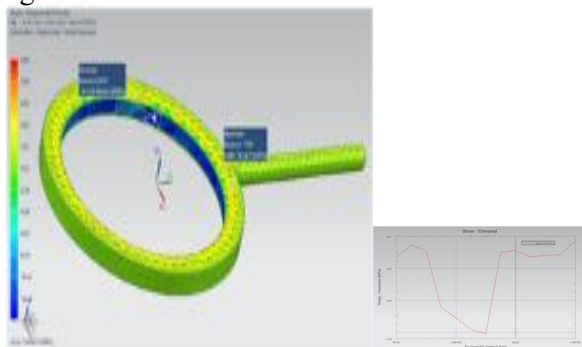


Figure 18. Subassembly and crack

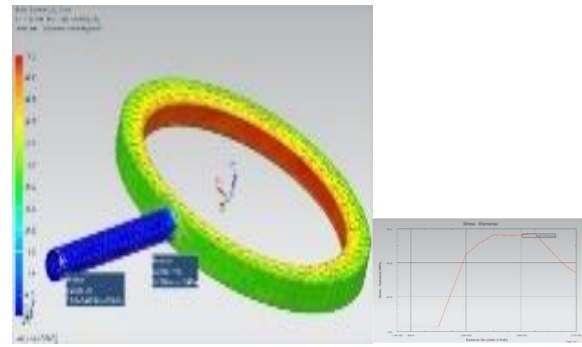


Figure 19. Breakage of the mechanism's eye

Propagation of the crack, it results that it is leading to the breakage of the eye, figure 19.

The specific computing cracks in the material axial direction, using only mode I is determined based on the equation 1:

$$G = K_I^2 \left(\frac{1 - \nu^2}{E} \right) \quad (1)$$

where G - strain energy release rate, K_I - the stress intensity factor only for mode I, E - Young's modulus, ν - Poisson's ratio

For plane stress conditions, which is applicable for the current situation, the first relation becomes equation 2:

$$G = K_I^2 \left(\frac{1}{E} \right) \quad (2)$$

For a plate of dimensions "h x b" containing an edge crack of the length "a", the dimensions of the plate are $h/b > 1$ and $a/b < 0.6$. Therefore, the stress intensity factor at the crack tip under an uniaxial stress is:

$$K_I = \sigma \sqrt{\pi a} \left[1.12 - 0.23 \left(\frac{a}{b} \right) + 10.6 \left(\frac{a}{b} \right)^2 \right] - \sigma \sqrt{\pi a} \left[21.7 \left(\frac{a}{b} \right)^3 + 30.4 \left(\frac{a}{b} \right)^4 \right] \quad (3)$$

5. Results

The cracks are mostly produced at the joint between the eye and the rod, which in time it produces the breakage of the mechanism, mainly due to the stresses exerted on the mechanism, figure 20. The propagation of a crack affects many areas, as presented in the figure 21.

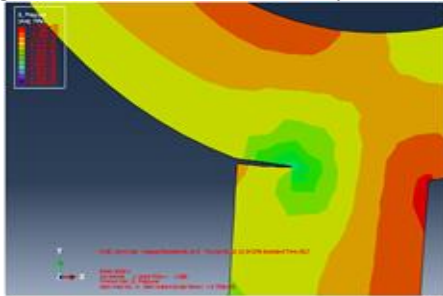


Figure 20. The evolution of cracks under stresses

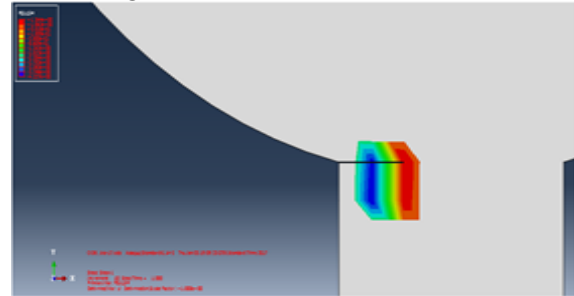


Figure 21. Areas of crack

The blue and green areas are not dangerous, the yellow area which is significantly thinner becomes dangerous and the red area can lead to the breakage of the mechanism.

The breakage is due to cracks that have been propagated under the action of the von Mises stresses, figure 22.

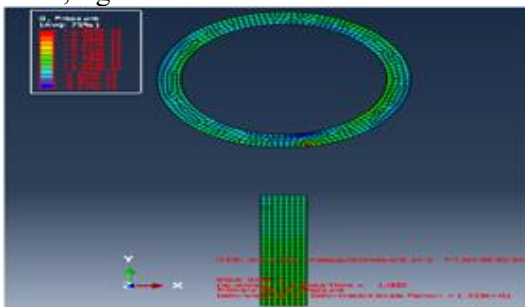


Figure 22. The breakage of the mechanism

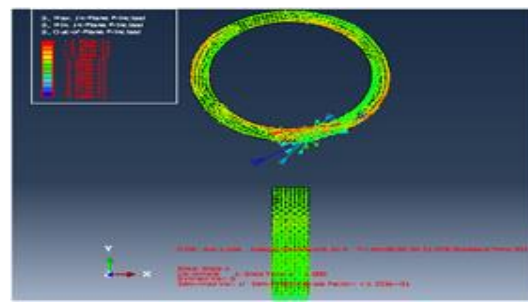


Figure 23. Plot symbols on deformed shape

The breakage of the eye-rod mechanism is rendered by the plot systems on deformed shape. This was achieved with the Abaqus /CAE 6.14-5 software, figure 23, [3].

6. Conclusions

For the analysis of the breakage, the authors presented the crack on the surface. There are situations where the cracks are present in the interior of the mechanism, and during the loading/unloading process, these could easily propagate through the mechanism without being detected by visual inspection. During the maintenance of the crane the eye-rod mechanism should be checked with the ultrasonic checking device, in order to detect hidden cracks in the mechanism.

The lifting mechanism is provided with a safety system, which is blocking the mechanism, in order to not damage the loading. This study considered a smaller sized lifting mechanism, placed between the boom crane and the initial one. Therefore, when the blocking mechanism is going to be de-blocked, the spare mechanism will take over the load and to safely lower it, in spite of the rolling and pitching or even lurch.

References

- [1] Surdu G., "Dezvoltarea durabilă o provocare pentru cercetarea din domeniul tehnicii militare și spațiului", Conferința (VII) IMPACTUL TRANSFORMĂRILOR SOCIO-ECONOMICE ȘI TEHNOLOGICE LA MIVEL NAȚIONAL, EUROPEAN ȘI MONDIAL, 22.05.2015.
- [2] www.plm.automation.siemens.
- [3] www.3ds.com