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ISSN 0974-5904, Volume 11, No. 02

DOI:10.21276/ijee.2018.11.0210

International Journal of Earth Sciences and Engineering

April 2018, P.P.159-161

Structural Analysis of Capstan for Loading Operation Using FEM

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Abstract: *Capstan is one of the shipping systems used for ship mooring on docks and between ships. The ship construction shall refer to the applicable and established standards. Loads received at the capstan during the operation of the vessel needs to be planned according to the load given. The design stage is finished by analyzing structure design with the help of finite element method (FEM). The planning stage cannot be separated from the standard used. This journal use BKI (Indonesian Bureau of Classification). If the stress occurs exceed the value of stress permitted by the standard will result in the failure of the structure designed due to the mismatch of loads with the standard construction used. Structural behavior analysis on capstan can be done through the distribution of load simulated. The given load structure permitted of the capstan is 1053.8 Pa and the actual stress generated is 1053.8 Pa. The deformation outcome is 3.73 x 10-7 mm.*

Keywords: *Capstan, Load, Stress, Deformation, Finite Element Method*.

1. Introduction

The development impact the marine transportation field. Especially to increase demands of the transportation including supporting facilities and infrastructure of sea transportation, it currently is considered addition strength analysis. These elements are needed to improve shipping system. The pier is part of the port which serves as a ship anchor and tethering during loading and unloading activities of goods and passengers. The efficiency use of the facility has to be considered as well. Every equipment located within the vessel has to met the requirements established by BKI as the only Shipping Bureau Certification in Indonesia. BKI also used as a reference to the feasibility of the vessel's safety for sailing. So it is with the tethering system must also be considered.

These system are needed regardless ship's moving equipment for the rope belay operation on the vessel. The tethering system is in an interconnected entity. The design of a capstan (warping drum) is designed, ought to be considering structural components if the loads that occur when the ship docking towards the dock and between ships. The rules specified in a ship design refer to the calculation of the structure components described in the calculation method. Perform structural design analysis on capstan (wiping drum) fast ferry when receiving load on ship is done by finite element method. Eventually FEM will be obtained by the form calculation of voltage and structural deformation. This is importance of this analysis is to reduce the failure of the operation of ship docking to the dock and between ships which can minimize the cause of the accident. In addition, the importance of this analysis is the maintenance of the structures to be safe and the duration of their use. In the design of this capstan by using a construction structure design with size Φ32,5 x 50 m and given a static loading of 250 kN in the structure can prove by using finite element method calculation that can withstand the load at the time of operation.

2. Basic Theory

2.1. Dock

Dock is a port building that serves as a ship's anchored and the process of mooring during loading and unloading activities of goods and passengers (Moedjion0, 2003). A tool used for tethering process for the era of development in the field of transportation is so managed and controlled properly. Knowing the result will affect all the Capstan Structure in dry dock.

Figure1: *Capstan in dock*

2.2. Capstan

Capstan or warping drum is a vertical roller associated with a rotating engine wheel axle used to pull a rope on a ship as it heads to the dock and between ships (Wikipedia, 2009). Capstan is also often referred to as a windlass-driven pulley rope, the power or strength released by the rotation is derived from the driving

Received: October 26, 2017; Accepted: March 24, 2018; Published: April 30, 2018
International Journal of Earth Sciences and Engineering, 11(02), 159-161, 2018, DOI:10.21276/ijee.2018.11.0210

force. Capstan is usually used to the placement of mooring rope so as not to block during the process of tethering.

Figure2: *Capstan*

2.3. Static Loading

Static loading is a load that has a change in load intensity with constant running time.it can be said that the static load is that it has a fixed value, working point and direction of the work line (Jahus, 2011). In this case the static loading is assumed to occur due to the extent of the forged capstan due to the exposed strap to the ocean waves.

2.4. Force in Capstan

Several factors may affect the forces acting on the capstan (warping drum). An important factor affecting the position was exempted by the pull of the rope on the bollard. However, for capstan on fast ferry ship to rope has a slope angle that is affected by stress, load and direction generated by strap when exposed to sea waves.

2.5. Stress and Deformation

2.5.1. Stress

According to Popov (1984), in general the stress is an inner force that acts on a small area not up to a piece and consists of various magnitudes (Adhi Y, 2016). Stress, mathematically defined as :

$$\sigma = \frac{F}{A} \quad (1)$$

F is the force and A is the cross-sectional area. The stress in this case lies between the capstan width by the pull of the rope that occurs when the mooring, and the rope is exposed to waves. In addition there is also a allowable stress. Allowable stress is the stress value used as the reference in the actual value generated.

2.5.2. Deformation

Deformation is a control of structural stability in strength. Deformation is declared as a form of a structural element with curvature and displacement from one point in the beam span to another point which is deflection due to loads along the span of the object. (Brahmantyo, 2003).

2.6. Safety Factor

The safety factor is a factor indicates the level of ability of an engineering material from the outside load to handle pressure load and the tensile load. Security factors can be defined: (Adhi Y, 2016)

$$FS = (\,Ultimate\ Stress).\big/(allowable\ stress)$$

3. Methodology

The most common used structural analysis program is the use of finite element method to calculate the total stress and deformation used with the following steps:

3.1. Stage of Finite Element Method

Analyze the problem to get the stress and strain distribution of all parts of the surface of the capstan due to static load using Finite Element Method (FEM).

3.2. Designing Stage

Before performing numerical simulation, the capstan design has to be made first using auto CAD software.

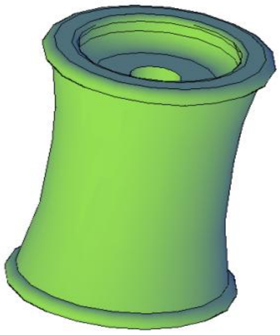

Figure3: *Capstan Modeling*

3.3. Define Load

Load determined have to adjust to the actual situation. In this case the static loading is assumed to occur at the center of the capstan's surface forged rope whirring when the mooring rope rolls.

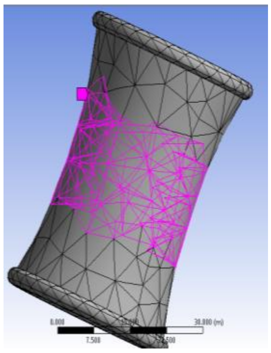

Figure4: *Capstan Loading*

3.4. Determining Boundary

Determine the condition of the structure attached to the windlass to the actual position on the actual conditions as bracing the rotation.

3.5. Meshing

Simulation in the form of a solid mesh which is a type of meshing used to find the number of elements and mechanical reaction.

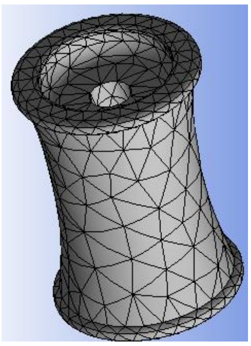

Figure5: *Capstan Loading*

3.6. Analysis

During analysis of capstan structure, static loading simulation process and total tension and deformation result are admissible.

4. Results

4.1. Stress On Capstan Structure

4.1.1. Actual Stress

The actual stress of the simulation result is shown by loading 250 kN in the area exposed to the strap area as shown in picture 4. On picture 4, it appears that the maximum stress value at a capstan is 1580.7 Pa and a minimum value of 0.074 Pa. This capstan experiences stress in the central area that is subjected to a static loading of 1053.8 Pa. it can be concluded to be medium voltage or has not reached the maximum value. From the stress analysis the capstan is obtained for the area close to the fixed support greater than the fixed support area.

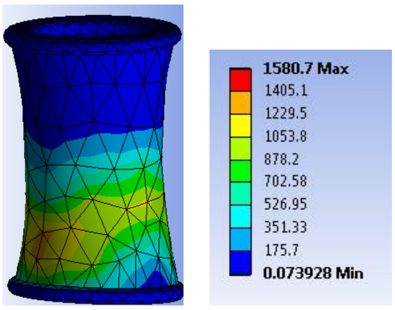

Figure6: *Capstan Stresses*

4.1.2. Allowable Stress

Based on the actual stress, safety factor used is 1.5 on allowable stress on the capstan with loading on the exposed surface area can be known as:

$$\sigma \text{ allowable} = \frac{\boxminus \text{ maksimal}}{\text{Safety Factor x k}} \quad (2)$$

$$\sigma \text{ allowable} = \frac{1580{,}7}{1{,}5 \times 1}$$

σ allowable = 1053,8 Pa.

From the calculation above, the permitted stress is 1053.8 Pa.

4.2. Capstan Structure deformation

The maximum deformation of the simulated results shown at 250 kN loading occurs on the capstan surface as shown in picture 6. In which, appears a total deformation value of the capstan occurring at the free end of the capstan on the other side of fixed support. In result analysis, the stress value is 3,73 x 10-7 Pa. Area in the middle get medium deformation. For areas closer to fixed support are not defromated or minimal deformation.

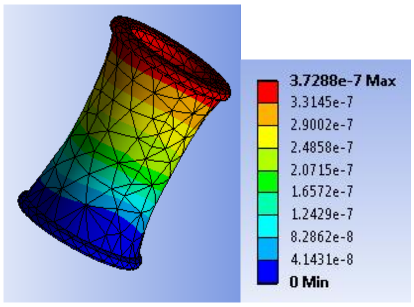

Figure6: *Capstan Deformation*

5. Acknowledgements

The authors thank Direktur PPNS for providing ANSYS student edition software and for their valuable assistance in loading numerical modeling of this study.

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