The Strength Evaluation of 5600 DWT Double Hull Oil Tanker Subjected to Fender Load

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Abstract. The double hull of the oil tanker is more critical on the fender load because the wing tank was void at the full load condition. The strength evaluation of the side hull oil tanker based on fender load using two variables. Scenario A shows that the hull structure was safe based on the fender load. Scenario B shows that the side plate and longitudinal structure were damaged. PIANC needs to review the allowable strength of the pressure of the fender load on the ship with the tank.

1. Introduction
Fender is designed to absorb energy when the ship is berthing or mooring. When the fender deflected on absorb energy, raising the reaction force which forwarded to berthing structure and ship structure. Based on the literature study, the reaction force based on the fender caused failure on pile dolphins [1]. The fender reaction will be continuous to the ship as a pressure load. The pressure on the ship will be damage the hull structure, based on ABS report the side hull of OSV deformed caused by a berthing load [2]. Based on PIANC maximum hull pressure on the Tanker up to 65.000 DWT is 300 KPa [3]. Based on Bross the hull ship proven safe based on hull pressure cylindrical fender (fender without frontal frame) which the pressure higher than allowable of PIANC [4].

Design of the fender based on requirement energy on the berthing point, the berthing point is between 25 – 30 % of length on the ship from the bow. The design fender has equal size and capacity between the berthing point and other points in the port. Based on this condition, the parallel middle needs to evaluate the structure based on fender load. Fender load The parallel middle body still have fender load on mooring condition in the port, in this condition, all the ship hull will have fender load on a random pattern. The parallel middle body on the oil tanker has more critical because has a side void tank. Side void tank on full load is empty, the outer shell when having the pressure of the fender only supported on the ship structure not have an effect of shipload. The aim of this study is to evaluate the allowable hull pressure on the ship with a wing tank.

2. Modelling
2.1. Fender Selection
Table 1 shows the berthing parameter in this study. The berthing parameter is composed of ship dimension, port condition, and berthing schema. The berthing condition on this study is assumed difficult berthing sheltered (B level). The berthing condition selected by the engineer based on multiple factors such as wind speed, current speed, wave height, port geographic, berthing facility, etc.
The fender parameter calculating using PIANC formulation (see equation 1). $Eb$ is berthing energy, $M$ is mass of the ship, $v$ is berthing velocity, $Ce$ is an eccentric factor, $Cm$ is added mass coefficient, $Cs$ is softness factor, $Cc$ is cushion Factor and $Fs$ is a factor of safety. Based on equation 1 the required energy absorption is 24.5 Ton.m. The Indonesian fender selected in this study based on required energy is Keman KNF700 (cone type fender). KNF 700 fender has an energy absorption is 25.9 Ton.m and a reaction force is 60.9 Ton.

$$Eb = \frac{1}{2} M v^2 C_e C_m C_s C_c F_s$$

A frontal frame is a structure from the fender to expand the contact area between the fender to ship structure, higher needed to reach lower pressure on the ship hull. Based on the reaction force KNF 700, to reach maximum allowable pressure 300 KPa based on PIANC, the area of the frontal frame is 2m2. The area of the frontal frame is the effective contact area between the side’s ship and the fender. The dimension of the frontal frame is 2-meter in height and 1-meter in breadth.

### 2.2. Modelling

Based on picture 2, the blue color is scenario A, and the brown color is scenario B. In scenario A, the hull pressure is between the transversal frame of the ship. In scenario B the hull pressure is on the center of the transversal frame. The area on the blue and brown is the contact area between the frontal frame and the ship hull.
The modeling of the oil tanker structure using shell elements. Figure 2 shows the modeling of this study using 12.35 meters length of hull structure on the parallel middle body, the end of this modelling is the transversal bulkhead. The green color is fixed of the structure as transversal bulkhead of the oil tanker. The red color in figure 2 shows the fix on the longitudinally fixed boundary.

![Figure 2. Boundary Condition](image)

2.3. Finite Element Setup

In this study, the calculation used finite element methods. The number of nodes in this study is 100,080 nodes. Table 2 shows the material properties of the oil tanker structure.

| Material  | Young Modulus (MPa) | Poisson Ratio | Yield Stress (MPa) |
|-----------|---------------------|---------------|-------------------|
| ASTM A36  | 200.000             | 0.26          | 250               |

3. Result and Discussion

Figure 3 shows the maximum stress on scenario A on the oil tanker structure is 212.97 MPa. The maximum stress is below the yield stress of ASTM A36. The side plate was affected by the stress near the location of the fender load. Figure 4 shows that the inner wing tank plate is not affected by the fender load.
Figure 5 shows the internal structure of the fender load. Based on figure 5 the structure affected is on longitudinal frame and transversal web frame near on the fender load. The maximum stress is on the transversal frame, not on the side plate, the maximum stress on the transversal structure is caused by the center of the fender load in the transversal frame.

Figure 4 Stress on the inner wing tank Scenario A
Figure 5 Stress on the profile structure Scenario A

Figure 6 show that the maximum stress is 361.67 MPa, higher than the yield stress. The side shell was damaged based on berthing in scenario B. The profile which direct load is the only longitudinal frame. Figure 7 show that the internal structure wing tank is not affected by fender load.

Figure 6 Stress on the side hull Scenario A
Figure 7 Stress on the inner wing tank Scenario B

Figure 8 shows that the maximum stress scenario B on the profile structure. The longitudinal frame was holding the berthing load directly, the longitudinal frame was fail based on the berthing load. The transversal frame can keep holding the berthing load without damage.

The von misses stress was over the yield stress, that caused by the void tank and longitudinal construction of the oil tanker. The other oil tanker without a wing tank, when the ship has the fender load, the cargo will give the pressure in the opposite direction. The load from the cargo will reduce the effect of the fender load. The characteristic of the longitudinal ship construction is to reduce effects from sagging and hogging. The longitudinal structure is less strong to hold transversal loads like cargo load and hydrostatic pressure load. This study showed that the fender load needed a transversal structure to reduce the von misses stress.

The DNV GL stated that the impact load included fender on the ship with displacement between 2.100 up to 17.000 ton is 170 KN (approximately 17 Ton) [6]. The load based on DNV DL is smaller than the fender load in this study (25.2 Ton). The fender load on the ship is varied based on required energy and fender characteristics.
4. Conclusion
The fender load on scenario A was safe the hull structure of the oil tanker. The fender load on scenario B was damage the side plate and longitudinal structure. The fender load on the parallel middle body is rarely, but on the random condition, the parallel middle body needs to hold the fender load. PIANC needs to evaluate the allowable pressure of the ship hull with a wing tank to avoid the ship structure.

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