Lifetime simulation of traditional boat propellers using Ansys

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Abstract. In this study an age-predictive simulation of propellers used by traditional fishermen in the Indramayu region was carried out. These boats were driven by gasoline or diesel motors to drive boat propellers. This boat propeller is made of aluminum alloy with gravity casting technique. The problem is that there are many fishermen who fail on their propellers which generally occur faults on the propeller fins, the purpose of this study is to predict fatigue and age of propellers used in traditional boats, with the observation and calculation method of Finite Element Analysis (FEA) using Ansys software. The results of lifetime propeller analysis with variability in boat hull loading and boat load, with different variations between 3488N and 4788 N, obtained a lifetime for the loading did not experience a significant difference with a lifetime of 277.7 hours.

1. Introduction
Propeller is one of the driving devices used by boats, and there are still many traditional boats used in Indonesia, especially in the Indramayu area, traditional boats used by Indramayu fishermen generally use fix pitch propellers with aluminum alloy. The age of propeller use as a boat driver needs to be controlled and monitored in its use, because propeller as the main tool for boosting the boat needs to be avoided conditions of damage to the propeller due to loading on the boat, especially in the condition of fishing in the middle of the sea.

Taking into account the problem, in the loading conditions that occur, the propeller fatigue lifetime is always the main focus, because it is a model for predicting fatigue [1], it is necessary to do a lifetime simulation to predict the use of the propeller used, Lifetime prediction model Estimate the remaining cycle for the hole or space that appears. surface cracks will occur due to cyclic contact loads [1]. Finally, the cracks become large enough to produce unstable growth, need material to escape from the surface, which one cause damage [1]. According to the research bertoglio et al stated that This fatigue load analysis is very suitable for boat characterized by varied operating conditions [2]. Lifetime simulations carried out by taking into account some of the effects of boat loading and hydrostatic on propellers, lifetime simulations were carried out using the Finite Element Analysis (FEA) method using Ansys software.
2. Methods

2.1. Geometry

Fix type pitch propeller depicted in figure 1 are used in the coastal area of Indramayu. Before carrying out a lifetime simulation of a traditional propeller boat, the dimensions of the propeller used by the traditional boat were carried out. The measurement process was carried out using AMATEK 3D Creator form handy scan, with the following results:

![Figure 1](image1.png)

**Figure 1.** Fix pitch propeller.

Figure 2 show the scan results obtained visually appear to resemble those of Figure 1. Propeller with a number of blades as much as 3, with diameter 322 mm, with a thickness of 110 mm, with a shaft diameter of 25 mm.

![Figure 2](image2.png)

**Figure 2.** Geometry propeller.

2.2. Material

Traditional boats use a fix pitch propeller, in this study propellers were used using aluminum alloy material with material specifications by testing compositions using the Inhouse Methode WI-4-02-22 method to determine the elemental content contained in the base metal. Metal composition testing was carried out with a Spectrometer machine with the following results:
Table 1. Chemical composition of boat propeller materials (New).

| Element      | Percentage (%) |
|--------------|----------------|
| Silicon (Si) | 3.81           |
| Manganese (Mn) | 0.176         |
| Chrome (Cr)  | 0.0338         |
| Nickel (Ni)  | 0.0451         |
| Zinc (Zn)    | 1.66           |
| Copper (Cu)  | 1.30           |
| Iron (Fe)    | 1.59           |
| Aluminum (Al)| 91.2           |
| Magnesium (Mg)| 0.0689       |

2.3. Parameters

2.3.1. Hydrostatic. Propeller used in traditional boats is used in water (h) 1 m, with density of sea water (\( \rho_h \)) in the amount of 1025 kg/m\(^3\), by using equations [3]:

\[
P_H = P_0 + \rho_h \cdot g \cdot h
\] (1)

The amount of hydrostatic pressure obtained is 10045 Pa with \( P_0 = 0 \) Pa, the hydrostatic pressure is used as a loading parameter in the propeller.

2.3.2. Angular velocity. The propeller speed used is rotated with the type of Dongfeng 24 HP diesel engine, with an average rotation of 2200 rpm, it can be obtained the angular velocity that occurs with the following equation:

\[
\omega = \frac{2\pi}{T}
\] (2)

Then the large angular velocity that occurs by changing the period to be the frequency of the number of engine turns [4], obtained by the angular velocity of 230.38 rad/s.

2.3.3. Bouyancy force. As a variable in the simulation of boat loading on a propeller that serves as a driving force for traditional boats, with raw materials from teak wood weighing 700 kg without payload and with a load of 300 kg, the propeller load if it contains a load of 1000 kg, then can be calculated the size of the buoyancy force of the boat with the following equation [3]:

\[
F = k \cdot \rho \cdot g \cdot V
\] (3)

The condition of the buoyancy of the boat (k) assumption 1/3, can be obtained by the amount of buoyancy force that occurs when unload is 3348 N, and the amount of buoyancy force with a load of 4788 N.

2.3.4. Initial condition

Figure 3. Initial condition (a) Propeller part, (b) Propeller mesh.
In figure 3. (a) shows the part to be simulated and in figure 3. (b) shows the part after the mesh is done with the number of nodes 25078 and the number of elements 102303 with size 2 mm, with visualization of loading as follows:

![Figure 4. Propeller load.](image)

The mechanical loads in propeller are the hydrodynamic pressure, the centrifugal force and the gravity. The non-uniform distribution of the hydrodynamic pressure on the surface of the propeller is obtained through a boundary element analysis [5]. In the figure above, visually shows the loading on the propeller given the loading speed of sea water current (A) 3 m/ s, rotation speed (B) 230.38 rad/ s, and the amount of sea water pressure (C) at a depth of 1 m of 10045 Pa.

3. Results and discussion

3.1. Unload boat

![Figure 5. Results simulation (a) Stress and (b) Total deformation.](image)

Simulation of loading on propellers with unloaded boat conditions with a calculated buoyant force of 3348 N, shown in figure 5. (a) visually shows stress with a maximum value of 3.08e3 MPa occurring on the area at the base of the propeller and stress value the minimum of 22.5 MPa, shown in the area of the propeller tip, in figure 5. (b) shows the deformation value with a minimum value of 0 mm in the propeller shaft and base area, and the maximum deformation value of 17.713 mm occurs at the end area propeller blade, according to the research bertoglio et al stated that the stress field in the blade material, varying depending on the position of the blade during one revolution [2].
Figure 6. Result visualization (a) Damage (b) Lifetime.

Damage visualization shown in figure 6. (a) shows the area of damage at the base of the propeller blade and other areas is quite safe, while in figure 6. (b) shows a lifetime with a minimum value of 565 s, or equal to 9.4 minutes, while in maximum conditions of 1e6 s, or equivalent to 277.7 hours.

Figure 7. Safety factor.

In Figure 7. shows the value of the safety factor that occurs in the propeller shows the minimum value of 0.120 is shown in the red area and the maximum safety factor value of 15 is indicated in the blue area.

3.2. Load boat

Figure 8. Results simulation (a) Stress, (b) Total deformation.
The simulation of loading on propellers with the condition of an unloaded boat with a calculated buoyant force of 4788 N, shown in figure 8. (a) visually shows stress with a maximum value of 3.13 MPa occurring in the area at each base of the propeller and the minimum stress value of 22.1 MPa, shown in the area of the propeller tip, in figure 8. (b) shows the deformation value with a minimum value of 0 mm in the propeller shaft and base area, and the maximum deformation value of 17.999 mm occurs in Propeller tip area.

![Figure 8](image1.png)

**Figure 8.** Loading simulation on propellers with a calculated buoyant force of 4788 N.

Damage visualization is shown in figure 9. (a) shows the damage area at the base of the propeller blade and the other area is quite safe, the minimum damage value indicates 1000 and the maximum damage value shows 1.811e6 while in figure 9. (b) shows lifetime with a minimum value of 552, 2 s, or equal to 9.2 minutes, while at maximum conditions 1e6 s, or equal to 277.7 hours.

![Figure 9](image2.png)

**Figure 9.** Result visualization (a) Damage (b) Lifetime.

In figure 10. shows the value of the safety factor that occurs in the propeller shows the minimum value of 0.119 is shown in the red area and the maximum safety factor value of 15 is shown in blue area.

![Figure 10](image3.png)

**Figure 10.** Safety factor.

In this study it can be concluded that in the existing loading, the cargo boat with a load weight of 3348 N has a greater buoyancy compared to a charged boat with a load weight of 4788 N, the maximum stress
value on a boat without a charge of 3.03e3 MPa and a minimum stress value 22.5 MPa, the boat with a maximum stress value of 3.1e3 MPa and the minimum stress value of 22.1 MPa shows that there is an effect of charge on the stress value, and has no effect on the total deformation value, for area damage showing the same on a charged boat and not charged, and minimum lifetime on 9.4 minutes unloaded boats and on boats with 9.2 minutes, with a maximum value of 277.7 hours.

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References
[1] Pritchard P J, Fox R W and McDonald A T 2010 Introduction to fluid mechanics (John Wiley & Sons)
[2] Yin Y, Chen Y X and Liu L 2017 Lifetime prediction for the subsurface crack propagation using three-dimensional dynamic FEA model Mechanical Systems and Signal Processing 87 54-70
[3] Rao R S, Mohan S and Kumar G S 2016 Determination of Fatigue Life of Surface Propeller by Using Finite Element Analysis International Journal of Engineering Science 2492
[4] Bertoglio C, Gaggero S, Rizzo C M and Viviani M 2014 Fatigue strength assessment of propellers by means of weakly coupled CFD and FEM analyses ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering American Society of Mechanical Engineers Digital Collection
[5] Yeo K B, Choong W H and Hau W Y 2014 Prediction of propeller blade stress distribution through FEA Journal of Applied Sciences 14(22) 3046-3054