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REDESAIN BALING-BALING KAPAL NELAYAN BERDAUN 4 (EMPAT) DI SALAH SATU GALANGAN KAPAL DI TEGAL JAWA TENGAH

Redesigning of 4 (Four) Blades Propeller Installed in a Wooden Fishing Boat in a Ship Yard in Tegal, Central Java Province

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ABSTRACT

For design of marine propeller, the energy supply from marine engine to the propeller should be converted to thrust force with minimum losses. Furthermore, the unwanted vibration and cavitation due to the overlooking a detail calculation of the propeller should be prohibited for increasing the fuel efficiency and life-span of the propeller. In the last few decades, most of small and medium sized enterprises (SMEs) focusing their work on ship component industry in Central Java Province Indonesia provide the marine propeller to the ship manufacturer and ship repairmen in some shipyards in northern part of Central Java port. The design of the propeller is never been observed and optimized. The aim of the present work is to redesign the installed propeller on a wooden fishing boat with the new optimized design using B-Series propeller theory approach. The reverse engineering method uses three-dimensional scanner to obtain the geometrical data of the installed ship propeller. The new optimized propeller design is obtained from free software calculation based on the boat and engine specification. The comparison shows that the new optimized propeller design has a wider blade and larger pitch and increases 20% of the open water efficiency of the propeller performance at lower engine rotation.

Keywords*: B-series design, fishing boat, marine propeller, redesign, optimization*

ABSTRAK

Pada desain baling-baling kapal, pasokan energi dari mesin ke baling-baling diubah menjadi gaya gaya dorong dengan kerugian minimal. Fenomena getaran yang tidak diinginkan serta kavitasi harus dikurangi untuk peningkatan efisiensi bahan bakar dan umur baling-baling. Dalam beberapa dekade terakhir, sebagian besar industri kecil dan menengah (IKM) komponen kapal di Propinsi Jawa Tengah, Indonesia mensuplai baling-baling ke perusahaan produsen kapal dan reparasi kapal di beberapa galangan di sisi utara pelabuhan Jawa Tengah. Desain baling-baling tidak pernah diamati dan dioptimalkan. Tujuan dari penelitian ini adalah meredesain baling-baling yang terpasang pada kapal kayu untuk nelayan dengan pendekatan desain optimal yang baru menggunakan teori

B-Series propeller. Metode reverse engineering menggunakan pemindai tiga dimensi untuk mendapatkan data geometris dari baling-baling kapal yang terpasang. Desain baling-baling yang dioptimalkan diperoleh dari perhitungan perangkat lunak berdasarkan spesifikasi perahu dan mesin. Perbandingan tersebut menunjukkan bahwa desain baling-baling yang dioptimalkan memiliki bilah baling-baling yang lebih lebar dan *pitch* yang lebih besar dan meningkatkan 20% efisiensi kinerja baling-baling pada putaran mesin rendah.

Kata kunci: baling-baling kapal, desain *B-series*, kapal ikan, optimasi, redesain

INTRODUCTION

Many Indonesian people live in the north coast of Java Island works as fishermen. They work in a small group, using a wooden boat crossing the Java Sea for fishing. With respect to the wood boat analysis, some of the researches focusing their research to analysis design and geometrical evaluation of the boat (Susanto *et al*. 2011a; Aydin and Salci 2007; Kang *et al*. 20017), static and dynamic stability analysis (Susanto *et al*. 2011b; Marjoni *et al*. 2010), hull design analysis (Utama and Aryawan 2016; Kiryanto *et al*. 2012) and feasibility analysis (Muhammad *et al*. 2018; Hadi 2010). Besides that, a propeller is needed to be design properly as well. This paper focuses on the analysis of the metal propeller design and its comparison between the present design and the optimum design.

Most of the boats use metal propeller from aluminium or brass material, made by small and medium sized enterprises (SMEs) which is provided around the shipyard. The fisherman wood boats, located in a port of north Java Island and the metal propeller with 4 blades are depicted in Figure 1.

Marine propeller is one of the critical components in the marine boat which should be designed and manufactured precisely and should consider many parameters such as: engine specification, the hull dimension, the expected velocity and torque of the boat (Carlton 2007; Kuiper 2010). The design of marine propeller, especially the blades, needs to be very efficient. The energy supply from marine engine to the propeller should be converted to thrust force with only a minimum of losses. Furthermore, the unwanted vibration and cavitation are also prohibited to increase the fuel efficiency and lifespan of propeller (Kuiper 2010). The improper selection of the propeller induces a lower fuel efficiency and thrust force efficiency.

The marine propeller design technique has a significant improvement in the few last decades (Martinez-Calle *et al.* 2002). It can be noticed by the availability of the propeller design and analysis with different scale of difficulties published by many researchers, such as the implementation of Reynolds-averaged Navier–Stokes (RANS) equations in three-dimensional viscous flow models (Black 1997), the lifting surface methods with respect to RANS equations to predict the viscous effects near the walls of the blade (Xie 2011), the use of multi-objective approaches (Benini 2004), the application of computational fluid dynamic (Yeo *et al.* 2014; Kuiper 1992; Abidin and Adji 2012), the additional of energy saving device (Putra *et al.* 2015) and the implementation of traditional series theory (Gaafary *et al.* 2009). Among the traditional series, Wageningen B-series is one of the commonly used series in designing the propeller with simpler calculation and iteration (Ghose and Gokarn 2004).

During the last decades in Central Java Province, some of the propellers for fisherman wood boat are supplied by small medium sized companies from the same province. However, the design, geometry and performance of the propeller are never been checked and observed. As a critical component, it influences the fuel consumption and the boat performance which leads to a serious and comprehensive study of the propeller design. The aim of the present work is to redesign installed propeller on a wooden fishing boat with the new optimized design using B-Series propeller theory approach. This research is carried out by conducts a design analysis of the installed propeller on a fishing boat, manufactured by SMEs, and then compare with the B-Series theory approach. The simplest calculation is selected to be discussed in this paper so the results can transfer easily on the several concerned parties, such as government, SMEs and shipyards.

METHODOLOGY

The present observation on the fishing boat is conducted in Tegal, Central Java, Indonesia where the boat is still repaired in a shipyard, in October 2016. The chosen of this boat is based on the easiness observation the installed propeller since the boat is being maintenance in the ship yard. The general boat specifications and the hull dimensions are showed in Table 1 and Table 2, respectively, obtained from the field measurement. Table 1 is related to boat capacity, the engine specification, the velocity, the existing propeller and airfoil design. Table 2 consists of the dimensions of the hull which have the correlation with the boat capacity, 28 GT and the maximum power of the boat, 110 HP.

The installed propeller of the boat was manufactured by an SME in Tegal which focused in manufacturing the boat components. Then, based on the boat specifications and dimensions a new optimized propeller is designed using B-series theory by implementing free propeller design software. The design and the analysis using free software follow the flowchart (Figure 2).

The new propeller design and the calculation for the observed marine boat are compared to the installed propeller design. The optimization constrains in this case are the diameter of the propeller and the number of the blades. The ship resistance is designed for the speed velocity 2-9 knots whereas the input data of appendages, waves and winds are neglected. The output of the propeller design is the main dimension of blades namely the pitch (P), the pitch-diameter ratio (P/D) and blade area ratio (Ae/Ao). The differences between the new propeller design and the installed propeller is showed to compare the dimension. The open water efficiency is then calculated using the same software and compared for the two designs.

(a) (b)

Figure 1 (a) Fisherman wood boats in a north Java Island port and (b) the propeller installed on the wood boats, made by SME in Tegal.

Table 1 Specification of the boat.

Parameters	Specification
Boat capacity	28 Gross Ton (GT)
Engine	4 cylinders Diesel Engine
Maximum power	110 HP
Maximum rotation	2900 rpm
Gearbox ratio	4 : 1
Hull type	Full displacement
Number of engine	1
Number of propeller	1
Number of blades	4
Velocity	7 knot

Table 2 The hull dimensions.

Parameters	Dimensions (m)
L_{OA}(length over all)	16.15
L_{WL} (length of water line)	14.324
B (breadth)	3.5
B_{WL}(breadth of water line)	3.7
B_{OA} (beam/ breadth over all)	3.461
D_s (draft)	1.4
I (immersion)	0.6

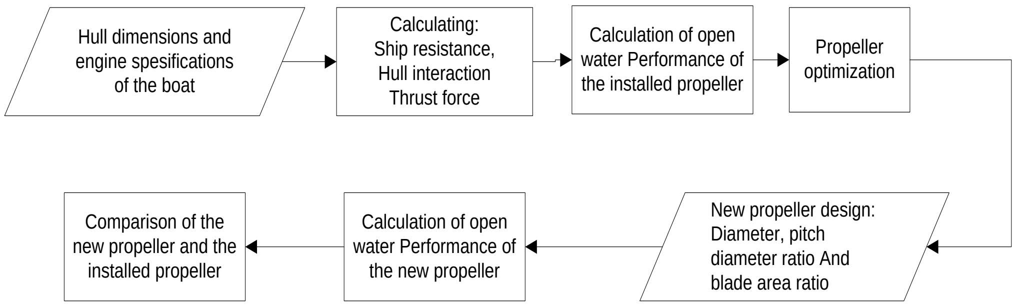


Figure 2 Flowchart of the B-Series propeller design and optimization using free software.

RSEULT AND DISCUSSION

The iteration of the B-Series design using the free software based on the condition discussed in the previous section results in the new propeller design. The reverse engineering method was used by implementing three-dimensional scanner to obtain the geometrical data of the installed ship propeller. The geometry of the propeller is successfully transferred to the CAD software.

The comparison of the pitch (P), the pitch-diameter ratio (P/D) and blade area ratio (Ae/Ao) of the new optimized design and the installed propeller design is shown in Table 3. With the same diameter, it is noticed that the new design has larger the pitch, the pitch-diameter ratio and blade area ratio. The pitch and pitch-diameter ratio of the new design is 80% larger that the installed design whereas the blade area ratio is 27% larger.

In order to see the detail of the propeller blade, the three-dimensional model is drawn for the new and the installed propeller. The chord length, blade thickness, maximum chamber for every blade section as a function of the radius is calculated as well as the air foil coordinate and pitch distribution. The comparison of the new optimized and installed propeller is shown in Fig. 3. The projected and expanded profile of the propeller blade is showed as a function of radius section. It is clearly found that the new dimension has larger blade dimension.

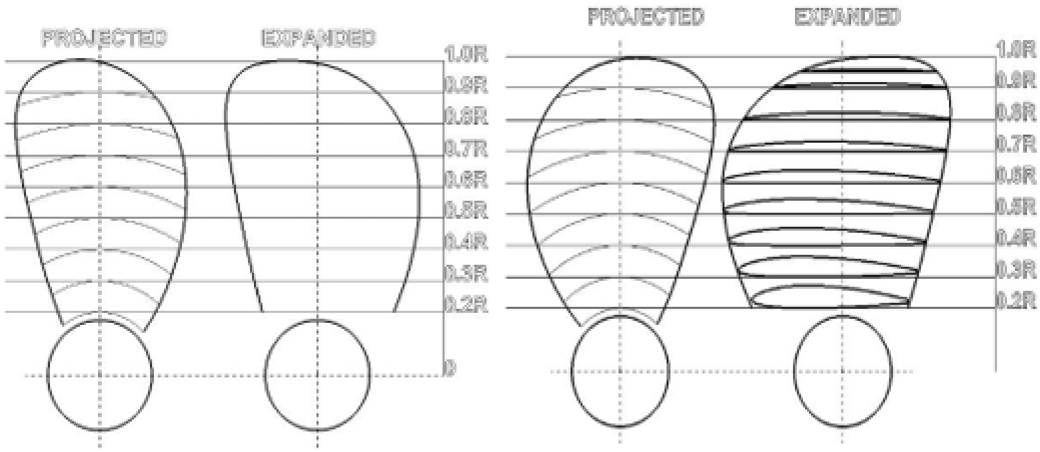
The calculation is then continued by comparing the open water characteristic of the new and installed propeller. Based on the software calculation, the open water efficiency for the installed propeller (boat speed= 7 knot) is 0.48 at 604 rpm. At the same boat speed, the open water efficiency for the new propeller increases 20% with respect to the larger the pitch (P), the pitch-diameter ratio (P/D) and blade area ratio (Ae/Ao). At the lower rpm (418 rpm), the open water efficiency is 0.58 for the new propeller design. It indicates the new propeller has a better design in providing the thrust force of the boat. The price of the new design will be higher compared to the installed propeller due to the larger blade and higher mass but is can be compensated with the lower fuel consumption.

The better performance of the new propeller compared to the installed propeller shows that naval engineer and SMEs in metal manufacturing company do not put more attentions on the design and dimension of the boat propeller. In some case, the engineer considers the propeller availability in the market with neglecting the detail calculation and the suitability of the propeller to the boat. In SMEs, the design of the boat propeller, made from brass or aluminium is frequently based on the former design in their company and overlook the propeller performance with respect to open water efficiency. However, the present study limits the discussion only on propeller design and the open water efficiency using free published software. The further computational analysis using computational fluid dynamic (CFD) and advance RANS calculation will increase the precise calculation and strengthen the propeller design results.

Based on the present study case, the government, SMEs and naval engineer, related to the marine ship components are need to be informed and pushed to put more attentions to the critical components which able to increase fuel efficiency and boat performance. With the higher fuel price, high competition level in the fisheries market and the requirement of ship standardization, the precise calculation of the boat propeller will give the significant impacts.

Table 3 Installed propeller versus the new optimized propeller.

Observed parameters	Installed propeller	Optimized propeller	Differences
Diameter (D) = 2R	0.8 m	0.8 m	-
Pitch (P)	0.4 m	0.72 m	80%
Pitch-Diameter Ratio (P/D)	0.5	0.9	80%
Blade Area Ratio (Ae/Ao)	0.55	0.7	27%



(a) (b)

Figure 3 The comparison of the propeller: (a) the installed propeller and (b) the new optimized propeller design using B-Series theory

CONCLUSION

Comparing to the installed propeller, by using the same diameter and the number of propeller blades, the new optimized propeller design has a wider blade and larger pitch. New optimized propeller design increases 20% of the open water efficiency of the propeller performance at lower engine rotation. The present study case can be used by all parties which related to the marine ship components to put more attentions to the marine propeller design which able to increase fuel efficiency and boat performance.

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