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The Performance of Single and Double Intake Designs of Propeller Flow Cooling System (PFCS)

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Abstract. In order to save spaces inside a small-sized fishing boat, the high-pressure flow behind propeller is utilized instead of a special cooling pump to cool the main engine. From the previous study, the system is referred to as the Propeller Flow Cooling System (PFCS). As a continuation of the previous study, the present study conducted more experiments in order to compare the performance of a single and a double intake designs of the PVCS with the same cross-sectional area. The designs with circular and elliptical intakes shapes were measured. The experiments were also conducted at the Circulating Water Channel (CWC) facility. The main parameter which was compared in the experiment and analysis was the flow capacity produced by both designs for various propeller revolution (RPM). The experimental results showed that single intake design has a higher flow capacity than the double intake one which was caused by higher flow losses inside the pipe of single intake design mainly due to higher surface friction as well as an additional elbow joint needed in double intake design. This tendency occurred for both circular and elliptical shapes cases.

1. Introduction

The main engine of a boat is used to produce power to drive the boat. The power generated from the main engine is obtained from the combustion of fuel that occurs inside the engine combustion chamber. The burning of this fuel will produce high power and heat which is used to drive the propeller. However, as a result of the heat generated from the combustion of fuel in the engine, it will increase the temperature, especially in parts that come in direct contact with the combustion chamber [1]. Therefore, a cooling system to reduce excessive heat in the engine is necessary.

In general, engine cooling systems on ships use seawater as the coolant in an open cooling system or fresh water in a closed cooling system [2]. However, there many traditional fishing boats today that only use an air cooling system. In particular, mainly because the boat uses a land-based engine that is modified to be fit for the boat. Air cooling has a disadvantage when the position of the engine placed in the inboard position because it can cause insufficient air to absorb heat from the operating engine [3].

One of the impacts of the engine when it is too hot or overheating is that the engine components will become soft which can cause abnormal combustion, knocking, or other abnormal conditions. Contrary, the impact when the engine is too cold is that it can cause other problems including the fuel will be difficult to evaporate on a gasoline engine. While on a diesel engine if the compressed air is cold, the

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1 resulting exhaust gas output is white smoke and will certainly produce an engine knock as well as the difficulty to turn on the engine [4].

Therefore, to support the operation of a fishing boat, the performance of the main engine is inseparable from the role of the cooling water factor. The main engine cooling water system serves to deliver or drain the cooling water from a lower place to the desired destination with the help of an additional engine or pump. Recently, in some boats, special arrangements are made where the cooling pumps or motors are driven or coupled with the main engine itself in order to reduce the power needed by the boat [5]. This arrangement also could make installation more compact aboard the boat.

As an alternative method to reduce energy usage by the boat, many relatively small-sized fishing boats especially in South Sulawesi, Indonesia utilize the high-pressure flow behind the propeller. The high-pressure flow is directed through an intake positioned in front of the propeller to cool the main engine. The hot water from the main engine is discharged outboard through hull. The system is referred as Propeller Flow Cooling System (PFCS) [6]. With this arrangement, the special pump for main engine cooling is not necessary anymore. Thus, reducing initial and operational costs as well as saving space inside the boat. An example of a boat that implements the system is shown in Fig. 1.



Figure 1. an example of a Propeller Flow Cooling System (PFCS) installed in a fishing boat

From previous research conducted by Mahmuddin et al. [6], it was found that an elliptical intake shape of the system has a better performance compared to the circular one. In the same study, it was also found that when the intake shape was placed in a vertical position of 0.7R where R is the propeller radius, the system had a better performance as compared to when the intake was placed exactly in front of the propeller hub. However, in that study, only a single intake was placed on the upper part of the propeller while the flow in the lower part of the propeller was still not utilized. Therefore, in the present study, 2 (two) intake design of the PFCS will be compared. The 1st design is the one with only 1 (one) intake while the 2nd design has double intake which was placed in upper and lower parts of the propeller. In order to make an equal comparison, both designs have the same intake cross-sectional area.

In addition, in order to measure the flow velocity and capacity inside the distributing pipe, the flow measurement system needs to be designed so that the amount of water that flows to the main engine can be determined. The system uses a microcontroller Arduino UNO and a flow sensor as the main components. The microcontroller is one of the common microcontrollers used for data collection such as the ones performed in references [7-10]. The measurement system developed in the present study includes a software interface that was developed using Microsoft Visual Basic software. The measurement system is able to transfer and record data in a computer for easy data analysis.

2. Research Methodology

2.1. Circulating Water Channel (CWC)

In the present study, the performance of the design with one (single) and two (double) intake of PVCS is compared. The main parameters to compare are flow velocity and capacity entering the intake. The main method adopted in the present study is an experimental method using a tank facility known as Circulating Water Channel (CWC). The tank facility belongs to Marine Structure System Laboratory, Marine Engineering Departement, Engineering Faculty, Hasanuddin University, Indonesia. The concept of the CWC is illustrated in Fig. 2.



Figure 2. The sketch illustrating the concept of CWC [6]

As illustrated in Fig. 2, in CWC, the water is circulated using a propeller. The propeller is assumed to be the boat propeller. The propeller is driven by an electric motor placed outside the tank. The use of an electric motor allows easy and convenient motor revolution adjustment by using an automatic voltage regulator (AVR). AVR is used to regulate the voltage reaching the motor so that the motor revolution will reduce and increase according to the voltage from AVR. A photo of the CWC facility is shown in. Fig. 3.



Figure 3. Photo of CWC facility

The total length of the CWC tank is 9.6 m, width 2.4 m, and height 1.5 m. It can accommodate around 25 tons of water. The main materials of the tank wall are iron plate and some sections are made from transparent acrylic to allow easy observation of the phenomena and interaction occurred inside the tank.

2.2. Flow Measuring System

In order to measure the flow velocity and capacity, a flow measuring system was designed and assembled. The main components of the system are a microcontroller Arduino Uno and a flow sensor. Those components are shown in Fig. 4.





(a) Microcontroller Arduino Uno

(b) Flow velocity sensor Sea YF-S201

Figure 4. The main components of PFCS flow measuring system

Using the components, the system is assembled using the following wiring scheme.



Figure 5. The flow measuring system wiring connection scheme

In order to connect to record the data, a program interface using Microsoft Visual Basic was built. The interface of the program is shown in Fig. 6.



Figure 6. The interface of the data collection program

As can be seen in Fig. 6, before starting to use the program, the user needs to determine COM and Baudrate parameters. The value of COM needs to be entered can be found in the device manager of the computer used while Baudrate value can be seen on Serial Port Properties. The common values are COM4 and 9600 for COM and baud rate text boxes, respectively.

Another component inside the interface is a square sign. If the sign is colored red, it means the program still not connected or fails to connect but if the sign is colored green, it means the program has successfully connected. The large size number at the bottom interface is the value recorded to the computer. After the data collection finishes, the data can be extracted to software Microsoft Excell or other similar software. The flow velocity measuring system was validated before used in the experiment by comparing the results from manual and automatic measurements. A good agreement between these results was found which could ascertain the accuracy of the measurement system.

2.3. Shape Description

There are 2 (two) inlet pipe shapes that were tested in the present study. They are circular and elliptical shapes. Their sketch and dimension are shown in Fig. 7.



Figure 7. Intake shapes dimension

As shown in Fig. 7, both of the shapes have the same cross-sectional area which is equal to 0.00028 m². The ellipse has an aspect ratio of 0.278 which is defined as the ratio between its vertical radius with its horizontal one.

2.4. Intake Designs

There are 2 (two) intake designs analyzed in the present study. They are shown in Fig. 8. The first shape has only 1 (one) intake pipe and was placed in the upper 0.7R part of the propeller. The second design has 2 (two) inlet pipes placed in the upper and lower 0.7R part of the propeller. The horizontal distance of each inlet pipe to the propeller blade was 0.1 m.





(a) Single intake

(b) Double intake

Figure 8. PVCS intake designs

3. Results Analysis and Discussion

The performance validation using numerical and experimental methods between circular and elliptical intake shapes had been conducted by Mahmuddin et al. [6]. Therefore, in the present study, only results from the experiment are shown and discussed.

3.1. Circular Intake

Based on the experiment models and setup described in the previous section, the first experiment was conducted using the circular intake as shown in Fig. 8(a). The measured parameters were flow capacity and the propeller revolution. 4 (four) various propeller revolutions were tested. They were 900, 1100, 1300, and 1500 rpm. The experimental results for circular intake shape are shown in Fig. 9.



Figure 9. Flow capacity of circle pipe for single and double intake designs

In Fig. 9, the *x*-axis of the plot is the motor revolution (RPM) while the *y*-axis is the flow capacity (Q) in m^3/hr . It can be seen from the plot that a single intake design has a higher flow capacity than the one with double intake for all RPM values. This phenomenon can be attributed to higher flow loss in double intake design due to friction inside the pipe. Moreover, an additional of 2 (two) elbow joints needed in double intake design as shown in Fig. 8(b) is also contributed to these higher losses.

3.2. Elliptical Intake

The next run of the experiment was conducted by measuring the flow capacity for elliptical intake which has shape and dimension shown in Fig. 8(b). The experimental results for this case are shown in Fig. 10.



Figure 10. Flow capacity of elliptical pipe for single and double intake designs

As can been from Fig. 10, for this case, a single intake design also has a higher capacity than the double intake one. The main causes of this trend have been explained in the previous case. From this figure, it can also be noted that the performance of elliptical intake is higher than the circular one both for single and double intake designs which is also consistent with the conclusion drawn from the previous results of Mahmuddin et al. [6]. Moreover, it can also be observed that the maximum flow capacity in the single intake is 0.85 m³/hr while in double intake is 0.78 m³/hr or approximately 8.97% difference. It is also interesting to note that the flow capacity differences between circular and elliptical intakes are 19.71% and 21.79% for single intake and double intake cases, respectively.

4. Conclusion

In order to compare the performance of 2 (two) different designs of a Propeller Flow Cooling System (PVCS), the present study had conducted experiments in the Circulating Water Channel (CWC) facility. A flow monitoring system including its monitoring interface had also been designed and assembled. The measurement system was used to measure the flow capacity of the PVCS in the experiments. The experiments were conducted for circular and elliptical intakes cases for various propeller revolution. From the experiments, it was found that the design with the single intake has a better performance compared to the system with double intake one. The results showed that flow losses were due to surface friction and elbow joint which was significant in reducing the flow capacity in double intake design. The tendency occurred for both circular and elliptical intake cases.

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