Optimasi Keel Cooler pada Sistem Pendingin Mesin Induk Kapal

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Abstract

OT ship Skylie is a type of tanker that uses a keel cooler as its engine cooling system. The keel cooler is a new type of heat exchanger that is applied in the shipping world because it is installed externally on the ship's hull below the surface of the water. This study aims to determine the optimum length dimensions of the keel cooler system. Methods of analysis and simulation using Ansys software. Based on the calculation results on several variations of the keel cooler length dimensions, the greatest heat transfer value is 6.655 x 105 W in the length variation II with an inlet pipe size of 53.85 meters, an outlet pipe of 47 meters, and a pipe length of 44 meters with the greatest effectiveness value of 80.138%. Meanwhile, the lowest heat transfer was 4,503 x 105 W in the length variation III with an inlet pipe size of 37.85 meters, 31 meters outlet pipe and 28 meters long pipe with the lowest effectiveness value of 79.910%. Therefore it can be concluded that the longer the dimensions of the keel cooler, the greater the heat transfer value and effectiveness and the size variations studied meet the standard values for the effectiveness of using the keel cooler

Kata Kunci: *Keel cooling system, heat transfer, length dimension variations.*

1. Introduction

In general, on ships there are two ways that are commonly used to cool the main engine or auxiliary engines, namely by using a direct (open) cooling system and an indirect (closed) cooling system, between the two systems most commonly used on ships is the cooling system. closed [1]. In an open cooling system, only one cooling medium is used, namely sea water, while a closed cooling system is a system with a cooling medium using fresh water which is used continuously to cool the ship's motor/engine.

Keel cooling system is a cooling system that uses a keel. The keel is part of the cooling system located outside the ship's hull. The cooling system using a keel cooler is a closed circuit cooling system that is installed externally on the ship's hull below the surface of the water. The concept of keel cooling is similar to applying a radiator to a car. Engine coolant is circulated through the keel cooler, which transfers heat away from the coolant before returning to the engine [2]. The keel cooler is in constant contact with the seawater which enables the cooling system [3].

OT ship. Skylie is a type of tanker that uses a keel cooler as the main engine cooling device for the ship's propulsion. and has previously been studied regarding the effectiveness of the keel cooler where the value is 79.985% [4]. Therefore, the authors want to develop this research by varying the long dimensions of the keel cooler in the ship's main propulsion cooling system.

This study aims to determine the overall heat transfer value of the keel cooler system heat exchanger to the main engine and the optimum long dimension of the keel cooler in the ship's cooling system.

2. Methodology

The research on the keel cooler for the OT. Skylie ship utilizes analysis and simulation methods using the Ansys software. The research was conducted at the Department of Naval Systems Engineering, Faculty of Engineering, Hasanuddin University.

2.1 Data Collections

The first stage of this research is the literature review. In this stage, the author seeks and collects relevant references related to the research topic.

The literature review includes gathering data on the ship, main engine data, power torque data of the ship's main engine, sea surface temperature data, and research data on the keel cooler.

Data Keel Cooler System

- Ship data

Long : 74.673m
Wide : 18m
Loaded : 4.5m
Dwt : 3700 tons

- Main Machine Data

Brand : Cummins
Model : KTA 50-M2
Rpm : 1900rpm
Engine Power : 1530Hp/1141 Kw

- Power/Torque data on Ship's Main Engine

In this study, the temperature will be used in accordance with the power/torque of the ship's main engine with the following details:

Mode	1
Power/Torque %	100
speed%	100
Power Kw	402
Exhaust Temperature ^{o}C	544
Cylinder Coolant Temperature in ^{o}C	82
Cylinder Coolant Temperature in ^{o}C	N/A
Lubricant Temperature in ^{o}C	110

- Sea Surface Temperature Data

In Indonesian waters, especially in the waters of the Java Sea, it has a maximum sea surface temperature of 31oC and a minimum sea surface temperature of 28oC.

- Keel Cooler Length and Number of Pipes

The first step is to make a research model, in this case the keel cooler which consists of plates arranged as pipes placed outside the hull, which will then be analyzed and simulated. The process of analysis and simulation is carried out using two software including, using

Rhinoceros 6 dan Ansys The left and right side plates on the keel cooler have 34 blocks each. The keel cooler consists of 1 inlet pipe, 1 outlet pipe and 8 long pipes with the same pipe size (Fig. 1).

Figure 1. variation of the dimensions of the keel cooler

The picture above is a variation of the dimensions of the keel cooler whose size corresponds to the actual size installed on the OT ship. Skylie in the field. This keel cooler system is in the form of a block, unlike the cooler in general, which has a cylindrical cross section.

This keel cooler was designed using the Rhinoceros 6.0 design application whose data was obtained from the shipyard. In this study, several variations of the length dimension were carried out under conditions of maximum engine power/torque, namely at 100%.

The type of fluid flow can be determined by finding the value of the Reynolds number. In this keel cooler, the casing shape used belongs to the non-circular category so that the hydraulic diameter approach can be used. Where the area of the casing (A) variation I = 246,870 m2, variation III = 193,910 m2, variation II = 299,830 m2 and perimeter/circumference (P) variation I = 1,492.724 m, variation II = 1,812.724 m, variation III = 1,172.724 m. Then obtained a diameter value of 0.6615 m for variation I, 0.6616 for variation II, and 0.6614 for variation III.

Before knowing the type of flow that forms outside the keel cooler, you must first know the value of the Reynolds number. In the keel cooler, the 36 cross-sectional shapes used belong to the non-circular category so that the hydraulic diameter approach can be used. Where the cross-sectional area (A) in variation I = 253.583 m, variation II = 307.983 m, variation III = 199.183 m, and perimeter/circumference (P) for variation I = 1492.76m, variation II = 1812.76m, variation III = 1172.76m. Then obtained a diameter value of 0.679m for variations I, II, and III (Table 1, Fig. 1-2).

Table 1. Main Dimensions of Keel Cooler

Pipes	Length(m)	Width(m)	Height(m)	Beam Surface Area (m^2)
Inlet	45.85	0.25	0.09	31,223
Outlets	39	0.25	0.09	26,565
Same Pipe	36	0.25	0.09	24,525

- The overall length of the pipe L = 372.85 m
- Pipe sheath area A = 246,870 m2

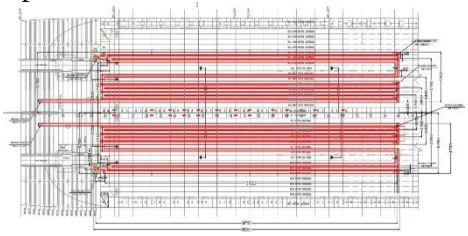

Figure 2. Location of the Keel Cooler on the ship

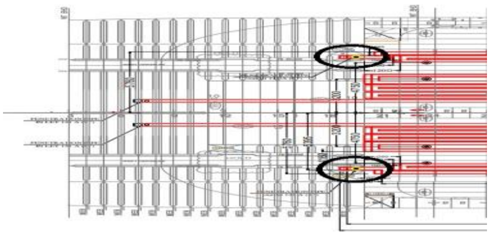

Figure 3. Location of Keel Cooler Penetration

3. Results and Discussion

The research includes the following steps: literature review, field study, analysis of the heat exchanger, calculation of the heat transfer area, calculation of the Reynolds number of the flow inside the pipes, calculation of thermal resistance, calculation of the overall heat transfer coefficient , calculation of the total heat transfer, and analysis of the influence of dimension variations on the effectiveness of the keel cooler system.

The first step is to create a research model of the keel cooler, which consists of plates arranged as pipes and placed outside the ship's hull. This model will be analyzed and simulated. The analysis and simulation process is carried out using two software programs: Rhinoceros 6 and Ansys.

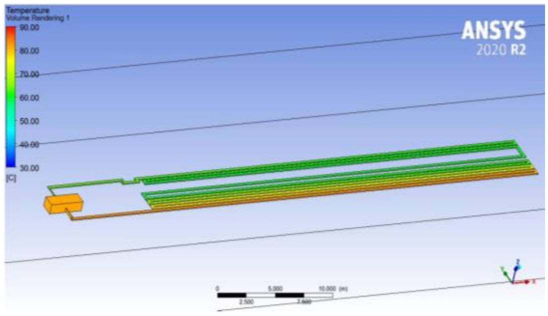

Figure 4. Variation 1 of the keel cooler

Fig. 4 above is the temperature result which can be seen from the result menu in the ansys simulation. The figure is the main dimension of the length of the keel cooler with an inlet pipe of 45.85 m, a pipe of the same size of 36 m and an outlet pipe of 39 m.

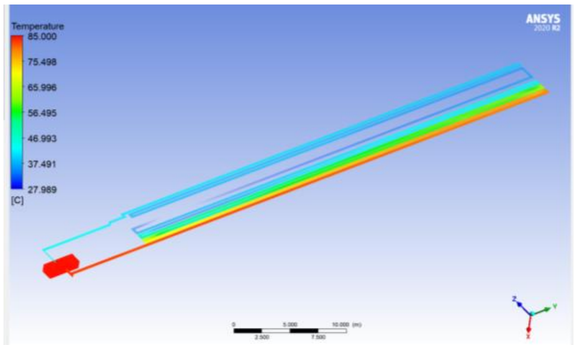

Figure 5. Variation 2 of the keel cooler

Fig. 5 shows the temperature results which can be seen from the results menu in the ansys simulation for the second variation. The figure is the main dimension of the length of the keel cooler with an inlet pipe of 53.85 m, the same pipe of 44 m and an outlet pipe of 47 m.

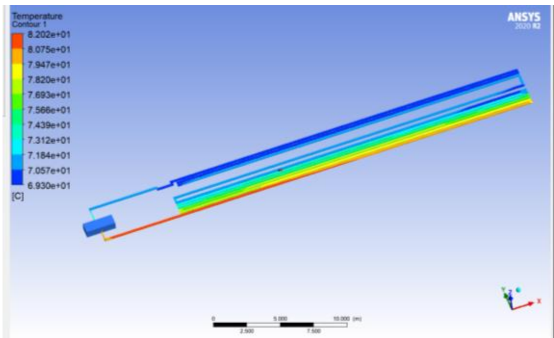

Figure 6. Variation 3 of the keel cooler

Fig. 6 shows the temperature results which can be seen from the results menu in the ansys simulation for the third variation. The figure is the main dimension of the length of the keel cooler with an inlet pipe of 37.85 m, the same pipe of 28 m and an outlet pipe of 31 m.

To calculate the Overall Logarithmic Mean Temperature Difference (ΔLMTD), since the values of the hot fluid inlet temperature to the keel cooler and the cold fluid temperature around the keel cooler are known from the analysis and simulation results in Ansys. Therefore, the value of ΔLMTD can be calculated using the following equation [5]:

ΔT1 = Thin – Tcout = (82°C – 31.1°C) = 50.9°C

ΔT2 = Thin – Tcin = (82°C – 30°C) = 52°C

Thus, the value of ΔLMTD is:

ΔLMTD = (ΔT1 - ΔT2) / ln (ΔT1/ΔT2) = 51.448°C

Table 2. Exit Fluid Temperature

Variation	*Power/Torque* (%)	th in (°C)	Sea water (°C)	Th out (°C)
I	100	82	30	51,730
II	100	82	30	65,311
III	100	82	30	71,405

Table 2 can be concluded that at the same power/torque and at the same inlet temperature and seawater temperature, the highest exit temperature value is 71.405°C and the lowest outlet temperature is 51.730°C.

Calculating Logarithmic Average Overall Temperature Difference

Because the temperature value of the hot fluid entering the keel cooler and the temperature value of the cold fluid around the keel cooler are known from the Ansys analysis and simulation results. So, the value of ΔLMTD can be calculated using the equation [6]:

ΔT1 = Thin – Tcout = (82°C – 31.1C) = 50.9C°°

ΔT2 = Thin – Tin = (82°C – 30C)° = 52°C

So, ValueΔLMTD namely:

ΔLMTD = (ΔT_1- ΔT2) / ln (ΔT1/ΔT2) = 51.448°C

Total heat transfer can be considered as a flow, which is the ratio of the thermal potential difference across the pipe to the thermal resistance of the pipe. Therefore, heat transfer can be calculated. To determine the total heat transfer in the keel cooler, it can be calculated as follows: Total heat transfer under power/torque conditions (100%)

Qtotal = ṁh x Cp x ΔT

ṁh = mass flow rate of the hot fluid = 7.794 kg/s

Cp = specific heat of the hot fluid (freshwater) = 4.2 kJ/kg°C ΔT = temperature difference between the inlet and outlet sides of the keel cooler = 16.688 °C

Thus, the value of Qtotal is obtained as 5.463 x 105W.

Table 3. Total Heat Transfers

Variations	power(%)	ṁh (kg/s)	Cp (kJ/kg°C)	ΔT (°C)	Qtotal (W)
I	100	7,794	4,2	30,269	9,910 x 105
II	100	7,794	4,2	16,688	5,463 x 105
III	100	7,794	4,2	10,594	3,468 x 105

Table 4. The Effectiveness of the keel cooler

Variations	power (%)	US (m2)	Utotal (W/m2°C)	NTU	Effectiveness (%)
I	100	308,388	145,163	1,616	80,138
II	100	253,988	145,168	1,608	79,985
III	100	199,588	145,176	1,604	79,910

From the table 3 & 4, it can be seen that the calculated results obtained according to the above NTU formula explain that the longer the dimensions of the keel cooler, the higher the effectiveness value obtained. The highest effectiveness value is 80.138%, and the lowest effectiveness value is 79.910%.

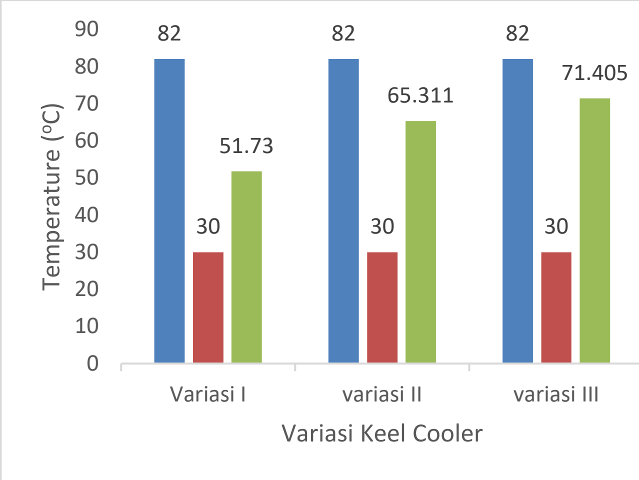

Figure 7. The Relationship Between Variations in Length Dimensions and Inlet and Outlet Fluid Temperatures

From Fig. 7 it is known that, the temperature value for the same power/torque in each variation of the length dimension experiences a change in the temperature of the exiting fluid. So it was found that the longer the dimensions of the keel cooler, the lower the Th out value produced.

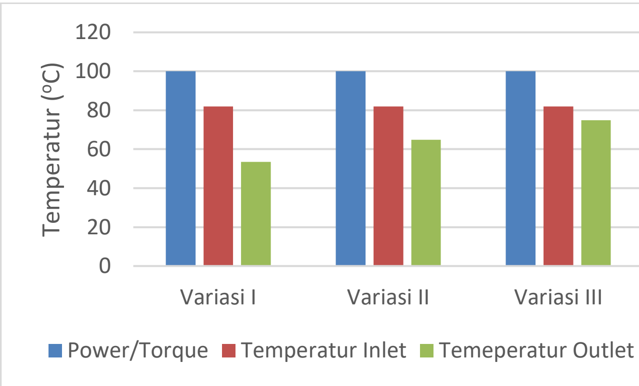

Figure 8. The Relationship Between Temperature and Length Dimensional Variations

From Fig. 8 it is known that the longer the dimensions of the keel cooler, the temperature value of the cooling fluid after passing through the keel cooler system will decrease. Where the highest temperature value is in variation III of 74.90 and the smallest value in the long dimension of variation II is 53.44.

Comparison of Analysis Results with CFD Simulations

After obtaining the results of the analysis, the next step is to compare them with the simulation results using the Ansys R20 software. With the comparison value of the outlet temperature for three variations of the long dimension of the keel cooler at 100% power/torque as follows:

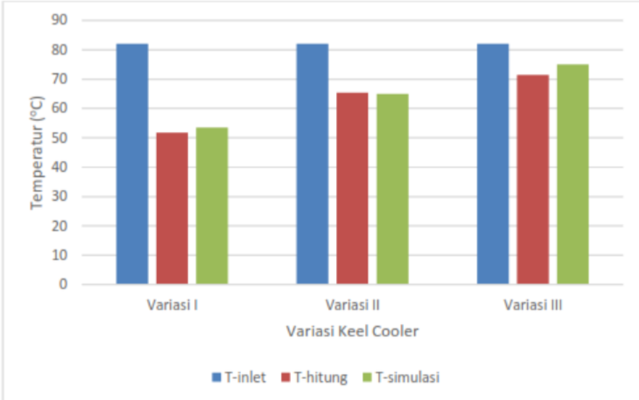

Figure 9. value after passing through the keel cooler

From the Fig. 9 above it is known that the temperature value after passing through the keel cooler has a very significant change. Comparison between the calculation of the analysis temperature value shows that there is only a slight difference with the simulated value. And it can be seen that both of them explained that the longer the dimensions of the keel cooler, the temperature value will decrease.

Mathematical Equations

- Heat Transfer By Conduction

$$qk = -kA\,\Delta T/L$$

Information:
qk = Heat Transfer Rate (kj/sec, W)
k = Thermal Conductivity (W/m.°C)
ΔT = Garden temperature in the direction of heat transfer (°C)
L = medium length (m)

- Heat Transfer By Convection

$$q = hA(\Delta LMTD)$$

Information :
Q = Heat Transfer Rate (kj/s or W)
h = Convection Heat Transfer Coefficient (W/$m2$. °C)
A = Surface Area of Heat Transfer ($ft2$, $m2$)
ΔLMTD = logarithmic mean overall temperature difference

- Average Temperature Difference

$$\Delta \text{TLMTD} = \frac{[(\text{Thin} - \text{Tcout}) - (\text{Thout} - \text{Tcin})]}{\ln [(\text{Thin} - \text{Tcout})/(\text{Thout} - \text{Tcin})}$$

Where :
Thin = Inlet hot fluid temperature (°C)
Thout = Hot fluid exit temperature (°C)
Tcin = Incoming cold fluid temperature (°C)
Tcout = Temperature of cold fluid coming out (°C)

- Flow in the Pipe

$$R_e = \frac{\rho \; x \; Vi \; x \; Di}{\mu}$$

Where:
Re = Reynolds number
P = Density of fluid (Kg/m3)
v = Fluid Velocity (m/s)
µ = Fluid dynamic viscosity (kg/ms)

- NTU Effectiveness Method

$$\text{NTU} = UAs \;/\; Cmin = UAs/(\dot{m}Cp)min$$

4. Conclusion

The total heat transfer value of the keel cooler at 100% power/torque conditions is 9,910 x 105 W. The longer the dimensions of the ship's keel cooler, the greater the total heat transfer generated. The optimum length dimension variation is obtained in variation I with a length of 53.85 m inlet pipe, 47 m outlet pipe and 44 m distribution pipe of 80.138%.

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