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Performance test of small fishing vessel refrigeration machine for fish storage

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Abstract

The refrigeration system in the fishing process is important for maintaining the quality of the catch. However, the design of small-scale refrigeration machines is still not common, so it is an interesting study. Therefore, this study aimed to evaluate the design of small-scale fishing vessel refrigeration machines. Field studies are needed in machine manufacturing to observe the components required to match the refrigeration machine components onboard fishing vessels. This uses a direct observation method to determine the components of the refrigeration machine on the ship. Furthermore, the performance of the machines produced will be tested through the load cooling process. Parameters determined in the performance test include monitoring temperature (suction and discharge), pressure (suction and discharge), evaporator temperature, load temperature, Coefficient of Performance (COP), and compressor power. Refrigerant temperature measurement uses an insulative principle so that ambient temperature does not affect it. The result is that the machine produced has a capacity of 35 ℓ or 15 kg of load. Meanwhile, in the performance test, the COP and electrical power generated while cooling the load for approximately 4 hours were 2.42 and 507 W, respectively. The results of this design were successful and did not experience failure. The significanceof this study can be used as a reference source for making cooling machines for storing the catch of small-scale fishermen.

Keywords:
COP, electrical power, refrigeration machine.

1 Introduction

The fishing process has several things that need to be considered, one of which is the quality of the fishermen's catch to increase the catch's economic value. To obtain quality catches, good handling is required. Storage is carried out to maintain the quality of the fish caught through freezing [1] . Refrigeration system technology [2] is used in this process. Implementing this technology requires a system to cool the cargo obtained on fishing boats [3] . However, the fact is that the thermal system in the refrigeration system on board consumes large amounts of energy, and a lot of it could be more effective because it is different from the capacity and use of energy required by the engine [4] . Therefore, the application of refrigeration system technology requires performance testing both on a small scale and on an accurate scale. The refrigeration system's performance must be evaluated in real-time to ensure efficiency is well-spent. The Coefficient of Performance (COP) is the ratio of the heat transfer rate to the evaporator and the input power of the compressor [5], which is important in designing a refrigeration machine.

Attention to the refrigeration system's performance must be carried out in real time because this lack of attention can fail to implement the refrigeration design. Performance evaluation studies on refrigeration systems are needed to detect failures quickly, although some failures from the analysis may not be detected through performance testing [6] . On the other hand, Bogadanovska [7] studied several causes of failure in refrigeration systems using refrigerators with various variables. The results show that failure can be detected through refrigeration testing. Most refrigeration machine failures occur due to refrigerant leaks and blockages. Therefore, performance testing is crucial in designing a cooling machine so that it does not fail. Machine design is one of the technological innovations to develop science and find solutions [8]. Many studies have been carried out on the design of refrigeration machines, such as Mathur [9], who designs and manufactures cylindrical chillers with a higher efficiency level than conventional chillers.Furthermore, Djetel-Gothe [10] designed, manufactured, and tested a beta Stirling cooling engine that improves performance in moderate-temperature applications. Goenaga et al. [11] designed a refrigeration system to optimize the space for compact refrigeration machines, resulting in high COP characteristics and low compression ratios. From these various studies, efforts to increase the effectiveness of cooling machines have been developed, making this topic interesting for further research.

Although many studies on the design of refrigeration machines and their performance measurements have yet to be carried out, studies focus on the design of cooling machines for fishing vessel fishermen. Even though the cooling system for the catch of many fishing vessels uses holds[12], it is still necessary to manufacture a cooling machine to store catches on a small scale. This research aims to evaluate the design of a small-scale fishing vessel refrigeration machine for storing catches. This research discusses the design and performance of a refrigeration system designed and built to make it easier for people to design and produce cooling machines on a smaller scale. The significance of this research is scientific development, especially in developing refrigeration machines as a tool for small fishermen to improve the quality of fish catches.

2 Materials and Methods

2.1 Design Process

This research began by surveying fishing vessel's existing cooling systems for fish catch cooling. The survey process was carried out through interviews and observations to understand the comparative scale of the refrigeration process and the working structure of the refrigeration machine components on board. This survey activity aims to ensure that the machines in the field and the laboratory-scale prototypes to be designed are the same. The next step is to design a cooling system based on the cooling work processes identified on board. The components that have been identified during the survey will be described and discussed. Fig. 1illustrates a schematic of the refrigeration machine design process that has been carried out. Various components used in this design include compressors, condensers, evaporators, expansion valves, thermometers, and pressure gauges. These components will be designed in such a way as to simulate field conditions. This design aims to modify the cool box to function as a refrigeration machine with a capacity of 15 kg.

2.2 Fabrication Process

The fabrication process uses a design process based on available specifications. The fabrication process is carried out by considering the pipe material's properties and the pipe's geometry so that the machine can be used. A copper pipe will later connect the assembly of these components. The placement of the thermometer is expected to produce temperature information in areas that have been determined. In contrast, a pressure gauge measures the pressure on the suction and discharge. This fabrication process will determine the bill of material and the manufacturing process level.

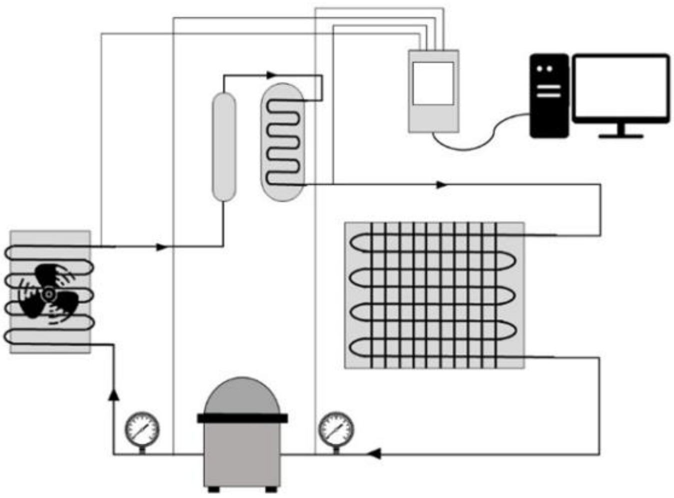


Fig. 1. Schematic of design refrigeration machine.

2.3 Refrigeration Performance Testing

Performance testing is carried out after the cooling machine can work normally. The refrigerant used is R134a. The use of refrigerant is intended to make it easier to analyze. In addition, the use of refrigerant is based on several components used. The test begins with checking the temperature using a thermocouple. A thermocouple for measuring refrigerant in a refrigeration machine uses a 4-channel thermocouple with a K-type data logger with the TASI TA612C brand. In contrast, they are measuring the air temperature in the evaporator container using a 2-channel thermocouple branded Benetech GM 1312. Refrigerant temperature measurements were carried out at 4 predetermined points. Then the point is divided into 2 regions as the basis for COP calculations. While measuring the temperature of the roar of the evaporator is carried out on 2 sides. Then the measurements were averaged. The workpiece/refrigeration load uses 2 kg of water as a simulation load measurement using product temperature measurement using a thermometer gun with a radius of approximately 30cm. The pressure is then measured with a Bourdon-type pressure gauge. Pressure measurement uses 2 points called low pressure and high pressure. Furthermore, current and compressor pressure measurements were carried out using ampere pliers with the Uni-T UT201 brand. Then the data is processed to get the COP value by comparing the output current. Assumptions are needed in modeling the COP calculation of a refrigeration machine [13] . Based on Moller analysis for refrigeration using compressor parameters. Based on this, the rate of heat released, and the capacity of the cooling machine can be calculated by Eq. 1 [14].

$$Q_{evap} = \dot{m} \cdot (h_4 - h_1) \quad (1)$$

Where Q_{evap} is the cooling capacity of the evaporator in kW, while $\dot{m}$ is the mass flow rate of the refrigerant at level 1 in kg/s; h_4 is the enthalpy value at the evaporator output, and h_1 is the enthalpy value at the compressor input. Work input on the compressor can be given in Eq. 2 [15].

$$W_{comp} = \dot{m}_1 \cdot (h_2 - h_1) (2)$$

Where W_{comp} is the compressor power input in kW and h_2 is the enthalpy value at the compressor input. The coefficient of performance or COP of the cooling machine is calculated in Eq. 3.

$$COP = \frac{rate\ of\ heat\ removal(Q_{evap})}{compressor\ work\ input(W_{comp})} \quad (3)$$

The cooling capacity of the refrigeration machine can be determined using Eq. 1 with the mass flow rate and enthalpy at the compressor input and evaporator output. Then use the refrigerant mass flow rate and the enthalpy value of the compressor input and compressor output in Eq. 2 to calculate the work done by the compressor. To measure the work of the compressor can be replaced with the power equation on electricity. This is because the compressor uses electric power as the driving force for the work. Compressor power calculation can use Eq. 4 [16], [17].

$$W_{comp} = V \,.\, I (4)$$

Where W_{comp} is the input power of the compressor kW, V is the result of measuring the electric voltage of the compressor working in the form of V, and I is the result of measuring the electric current in the compressor in the form of A.

3 Results and Discussion

3.1 Refrigeration Machine Manufacturing Process

The refrigeration machine was designed based on observations from several fishing vessel components at TanjungBalaiAsahan, North Sumatra, Indonesia. The refrigeration machine's main components, from the observations on fishing vessels, are the compressor, evaporator, expansion valve, and condenser. The main component of the refrigeration machine is an important component so that the cooling machine can operate[18], [19]. The results of the input of the main components will then be designed as a laboratory-scale prototype using components on the market. The compressor used is a hermetic compressor with a capacity of ½ HP. In comparison, the evaporator used on the ship uses a bare tube type which can store about 4-5 tons of catch. Meanwhile, the design of the evaporator is made by bending the copper pipe to surround the wall of the coolbox pad. A coolbox on the evaporator uses a capacity of 35ℓ, accommodating up to 5kg of load. The following design is to maintain the temperature conditions inside the evaporator; an aluminum plate is needed, which is attached to the surface wall of the evaporator. The use of expansion valves in the manufacturing process is replaced with filter drier components and capillary pipes. Furthermore, the condenser used adjusts to the compressor's capacity. The results of the comparison between the components on board and the manufacturing process are shown in Table 1. The refrigeration machine that has been made can accommodate a range of 35ℓ or around 15 kg.

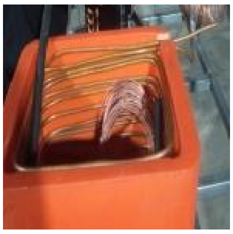
Table 2 shows the specifications for the refrigeration machines that have been fabrication. Fig. 2 shows the fabrication results of the refrigeration machine with the specified criteria.

3.2 Refrigeration Machine Performance Test

The cooling machine performance test uses water loading to be made into ice cubes. The test uses refrigerant type R-134a with an optimum mass of 0.2 kg. The performance test results were carried out in the range of 4 hours with the parametric water completely frozen. Fig. 3 displays the results of temperature measurements on the refrigerant temperature in the suction and discharge, the temperature of the evaporator room, and the temperature of the test object used. Based on the results, the temperature of the refrigerant in the suction and discharge during the freezing process has a constant trend. The constant trend has an average value of refrigerant temperature at the suction of -9.29^{o}C. While the temperature value of the refrigerant on the discharge condenser of 59.78^{o}C. The constant trend value of the refrigerant temperature at suction and discharge indicates that the refrigerant shows no leakage in the refrigeration system used. In comparison, the evaporator temperature has a decreasing trend until the 90thminute.

After that, the temperature will experience a gentle slope or a constant value. Likewise, the temperature of the test object will decrease until the 90th minute, and after that, it will experience a constant trend. The decrease in temperature to a constant temperature is called chilling time [20], [21]. In this study, at one time, the freezing process experienced 1-time cut-off at temperature.

Table 1. Comparison of refrigeration components in fishing vessel and prototype

Part	Picture in fishing vessel	Design picture	Explanation
Compressor			1. The difference in capacity of the compressor on board with the prototype 2. Differences in specifications of each compressor 3. The use of compressors on ships used in a large enough cooling capacity
Evaporator			The different types of pipes used on ships and coolbox
Expansion valve			The ship's refrigeration system uses an expansion valve, while the prototype uses a capillary tube
Condensor			The ship condenser uses a shell and tube type with seawater cooling, while the prototype uses wind as a coolant

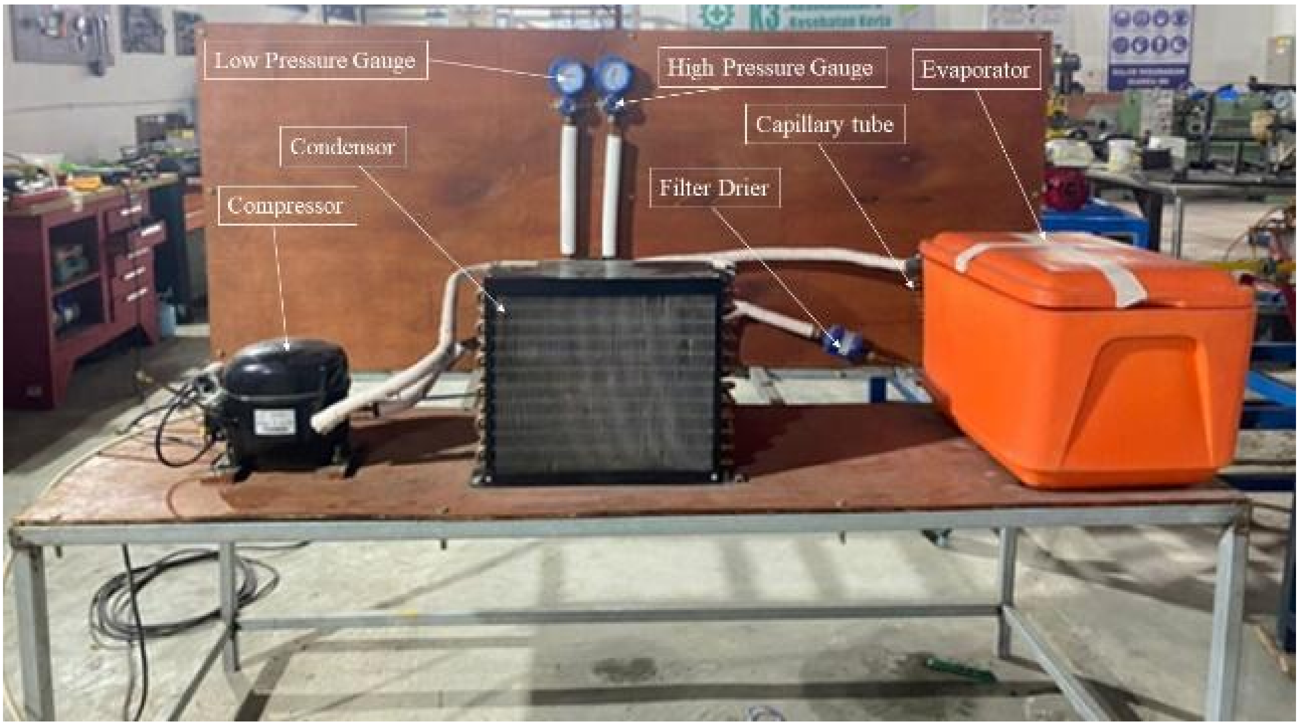


Fig. 2. Refrigeration machine unit.

Table 2. Specification of refrigeration machine

Part	Material	Specification	
Compressor	Metal alloy	Power	: ½ HP
		Frequency	: 50 Hz
		Refrigerant type	: R134a
		Voltage	: 220-240 V
Condensor	Metal alloy	Power	: 1 HP
		Elbow	: 18 u
Pipe	Copper alloy	Lenght	: 30 m
		Diameter	: 5/16 inch
Filter drier	Metal alloy	Diameter inlet & outlet	: 3/8 inch
Capiler	Copper alloy	Dimension	: 0.054”×0.106×30 m
Coolbox	Polimer	Dimension	: 53×32×39 cm
		Capacity	: 35ℓ

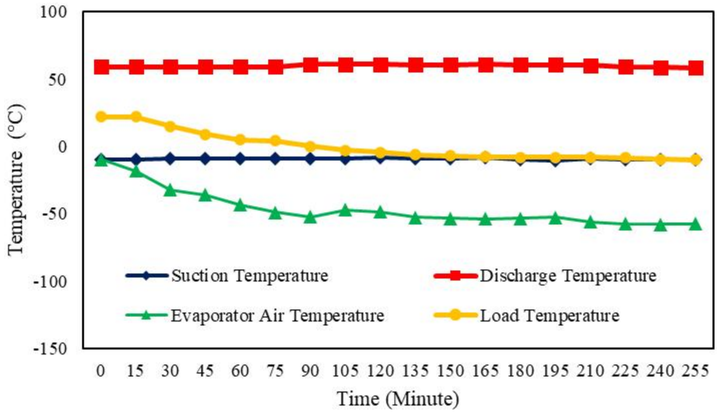


Fig. 3. Measurement of temperature in 4 point.

Discharge and suction pressures influence the product cooling process [22] . The results of the pressure measurement obtained based on the resulting cooling time can be shown in Fig. 4. Based on the figure, the values for the suction and discharge pressures have a constant value. The discharge pressure has an average pressure of 12.86 bar, while the suction pressure averages 1.013 bar. The results of this pressure test are used as a basis for the refrigeration system not experiencing failure or leakage. This is because the pressure during the cooling process does not increase or decrease. So, it can be said that the system is running well.

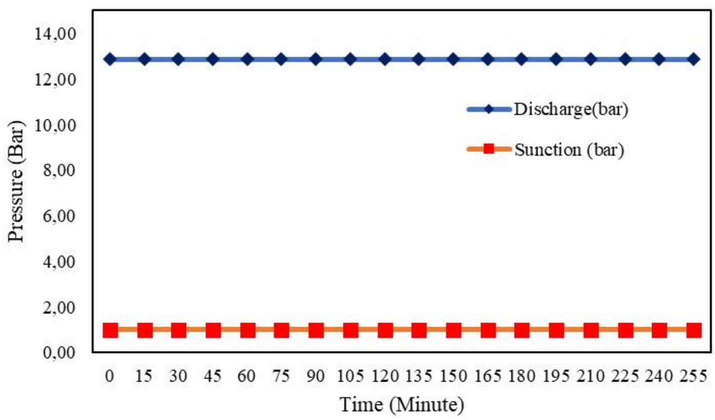


Fig. 4. Measurement of pressure in refrigeration machine.

Fig. 4 shows the COP results of the cooling machine during the cooling process. The results of the COP calculation on the cooling machine obtained the highest and lowest COP values, namely 2.49 and 2.29.Judging from the graph from the cooler's beginning to the cooling's end, the COP obtained tends to be constant but has 2 valleys at 90 and 195 minutes. This situation is due to the condition of the evaporator temperature, which decreased at that time. This is the same as the research of Susila et al. [23] . The average COP produced by this cooling machine during the load-cooling process is 2.42. The electric power generated by the cooling machine's performance against the cooling time can be seen in Fig. 4. Based on testing, the value of electric power is more likely to be dynamic. However, in the first 15 minutes, the resulting power increased. This is due to the small compression ratio in the compressor. However, it will experience constant [23]. However, in this study, it was seen that at 60, 75, 90, and 120 minutes, there was a decrease. This is because the compression in the compressor is not maximal. The average power required for this cooling machine during the load-cooling process is 507 W (Fig. 5).

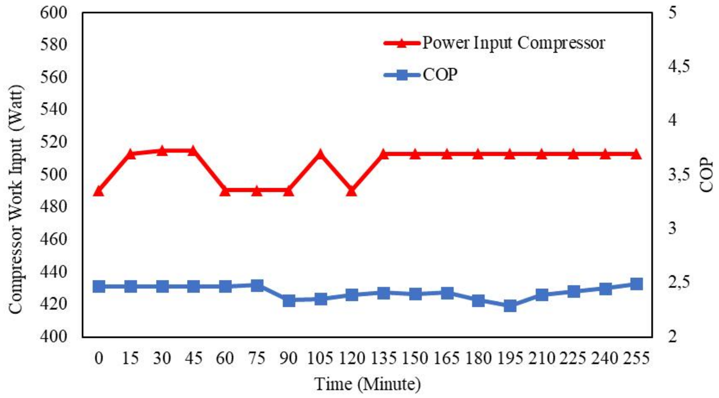


Fig. 5. COP and Power Input Compressor vs Time colling of load in machine refrigeration.

4 Conclusion

This study discusses designing and constructing small-scale fishing boat cooling machines for catches. Based on the discussion results, small-scale refrigeration machines can be manufactured to produce refrigeration machines with a capacity of 35ℓ or 15kg with R134a refrigerant and ½ HP compressor and 18u condenser specifications. These results are supported by performance testing by looking at the temperature and pressure on the suction and discharge, which have no leaks. Furthermore, for COP and electrical power generated during cooling, the load lasts approximately 4 hours to get a value of 2,42 and 507 W, respectively. Overall cooling machines can be made to impact fish production in the sea on a small scale. The recommendation of this research is to carry out further research on using other liquid refrigerants and variations of capillary pipes to improve the performance of this small-scale refrigeration machine.

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