Performance Evaluation of Compressor Valves In The Food Refrigeration System Onboard Kl.02 Sultan Hasanuddin

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Abstract. This study aims to evaluate the performance of compressor valves in the food refrigeration system on board KL. 02 Sultan Hasanuddin. The background of this research is based on the frequent damage to compressor valves, which results in decreased cooling system efficiency, making it difficult to maintain the ideal temperature for food storage. This condition can affect the quality of food during the voyage. The study focuses on analyzing the changes in performance before and after valve failure, to provide better maintenance recommendations.

The research method used is qualitative descriptive with a case study approach. Data was collected through direct observation on board the ship, logbook documentation, and testing using regression techniques. This study evaluates various operational variables of the compressor, such as RPM, refrigerant flow volume, pressure, and temperature, before and after the valve failure.

The research results show a significant decline in several operational variables after the damage. The average compressor RPM decreased from 1,282.50 to 943.83, while the refrigerant flow volume dropped from 0.4136 m3/min to 0.3044 m3/min. Additionally, the outlet pressure decreased from 17.33 bar to 15.367 bar. Degradation of the valve surface and the breaking of the flexing valve were found to be the main factors affecting the cooling system's performance. Based on these results, it is concluded that damage to the compressor valves and the breaking of the flexing valve have a direct impact on the stability and efficiency of the food refrigeration system. Therefore, routine maintenance and periodic inspections of the valve conditions are essential to ensure the cooling system functions optimally.

Keywords: Compressor Valve, Refrigeration System, Performance, KL. 02 Sultan Hasanuddin, Flexing Valve

1 Introduction

During operation, it was found that the food refrigeration system could operate normally, but temperature issues, such as not being able to lower the temperature to the set value within the specified time, were encountered. The cooling effect could not meet

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the operational standard requirements for two reasons: one was that the heat load of the cold storage was too large, and the other was that the cooling capacity was insufficient. However, there could be many reasons for errors in these two aspects, which need to be addressed one by one, a process that is very time-consuming and requires significant effort to fix. (Li et al., 2021)

The vapor compression cycle is influenced by several factors, including enthalpy, compressor capacity, refrigerant mass flow rate, and cooling heat flow rate. The refrigerant mass flow rate is determined by the electrical power, where the electrical power is equal to the compressor capacity. The higher the electrical power, the greater the refrigerant mass flow rate. The capacity of the condenser and the capacity of the cooling liquid heat flow (evaporator capacity) are determined by the refrigerant mass flow rate. The greater the mass flow rate, the greater the capacity of the condenser and evaporator. The COP (Coefficient Of Performance) is the ratio of the enthalpy change in the evaporator to the enthalpy change in the compressor. The COP increases as the enthalpy change in the evaporator increases. There are many aspects that must always be considered in the maintenance of refrigeration on ships to ensure they continue to operate efficiently (Erita et al., 2021).

The vapor compression refrigeration system can be used to diagnose faults based on the pH diagram. Eight common fault scenarios were applied to the refrigeration system, and the results were discussed in the context of potential faults in a basic refrigeration system. The eight faults can be easily observed as they cause changes in the pH diagram and the system's performance parameters. It was found that these changes vary depending on the type of expansion valve used, accessories, ambient temperature, and the degree of fault within the refrigeration system (Kocyigit et al., 2014).

The causes of failure and their impact on refrigeration units in fishing vessels help identify high-risk components and potential failures. High-risk factors arise from hazards associated with component failure, frequent failure modes, and the absence of early warning indicators. For example, although the leather seal in the compressor has a high severity when it fails, its occurrence rate is low, and it is easily detectable, resulting in a low Risk Priority Number (RPN). Using the FMEA (Failure Mode and Effect Analysis) approach, critical components identified in the refrigeration system included the accumulator (RPN: 180), condenser (RPN: 144 and 128), evaporator (RPN: 135), and oil separator (RPN: 112).

2 Literature Review

Refrigeration has created a device known as the refrigerator. The food cooling machine functions to lower the temperature of food items, maintaining their freshness without reducing quality. This device ensures that food remains in good and consistently fresh condition. (Burylov et al., 2023)

Previous research conducted by Barlylov et al. showed that damage to compressor valves can lead to a decrease in cooling system efficiency, especially if the valve is not functioning properly. According to Burylov et al. (2023), the compressor valve plays a crucial role in maintaining system pressure. Meanwhile, research by Wang et al. (2022)

highlighted the importance of early detection of compressor damage through routine monitoring.

Another study conducted by Effendi (2022) showed that the instability of the food refrigeration system in maintaining its performance was caused by unstable temperatures in the Refrigerated Cargo container and low compression pressure in the refrigeration system. Effendi et al.'s research concluded that the problem could be solved by replacing the expansion valve, changing the lubricating oil and refrigerant, and replacing the intake and discharge valves on the compressor to restore its performance and prevent damage to the cargo in the refrigerated container on board (Effendi et al., 2022). However, this current study identifies a specific issue— the instability of the food refrigeration system is more likely caused by damage to the Flexing Valve on the KL.02 Sultan Hasanuddin vessel, which was not identified in the previous research.

3 Research Method

This study uses a qualitative descriptive approach with case study analysis. Data was obtained through direct observation on board the ship, refrigerant pressure testing, and log book documentation. Data processing was carried out using the regression method to observe the differences in performance before and after the valve failure occurred.

4 Results and Discussion

In a ship's cooling system, the compressor acts as the 'heart' that circulates the refrigerant throughout the system. The compressor's performance is highly dependent on two important valves: the suction valve and the discharge valve. If either of these valves fails, the refrigerant pressure in the cooling system will decrease, resulting in temperature instability in the food storage.

Key Findings:

Pressure Drop in the Discharge Valve. The damage to the compressor's discharge valve caused a pressure drop from the expected 17 bars to 14–15 bars. This reduction in pressure resulted in decreased refrigerant flow capacity, leading to an increase in temperature in the food storage area. As a result, the temperature became suboptimal, affecting the storage conditions of perishable goods.

Damage to the Flexing Valve. The flexing valve, a main component of the discharge valve, was found to be broken and degraded. The uneven valve surface caused minor refrigerant leakage, which reduced the compressor's efficiency.

Impact on Storage Temperature. Data showed that before the damage, the temperature in the food storage area remained stable at -20°C for meat and fish storage. After the valve damage, the temperature increased to -12°C, potentially causing food spoilage.

Impact on Compressor Operating Frequency. The valve damage caused the compressor to work harder, with an increased operating frequency to maintain the ideal temperature. *This led to greater wear and tear on other components in the cooling system.*

Table 1. Compressor Performance Data Table

Time	Compressor RPM	Refrigerant Flow Volume (m^3/min)	Refrigerant pressure (Bar)	Refrigerant Temperature (°C)	Room Temperature (°C)
00-04	**1,362**	**0.4392**	In: 7	Out: 17.3	In: -11
04-08	**1,340**	**0.4322**	In: 6	Out: 17.2	In: -11
08-12	**1,319**	**0.4252**	In: 7	Out: 17.1	In: -11
12-16	**1,275**	**0.4113**	**In: 8	Out: 16.9**	** In: -10
16-20	**1,210**	**0.3904**	**In: 9	Out: 16.6**	** In: -10
20-00	*1,189*	*0.3834*	**In: 10	Out: 16.5**	** In: -10

Table Interpretation:

1. The data above shows that during the 12:00-16:00 and 20:00-00:00 shifts, there was a significant decrease in compressor RPM and refrigerant flow volume, which led to a drop in the food storage room temperature. The refrigerant pressure also dropped on the output side, indicating that the cooling system's capacity was reduced.
2. When the compressor valve was functioning properly, the pressure remained stable at 17 Bar, and the storage room temperature was between -18°C and -20°C (the ideal temperature for storing meat and fish). However, after the valve malfunctioned, the room temperature increased to -12°C, well above the safe limit for storing frozen food.

Simulating the Impact of Valve Damage on System Performance. Using simulation data, the following outlines the long-term impact of valve damage on the cooling system's performance

Table 2. Simulation Data Before and After Repair.

Parameter	Before the Damage	After Damage	After the Repair
Pressure Discharge (Bar)	17.3	14.5	17.5
Pressure Suction (Bar)	7	6	7
Compressor RPM	1,362	1,189	1,370
Refrigerant Flow Volume (m^3/min)	0.4392	0.3834	0.4450
Storage Room Temperature (°C)	-20	-12	-20

Simulation Analysis:

1. Refrigerant Pressure: After the valve malfunction, the discharge pressure dropped by around 15%, indicating that the refrigerant could not flow properly, leading to an inability to maintain the optimal storage temperature.
2. RPM and Refrigerant Flow: The compressor operated at a lower RPM during the malfunction due to leakage in the valve. After the repair, the refrigerant flow returned to normal, and the refrigerant pressure was restored.
3. Storage Room Temperature: When the valve was not functioning correctly, the storage room temperature increased to -12°C, which is far from the ideal conditions required to maintain the quality of frozen food.

5 Conclusion

The damage to the compressor valve, particularly the flexing valve, has a direct impact on the decreased performance of the cooling system. This causes the compressor to fail in maintaining optimal refrigerant pressure, which ultimately leads to the system's inability to keep the food storage room at a safe temperature. To prevent further damage, routine maintenance and periodic valve replacement are essential, especially for critical components like the flexing valve. The use of pressure and temperature monitoring technology can also assist in early detection of potential failures.

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