Comparison of parallel evaporator distribution models in ice cream rolling machines

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Abstract. This research was conducted to determine the effect of performance on the use of the parallel distribution evaporator on the ice cream roll machine. This research was made using 3 variations of parallel distribution evaporator model, in which the model has a different shape. Model 1 has 3 inputs and 3 outputs, Model 2 has 2 inputs and 2 outputs and Model 3 has 1 input and 1 output. The evaporator is made with a size of 45 cm x 40 cm x 4 cm from stainless steel thickness 0.3 mm so that most of the products produce crystallization then it needs to be set points at a temperature of -18°C. the effect of the superheat process, where the smaller the superheat that occurs, the temperature in the evaporator can be more stable. Based on the results of the testing that has been done, the COP system's work performance is 4.3, 3.6, and 3.4 for each evaporator model. Efficiencies generated respectively for the evaporator model of 86%, 78%, and 76%.

1. Introduction
In this modern era, the development of science and technology is very rapid, not only centered on one field, almost all fields follow its development. One of them is the development of refrigeration systems. The most widely used refrigeration system is the steam compression refrigeration system. Refrigeration itself has many applications including domestic refrigeration, commercial refrigeration, industrial refrigeration, transportation refrigeration, and others. In Indonesia itself, the use of cooling machines will become more widespread because we know that our country has a tropical climate (heat) so many people need food that can help the body's condition in dealing with daily activities where one of them is ice cream [1].

This type of variant is very popular with not only children but adults also like to consume it. The type of ice cream consumed is usually in the form of topping. In the present study, the type of ice cream that will be developed is the type of fried ice cream roll. Where fried ice cream is fried ice cream dough on a refrigerated container, the common name used by the industrial maker is usually fried ice cream [2].

This machine is considered inefficient because it still requires a relatively long time, judging by these conditions the researchers conducted experiments by varying the squid evaporator distribution on the ice cream roll machine. By utilizing the superheat process on the evaporator and the addition of secondary fluid, it is expected to be able to handle this and be considered more effective and can be seen what models produce the best performance and energy consumption [3].

The influence of time on the lowest temperature decrease is obtained by a single-chamber series evaporator type, which is 21.2 °C. The speed of temperature reduction in the type one-chamber series...
The evaporator is due to the series evaporator uses two evaporators to cool one small chamber and all refrigerants are used in full so that the upper evaporator can be cooled faster. Then the highest compression work is obtained in one-chamber series evaporator testing 64,385 kJ / kg, this is due to the type of channel series evaporator that must be passed longer [4].

Research shows that the value of Coefficient Of Performance(COP) for parallel evaporator types (with boundaries and without borders) is better than that of series evaporators (with borders and without borders), single-chamber parallel evaporator types can increase COP by 1.17% greater than COP type one chamber series and two-chamber parallel by 1.49% larger than the two-chamber series, the cause is in the parallel evaporator to cool the upper chamber and the lower chamber the time for the incoming refrigerant is almost the same (shorter route) so that the compression work is lower, and if the compression work is low then it results in a better COP value [5].

Another cooling machine research was carried out using a multi evaporator. This research involves components in the form of multi evaporators, two expansion valves, one compressor, a condenser, a heat exchanger, and a solenoid valve that is connected with the refrigerant flow to the freezer and fresh food evaporator. The results in the work cycle in the series obtained an increase in efficiency of 8.5% [6].

By seeing the problems that have been described, this study was conducted to know the effect of the parallel distribution evaporator model on the performance of the ice cream roll machine.

2. Steam compression refrigeration cycle

The cooling process is essentially a process of transferring heat energy contained in the room. Where this is under the law of conservation of energy, we cannot eliminate energy but can only move it from one substance to another. To transfer the heat energy of the room, a heat exchange fluid called a refrigerant is needed.

A gas or steam compression system is a refrigeration machine that contains a continuous fluid-exchanging fluid (refrigerant). During circulating in the unit, the refrigerant will always change shape from gas to liquid and back to gas. The process takes place at different temperatures and pressures, namely high pressure and low pressure. High pressure is obtained because of the compression effect, which is done by the compressor. Therefore, this refrigeration system is commonly referred to as a gas or steam compression system.

The process or cycle in a steam compression refrigeration machine includes four main processes namely compression, condensation, expansion and evaporation. All four processes occur repeatedly accompanied by changes in the refrigerant phase from steam to liquid and vice versa. This process is also accompanied by absorption of heat from the environment by the evaporator and the removal of environmental heat by the condenser. Here is a diagram of a steam compression refrigeration system [7,8].

![Diagram of a refrigeration system](image)

**Figure 1.** Schematic of a refrigeration system [7,8].

In the compressor, the refrigerant vapor is compressed, so that when it exits the compressor, the refrigerant vapor will become high pressure and high temperature. Then the refrigerant vapor is flowed into the condenser through a discharge channel (discharge).
In the condenser, the steam will release heat, so that there is a phase change from steam to liquid (condensed). High pressure refrigerant liquid expands on the expansion valve. So out of the expansion valve the pressure and temperature change to low. The working fluid at that time becomes a saturated liquid so that it can absorb heat from the surrounding air and heat absorption results in a phase change from liquid to vapor. This process takes place at the evaporator. Then the refrigerant vapor will be sucked by the compressor and so on where these processes repeat themselves. The processes that occur in the vapor compression refrigeration cycle as in Figure 2. above are as follows:

2.1. Compression process (1-2)
This process is carried out by a compressor and isentropically carried out.

\[ W_k = \dot{m}(h_2 - h_1) \] (1)

2.2. Condensation process (2-3)
High-pressure refrigerants and high temperature from the compressor will remove the heat so that the phase turns to liquid. This process takes place in the condenser.

\[ Q_H = \dot{m}(h_2 - h_3) \] (2)

2.3. Expansion process (3-4)
This expansion process is isenthalpic. This means there is no change in enthalpy but a pressure drop and a decrease in temperature, or can be written as:

\[ h_3 = h_4 \] (3)

2.4. Evaporation process (4-1)
This process takes place isobaric (constant pressure) inside the evaporator.

\[ Q_L = \dot{m}(h_4 - h_1) \] (4)

Work ability / system performance
The capability of a refrigeration system is expressed by a quantity called Coefficency of Performance (COP). To find out the value of COP, use the equation:

Refrigeration of effect, (kJ/kg), \( RE = h_1 - h_4 \)

Compressor work, (kJ/kg), \( W_k = h_2 - h_1 \)

\[ COP_{actual} = \frac{RE}{W_k} = \frac{h_1 - h_4}{h_2 - h_1} \] (5)

\[ COP_{carnot} = \frac{T_L}{(T_H - T_L)} \] (6)

Efficiency = \( \frac{COP_{actual}}{COP_{carnot}} \times 100\% \) (7)
3. Method

In conducting research the method used is to directly compare the parallel distribution evaporator model as shown in Figure 3 below:

![Figure 3. Pipe diagrams.](image)

4. Results

Based on the results of research that has been done, the performance of the refrigeration system on ice cream roll machine in terms of COP's performance can be seen in Figure 4, the graph shows the comparison of COP on each evaporator model. The highest COP performance value of the three models is model 1 which is an average of 3.697 because this model has 3 inputs and 3 outputs where this model has a maximum superheat so that heat absorption from the media it cools is better and more evenly distributed. Whereas in model 2 and model 3 the COP performance value is lower that is an average of 2.564 this model has 1 input and 1 output or conventional type evaporator where this type of model does not or has a small superheat.

![Figure 4. COP performance.](image)
In Figure 5 shows the performance results of the highest efficiency variation of the evaporator model in the application of ice cream roll machines using model 1 that is an average of 68%, model 1 is a type of evaporator with 3 inputs and 3 outputs it gives a better superheat effect compared to 2 other models. Where superheat one of its functions is to produce a greater cooling effect. While in model 2 and model 3 have lower performance values, namely an average of 62.20% and 61.79%, this is because the ability of advanced heating (superheat) is less than the maximum.

In Figure 6 shows the performance of the Evaporator on the ice cream roll machine using model 1 has a higher performance that is an average of 0.782 kW compared to model 2 and model 3 the average performance value of 0.718 kW and 0.726 kW this is due to the presence of heat absorption more optimal in the distribution of fluid flow in the evaporator.

In Figure 7 shows the condenser performance ability to release heat in a greater environment show by using model 1 and model 2, both models use a parallel distribution with an average value of 0.983 kW and 0.982 kW and 0.968 kW for the ability of model 3 using conventional evaporator types.
5. Conclusions
Based on the results of data collection and processing can be concluded as follows:

a. The performance of 3 variations of the parallel distribution evaporator model on the ice roll machine obtained by model 1 has a better performance that is equal to COP 3.695 efficiency value 68.02%. The ability of heat absorption is 0.78 kW and the ability to release heat is 0.983 kW.

b. The variation of the parallel distribution evaporator model will have a better impact on the system.

c. Evaporator model 1 is faster for making ice cream roll compared to evaporator model 2 input and 2 output and compared to conventional type evaporator model.

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