Application of Shell and Tube Model Condenser on Alcohol Content on the Arak Distillation Prototype Equipment

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Abstract: The process of making Balinese wine using a coconut sap distillation tool (*tuak*) into arak still uses the traditional way with firewood, through a heating and cooling process of sap steam which is heated so that it becomes arak with an alcohol content. The research method is the application of a shell and tube condenser model in a distillation apparatus, where the condenser cooling water is circulated through a tube using cooling water from the reservoir tube to release heat into the atmosphere. The results of the study at a reactor tube temperature of 80°C, a condenser temperature of 40°C with an alcohol content of 25%, and a reactor tube temperature of 85°C, a condenser temperature of 35°C with an alcohol content of 48%, and a reactor tube temperature of 90°C, condenser temperature 35°C alcohol content of 46%. The highest alcohol content of the distillation apparatus is 48% and the lowest alcohol content is 25%, while the volume of alcohol produced increases with each heating of the reactor tube, this is influenced by the heating rate of the reactor tube and the cooling temperature of the shell and tube condenser.

1 INTRODUCTION

Balinese wine is made by distillation from coconut sap through a heating process and condensation of the juice vapor which triggers the process of producing alcohol with alcohol content. The tool for distilling coconut sap into arak is still using the traditional method with firewood.

The condenser is a very important cooling component that functions to maximize the efficiency of the cooler. In general, using a surface type condenser (surface condenser), this type of condenser is a shell-tube type in which cooling water is circulated through the tube. Condensers usually use circulating cooling water from the cooling tower to release heat to the atmosphere, or once-through water from the reservoir tube. (Ratnawati et al.,2018)

Shell and tube type heat exchangers are the most widely used heat exchangers in various industries and the simplest compared to other heat exchangers, this is because:

a. It only consists of a tube and a shell, where the tube is located concentrically inside the shell.
b. Ability to work in high pressure and temperature.
c. Its ability to be used on one large volume stream.
d. Its ability to work with working fluids that have a large volume flow difference.
e. Available in various materials or materials.
f. Sturdy and safe construction.
g. Mechanically can operate properly and reliably (high reliability).
h. Tube is called shell side (Budi et al.,2018)

Arak Bali is one of the two types of traditional Balinese drinks that are popular and favored by young and old people. Besides drinking wine, it is also commonly used as a means of offering in Hindu religious ceremonies in Bali. Arak is a type of fermented liquor containing 37%-60% alcohol (ethyl alcohol) which has been known in Bali since ancient times. Arak is generally made from palm wine by distillation. Arak is divided into several grades of alcohol content. For class one, the alcohol content is between 35 and 40 percent, for class two the alcohol content is 30 percent, while for class 3 the alcohol content is 25 percent. (Kadek et al.,2020)

The distillation method is usually taken if you want to increase the alcohol content in the previous fermented product which after being distilled to separate the ethanol from the ethanol mixture, the

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levels increase to a minimum of 29% and a maximum of 50%, distillation is the easiest and most efficient way to operate a solution consisting of components - components with different boiling temperatures (Ratnaningtyas et al.,2017)

Through research on the application of shell and tube condensers in wine distillation equipment, it is hoped that this can be one of the innovations in developing appropriate technology to support home industries, especially wine distillation.

2 RESEARCH METHOD

This research includes experimental research through testing the shell and tube condenser distillation apparatus with a reactor tube heater using an LPG stove. Before carrying out the test (distillation process), the coconut sap was treated with the sample material by fermentation for 8 hours, so that the sap / raw material for the sample to be tested included good quality sap. Furthermore, testing was carried out on the distilled wine to obtain the alcohol content.

2.1 Distillation Equipment Test

1. Setting the heating temperature on the reactor tube with a Solenoid Valve Gas to regulate the flame of the stove in order to get the desired temperature in the reactor tube so that the temperature of the palm wine heating can be adjusted and equipped with a temperature detection device (thermo-couple) to determine the temperature rate in the process of heating palm wine in the reactor tube.
2. Setting the temperature of the cooling water in the shell and tube condenser tube which distributes the steam from the heating of palm wine in the reactor tube to the condenser tube, to control the cooling water, a Solenoid valve is installed. so that the water temperature can be controlled.
3. Measurement of the percentage of alcohol content. To get the alcohol content in the distillation apparatus using an Alcoholmeter measuring instrument, in this test using palm wine fermentation for 8 hours at a heating temperature of 80°C, 85°C and 90°C reactor tubes and shell and tube condenser cooling temperatures of 30°C, 35°C and 40°C

2.2 Alcohol Level

The instrument used to measure alcohol content is an alcoholmeter. Measurement of alcohol content was carried out after each distillation and the measurement was stopped when the measured alcohol content was 90% (alcohol content according to ASTM for liquid fuel) and the ethanol content was 94%. The measurement steps using an alcoholmeter are to put 100 ml of distillate into a measuring cup, then the alcoholmeter is dipped into the distillate. The immersed boundary on the surface of the distillate indicates the alcohol content of the sample being tested. (IM Sudana et al.,2019)

2.3 Shell and Tube Condenser

This type of heat exchanger is one type of heat exchanger which according to its construction is characterized by a set of tubes mounted in a cylindrical shell in which two types of heat exchange fluids flow separately, respectively through the tube side and the shell side. (Devia et al.,2018) As in Figure 1.

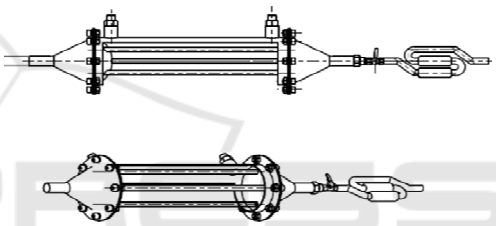

Figure 1: Condenser *Shell And Tube.*

Condenser Tube cooling water volume
The condenser tube is 36cm high and 5,08cm in radius as follows:

$$V = \pi \cdot r^2 \cdot t \quad (1)$$

$V = 2.917\ cm^3 = 2,9$ liter

Convective heat transfer in the reactor tube Is known:

Q_{konv} = Heat transfer rate (W/m²°C)
h = Convection coefficient (14 W/m² °C)
A = Cross-sectional area (31,5 cm) = (0,035 m^2)
T_1 = Tube outer wall surface temperature (30°C)
T_2 = Fluid temperature (90°C)

$$Q_{konv} = h\,(A) \cdot (T_1 - T_2) \quad (2)$$

$Q_{konv} = 26,46\ w/m$℃

So the heat transfer rate in the reactor tube is 26,46W/m℃

2.4 Shell and Tube Condenser Distillation Working Principle

Arak distillation equipment using a Shell and tube condenser is designed with a controlled heating and cooling system, the heating system uses a gas stove with a solenoid valve controlled by thermo control in

order to stabilize the temperature in the reactor tube as a place for heating coconut sap. The reactor tube is cylindrical in shape which is equipped with a conical cap so that it can close the gap for steam exit from the reactor tube so that the process of flowing steam to the condenser tube is more optimal. When steam flows from the reactor tube to the shell and tube condenser tube, a condensation process will occur. In the condenser the cooling system uses water which is circulated using a pump equipped with a solenoid valve controlled by thermo control, aiming to maintain the temperature of the cooling system in the shell and tube condenser to remain stable.

In this process, the steam will change phase to liquid where the liquid is the result of the distillation device, namely the wine that comes out dripping from the condenser tube channel. The distillation apparatus uses a shell and tube condenser as shown in Figure 2.

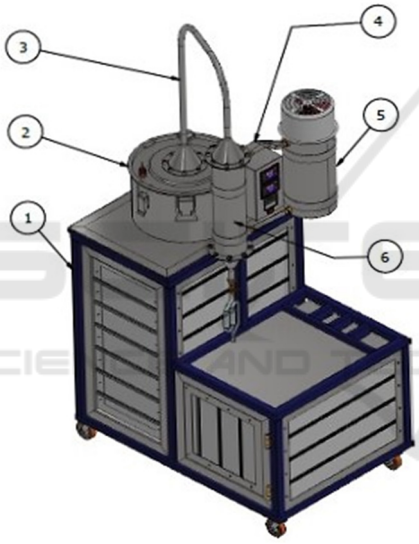

Figure 2: Shell and Tube Condenser Distillation Equipment.

Information:

1. Stove Storage Rack and LPG Gas Cylinder
2. Reactor
3. Distillation pipe
4. Temperature Control Box
5. Reservoir (Cooling water)
6. Shell and tube condenser

3 RESULTS AND DISCUSSION

The process of distillation of coconut sap into arak is carried out using a shell and tube condenser equipped with cooling water temperature control, and heating the reactor tube using a gas stove fueled by LPG.

3.1 Discussion

The results of the first test of the application of a shell and tube condenser on a distillation apparatus for a reactor tube heating temperature of 80°C with respect to alcohol content with condenser temperatures of 30°C, 35°C and 40°C as shown in Figure 3.

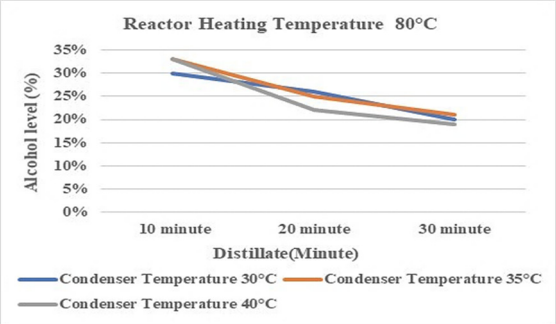

Figure 3: Heating reactor tube 80ºC.

The alcohol content of the shell and tube condenser application after distillation was seen to decrease. A drastic decrease occurred in the third distillation at a condenser temperature of 40ºC with an alcohol content of 22%. Based on the results of distillation, it can be seen that the average alcohol content decreased gradually by 5%, 6% and 7% this is because at a temperature of 80°C the coconut sap in the reactor tube has not experienced an increase in evaporation.

1. Reactor Heating 85ºC to Alcohol Content

The results of the second test apply the shell and tube condenser to the distillation apparatus for the reactor tube heating temperature of 85°C to the alcohol content with condenser temperatures of 30º C, 35ºC and 40ºC as shown in Figure 4.

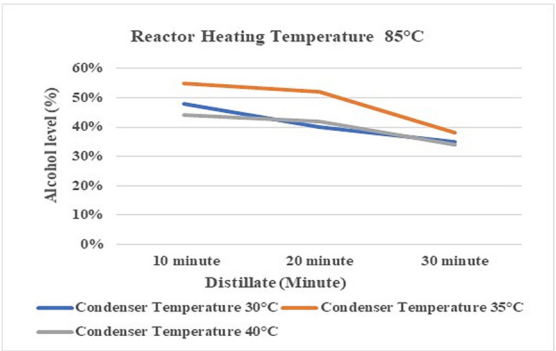

Figure 4: Heating reactor tube 85ºC.

The alcohol content in the application of shell and tube condenser distillation seems to have decreased.

A drastic decrease occurred in the second and third distillations at a condenser temperature of 30ºC and 40ºC, while at a condenser temperature of 35ºC the highest alcohol content was 55%. Based on the results of three times distillation, it can be seen that there was a decrease in the alcohol content not too large an average of 6%, 4% and 5% this is because at the heating temperature of 85ºC coconut sap has occurred stable evaporation in the reactor tube.

2. Reactor Heating 90ºC to Alcohol Content

The results of the third test apply the shell and tube condenser to the distillation apparatus for the reactor tube heating temperature of 90ºC to the alcohol content with condenser temperatures of 30ºC, 35ºC and 40ºC as shown in Figure 5.

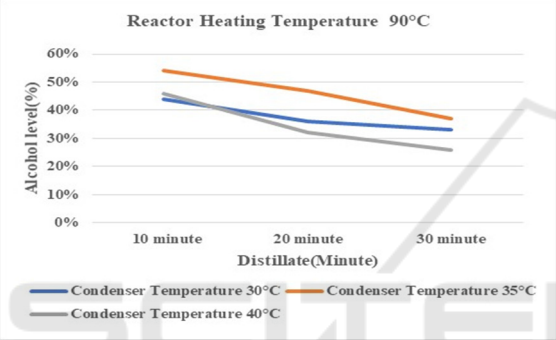

Figure 5: Heating reactor tube 80ºC.

The alcohol content for the application of shell and tube condensers seems to have decreased. A uniform decrease occurred in the second and third distillations at a condenser temperature of 30ºC and 40ºC, while at a condenser temperature of 35ºC the highest alcohol content was 54%. Based on the results of three times distillation, it can be seen that there is a decrease in alcohol content that is not too large an average of 3%, 7% and 6% this is because at the heating temperature of 90ºC coconut sap has occurred too fast evaporation so that the alcohol content will quickly decrease because it is approaching boiling point of water

3. Effect of Reactor and Condenser Temperature on Alcohol Content and Alcohol Volume

Based on the test results at reactor tube temperatures of 80°C, 85°C and 90°C with shell and tube condenser cooling temperatures of 30°C, 35°C and 40°C, it can be seen as Figure 6.

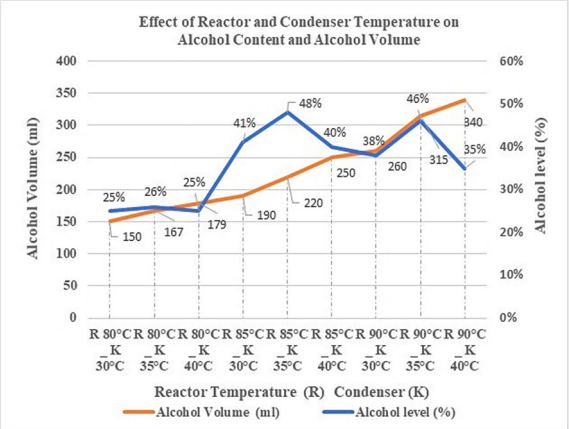

Figure 6: Effect of temperature on alcohol content and alcohol volume.

Based on the results of graphic observations about the effect of the 80°C reactor temperature and the shell and tube condenser cooling temperature for three times, the condenser temperature test of 30°C, 35°C and 40°C obtained a stable alcohol content of 25% while the alcohol volume continued to increase. In testing the reactor temperature of 85°C and the condenser cooling temperature of 30°C, 35°C and 40°C, the alcohol content increased by 48% at the condenser temperature of 35°C, while the alcohol volume continued to increase. For testing at a reactor temperature of 90°C and condenser cooling at 30°C, 35°C and 40°C, the highest alcohol content was up and down 46% and the lowest was 35%, while the alcohol volume continued to increase.

The average alcohol content produced in the application of the shell and tube condenser in the distillation apparatus will be influenced by the heating temperature of the reactor and the cooling temperature of the shell and tube condenser. (Mardiyah, 2017)

The highest alcohol content of the distillation apparatus is 48% and the lowest alcohol content is 25%, while the volume of alcohol produced increases with each heating of the reactor tube, this is influenced by the heating rate of the reactor tube and the cooling temperature of the shell and tube condenser.

4 CONCLUSION

Based on the data analysis of the test results of the shell and tube condenser application in the distillation apparatus, it can be concluded that the alcohol content

produced is influenced by the heating temperature of the reactor tube and the cooling temperature of the shell and tube condenser. The average alcohol content of the highest distillation apparatus is 48% and the lowest alcohol content is 25%, while the volume of alcohol produced increases with each heating of the reactor tube, this is influenced by the heating rate of the reactor tube and the cooling temperature of the shell and tube condenser.

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