Effect of modification of spiral pipes on mini boiler to steam temperature and boiler efficiency

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Abstract. The purpose of this study is to modify the water pipe in the mini boiler into a spiral pipe, with a pipe length of 196.8 cm. With the aim of increasing the efficiency and temperature produced by mini boilers. In addition, it is also to determine the shape and length of the pipe that is better for use in mini boilers. The results of the test show the temperature rise that passes through the superheater pipe. In the spiral pipe model there is a temperature increase of 10.92 °C, with a steam inlet temperature of 277.62 °C. While the temperature of steam coming out of the superheater pipe is 288.54 °C. This shows a temperature increase of 16.6 °C, with a superheater pipe steam temperature of 267.4 °C and a steam temperature of 284 °C from the previous pipe model. Testing for heating water, until it becomes steam in the mini boiler is carried out for 90 minutes. The temperature value of the spiral pipe model is better than the previous pipe model. And the efficiency value obtained in the mini boiler using the spiral pipe is 15.055%, while in the previous study only 5.73%.

1. Introduction

One of effect from high rate of population growth on some place is the increases of electrical needs in that area. It is because of everyone has their own electrical needs on some certain quantity, because of that increases in demand and need on electrical resource become a main problem. Along with electrical energy crisis is fossil fuels crisis such as crude oil, natural gas and coal. Electrical energy crisis and fuel crisis occurs because of there are so many power plant still using fossil fuels as their main fuel (1).

To decrease the needs of fossil fuels power plant we can use another alternative energy such as potential energy that is renewable and also easy to get around us in daily life. One of an energy potency that renewable is wood sawdust waste biomass energy (2)(8). Reason why writer make device to decrease use of fossil fuels with a alternative energy, especially biomass energy. So that alternative energy can be a solution for electrical energy crisis that happen in Indonesia.

Wood sawdust can be used for fuels to heat mini boiler where steam that will be produced from the burning process can be used again to move a simple turbine and then it will produce electricity.

System that used on this device was almost the same with boiler’s ways of working where burning heat streamed the water until steam formed but there were pump on steam power plant in factory to pump the water into the boiler while on this device there is no pump. Steam that generated from the pipe will get heated again that will form saturated stream into further hot steam.

On testing device (Ismail Thamrin, 2010), there are pipes to stream the steam, however when tested that pipe instalation still on wet condition with temperature on 197,1°C with 70 minutes of testing time and wood sawdust still got stucked on the pipe because of steam that generated still on wet condition. So that writer want to modify that device to change the pipes that already existed into 0,5 inch sized pipes that made in form of spiral and using pipe with 196,8 cm of length to compare it with previous...
2. Literature Review

2.1. Definition of Heat

Heat is one of the energy from that can be acceptable or released by something because there is temperature difference (5). Temperature unit is joule or calory. Measurement in general is a way to detect calory in a thing. If the temperature go high then the heat contained in that thing is really big also on the other hand if the temperature go low then the heat contained in that thing is less. Three factors that determine how much heat that a thing need is:

a. Substance mass
b. Type of substance
c. Temperature change

Systematically heat can be formulated as

\[ Q = m \cdot c_p \cdot \Delta T \] …(2.1)

With \( Q \), \( m \), \( c_p \) and \( \Delta T = T_2 - T_1 \) continuously is heat that is needed (J), substance mass (Kg), heat of substance (J/Kg℃) and change in temperature (℃). Heat can become into 2 kinds, which is (5):

1. Heat that used to increase the temperature (sensible heat)
2. Heat to transform the form (latent heat)

There are 2 kinds of formula that is used to latent heat

\[ Q = m \cdot L_v \] dan \[ Q = m \cdot L_f \] .....(2.2)

With \( L_v \) as a heat of the steam (J/Kg) and \( L_f \) is melt heat (J/Kg). Melt heat is heat that is needed to change a substance from solid form into liquid form, where steam heat is heat that is needed to change substance from liquid form into steam form.

2.2. Heat Transfer Mechanism

Heat transfer is process where energy from a place move to another place through a media because of temperature difference (3). Heat move from thing that has higher temperature to thing that has lower temperature until a balance in temperature or similiarity in temperature is created. Heat transfer process, between things is not always the same. There are three mechanism or ways to transfer heat which is: conduction, convection and radiation.

2.3. Mini Boiler Component

2.3.1 Furnace

This part is where combustion happens which will become source of heat, heat heat reception process by water media was done through pipe that already streamed with water, those pipe stick to the wall of furnace. Heat transfer process on furnace happens in three ways (4), (6),(7):

a. Radiation, where heat radiation will happen from flame that sticks to the boiler wall and pipe.

b. Conduction, heat move from the side of the pipe that receive the heat to the side of the pipe that give heat to the water.

c. Convection, heat that happens with water molecules alluction so that heat will spread into every water stream.

2.3.2 Superheater

Superheater is a steam drying area, because of steam that produced from stream drum was still on wet condition si it was not usable. Superheater pipe was used on next heating process and it was heated.
with temperature more than 100°C until steam really became dry and can be used to move the turbine or any other industry needs.

2.3.3 Economizer
This component is a heating room that used to heat the water from condensed water that came from previous system aso for new water feed that got solid before the side of that mini boiler.

2.3.4 Safety Valve
This device is used to throw up the steam if the pressure already exceed standart that had been decided. This valve consists of two pieces which is safety valve for wet steam and safety valve for dry steam. Safety valve on mini boiler also made to take care so that if in the future excessive pressure from mini boiler will not damage the mini boiler itself.

2.4. System on Mini Boiler
On mini boiler device that can produce steam is different with any general steam power plant (4). On this mini boiler there was not any condenser device and pump so that when the system continue to going on water was added manually because there was not any pump and condenser on this system to change half of steam form into saturated liquid. On this system only mini boiler that could move the turbine to produce electricity.

![Figure 2.1](image)

**Figure 2.1** Working scheme of powerplant with mini boiler

Because of that from working scheme on mini boiler it seems that there was not any temperature – entropi cycle diagram just like power plant in general.

3. Research Metodhology

3.1. Device Description General Description
Mini Boiler device which was made as a steam power plant system to produce electricity that spin the turbine to move that generator. This device has burning room where that burning room locared in the middle of the boiler. There was also room to fill the water that would get heated and economizer was located next to that device to heat the water which was utilization of heating that was done by that boiler. Fuel box place also got placed on the top of that device that got streamed with pipe to the burning room to place the fuel so that it will not hard to fill the fuels on that device continuously. Safety valve was made to take care if the stream that was generated exceed the limit that can cause damage to the device. On the fuel box place there was also added steam channel fuel sprayer pipe. In the middle of burning room was made pipe chanel for steam that already heated will pass which aim to reheating the steam that pass throught it so that the output temperature will be higher or was called with re heater.
### 3.2. Work Principle of Mini Boiler

This mini boiler was made from steel plate that was 2.5 mm thick with size of Length x Wight x Height = (80 x 80 x 60) cm. There is burning room in the middle of this device while on the sides there is room to fill the water that will become steam. Steam that is generated from the burning room will pass through pipe that is located on the middle of the burning room so that steam that pass through this pipe will get reheated again and produce dry steam (superheated). That come out and push the turbine to move the electrical generator.

![Figure 3.1 Mini Boiler working Scheme (Ismail Thamrin, 2010)](image)

### 3.3. Planning Method

On this mini boiler device, writer tried to raise the topic of the problem that existed on the boiler itself. Writer will examine the effects of form and length increases of spiral pipe against temperature and calculate the efficiency that is produced from the boiler. This is flow diagram of boiler efficiency calculation also effects of length increases and form of the pipe against temperature.
3.4. Study of Literature
On the testing device (Ismail Thamrin, 2010), there was pipes to stream the steam, however the installation on the pipes itself when tested the steam condition still on wet condition with 197.1°C of temperature with 70 minutes of testing time and wood sawdust still got stucked in the pipe because the steam that was generated still on wet condition. So that writer want to modify the device with changing the pipes with 0.5 inch pipe that was made on the spiral form and using pipe that 196.8 cm length pipe. Pipe got modified longer than previous pipe so that speed of heat transfer on the mini boiler can be bigger so that the efficiency will be bigger. The spiral pipe form was made with the intention of there will be no elbow that caused losses which means efficiency from mini boiler will be more maximal.

3.5. Analysis of The Heat That Got Released And Heat That Got Received on Mini Boiler
1 Heat that got received from the result of burning in burning room
   \[ Q_{BB} = HHV \times BB \]
2 There are also heat that was used to change the water into steam on the side cavity of the boiler are as follows:
   a. Heat that needed to increase the water temperature become 100°C
      \[ Q_1 = m \cdot c_p \cdot \Delta T \]
   b. Heat that was used to change the water into a steam while in the 100°C
      \[ Q_2 = m \cdot L \]
c. Heat that had to add to increase the temperature above 100°C

\[ Q_3 = m \cdot c_p \Delta T \]

The analysis of water change of phase that was heated until become steam. On this chart can be seen every heat that got used to.

![Chart of Relation Between Heat and Temperature](image)

**Figure 3.3** Chart of Relation Between Heat and Temperature (Agus Kartono, 2006)

Explanation: On \( Q_1 \) there is temperature increases in water until temperature of 100°C then heat that got received will be used to change the phase into steam, then after all of it change into steam there will be increases in temperature again.

3 Heat that is needed to change saturated steam into further hot steam on superheater pipe

\[ Q_{superheate} = \dot{m} \cdot c_p \Delta T \]

4 Mini Boiler Efficiency

\[ \eta_{boiler} = \frac{Q_{in} - Q_{out}}{Q_{in}} \times 100\% \]

4. Result and Analysis

4.1. Test Results Data

Testing process was done by using spiral pipe model that 0.5 inch size with 196.8 cm length. The test was carried out five times so that the data results will be more accurate. These are the initial parameter before carrying out the research process:

1. Water mass on boiler : 83.7 Kg
2. Mini boiler size : 80 cm x 80 cm x 60 cm
3. Spiral pipe length : 196.8 cm
4. Inner pipe diameter : 0.622 in = 1.579 cm
5. Outer pipe diameter : 0.840 in = 2.133 cm
Table 4.1 Average Value of Test Results

| Testing on | Water Mass (kg) | Water Temp (°C) |
|------------|----------------|----------------|
|            | Before (kg)    | After (kg)     | Before (°C) | After (°C) |
| Pipe 1     | 83,7           | 73,32          | 29,1        | 100        |
| Pipe 2     | 83,7           | 73,65          | 28,12       | 100        |

Table 4.2. Table of Average Results of Steam Temperature on Boiler Cavity

4.2. Analysis of Calculation Results

| Testing on | Steam Temp       |
|------------|------------------|
| Pipe 1     | 272,62 °C        |
| Pipe 2     | 267,4 °C         |

Figure 4.1 Chart of The Temperature of The Entering Steam Comparison Between Spiral Pipe and Pipe Model 2

On the chart above can be seen that comparison of steam temperature that entering the superheater pipe on the boiler with spiral pipe and entering steam temperature on the superheater pipe model 2 can be seen steam temperature on spiral pipe is 272,62°C while steam temperature on pipe 2 is 267,4°C.
Table 4.3 Table of Average Value of Steam Temperature that Come Out from Boiler

| Testing on | Temperature of Steam Out from Boiler |
|------------|--------------------------------------|
| Pipe 1     | 288.54 °C                            |
| Pipe 2     | 284 °C                               |

Figure 4.2 Comparison of Temperature of Steam That Come Out from The Boiler Between Spiral Pipe and Pipe Model 2

From the chart above can be seen that efficiency comparison between boiler that used spiral superheater pipe and boiler with superheater pipe model 2. Efficiency that generated by boiler with spiral superheater pipe was 15.005%, while efficieny from boiler with superheater pipe model 2 was 5.73%.

5. Conclusion
Based on research that had been done against mini boiler that the superheater pipe got modified with spiral pipe and there were additional length from previous pipe that had been researched, can be concluded as follows:

a. Additional length on superheater pipe take effect on steam temperature that was produced by mini boiler itself, the longer it is then the temperature will become higher too, because the steam that entering the superheater pipe will take longer time.

b. Optimal length of superheater pipe to increase the temperature was done by this research is spiral pipe with 196.8 cm length produced steam temperature up to 288.4°C and boiler efficiency that was produced as much as 15.005%, which was bigger than superheater pipe model 2 which was 5.73%.

Suggestion to this research was to do it with modified the pipe on mini boiler and to add length and change the spiral pipe form that made from still so that it will not have elbow, for the next research it suggested that fuel such as merawan wood and racok wood get multiplied or get changed with another fuel so that the heat that come in will be bigger so that it can produce better steam.
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