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# Analysis of Air Heater Usage with Steam Heat Source Extracted from Turbine Against Fuel Savings Recovery Boilers

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**ABSTRACT**

Electricity is one of the biggest needs in Indonesia, especially in the fields of industry, therefore, every industry should be able to meet its own electricity needs. One company that can meet the needs of industry's own electricity is PT. Toba Pulp Lestari Tbk. The need for electricity met by operating two units of thermal power generation is Multifuel Boiler and Recovery Boiler. Recovery Boiler is a unit Boiler special used to purify compounds-chemical compounds inorganic contained in Black Liquor (waste cooking of the digester) as well as a steam generator of high pressure (High Pressure Steam. There are also some of the factors supporting the recovery boiler including: soot Blowing system, Medium Pressure steam, Low Pressure steam, Condensate, Electrostatic Precipitator (ESP). the air flow system in the recovery boiler which air enters through secondary air fan to the water heater, in the water heater outside air is heated using steam results from the extraction of the turbine, while to heat the steam into steam superheat before entering to turbine used flue gas originating from the combustion of fuel supplied to the superheater 2, superheater 1, and economizer is further from the economizer flue gas directly in the exhaust into the atmosphere through the chimney. In this study, obtained the heat absorbed water heater is equal to 7,525,904 kJ/ hour. The heat absorbed from the water heater ANSYS analysis calculations amounted to 9,854,555.38 kJ/h and fuel savings after using the tool air heating (air heater) is approximately 883 liters / hour. The fuel savings after using the tool air heating (air heater) from ANSYS analysis calculation is equal to 1,115 liters / hour. And to the calorific value which absorbed components in the boiler can be a data-data following data: HTS heat energy absorbed by 11,633,444 kJ/ hour, the heat energy absorbed by LTS 15,740,779 kJ / h and heat energy absorbed Economizer amounting to 21,516,347 kJ / h.



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## 1. INTRODUCTION

Electricity is one of the biggest needs in Indonesia, especially in the industrial sector, therefore each industry is expected to be able to meet its own electricity needs (Situmorang, 2016). One of the industrial companies that can meet their own electricity needs is PT. Toba Pulp Lestari,Tbk

(Sitompul & Rinawati, 2019). The need for electricity is met by operating 2 units of steam power plants, namely the Multifuel Boiler and the Recovery Boiler. PT. Toba Pulp Lestari, Tbk is one of the companies engaged in the processing of paper raw materials, namely pulp (Marpaung, 2020). The operating period of the steam boiler starts in January to December every year because the factory must continue to produce power to operate and also the availability of adequate raw materials for daily production (Utami, 2008). Steam boiler at PT. Toba Pulp Lestari, Tbk serves as a steam supply station which will later produce new steam (to drive a turbine in an electric generator, for heating in a heater, evaporation in an evaporator, and cooking in a cooking kitchen). One way to increase the efficiency of the boiler (boiler) is to exploit the heat energy extracted from the steam turbine (Patoding & Sau, 2019). To exploit this energy, skilled human resources are needed in the utilization of this energy in order to get optimal results (Setiawan, 2010).

Power plants in operation require relatively large amounts of fuel (Gultom, 2015). For this reason, optimization of boiler performance is very necessary for fuel economy (Rudiny, 2013). One way that can be done to save fuel is to add components to the boiler such as an air heater (St Bahrudin & Xiv, 2014)The power plant that will be discussed further in this research is the Recovery Boiler (Fatimah, 2009). The fuel used in the recovery boiler is black liquor, which is a liquid containing 70%-72% solids which is recycled from the digester in the paper-making process. Black Liquor is black in color due to a chemical reaction that occurs between wood chips and the chemicals used for cooking in liquor (TPL, 2002) (Arfenti & Sofia, 2015). In its design, the use of air heaters in the recovery boiler uses a heat source which is the result of extraction from the turbine (Deni Mulyadi, 2020). This is because the flue gas in the recovery boiler contains chlorine compounds and salts with a high acidity level (PH<4) so it is not possible to use it because it can cause damage to the air heater tube material (Yuliwati, 2020). The air heater in this recovery boiler also functions as condensate because the heating material, namely steam extracted from the turbine, will turn into condensate steam after being used to heat the air (Atthoriq & Prabowo, 2020). With this air heater (air heater) in the boiler, it will save fuel consumption and also help the boiler work in heating water to produce steam (Haryanto et al., 2019)the use of this air heater can reduce the need for new water because it also functions as condensate. It is also expected to achieve a complete combustion process in the combustion chamber (Saechu, 2012).

The objectives of the research on air heaters are as follows: (1) To determine the amount of heat absorbed by the air heater (air heater). (2) To analyze the use of fuel savings after the use of an air heater (air heater). (3) To determine the amount of heat absorbed in the superheater and economizer boiler components.

The benefits to be achieved in this paper are: (1) To determine the amount of heat absorbed by the boiler components (Kurniawan, 2019). (2) Provide input to the factory in order to optimize the use of fuel because this air heater will save fuel consumption (Yanuar, 2020). (3) To determine the calorific value of the black liquor fuel used in the Recovery Boiler (Syamsudin, 2015).

## 2. RESEARCH METHOD

### 2.1 Data Analysis

After getting the data needed, the writer then analyzes the data obtained in accordance with the literature study that has been made previously (Rfid, 2018). The analysis carried out is about the amount of heat energy absorbed by each heating device in the boiler (Budiman & Syarief, 2014). (1) Analyze the fuel used (black liquor) (Pratiwi et al., 2012)(2) Calculate the energy absorbed by each heating device in the boiler (Santia et al., 2019). (3) Analyzing the air heater (4) Analyzing the flue gas resulting from combustion in the combustion chamber (Anam et al., 2018).

### 2.2 Thesis Workflow Schematic

The flow chart in analyzing this air heater can be seen below, the scheme of the thesis work flow:

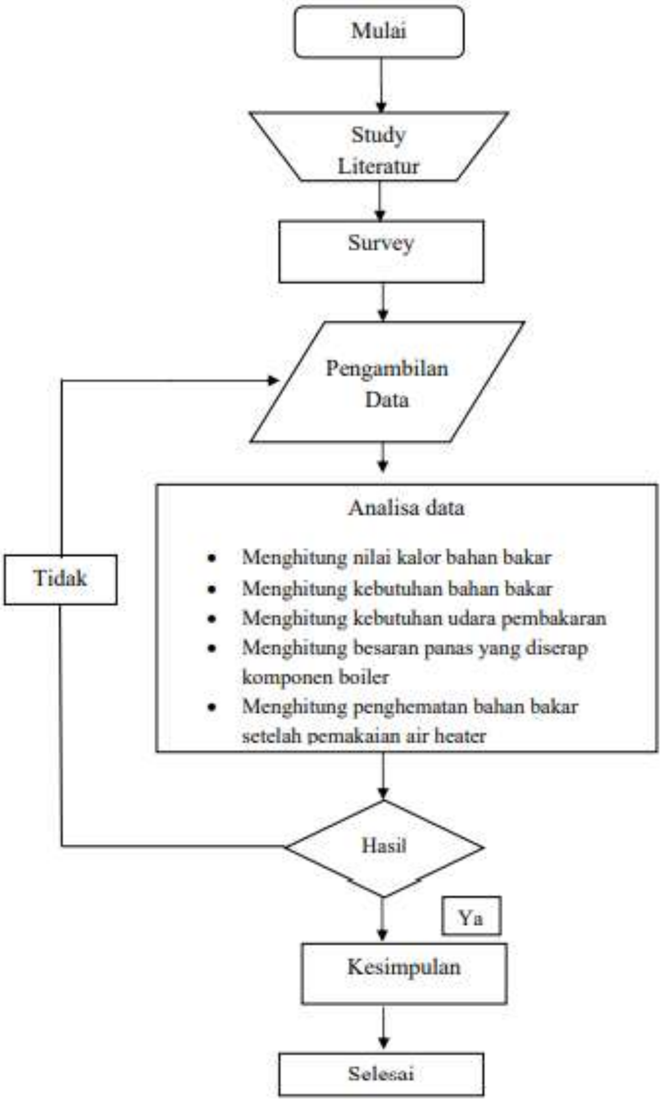


**Figure 1.** Thesis Workflow

### 2.3 Methodology Used

In completing the analysis of the effect of using a water heater on this boiler, several methods are used to solve problems that may arise in the process of analyzing the effect of using a water heater on the boiler in this arrangement, including: (1) Data collection. This data collection begins with an initial survey at the research site at PT. Toba Pulp Lestari, Tbk to collect data from the water heater which will be processed to determine the effect of this water heater on the boiler. Technical Data on Recovery Boiler: (1) Boiler Manufacturer A. Ahlostrom Corp. (2) Made in Finland (3) Design Pressure 80 kg/□2 G (4) Capacity, dry solids 903.9 TDS/D (5) Steam generation 43 kg/sec (154.8 T/H) (6) Steam Pressure 65 bar (7) Food Water inlet temperature 411 K. ( 2) Literature study method. This is done to select supporting materials obtained from reference books, the internet and journals. (3) Suggestions and guidance from supervisors. Provide assistance to supervisors for advice and guidance in order to correct and refine the material from each discussion that is compiled. (4) Discussion analysis, Processing the data obtained from the research site regarding the effect of the air heater on increasing boiler efficiency at PT. TOBA PULP LESTARI, Tbk. (5) Cover. Consists of the conclusion that the overall effect of the air heater on increasing boiler efficiency at PT. TOBA PULP LESTARI, Tbk obtained from the analysis of calculations, suggestions and a list of books (references) used in completing this thesis.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Boiler Fuel

The fuel used in the recovery boiler at PT. Toba Pulp Lestari, Tbk is a type of liquid fuel, namely black liquor. Composition of fuel The following data were obtained from PT. Toba Pulp Lestari, Tbk regarding the content of elements contained in black liquor fuel.

**Table 1.** Composition of the chemical elements of the fuel
Source: PT. Toba Pulp Lestari, Tbk

| Nama Unsur | Nilai (%) |
|---|---|
| Karbon (C) | 27,20 |
| Hidrogen ($H_2$) | 4,40 |
| Nitrogen ($N_2$) | 0,10 |
| Natrium (Na) | 19,80 |
| Kalium (K) | 1,90 |
| Total Sulfur (S) | 5,20 |
| Chloride content (Cl) | 0,10 |
| Oksigen ($O_2$) | 31,10 |
| Ash | 0,20 |
| Jumlah | 100 % |

### 3.2. Fuel Calorific Value

The heating value is the amount of heat energy obtained from the combustion of 1 kg of fuel. This calorific value is divided into two: (a) Highest Heating Value (HHV). The highest calorific value or High Heating Value (HHV) is the amount of heat produced in the process of burning 1 kg of fuel without any water content in the fuel. To calculate the highest calorific value (HHV) the following Dulong and Petit equations are used:

HHV = (33950 x C) + 144200 ($H2$ –$O28$) + (9400 x S) kJ/kg (1)
= (33950 x 0,372) + 144200 (0,044 –0,3118) + (9400 x 0,052)
= 12.629,4 + 749,84 + 488,8
= 13.868,04 kJ/kg

(b) Low Heating Value (LHV). The lowest calorific value or Low Heating Value (LHV) is the amount of heat produced in the combustion process of 1 kg of fuel and part of it is used for evaporation so that the water content in the fuel will be exhausted. To calculate the lowest calorific value (LHV) the following equation is used.

LHV = HHV – 2400 ($H2$O + 9 $H2$ ) kJ/kg (2)
= 13.868,04 – 2400 (0 + 9 x 0,044)

= 13.868,04 – 950,40 kJ/kg
= 12.917,64 kJ/kg

### 3.3. Fuel Needs

Recovery boiler PT.Toba Pulp Lestari, Tbk produces a maximum of 180 tons of steam/hour, but the amount of steam included in the calculation is the average steam generated in the period 1 April– 30 April 2016 which is 160.13 tons/hour (can be seen in the research table TPL boilers). To produce this steam, a certain amount of fuel is needed. The amount of fuel needed to produce such a large steam can be found by the following equation:

$$W_f = \frac{w_s(H_{Sat} - H_a)}{LHV \times \eta_K} \quad (3)$$

Where :
: amount of fuel needed (kg fuel/hour)
: steam capacity of 160.13 tons/hour
: enthalpy of steam leaving the superheater
$Ha$ = enthalpy of water filling the steam boiler
T = 210℃
P = 6.1 MPa
H = ... kJ/kg
For pressure 10 MPa
Interpolation at 210
By using a thermodynamic table, the value of h is 900.8 kJ/kg
So for a pressure of 6.1 Mpa
x = 896.9
the value of h sought by interpolation from the thermodynamic tablet is 896.9 kJ/kg
LHV = low calorific value of fuel 12,917.64 (kJ/kg) k = boiler thermal efficiency (0.70)

$$Wf = \frac{160.130 \frac{\text{kg}}{\text{jam}} (3072{,}1 - 896{,}9)\ \text{kJ/kg}}{12.91764 \times 0{,}70} \quad (4)$$

$$= \frac{384.314.776}{9.042{,}384}$$

= 38,520 kg/hour
= 38.52 tons/hour

### 3.4. Heat

The heat balance is the ratio of the heat energy produced in the combustion process to the energy used:
$Qin = Wf\ x\ LHV\ x\ \eta f$ kJ / hour (5)
Where:
$Qin$ = heat energy produced (kj/hour)
$Wf$ = fuel capacity (kg/hour)
LHV = Low calorific value (kJ/kg)
$\eta f$ = theory kitchen efficiency is around 90% 97% assumed 97% (syamsir A Muin:47)
So:
$Qin$ = 38,520kg/hr x 12,917 kJ/kg x 0.97
= 482,635,954 kJ/hour
Furnace temperature is around 900 ℃ - 1000 ℃, so

$$T_{rb} = \frac{Q_{in}}{W_g \text{ x } Cp} \quad (6)$$

Where:
$Trb$ = furnace temperature, ℃
$Qin$ = amount of incoming heat, kJ/hour
$Wg$ = weight of wet flue gas, kg/hour
Cp = specific heat of exhaust gas, kJ/kg℃
Meanwhile, to find the value of exhaust gas Cp can be determined by:

$$Cp = \frac{Q_{in}}{W_g \; x \; \mathrm{Tr}} \quad (7)$$

Where:
Tr = average temperature (℃)

$$\frac{900℃ + 1000℃}{2} = 950\ ^0C$$

So:

$$Cp = \frac{482.635.954}{236.120 \; x \; 950^0C}$$

Cp = 2.15 kJ/kg $^0$C
Then the temperature of the exhaust gas in the combustion chamber is:

$$T_{in} = \frac{482.635.954}{236.120 \; x \; 2,15}$$

Cp = 2.15 kJ/kg $^0$C
Then the temperature of the exhaust gas in the combustion chamber is:

$$T_{in} = \frac{482.635.954}{236.120 \; x \; 2,15}$$

$Tin$ = 950.710C

### 3.5. The Amount Of Heat Absorbed By The Water Heater

Broadly speaking, the steps to perform a CFD simulation are: Geometry preparation, mesh formation, determination of simulation conditions, iteration calculations, and processing of simulation results. In this simulation, Fluent software on Ansys 15 is used to perform calculations. The image below is a cell that shows the steps that need to be prepared to carry out the simulation. (1) Geometry Preparation. In this step, the geometry created in 3D with parasolid format (x_t) is imported into ansys so that it can be processed in the next step.

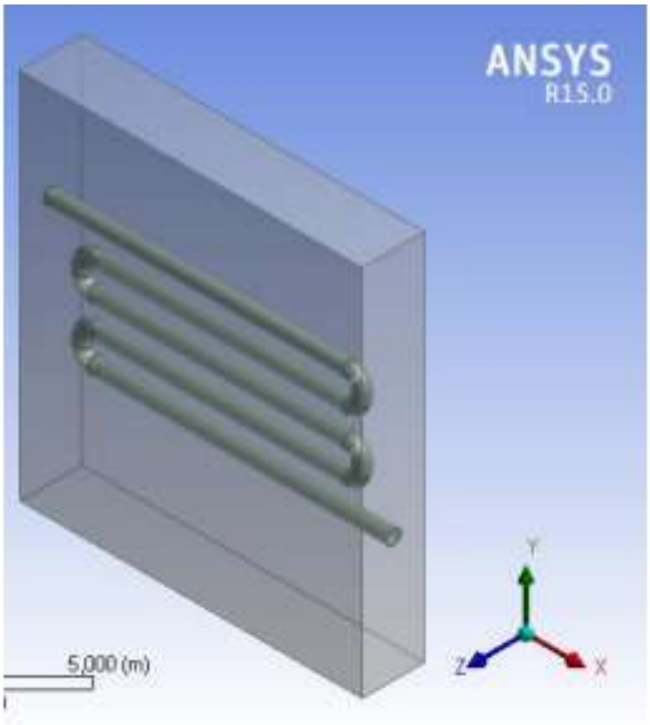


**Figure 2.** Geometry of Air Heater in 3D

(2) Mesh Formation, In this step, after the geometry to be simulated has been successfully entered into Ansys, the next step is mesh formation. The mesh that will be formed will automatically be determined by Ansys of all sizes and shapes as needed.

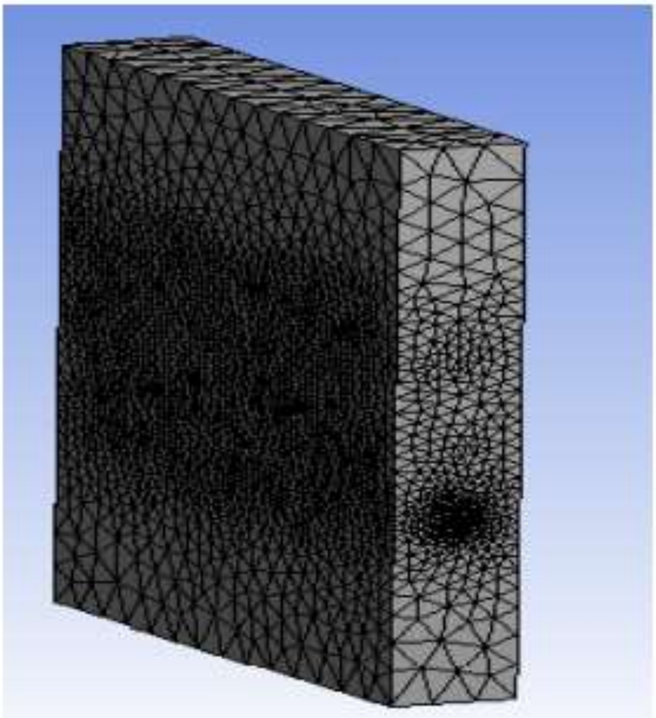

**Figure 3.** Mesh Formation in Water Heater Geometry

(3) Calculation Condition Setup, In this step all calculation conditions are determined in order to obtain the desired result. Some of these conditions can be seen in the image below in the problem setup section.

a. First is the General section. Things that need to be prepared can be seen in the image below.

In the mesh section, to scale we must determine the size scale of the geometry we have created. Sometimes the geometry that we prepare is made in meters while fluent reads it in millimeters, this will cause the geometry to be smaller than the size it should be. To fix this, we have to scale the geometry first. At check we can check the mesh that has been formed and to get the quality of the mesh is it worth using the Quality Report. And to show the mesh you can use Display. In the Solver section, calculations are carried out on a pressure basis, using absolute velocity, constant flow therefore we choose Pressure-Based for Type, Absolute for Velocity Formulation, and Steady for Time. To include gravity in the calculation of the tick in Gravity,

b. Next is the determination of the calculation model

In this model, only Energy needs to be activated because it involves temperature changes in the calculated fluid. And to activate the turbulence flow, in the Viscous section it is activated with the Realizable option to, Scalable Wall Fn.

### 3.6. Fuel Saving After Using Air Heater (ANSYS)

The incoming heat given by the fuel before using the air heater is 482,635,954 kJ/kg
Formulated:
$Qin = Wf \text{ x LHV x } \eta f$ (8)
= 38,520 x 12,917.64 x 0.97
= 482,635,954 kJ/kg
So, after getting big $QAH$ so $Qin$ The amount of fuel required is:
$Qin\text{awal} = Qin \text{ baru} + QAH$ (9)
482,635,954 = $Qin$ new + 9,845,555 $Qin$ new = 482,635,954 – 7,525,904
= 472,790,399 kJ/kg
So, $Wf$new is equal to:
472,790,399 = $Wf$ x 12,917.64 x 0.97
$Wf - Wf$= 37,732 kg/hour
Then it can be calculated fuel savings after using the tool
air heaters, namely:
Fuel savings
=$Wf - Wf$new (10)
= 38,520 – 37,732
= 788 kg/hour
Then the volume of fuel saving is
$V = \frac{m}{\rho}$ (11)
= 1.115 $m^3$/ hour (1,115 liters/hour)
The following is a comparison of the use of fuel before the use of the air heater, after the use of the air heater, and also before the use of the air heater with software simulation using ANSYS in liters/ hour.

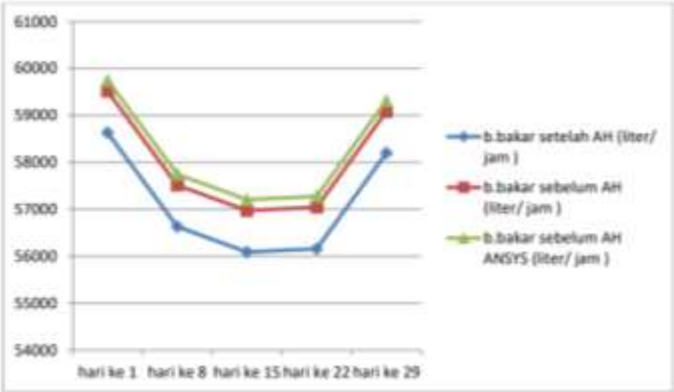


**Figure 4.** Fuel Usage Comparison

From the graph above, it can be seen that the use of fuel before using the air heater from the calculation results (red) is close to the use of fuel before using the air heater from the results of software simulations using Ansys (green) while the use of fuel after using the air heater has quite a difference. long before the use of the water heater. The percentage comparison of fuel use between the results of the calculation analysis compared to software analysis using Ansys can be calculated:

$$\% \text{ Perbandingan b.b} = \frac{57.575 - 57.343}{57.575}\frac{liter}{jam} x\ 100\ \%$$

= 0.4%

## 4. CONCLUSION

The conclusions obtained by the author from this research are as follows: (1) The amount of heat absorbed by the air heater is 7,525,904 kJ/hour. The amount of heat absorbed by the air heater from the calculation of software analysis using ANSYS is 9,854,555.38 kJ/hour. (2) The fuel savings after using an air heater is 883 liters/hour. The fuel savings after using an air heater from the calculation of the analysis software using ANSYS is 1,115 liters/hour. While the percentage comparison of fuel use before the use of the air heater between the results of the calculation analysis and the results of software analysis using Ansys is 0.4%. It can be concluded that the results of this test are acceptable because the comparison of the results of software analysis is close to the results of theoretical calculations. (3) From the calculations obtained the following data: (a) Heat energy absorbed by HTS : 11,633,444 kj/hour (b) Heat energy absorbed by LTS : 15,740,779 kj/hour (c) Heat energy absorbed by Economizer : 21,516,347 kj/hour.

Suggestions in this study are: (1) It is necessary to optimize the performance of boiler components in order to increase the amount of fuel savings used. (2) It is necessary to carry out comprehensive maintenance on boiler components so that these components are able to produce performance according to or close to their design capabilities. (3) It is necessary to conduct research with other methods to develop further research.

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