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SHELL AND TUBE TYPE HEAT EXCHANGER DESIGN TO UTILIZE EXHAUST GASES FROM THE GENERATOR

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Abstract
Heat exchangers or often called heat exchangers (HE) are widely used in industry. There are many types of heat exchangers, there are fire pipes or water pipes with cross flow or unidirectional flow. Utilizing exhaust gas is an alternative to reduce costs and increase effectiveness so that wasted energy can be utilized as optimally as possible. A generator is one that can produce electrical energy which produces flue gases with a high temperature so that it can be utilized using a heat exchanger. A shell and tube heat exchanger with a fire tube type was designed. The number of pipes designed was 131 with a pipe diameter of 2.5 inches. The design results obtained from heating water are steam with a capacity of 1 ton. The dimensions of the heat exchanger are 3 meters long with a diameter of 2 meters. The heat energy produced by steam is 2852.2605KW, with a steam temperature produced of 2000C. The resulting LMTD is 360.50K. With this heat exchanger, it is hoped that the costs for producing bias steam will be as minimal as possible.

Keywords: *Heat Exchanger, LMTD, Heat Energy, flue gas, generator*

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Introduction

Electrical energy is currently still receiving attention from industry where its need both in industry and in society is a basic need that cannot be eliminated, the availability of electrical energy is increasing every year along with many industrial sectors developing both in manufacturing and other fields.

To balance the need for electrical energy, many industries use power plants that can be used by internal parties in the industry without taking it from the State Electricity Company (PLN). Currently, many industries are installing generators to produce electricity with different capacities. In general, the manufacturing industry requires three to four generators with an average capacity of more than 4 mW for each generator, because the need for electrical energy is very large, such as for processes in the manufacturing industry. The generator used produces exhaust gas which can be used as an alternative fuel to produce steam can be reused for the production process so that operational costs can be smaller [1].

The process of using a generator will produce exhaust gas with a fairly high temperature which is still used to heat the water in the reservoir.

Utilizing heat from flue gas is an alternative form of energy to reduce costs for the company [2].

The exhaust gas emitted by the generator reaches a temperature of 4000C with a mass flow rate of 3.03 kg/s. with exhaust gas pressure of 2 bar. The exhaust gas temperature from the generator can still be used to heat water before it enters the APK. Thus, this effort is useful as alternative energy and reduces production costs.

Utilizing waste energy can use a heat exchanger, the type that is widely used is the shell and tube type, for the reason that this type of heat exchanger has a fairly large ratio of volume to fluid weight, this type is easy to make and easy to carry out the cleaning process.

The process of entering exhaust gas into the shell and tube can be via a fire pipe or water pipe.

From this design, it is hoped that a heat exchanger that has high effectiveness will be produced. The aim of this design is:

1. Understand the influence of tube size, distance between tubes and their arrangement on the performance of
   the APK.
2. The influence of tube size, distance between tubes and the shape of the tube arrangement on the performance of the APK.
3. Identify the most economical design conditions [3].

Research Method

In designing this heat exchanger, consideration must be taken starting from the material for the shell and the material for the tube in order to produce maximum heat transfer.

2.1 Planning Stage

The planning stage is the stage where the process of making or designing the tool will be formed. In planning, you must really be able to choose the materials that will be used as well as take the dimensions of these materials. Below are the materials used and the dimensions used:

The material used as the shell is medium carbon steel,

while the material for the Tube is A335 P11, a seamless ferritic alloy steel for high temperatures with a diameter of 33.6 mm (ASME. B3.1.1) [4].

The process of making the shell is by bending it in stages until it is cylindrical and then welded.

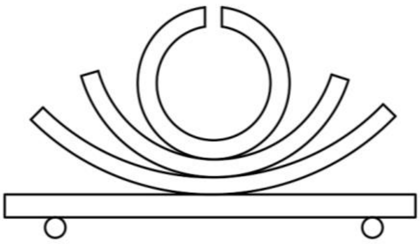


Figure 1. Shell bending process

The steel plate is curved with a roller machine, thus forming a cylindrical circle. If the plate is more than 5 mm thick.

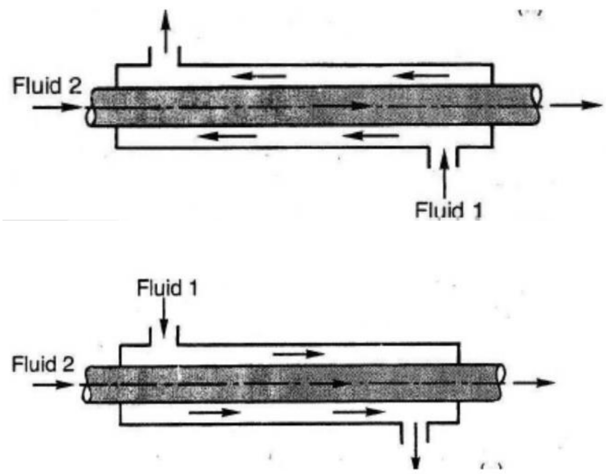


Figure 2. Schematic of the Heat Exchanger

1. Shell and tube type heat exchanger

Based on Shape, Shell and tube heat exchangers are characterized by a collection of pipes, which are enveloped by a cylindrical shell. Two types of fluids that exchange heat pass through the tube side and the shell side constantly [5].

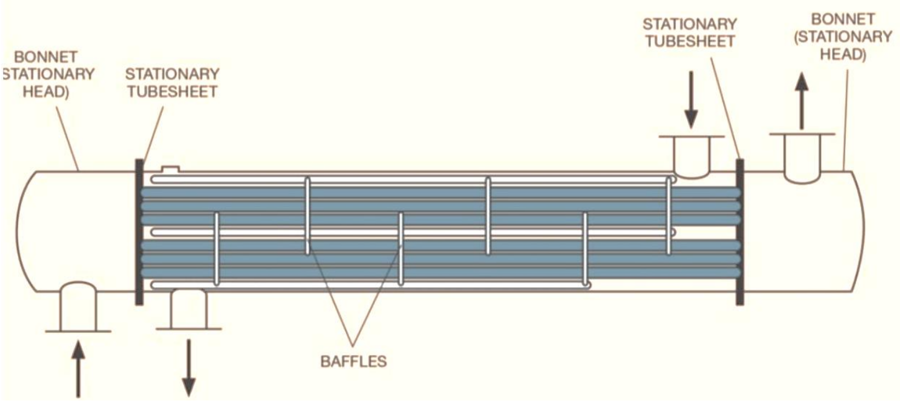


Figure 3. Shell and Tube type heat exchanger

tube. As a result, the convection heat transfer coefficient will be higher than if the flow had no partitions and flowed axially along the tube axis. The degree of flow turbulence and pressure loss increases with the number of baffles used, or in other words, the narrower the baffle spacing (distance between baffles). [8].

Optimal cuts for bafflecuts, according to Kreith (1991), are made between 20% and 35% of the shell diameter. To lower the convective heat transfer coefficient on the shell side, the baffle cutting should be less than 20%. [8]

2. Calculation data for designing specific heat exchange equipment

1. Shell and Tube.

Before designing a heat exchanger, supporting data is needed for the calculations and analysis that will be carried out so that the design process can be completed, these data include: Pressure and flow rate of exhaust gas, fluid and other properties.

The heat exchanger designed is a shell and tube type where the type of heater is a fire pipe. This heat exchanger utilizes exhaust gas coming out of the generator which is still at a temperature of 4000C.

The APK design process follows the flow diagram below:

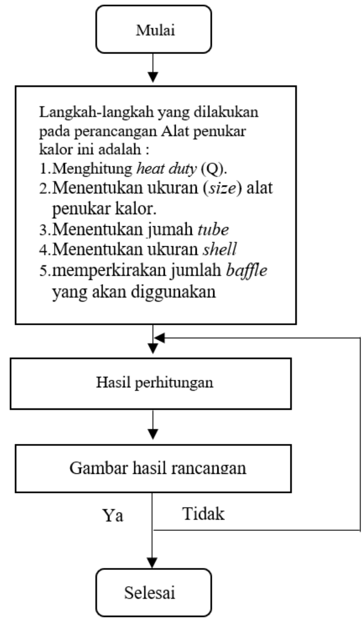


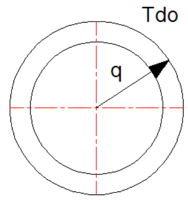
Figure 5. Flow diagram for designing a heat exchanger

2. Heat Exchanger Design Data

Exhaust Gas Temperature From 4000C Generator
Td1 = Internal wall temperature 375oC
T ~ = Surrounding air temperature 270C
Tin = Flue gas temperature 375oC
T = Chimney thickness 3 mm = 0.003 m
L = Length of the analyzed chimney 300 cm
= 3 m
Di= Internal diameter 52 cm = 0.52 m
Do= Outer diameter 60 cm = 0.6 m
High Speed Diesel (HSD) fuel
Exhaust gas velocity (vflue gas) 9.09m/s
The density of flue gas (ρflue gas) is 1.1799 kg/m3
Exhaust gas outlet pressure (Exhaust gas)2 bar
μ water 0.31202kg/ms
Cp 2.5327 kj/kg.K

Results and Discussion
Calculating the exhaust gas flow rate
To determine the type of exhaust gas flow, the Reynolds number is searched [8]
$Re=(\rho.V.D)/\mu$
$=(1.1799\ kg/m^3\ .9.09\ m/s.0.52m)/(0.31202\ kg/〖m.s〗^\ )$
=17.87
So the flow that occurs is laminar flow
Calculating the mass flow rate of flue gas (kg/s)
$\dot{m}_{GB}= \rho.V.A$
$\dot{m}_{GB}= 1.1799,kg/m^3\ .\ 9.09\ m/s\ .\ 0.2826\ m2$
$\dot{m}_{GB}=3.03\ kg/s$

Then the flue gas mass flow rate is found to be m ̇_GB= 3.03 kg/s
Calculation of the outer wall temperature of the outer flue gas pipe (T_do) in the radial direction



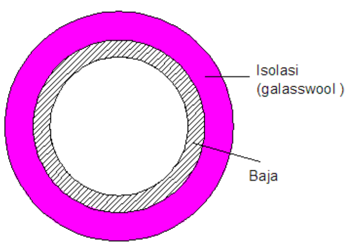
$$q_{kr} = 2.\pi.k_r.L.\frac{\Delta T}{\Delta r}$$
$$q_{kr} = 2.3{,}14.20\ \frac{w}{m^2.k}.3m.\frac{(T_{di} - T_{do})}{0{,}3m - 0{,}26}$$
$$T_{do} = 345{,}21°k\ (72{,}21°C)$$

Finding the value of the nusellt number in the chimney [8]

$$Nu = 0{,}023\ [\ 1 + (\frac{Di}{L})^{0,7}\ Re^{0,8}.pr^{0,3}$$
$$Nu = 0{,}023\ [\ 1 + (\frac{0{,}52}{3})^{0,7}].17{,}87^{0,8}.0{,}69^{0,3}$$
$$Nu = 0{,}19$$

$$h_u = \frac{Nu.k_{gas\ buang}}{D}$$
$$h_u = \frac{9{,}77.0{,}02811}{0{,}6}$$
$$h_u = 0{,}45$$

Then the convection value of the chimney wall to the outside air is obtained 〖h〗_(u)= 0.45
From the convection heat transfer equation:
q_c=h_u .A .ΔT
Where A is the blanket area of the outer chimney being analyzed:
A=п .D_o .L
A=3.14 .(0.6m).3m
A=5.65 m^2.
Then the outside area of the chimney is A = 5.65 m^2.
Then the value of q_c =
q_c=h_u .A .(T_do-T~)
q_c=0.45 w/m^2 K (5.65m^2) .(345.2-300)K
q_c=114.921 watts
Look for insulation on glass wool and aluminum foil
Where: The thermal conductivity value of glass wool is 0.04 w/(m^2.k)
The thermal conductivity value of aluminum foil is 0.00016 w/(m^2.k)



$$R_{o\ glasswoll}$$
$$R_{o\ glasswool} = \frac{k}{h}$$
$$R_{o\ glasswool} = \frac{0{,}04\,\frac{w}{m^2.k}}{0{,}45\,\frac{w}{m.k}}$$
$$R_{o\ glasswool} = 0{,}08\ m$$

So thick glaswool insulation is obtained
R_(o glasswool)= 0.08m 〖R〗_(o Aluminum foil)
R_(o Aluminum foil)=k/(h)
R_(o Aluminum foil)=0.00016/(0.45)
R_(o Aluminum foil)=0.0035
So the thickness of the aluminum foil insulation is obtained R_(o Aluminum foil)= 0.0035m
Calculates the number of tubes used for the designed APK.
Nt=0.785(C_TP/C_L).〖D_2〗^2/(〖PR〗^2)(〖d_o〗^2)
Where :
Shell diameter = 1000 mm
Tube diameter = 63.5 mm
Tube layout 300C (CL) = 0.87
Fluid flow in the tube 1 pass CTP = 0.93
Pitch ratio (distance between tubes / tube diameter) = 1.25
So we get:
Nt=0.785(0.93/〖0.87〗_).1000^2/(〖1.25〗^2)(〖63.5〗^2)
= 131 pieces

Conclusion

The heat exchanger designed is a Shell and Tube type heat exchanger with opposite flow direction. This heat exchanger utilizes heat released from a generator at the Textile Factory. The aim of this design is expected to increase the efficiency of using heat exchange equipment that uses fuel.
From the design results, the following data was obtained:

1. The exhaust gas temperature from the generator is 400oC
2. APK inlet temperature 375oC
3. Exhaust gas mass flow rate 3.03kg/s, steam mass flow rate 0.228 kg/s
4. Thermal energy produced by flue gas = energy produced by steam of 2852.2605 KW
5. Dimensions of shell and tube type heat exchanger
6. Shell Diameter: 2 meters
7. Tube Diameter: 2.5”
8. Number of Tubes: 131 pieces
9. Shell Length: 3 meters
10. Type of cross flow contra flow
11. The material used for the shell is AISI 1040 with a tensile strength of 91 MPa, yield strength of 77 MPa.

12. A335 P11 is a seamless ferritic alloy steel for high temperatures with a diameter of 33.6 mm (ASME. B3.1.1)
13. Insulation uses glass wool and aluminum foil
14. The designed working pressure that the shell can withstand based on the mechanical properties of the material is 38 Bar, while the calculated working pressure is 4 bar so that the shell condition can be said to be safe to withstand this working load.
15. The designed heat exchanger has a lifespan of 33 years according to the calculation of the corrosion increase rate

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