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ANALYSIS OF HEAT TRANSFER CHARACTERISTICS OF TUBE BANKS ECONOMIZER USING NUMERICAL METHODS

Mohd. Qobar[1], Ahmad Syuhada[2], M. Ilham Maulana[3]
Mechanical Engineering (Universitas Syiah Kuala)[1,2,3]
*Correspondence Email: qobarm05@gmail.com

Abstract
The economizer is a heat exchanger that functions as a preheater for feed water in the boiler which is used to utilize flue gas which will improve the performance of the boiler by increasing the water temperature before entering the steam drum. The flue gas used comes from the furnace output which has a temperature of 1337oC, then the flue gas passes through the superheater with a temperature of 1070oC and enters the economizer with a temperature of 389oC. In order to maximize the use of the high temperature flue gas that enters the economizer, therefore in this scientific work we will analyze the heat transfer characteristics of the economizer in the MACCHI TITAN M package boiler at PT. PIM-2. This water tube type boiler has a capacity to produce steam of 120 tons/hour or 33. 3 kg/s with a pressure of 44 kg/cm2 and an economizer with a design surface dimension of 2345 m2, an in-line arrangement of tube banks, a tube diameter of 70 mm, a tube length of 1122 mm and a tube width of 2000 mm. Based on these data, an economizer will be analyzed by comparing the arrangement of tube banks and variations in the number of tubes (150, 200 and 250) in each tube bank using numerical simulation methods. From the simulation, it was found that the staggered tube banks with the 250 tube variation showed better heat transfer characteristics than the other variations, where the flue gas inlet temperature of 389 oC decreased to 257.7 oC and the increase in water temperature (H2O) from 110 oC increased to 193 oC or 75.45% of the inlet water temperature. tube length 1122 mm and tube width 2000 mm. Based on these data, an economizer will be analyzed by comparing the arrangement of tube banks and variations in the number of tubes (150, 200 and 250) in each tube bank using numerical simulation methods. From the simulation, it was found that the staggered tube banks with the 250 tube variation showed better heat transfer characteristics than the other variations, where the flue gas inlet temperature of 389 oC decreased to 257.7 oC and the increase in water temperature (H2O) from 110 oC increased to 193 oC or 75.45% of the inlet water temperature. tube length 1122 mm and tube width 2000 mm. Based on these data, an economizer will be analyzed by comparing the arrangement of tube banks and variations in the number of tubes (150, 200 and 250) in each tube bank using numerical simulation methods. From the simulation, it was found that the staggered tube banks with the 250 tube variation showed better heat transfer characteristics than the other variations, where the flue gas inlet temperature of 389 oC decreased to 257.7 oC and the increase in water temperature (H2O) from 110 oC increased to 193 oC or 75.45% of the inlet water temperature.

Keywords*: Economizer, Tube Banks, Heat Transfer, Numerical Methods*

INTRODUCTION

Continuous use of energy has a positive impact on advances in industrial technology so as to make the industry a target for implementing and applying current technology, including the petrochemical industry, especially PT. Pupuk Iskandar Muda is a fertilizer producing company that has contributed to the implementation and application of advanced technology to date. One of the technologies that has an important role in PT. PIM is a steam boiler or boiler. PT. PIM itself uses the Italian MACCI TITAN M boiler package with the type of water tube boiler with item number 63-BF-4002 with a capacity of 120 tons/hour or 33.33 Kg/s with a temperature of 390 ± 5oC and a pressure of 44 kg/cm2.G

In the process of producing steam, the boiler package is supported by several components, one of which is the economizer [1]. The economizer is a component that functions as a preheater for boiler feed water in producing steam that utilizes flue gas temperature, where the flue gas temperature produced by the furnace reaches 1337 oC then after passing through the superheater it reaches 1070 oC then passes through the economizer with a temperature of around 389 oC.

With the economizer of a steam boiler or boiler, fuel savings of up to 7% can occur, thus increasing the efficiency of the boiler [2]. One study explained that the economizer performance could be improved by adding and adjusting the arrangement or adjusting the tubes and fins to increase the heat transfer area [3], also another study explained that the configuration of the tube arrays arranged in a staggered manner in the baseline model has a lower average outlet temperature when compared to the modified model which increases the work of the economizer [4].

From some of the research above, the author in this final project tries to analyze heat transfer in the MACCHI TITAN M package boiler economizer at PT PIM, lhokseumawe Aceh Utara by modifying the in-line arrangement of tube banks to become a staggered arrangement of tube banks and seeing the effect of variations in the number of tubes in the economizer tube banks and comparing the results of temperature distribution and speed distribution. This simulation uses the Ansys Fluent numerical simulation method in 2 dimensions

LITERATURE REVIEWS

Economizer

The economizer functions to heat boiler fill water by utilizing heat from the residual combustion gases in the boiler, so that as the boiler fill water temperature increases, efficiency will also increase. By increasing the efficiency of a boiler, it will make the company's expenses more economical in terms of reducing boiler fuel usage.

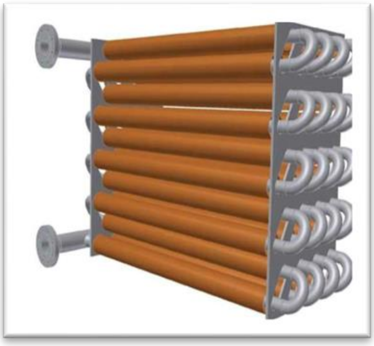

Figure 1. Economizer

Heat Transfer

The economizer receives heat energy from the flue gas (exhaust gas) through convection heat transfer [5]. There are two types of convection, namely natural convection and forced convection. In natural convection, fluid movement occurs due to differences in density. In forced convection, the heat flow is forced to be directed to the destination with the help of certain devices, for example a fan or blower. Forced convection is widely used in heat exchanger systems such as economizers.

Regardless of whether the convection is free or forced, the heat transfer rate or qc can be written in Newton's law form:

$$Q_c=hA(T_s- T_\infty) \quad \dots (1)$$

The heat transfer coefficient h can be calculated using the following equation:

$$h=\frac{k}{D} Nu \quad \dots (2)$$

METHODS

In this study, several preparations will be made from the initial stage or the start of the research process to the final stage. For the stages as shown by the flow chart as follows:

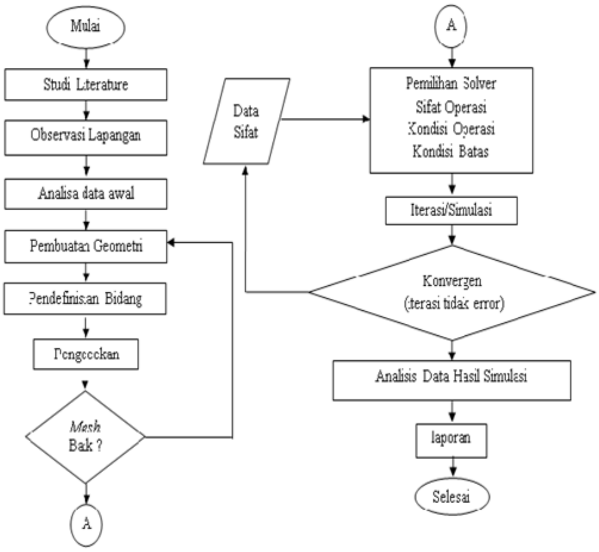

Figure 3. Research flowchart

The research method used in this study is a numerical method using computational assistance but the data obtained at the stage of literature study and field observation is still very limited. Therefore, to complete the data needed/used in the numerical method, calculations using analytical methods are included, but overall the method used is still a numerical method. The following is the data used in the analytical method:

Table 1. Economizer input data[

Properties	Mark
Economizer inlet temperature, T(water)in	110oC
Wall temperature, Twall	260oC
Ambient temperature , Tambient	37oC
Economizer design temperature	371oC
Bulb water temperature	146oC
Economizer inlet speed, Vwater in	1.1m/s
Heating surface economizer	2325 m2
*press*inlet economizer	49.7 Kg/cm2.
Flue gas inlet temperature, T(flue gas) in	389oC
Economizer flue gas inlet speed, V(flue gas) in	19.3m/s
Economizer flue gas outlet speed, V(flue gas) out	13.5m/s
Temperature bulb flue gas	289.5oC

Table 2. Dimensional data from the economizer

ECONOMIZER DIMENSIONS	Mark
Water tube inlet diameter, Din	0.0474m
Water tube outlet diameter, Dout	0.0510m
Thickness tube water	0.0036m
Flue gas tube inlet diameter, Din	0.1683m
Flue gas tube outlet diameter, Dout	0.1683m
Thickness of flue gas tube	0.0143m
Friction factor, f	0.019
Roughness (roughness) on the water tube, ε	0.0008m
Transverse pitch, ST	0.102m
VERTICAL TYPE	
IN-LINE TYPE	
SPIRAL FIN TUBE TYPE	
CROSS-FLOW	

The numerical method requires 3 main steps to be carried out, including: pre-processing, processing (solving) and post-processing. Before entering the simulation or numerical method stage, data collection is carried out which will be input to the numerical method. The following are the input data used in this study:

Table 3. Economizer input data for simulation

Input data	Mark
Flue gas inlet temperature	389oC
Heat transfer coefficient flue gas	251.983 W/m2.K
Temperature(f) gas flue gas	274.75oC
Heat transfer coefficient of water	10558.8 W/m2.K
Temperature(f) water	203 oC
Material	SA 210 A1

Table 4. Properties of flue gas at 389^{o}C

Properties flue gas at 389 oC	Mark
Density (ρ)	0.29597 kg/m3,
Specific Heat (Cp)	3417.28 J/Kg.K
Thermal Conductivity (k)	0.097068 W/mK,
Dynamic Viscosity (μ)	2.09337 x10-5 kg/ms,

Table 5. Modeling dimensions of tube banks economizer

Tube Banks In-line			
name	*150 Tubes*	*200 Tubes*	*250 Tubes*
Transverse Pitch (ST)	135mm	100mm	78.9mm
Longitudinal Pitch (SL)	112mm	111.5mm	110mm
Spiral tube diameters	70mm	70mm	70mm

Tube Rows	10	10	10
length	1122mm		
width	2000mm		
Tube Banks staggered			
name	*150 Tubes*	*200 Tubes*	*250 Tubes*
Transverse Pitch (ST)	220mm	188mm	164mm
Longitudinal Pitch (SL)	62.5mm	55mm	50mm
Diagonal Pitch(SD)	126.5mm	108.9mm	96mm
Spiral tube diameters	70mm	70mm	70mm
Tube Rows	17	19	21
length	1122mm		
width	2000mm		

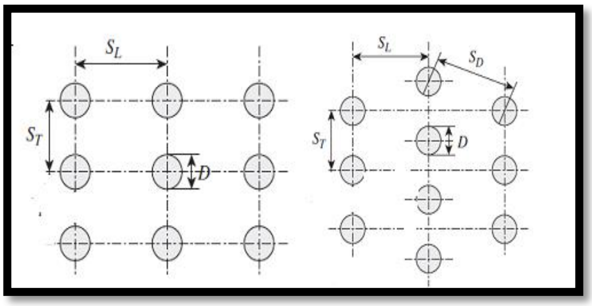

Figure 4. tube banks in-line and stragger

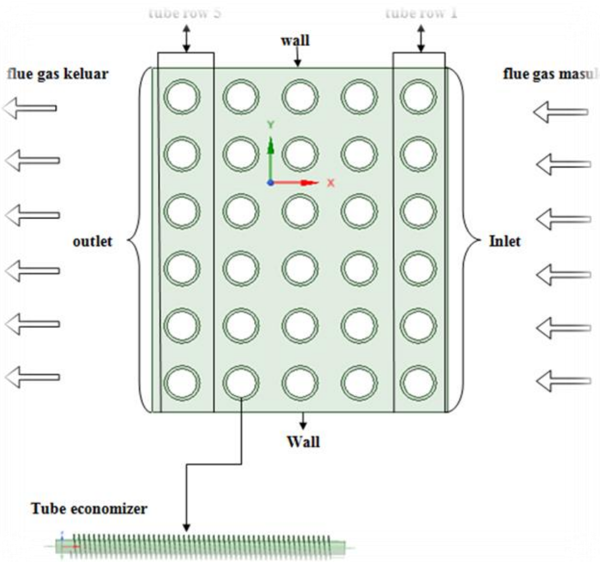

Figure 5. Modeling example for simulating in-line tube banks

This research will vary the position of the arrangement of tube banks, in-line and staggered as well as variations in the number of tubes for each tube bank with 150 tubes, 200 tubes and 250 tubes. The working fluid is flue gas (Ch4) with an inlet temperature of 389 oC and a speed of 19.3 m/s and the input data used is shown in Tables 3, 4 and 5.

There are three stages in numerical simulation, namely:

A. Pre-processing

Pre-processing is the first step in research aimed at building a computational model based on the required data. The stage itself consists of several sub-stages such as:

- Making geometry, in this study making geometry using spaceclaim software.
- Making the meshing and determining the tag-name, in this study the selected form of the mesh is a quadrilateral map with the addition of refinement to the mesh. To determine the tag-name based on the data obtained from the data sheet as shown in Figure 4.

B. processing

Processing is a stage to get results. At this stage the research was carried out using CFD-based software which consisted of several sub-stages as follows:

- Solver selection
- for the solver used is fluent software, when running it a display will appear to choose to use a 2D or 3D solver with single or double precision (single precision/double precision) so the chosen one is a 2D simulation with double precision (double precision).
- The choice of turbolance modeling, the turbulent model that will be used in this study is the k-omega sst modeling.
- Selection of operating conditions

C. Post-processing

Post-processing is the last sub-stage of numerical simulation. This sub-stage is the final process of the simulation, where the simulation results appear after the completion or convergence of the iterations carried out in the processing sub-stage. The results that emerged were data that I grouped into qualitative data and quantitative data. Qualitative data is in the form of flow visualization which is displayed in the form of images while quantitative data is in the form of data from the distribution of temperature and speed which is then processed using Microsoft Excel 2010 software so that later it can be displayed in the form of tables and graphs.

RESULTS AND DISCUSSION

In this study, qualitative and quantitative data were obtained. Qualitative and quantitative data analysis was carried out by displaying flow patterns from temperature contours and velocity contours from each tube bank with variations in the number of tubes for each tube bank. Furthermore, quantitative data analysis was carried out by presenting the data in the form of tables and graphs along with a discussion for each tube bank which includes the temperature distribution and velocity distribution for each tube bank.

Figures 8 and 12 show a flow visualization based on the contours of total temperature and in Figures 6 and 10 you can see a flow visualization based on the contours of velocity magnitude, for in-line and straggered tube bank flow with tube variations totaling 150, 200 and 250 tubes with a flue gas inlet speed of 19.3 m/s for each variation of the number of tubes in in-line tube banks. In the in-line and straggered tube bank models, the inlet temperature (flue gas) is 389 0C, the flue gas heat transfer coefficient is 251.983 W/m^2 K is modeled as the h value on the wall tube banks and the heat transfer coefficient of water is 10558.8 W/m^2 K is modeled as the h value on the tube. the temperature distribution in each tube bank can be seen and interpreted from the color groups formed, with a red indication is defined as the highest temperature or speed while the dark blue color is interpreted as the lowest temperature or speed. The variations in the number of tubes in in-line tube banks have the same number of tube rows, namely 10 tube rows. Whereas in staggered tube banks there are tube banks with the number of tubes 150 having 17 rows of tubes, the number of tubes of 200 having 19 rows of tubes and the number of tubes of 250 having 21 rows of tubes.

Tube Banks In-Line

A. Distribution of velocity magnitudes

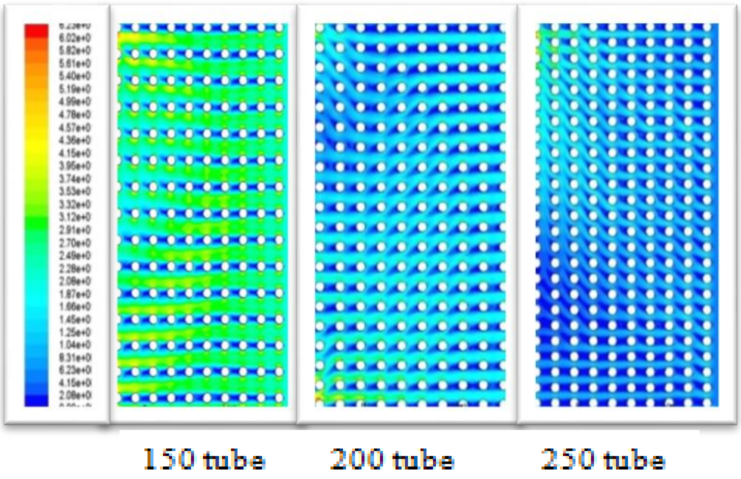

Figure 6. Speed distribution on in-line tube banks

Based on Figure 6 (velocity distribution on in-line tube banks) it is found that when the flow position hits the first tube on tube row 1 the velocity will be 0 m/s. this is called the stagnation point, where the flow of flue gas at high speed must stop just before it hits the tube. After passing through that position, the speed will experience acceleration (increased speed) with a value of:

- At 150 tubes of 62.3 m/s
- At 200 tubes of 127.5 m/s
- At 250 tubes of 227.2 m/s

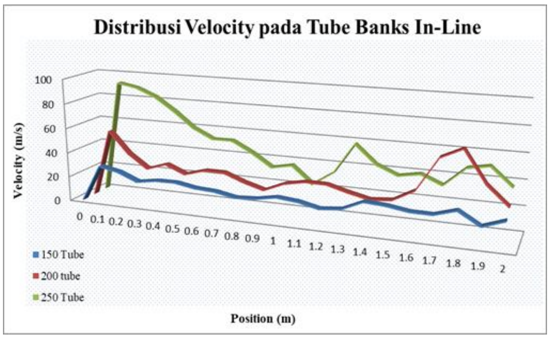

Figure 7. Graph of velocity output comparison to position in in-line tube banks

After the speed has accelerated to tube row 10, the flue gas speed will decrease with the speed value:

- At 150 tubes of 19.6 m/s
- At 200 tubes of 30.9 m/s
- At 250 tubes of 47.8 m/s

B. In-line tube bank temperature distribution

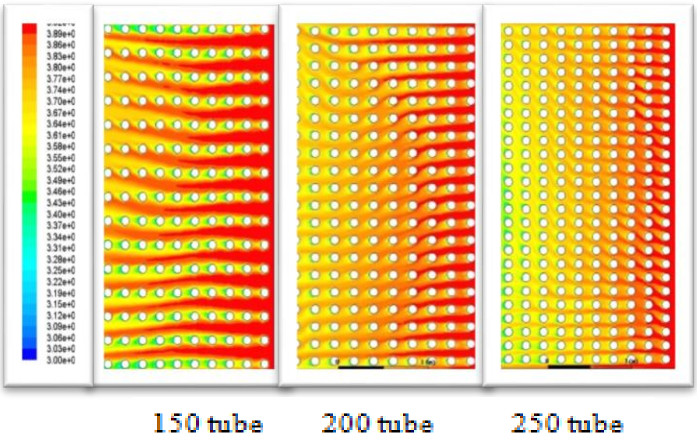

Figure 8. Temperature distribution on in-line tube banks

Based on figure 8 (contours of total temperature) at the beginning of the tube line it looks red which indicates high temperature which is the stagnation point. Where this is caused when the airflow velocity has a minimum temperature difference between the surface of the tube and the air around the tube. In each variation the number of tubes has a different temperature, as in the in-line ube banks with variations in the number of tubes

- 150 tube has a max temperature: 391.9 oC and drops to 300 oC
- 200 tube has a max temperature: 389.15 oC and down to 279.3 oC
- 250 tube has a max temperature: 389 oC and down to 260 oC

As can be seen, the number of tbe with 250 in in-line tube banks causes the temperature to drop faster than the variations in the number of tubes, which are 150 tubes and 200 tubes.

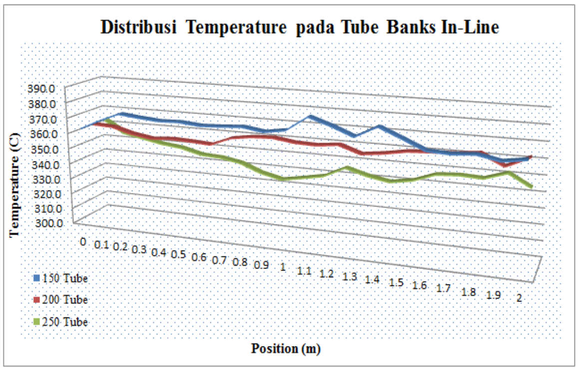

Figure 9. Graph of comparison of total temperature to position in in-line tube banks

Based on the graph in Figure 9 (comparison graph of temperature to position) it can be seen that the comparison of each number of tubes in in-line tube banks shows that the 250 tubes have good heat transfer compared to the other tubes due to the lower output temperature than the others.

Tube banks straggered

A. Speed distribution

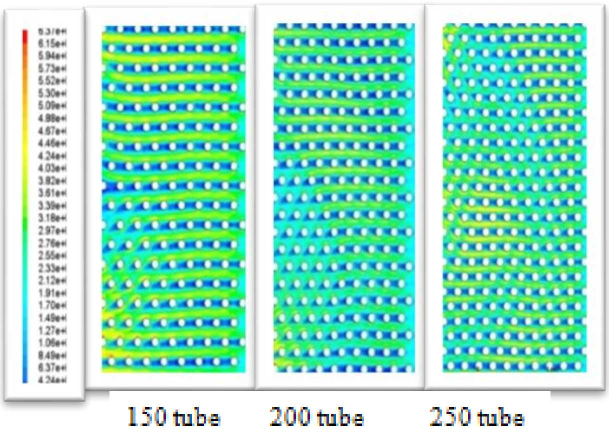

Figure 10. Speed distribution at staggered tube banks

Based on Figure 10 (velocity distribution on in-line tube banks) the result is that when the flow position hits the first tube on tube row 1 the velocity will be 0 m/s. this is called the stagnation point, where the flow of flue gas at high speed must stop just before it hits the tube. After passing through that position, the speed will experience acceleration (increased speed) with a value of:

- At 150 tubes of 63.65 m/s
- At 200 tubes of 78.47 m/s
- At 250 tube of 78.77 m/s

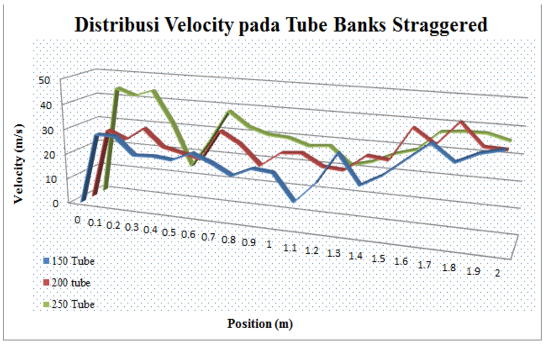

Figure 11. Graph of velocity output comparison against the position in staggered tube banks

After the speed has accelerated to the outlet, the flue gas speed will decrease with the speed value:

- At 150 tubes of 23.55 m/s
- At 200 tubes of 26.8 m/s
- At 250 tube of 29.55 m/s

B. Distribution of total temperatures

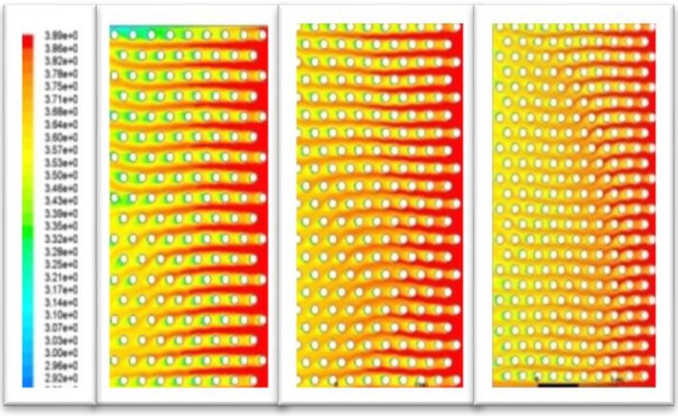

Figure 12. Temperature distribution on the tube banks straggered

Based on figure 12 (contours of total temperature) at the beginning of the tube line it looks red which indicates high temperature which is the stagnation point. Where this is caused when the airflow velocity has a minimum temperature difference between the surface of the tube and the air around the tube. In each variation the number of tubes has different temperatures, such as in straggered tube banks with variations in the number of tubes

- 150 tube has a max temperature: 389 oC and down to 281.59 oC
- 200 tube has a max temperature: 389.15 oC and down to 278.35 oC
- 250 tube has a max temperature: 389.3 oC and down to 257.74 oC

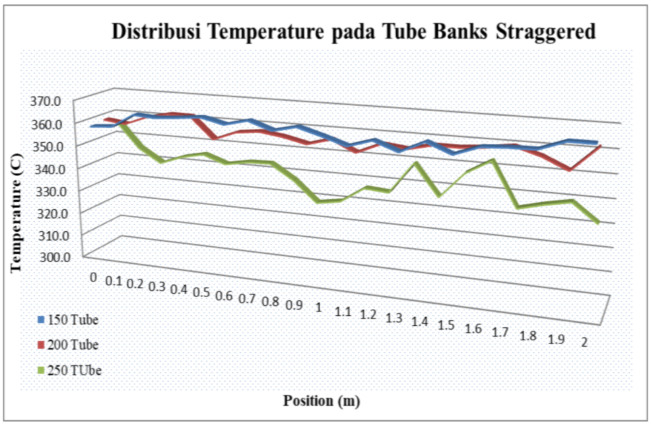

Figure 13. Graph of total temperature comparison against the position on the tube banks straggered

Based on the graph in figure 13 (comparison graph of temperature to position) it can be seen that the comparison of each number of tubes in tube banks straggered that the 250 tubes have good heat transfer compared to the other tubes due to the lower output temperature than the others.

Comparison of in-line tube banks and straggered tube banks

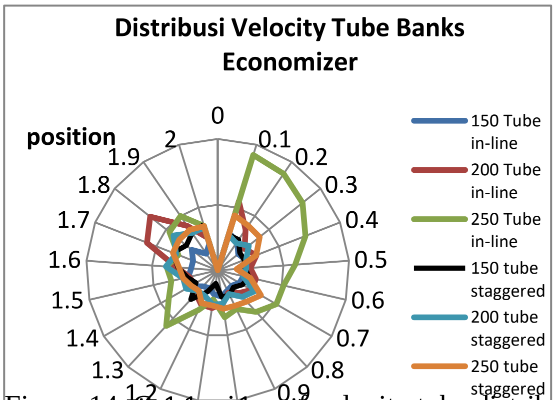

Figure 14. Comparison of velocity tube distribution in-line and straggered banks

In Figure 14 it can be seen that:

- The lowest velocity is in the in-line tube bank, the number of tubes is 150 with an average velocity value of 19.6 m/s.
- The highest velocity is in the tube banks in-line, the number of tubes is 250 with a speed of 47.84 m/s

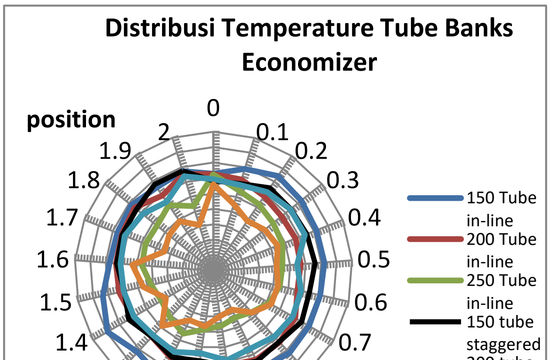

Figure 15. Comparison of distribution of tube banks in-line and straggered

In Figure 15 it can be seen that:

- The lowest temperature is in the straggered tube bank, the number of tubes is 250 with a temperature of 340 oC
- The highest temperature is in the in-line tube banks, the number of tubes is 150 with a temperature of 371.7 oC

The effect of variations in the number of tubes on the water output temperature in the economizer

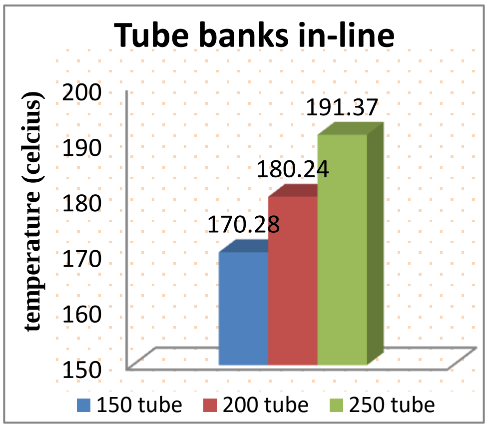

Figure 16. Output comparison diagram water temperature in the economizer

In essence the expected performance of the economizer is a decrease in flue gas temperature and an increase in the output water temperature in the economizer, in this study variations in the number of tubes in each tube bank turned out to affect the performance of the economizer as shown in Figures 16 and 17. The increase in the outlet water economizer temperature is influenced by the high temperature of the flue gas resulting in heat transfer between the fluids and causing an increase in the outlet water temperature.

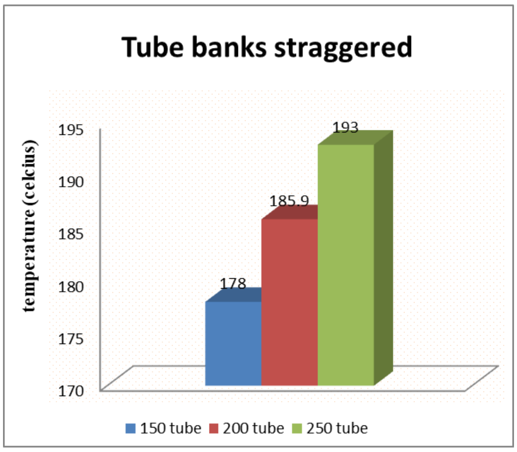

Figure 17. Output comparison diagram water temperature in the economizer

In Figure 16 (variation of the number of tubes in in-line tube banks) it can be seen that the tube banks in-line with the number of tubes of 250 have the highest temperature water economizer which is 164 oC, the variation with 200 tubes is 153.4 oC and the lowest is the variation with 150 tubes which is 142.5 oC. The same thing also happens in Figure 17 (variation of the number of tubes in straggered tube banks) water outlet temperature in straggered tube banks where the tube variation with 250 tubes has the highest water outlet temperature of 166 oC and overall the straggered tube banks have a high water outlet temperature for each tube variation.

CLOSING

Conclusion

Based on the description of the results and discussion above, it can be concluded that the effect of the arrangement of in-line tube banks and straggered tube banks with variations in the number of tubes (150, 200 and 250 tubes) on the heat transfer characteristics of the economizer is as follows:

A. Configurations with variations in the number of tubes in in-line and straggered tube banks affect heat transfer in the economizer.
B. The in-line tube bank variation with 250 tubes has better heat transfer characteristics than the other in-line tube bank variations with flue gas outlet temperature values of 260.32 oC and water outlet temperature of 191.3 oC. when viewed from the inlet water temperature of 110 oC, the percentage increase is 73.9%
C. The same thing happened to straggered tube banks, where the 250 tubes had the highest heat transfer characteristics of the others with flue gas outlet temperature values of 257.7 oC and water outlet temperatures of 193 oC. when viewed from the inlet water temperature of 110 oC, the percentage increase is 75.45%
D. When compared to the arrangement of in-line tube banks (200 tubes) which has an outlet water temperature of 180.24 oC, the percentage increase in temperature for in-line tube banks is 63.8% while for straggered tube banks the 250 tube variation with an outlet water temperature of 193oC has an increase of 7.1%.
E. Overall the straggered tube bank arrangement has better heat transfer than in-line tube banks.

Suggestions

The suggestions that can be given from the results of this study include:

1. Moving on to the next category, it is better if the analysis is reviewed further on the fin area such as its geometry on heat transfer characteristics.
2. The analysis of this study only covers the external area (flue gas), so it is necessary to carry out further research involving numerical analysis of the internal flow

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