Hydrodynamic and Thermal Characteristics Study of Heat Exchanger for Micro Gas Turbine Application

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INTRODUCTION

Gas turbine which informally known as burning turbine is an internal combustion engine operating in the rotation and is widely used in power generation applications, vehicles and various other application processes. Gas turbine cycle efficiency can be improved in various ways and one of them is by using a heat exchanger. Heat exchangers are widely used in heat transfer process in which the gas turbine, the air leaving the turbine is very high in temperature. This study aims to design the heat exchanger in micro gas turbines, and to analyze numerical of the rate of heat transfer and pressure drop in a heat exchanger which has been designed. The study uses computational fluid dynamics simulation methods (CFD). The shell and tube heat exchanger was selected and the mass flow rate of the cold water fluid changed during each simulation. Based on the simulation conducted, it is observed that the pressure drop of the fluid related to the mass flow rate. It is also noticed that the heat transfers between fluids increased when the mass flow rate increased.

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Keywords: Micro gas turbine, Shell and tube heat exchanger, pressure drop

Research parameter

i. Shell-and-tube heat exchanger
ii. Length of the copper tube 12 m
iii. Using ANSYS software to analyze the pressure drop and heat transfer
iv. Mass flow rate of hot air 0.042 kg/s
v. Case: change the mass flow rate of cold inlet fluids from 0.2 kg/s, 0.4 kg/s and 0.8 kg/s.
vi. Heat exchanger

Heat exchanger

Heat exchangers are devices that encourage the trading of energy between two liquids that are at various temperatures while keeping them from blending with each other [1-2].

Shell and tube heat exchanger

Shell and tube heat exchanger is generally built of a bundle of round tubes mounted in a cylindrical shell with the tube axis parallel to that of the shell. One fluid flows inside the tubes, the other flows across and along the
tubes. The major parts of this heat exchanger are tubes (or tube group), shell, frontend head, backside head, astounds, and tube sheets [3].

Flow arrangement
In cross flow arrangement, the two liquids for the most part usually move perpendicular to each other. The cross flow is further delegated unmixed and mixed flow. The cross flow is said to be unmixed when there is divider between tubes. The liquid is constrained through the interfin dividing and keep it from moving in the transverse direction whereby the stream is thought to be blended stream when there is no divider connected between tubes and the liquid is allowed to move in transverse direction [1].

Mass flow rate and pressure drop
Pressure drop or head loss is the reduction of in the total head or pressure of the fluid as it moves through a fluid system. The pressure drop of fluid is directly proportional to the length of pipes [4]. By forcing fluids to pass through the heat exchanger at higher mass flow rate, the efficiency of heat transfer might increase, but it also will produce a higher pressure drop [5].

METHODOLOGY
Experiments on the flow of air and water in the heat exchanger is carried out by using computational fluid dynamics (CFD) that contains the application of FLUENT. In this study, there are only one parameters are varied to obtain pressures drop and heat transfer in heat exchangers. Each simulation is different in mass flow rate of the cold water inlet in the heat exchanger.

The model of heat exchanger is simulated in FLUENT. The design parameters used for model is shown in Table 1.

<table>
<thead>
<tr>
<th>Case</th>
<th>Length of tube (m)</th>
<th>Mass flow rate of cold water (kg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>0.4</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Figure 4.1: Comparison of the scheme with different pressure-drop for cold fluid

Figure 4.2: Comparison of the scheme with different pressure-drop for hot fluid

Mesh independent check

There are three different cases were studied. The boundary conditions at inlet are set of velocity inlet, the outlets are set of pressure outlet and the wall are set of wall. Tri-pave elements are used in 3D model of heat exchanger.

Model for pre-processor exported to the solver as a parasolid format (*.x_t). A mesh independent check is performed in order to ensure which size of element suitable. Here, the material properties were defined. Boundary condition and operating condition is defined followed by initialization of calculation.

The inlet temperature for cold water is set 20°C and set 600°C for the hot air. The mass flow rate for hot air is set 0.042 kg/s.
Temperature

**Figure 4.6**: Comparison between the outlet temperature of cold fluid at different mass flow rate

It was observed that when mass flow rate of water inlet is 0.2kg/s, the temperature of water outlet is 340K which is an increment of 47K from 293K at inlet. When the mass flow rate increased from 0.2kg/s to 0.4kg/s, it was noticed that the outlet temperature of water is 332K which is slightly lower than when the mass flow rate is 0.2kg/s. However, doubling the mass flow rate from 0.4kg/s to 0.8kg/s will not double the result, the outlet temperature for water is 328K.

Pressure

**Figure 4.8**: Pressure drop at different mass flow rate

From the chart obtained, we can say that the higher mass flow rate of water inside tube, the higher the pressure drop. When the mass flow rate is 0.8kg/s the pressure drop is 351118Pa inside the tube. When we decreased the mass flow rate from 0.8kg/s to 0.4kg/s, the pressure drop for water inside tube massively alleviated from 351118Pa to 94911Pa. Finally, reduction of mass flow rate from 0.4kg/s to 0.2kg/s lessen the pressure drop even more which is 26093Pa. The pressure drop inside shell remain the same through out the case.

CONCLUSION

Overall, from the simulation conducted, we observed that by changing the size of the mesh, it will affect the result of the simulation. It is also noticed that by using different values of the mass flow rate, it will affect the value of pressure drop. It is also important for us to know the value of parameters and what materials needed to perform the simulation. Besides, the boundary conditions play as an important factors which will determine whether the
results obtained at the end of the simulation is similar with the objectives of the research.

From the simulation, the lowest pressure drop inside tube achieved when the mass flow rate is 0.2kg/s. Other than that, we can say that the heat transferred between fluids is directly proportional to the mass flow rate. The objective of the experiment was achieved when we managed to reduced the hot air temperature from 873K to 631K.

Acknowledgement
The authors also would like to thank the Fundamental Research Grant Scheme (FRGS) Vot. K 218 and also Research Fund Universiti Tun Hussein Onn Malaysia (B057) and U749.

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