CFD Analysis of Circular Pin Fin

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Abstract: ***This research presents the numerical analysis of heat transfer and pressure drop in a heat exchanger designed with inline arrangement of circular pin fin. The heat exchanger used for research consists of rectangular duct fitted with circular pin fins. Ansys software is used for the analysis of heat transfer.***

Keywords: heat transfer, velocity and pressure drop, turbulence, reynold's number.

1. Introduction

In this analysis a numerical study using FLUENT© will be conducted to study heat transfer analysis through circular shaped pin fin heat exchanger..A numerical simulation will investigate using three dimensional model of a compact heat exchanger consisting of a rectangular duct with inline arrays of circular and pin fins in a cross flow of air. The heat transfer and associated pressure drop behavior are characterized. Different parameters will be investigated.

A thorough experimental characterization of different possible shapes is a very expensive and time consuming task, due to the enormous cost of experimental parts and tools. In addition, there is little geometric flexibility built into test models, and a new model has to be constructed for each different configuration. Numerical study can be the remedy for that by offering a quick and cost effective means of study with the advantage of having great flexibility in the geometry and boundary conditions. Many configurations can be studied at different Reynolds numbers and turbulence levels, and many different pin shapes and arrangements can be investigated.

2. Literature Review

Hamid Nabati [3] focused on the investigation of the effects of fin morphology in prediction of the flow and heat transfer in a typical heat exchanger passage. A numerical study using FLUENT© was conducted to select the optimum pin shape considering maximum heat transfer and minimum pressure drop across the heat exchanger. A numerical simulation had been investigated using three dimensional models of a compact heat exchanger consisting of a rectangular duct with inline arrays of three different shapes pin fins in a cross flow of air. The heat transfer and associated pressure drop behavior were characterized. Different parameters were investigated and an optimum geometric configuration together with a pin shape was selected based on the overall heat exchanger performance. Finally a comparison between pressure drop and heat transfer was carried out.

David Ramthun [2] has performed a detailed experimental study on the heat transfer and pressure drop characteristics of a compact heat exchanger with pin fins. The results from this study provide useful empirical data to validate ongoing numerical studies of such heat exchanger designs.

Jihed Boulares [1] first conducted A numerical study using ANSYS to select the optimum pin shape and configuration for the CHE and validated by experimental study. The results indicate that the drop shaped pin fins yield a considerable improvement in heat transfer compared to circular pin fins for the same pressure drop characteristics. This improvement is mainly due to the increased wetted surface area of the drop pins, and the delay in the flow separation as it passes the more streamlined drop shaped pin fins.

3. CAD Model

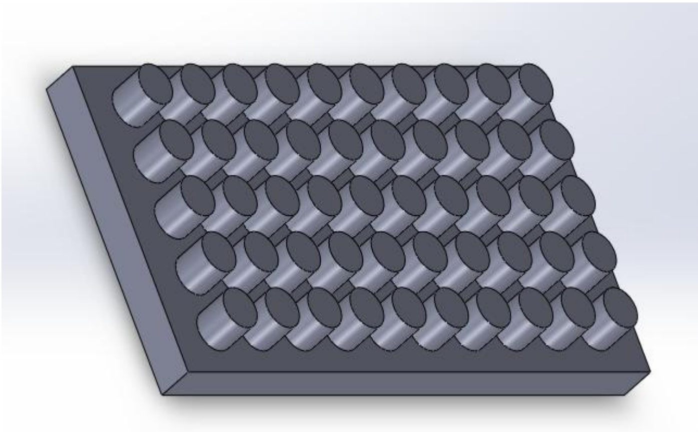


Figure 3.1: CAD model of inline array of circular pin fin

4. Numerical Model

The finite element modeling was conducted using the FLUENT simulation software ANSYS version 16.2. This study examined laminar flow (for low Reynolds numbers), turbulent Flow (for high Reynolds numbers) and heat transfer characteristics within a 3-D inline and staggered short circular and drop-shaped pin fin array compact heat exchanger respectively. Taking advantage of the symmetry planes in the heat exchanger, and in order to minimize the computational requirements and time, only one fourth of the heat exchanger was modeled.

Also, to simplify the model and reduce the number of required elements, nodes and time required for the calculation, only the fluid (air) was modeled and the solid walls, as well as, the pins were considered as isothermal boundary conditions eliminating the need to calculate the temperature distribution in the solid pins and the walls. This was especially justifiable for the short pins being considered in this study.

Based on these simplifications, the model appears as shown in Figure . The model is composed of three parts. The first part is a smooth entrance duct upstream of the test section having the same cross section as the test section and long enough to provide a fully developed flow condition at the entrance to the heat exchanger. The length of this section varies with Reynolds number. The air then passes through the test section composed of 10 rows of drop shaped pin fins. After the test section the air continues through a smooth exit section design to prevent boundary condition feedback into the test section.

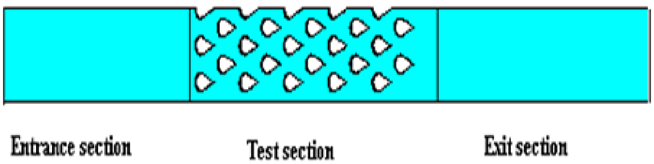


Figure 4.1: Finite element model

5. Numerical Mesh

To mesh the model, hexahedral 8-node element spacing was specified along the boundary and swept later to cover the entire model volume, as shown in Figure 5. Meshing also was refined in some critical areas to ensure coverage for satisfactory resolution. It was refined near the no slip walls where velocity and temperature gradients were expected to be high, and also between the pins to capture the flow acceleration due to the decrease in the cross section area. Nodes were also concentrated around the pins to account for the change of the velocity and temperature gradient and pressure drop and at the end wall were the temperature gradients are expected to be higher. Grid independence was always verified. Since the current ANSYS license is limited to 256, 000 nodes, two runs were done for each configuration at a certain Reynolds number. The first one was completed at a number of nodes close to 256, 000 and the second at approximately 25-30% less nodes. A run was considered to be grid independent, if the overall heat transfer rate difference between the two remained below 2%.

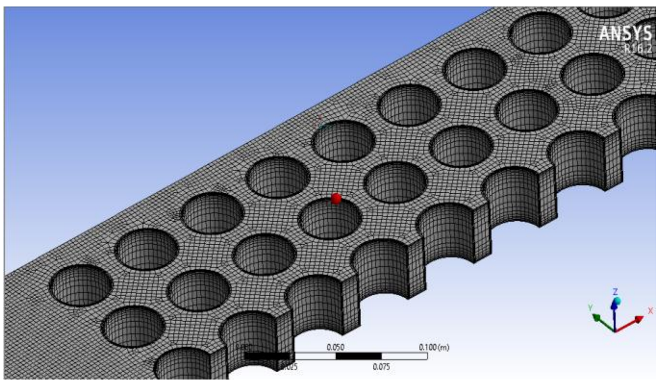


Figure 5.1: Sample Mesh Model

6. Boundary Conditions

a. Pins

The pins are treated as short and with very high thermal conductivity. The pins are therefore assumed to be isothermal with a uniform temperature of 306 K. The no slip condition was applied to the pin surfaces.

b. End Wall

The end wall is kept at a constant temperature of 306 K. Since it is a rigid boundary the no slip condition was applied leading to a zero velocity in the 3 directions, Ux=Uy=Uz=0. The inlet and exit end walls are modeled as adiabatic walls with zero velocity in the three conditions.

c. Symmetry Walls

The symmetry walls are assumed to be adiabatic modeled with zero heat flux. The midheight plane was given zero velocity in the z direction (Uz=0) and the mid-width plane was given a zero velocity in the y direction (Uy=0) thus preventing the flow from crossing the boundary but yet allowing a velocity profile to develop. The inlet and exit symmetry walls have the same features as in the test section.

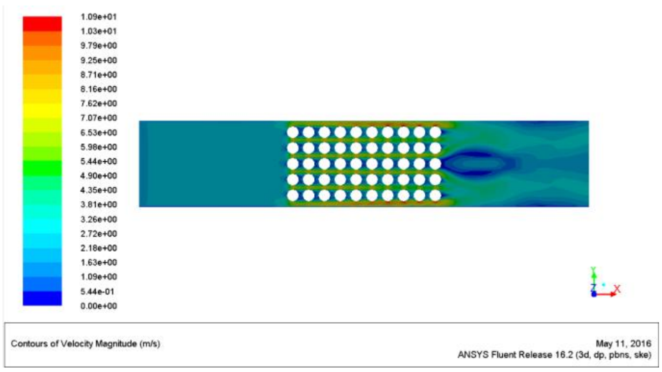
d. Side Wall

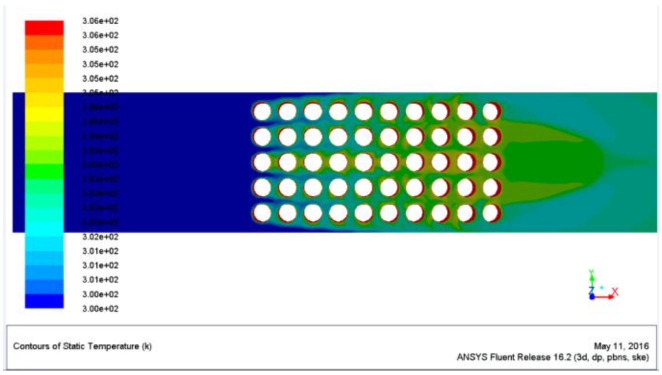
The sidewall is modeled to be adiabatic with zero heat flux. The no slip condition was applied and zero velocity in the tree direction (Ux=Uy=Uz=0) was used. The inlet and exit sidewalls have the same properties as the same properties as the test section ones.

e. Inlet

The inlet air temperature is set to 300 K. The inlet velocity depends on the chosen Reynolds number, which is set based on the wetted surface area.

7. Results





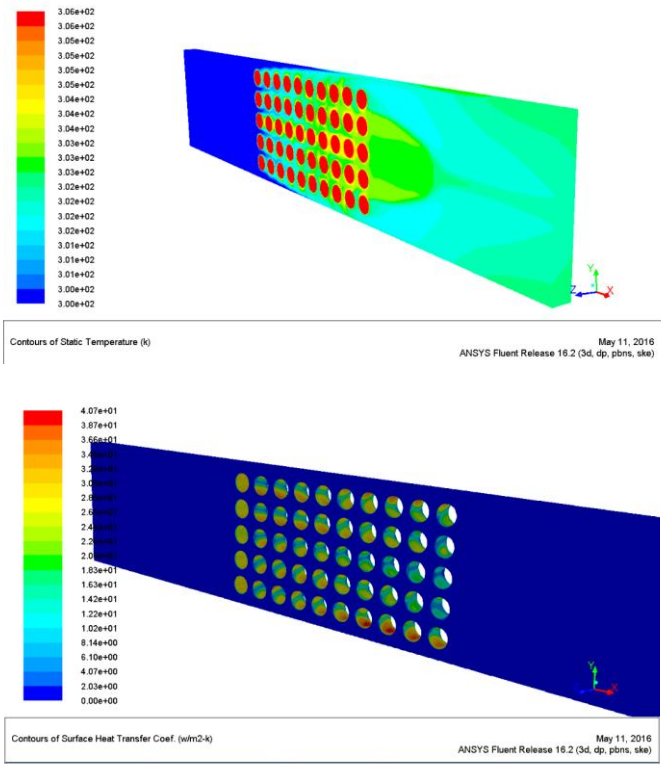


Figure 6.1: Temperature, velocity, nusselt number and heat transfer coefficient contour at Re=5000

8. Conclusion

Three dimensional numerical model of inline circular pin was studied in cross flow of air with isothermal heat transfer surfaces and its various parameters were studied.

References

[1] Jihed Boulares, June 2003 “Numerical And Experimental Study Of The Performance Of A Drop-Shaped Pin Fin Heat Exchanger” a Thesis.
[2] David Ramthun, June 2003 “An Experimental Study Of A Pin Fin Heat Exchanger” a Thesis
[3] Hamid Nabati, 2008“Optimal Pin Fin Heat Exchanger Surface” a Thesis.
[4] Sanjay Kumar Sharma and Vikas Sharma. Aug 2013 “Maximizing The Heat Transfer Through Fins Using CFD As A Tool” International Journal of Recent advances in Mechanical Engineering (IJMECH) Vol.2, No.3
[5] Mukesh Didwania, Gopal Krishan and Ravikant “Study and Analysis of Heat Transfer through Two Different Shape Fins using CFD Tool “International Journal of IT, Engineering and Applied Sciences Research (IJIEASR Volume 2, No. 4, April 2013.
[6] Z. Chen, Q. Li, D. Meier and H.-J.Warnecke 1997 “Convective heat transfer and pressure loss in rectangular ducts with drop-shaped pin fins” Heat and Mass Transfer 33 (1997), 219-224 Springer-Verlag 1997
[7] Fengming Wang, Jingzhou Zhang and Suofang Wang, Sept 2012 “Investigation on flow and heat transfer characteristics in rectangular channel with drop-shaped pin fins” Propulsion and Power Research 2012;1(1):64–70.
[8] Christopher L. Chapman, and Seri Lee , 1994 “Thermal Performance Of an Elliptical Pin Fin” IEEE.
[9] O˘ guz Uzol _, Cengiz Camci, “Elliptical Pin Fin As an Alternative To Circular Pin Fin For Gas Turbine Blade Cooling Applications” 22
[10] Hsien-I You and Chung-Hsing Chang, 2000 “Experimental Study On Heat Tranfer And Friction In Pin Fin Channel Flow” Journal Of the Chinese Institute Of Engineers, Vol 23, No.1, pp.117-123
[11] Rao Yu*, Wan Chaoyi and Zang Shusheng, April 2009 “Transitional Flow and Heat Transfer Characteristics in a RectangularDuct with Stagger-arrayed Short Pin Fins” Chinese Journal of Aeronautics 22(2009) 237-242.
[12] G.James Van Fossen, March 1981 “Heat Transfer Coefficient For Staggered Arrays Of Short Pin Fins” Nasa.
[13] Akash Pandey, 2011 “Performance Analysis Of Compact Heat Exchanger” NIT Rourkela
[14] Jainender Dewatwal, 2009 “Design Of Compact Plate Fin Heat Exchanger” NIT Rourkela.
[15] Monoj Baruah, Anupam Dewan and P. Mahanta, June 2011 “Performance of Elliptical Pin Fin Heat Exchanger with Three Elliptical Perforations” CFD Letters Vol. 3(2) 2011

Author Profile

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