NUMERICAL ANALYSIS OF PLATEFIN HEAT EXCHANGER AT CRYOGENIC TEMPERATURE

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Abstract: The objective of this study is to provide experimental data that could be used to predict the effectiveness and performance of a plate fin heat exchange for low temperature conditions. In this study, plate fin heat exchangers are tested with a variation of their mass flow rate. Plate fin heat exchangers are widely used in cryogenic liquefaction. Such heat exchangers have high fin density and offer narrow passages for the fluid flow which often leads to significant pressure drop. The stringent requirement of high effectiveness and excessive pressure drop occurring in plate fin heat exchanger makes it necessary to test the heat exchanger before using in any system. An Numerical setup is made in the laboratory to test the plate fin heat exchanger at cryogenic temperature. In this setup compressed Nitrogen gas will be passed through the plate fin heat exchanger as hot stream. The hot stream gas will be passed through a liquid Nitrogen coil heat exchanger to cool the high pressure gas. The cold gas is then passed as a reverse stream of the plate fin heat exchanger. The effectiveness and pressure drop data is simulated with ANSYS software and also compared with other correlations to confirm the accuracy of the experiment.

Key words: Plate fin heat exchangers, Numerical setup, ANSYS software.

I. Introduction:

Heat transfer in heat exchanger is based on laws of thermodynamics mostly the second law of thermodynamics i.e. heat flows from one object to another object at a lower temperature. The application of the heat exchangers is very vast and is widely used for the transfer of heat in industrial and household equipment’s such as refrigeration and air conditioning, process and distribution plant, manufacturing industry, cryogenic and air separation plant etc.

However, especially in cryogenics, a wide range of heat exchangers is used. It is one of the most important equipment of any liquefaction process in the industry. The heat exchangers are relevant for liquefaction to storage, loading and transportation. The thermal energy is transferred by the fluid from one surface to another surface predominantly by the phenomena of conduction and convection.
The two ways of transferring energy are direct contact and indirect contact methods lead to two types of heat exchangers called recuperative and the regenerative. In one of the such classes, the heat transfer surface separates fluids, and preferably they do not mix or leak such type of heat exchangers are mentioned as direct transfer type of heat exchanger, or simply recuperators. In contrast, the other class of heat exchanger transfers heat alternatively between the hot and cold fluids through stored heat energy in a matrix. This is known as an indirect transfer type of heat exchanger, or simply regenerators.

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2. Practical applications

Specifically, the application of heat exchanger is to heat or cool the system as per the necessity. There is a numerous application of heat exchanger. Some of the applications are given below.

i. In industry, heat exchangers are used for various purposes. The major use of industries which used different types of heat exchangers are:

- Transformer oil coolers
- Motor and generator coolers
- Chemical plants
- Food processing plant
- Petroleum Processing
- Mining
- Textiles

ii. Heat Exchanger are used in aircrafts mainly for keeping the engine cool. Highly inflammable fuel used in aircrafts makes the use of heat exchanger very crucial.

- Aerospace liquid cooling
- Liquid cooling in an airplane
- Duct heater for a military helicopter
In cryogenics the heat exchanger plays major role in the field of liquefaction of gases and also in the other equipment’s such as given below.

- Gasturbinepowerplant
- Gasliquefaction
- Chiller’s
- Cryorefrigerators
- Biopharmaceutical
- Cryogenic packaging and treatment equipment such as MRI
- Cryogenic fuel lines

The heat exchangers are mainly divided into two parts ‘recuperative and regenerative type’ as shown in figure 1.1. The classification of plate heat exchanger is shown in Figure 1.2.
iv. Automobiles too need heat exchanger technically the heat exchangers effectiveness required for automobile is comparatively low as compared to the heat exchanger used in cryogenics purpose.

- Radiator
- Oil coolers
- Exhaust gas recirculation coolers
- Airconditioning
- Unmanned aerial vehicles

Varieties of Compact Heat Exchanger [18]

- Plate heat exchanger (PHE)
- Plate fin heat exchanger (PFHE)
- Printed circuit heat exchanger (PCHE)
- Themarbond heat exchanger
- Ceramic heat exchanger
- Spiral heat exchanger (SHE)

3. RESULTS:

The present investigation deals with the simulation of the test heat exchanger with cold layer test and hot layer test at different mass flow rates and at different cold fluid inlet temperatures and the evaluation of the thermal performance factors like effectiveness and pressure drops. In this chapter, the results obtained from the simulation are presented in the tabular form and also the comparison between the cold and hot layer test is shown with the help of graphs.

**Simulation with Cold Layer Test:**

Table 6-1 Results obtained at 80K

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<th>ΔP2 (Pa)</th>
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Results obtained at 110K

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Comparison between Cold layer test and Hot layer test

The above comparison graphs (fig. 2.0) show that the effectiveness for both the layer test shows similarity at all temperatures and mass flow rates. The effectiveness in between the mass flow rates of 5 gm/sec and 6 gm/sec shows absurd behaviour, i.e. does not match with the rest of the trend even after steady state.

4. Conclusion:
The comparison between cold and hot layer test reveals that the pressure drop ranges for cold test method is higher than that for the hot test at all temperatures and the graphs for effectiveness shows that for low mass flow rates there is a deviation in the values of effectiveness occurring due to the divergence of results. The pressure drop is found to be increasing with increasing mass flow rate.
The fin efficiency is decreasing with the increasing temperature across the length of the exchanger for both the hot and cold fluids.

References: