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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 themass 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 thermodynamicsmostlythesecondlawofthermodynamicsi.e.heatflowsfromoneobjectofhighertemperatureto another object at a lower temperature. The application of the heat exchangers is very vastand is widely used for the transfer of heat in industrial and in house hold equipment’s such asin refrigeration and air conditioning, process and distribution plant, manufacturing industry,cryogenic and air separation plant etc.

However,especiallyincryogenics,awiderangeofheatexchangersisused.Itisoneofthemostimportantequipmentofanyliquefactionprocessintheindustry.Theheatexchangersare relevant for liquefaction to storage, loading and transportation. The thermal energy istransferred by the fluid from one surface to another surface predominantly by the phenomenaofconduction and convection.

Thetwowaysoftransferringenergyaredirectcontactandindirectcontactmethodleadsto two types of heat exchangers called recuperative and the regenerative. In one of the suchclasses, the heat transfer surface separates fluids, and preferably they do not mix or leak suchtype of heat exchangers are mentioned as direct transfer type of heat exchanger, or simplyrecuperators. Incontrast, theotherclassofheatexchangertransfersheatalternativelybetweenthe hot and cold fluids through stored heat energy in a matrix. This is known as an indirecttransfertypeof heat exchanger, or simplyregenerators.

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2. Practical applications

Specifically, the application of heat exchanger is to heat or cool the system as per thenecessity.Thereisnumerousapplicationofheatexchanger.Someoftheapplicationsaregivenbelow.

i. InindustryheatexchangersareusedforvariouspurposesThemajoruMATsofindustrieswhichusedifferent types of heat exchangers are:

- Transformer oil coolers
- Motorandgeneratorcoolers
- Chemical plants
- Foodprocessing plant
- Petroleum Processing
- Mining
- Textiles

ii. Heat Exchanger are used in aircrafts mainly for keeping the engine cool. Highlyinflammablefuel usedinaircrafts makesthe useofheat exchangerverycrucial.

- Aerospaceliquidcooling
- Liquidcoolingin anairplane
- Ductheaterfor amilitaryhelicopter

iii. In cryogenics the heat exchanger plays major role in the field of liquefaction of gasesandalso in the other equipment'ssuchasgiven below.

- Gasturbinepowerplant
- Gasliquefaction
- Chiller's
- Cryorefrigerators
- Biopharmaceutical
- CryogenicpackagingandtreatmentequipmentsuchasMRI
- Cryogenicfuellines
- Superconductingmagnets

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 Figure1.2.

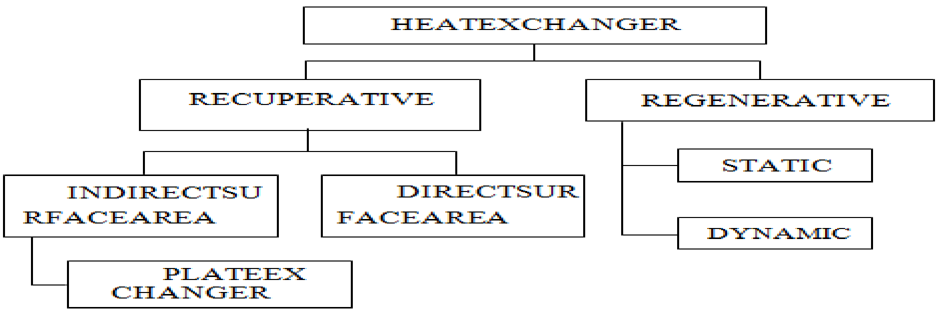

Figure1.1Classificationofheatexchangers

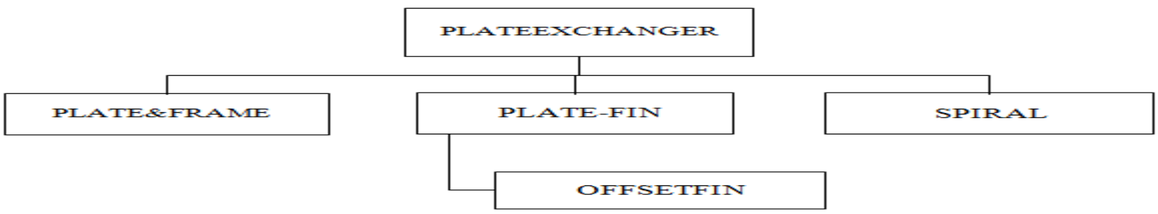

Figure1.2Classification of Plate exchangers

iv. Automobiles too need heat exchanger technically the heat exchangers effectivenessrequired for automobile is comparatively low as compared to the heat exchanger usedincryogenics purpose.

- Radiator
- Oilcoolers
- Exhaustgasrecirculation coolers
- Airconditioning
- Unmannedaerialvehicles

Varieties of Compact HeatExchanger [18]are,

- Plate heat exchanger (PHE)
- Plate fin heatexchanger(PFHE)
- Printed circuit heatexchanger(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

m	ΔP_h	ΔP_c	T_{ho}	T_{hi}	T_{co}	T_{ci}	ε
(gm/sec)	(Pa)	(Pa)	(K)	(K)	(K)	(K)	
5	162	167	112.95	315	286.47	80	0.859787
6	177	219	107.76	315	290.21	80	0.881872
7	193	274	107.46	315	291.85	80	0.883149
8	209	330	106.9	315	292.48	80	0.885532
9	227	391	106.53	315	292.96	80	0.887106
10	245	453	105.66	315	293.58	80	0.890809
12	283	593	105.81	315	293.81	80	0.89017
15	349	832	106.13	315	293.78	80	0.888809

Results obtained at 110K

m	ΔP_h	ΔP_c	T_{ho}	T_{hi}	T_{co}	T_{ci}	ε
(gm/sec)	(Pa)	(Pa)	(K)	(K)	(K)	(K)	
5	168	256	131.65	315	292.59	110	0.88127
6	176	268	133.94	315	293.42	110	0.88322
7	190	308	132.6	315	296.02	110	0.889756
8	208	368	132.57	315	295.5	110	0.889902
9	227	438	131.74	315	296.73	110	0.893951
10	246	504	131.7	315	296.3	110	0.894146
12	266	578	131.34	315	296.61	110	0.895902
15	288	657	131.52	315	296.55	110	0.895024

Comparison between Cold layer test and Hot layer test

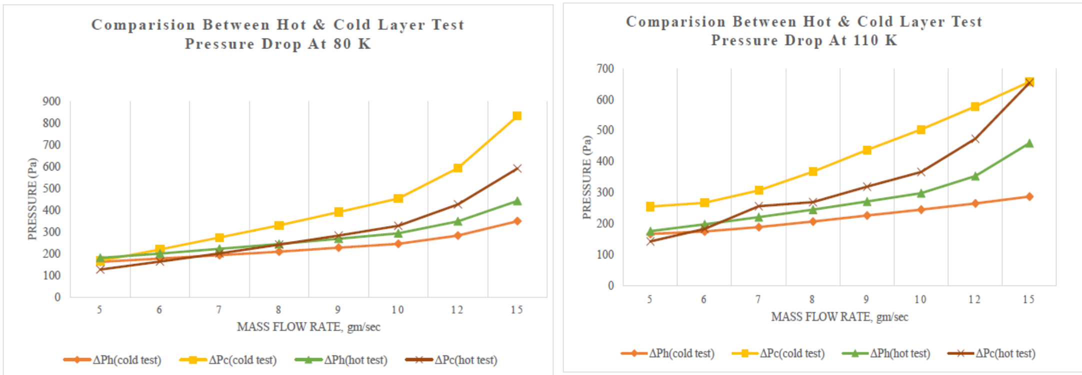

Fig2.0 Comparison of hot and cold layer

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.

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