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CFD AND NUMERICAL ANALYSIS OF HEAT TRANSFER ENHANCEMENT IN CORRUGATED PLATE TYPE HEAT EXCHANGER

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***Abstract**—According to research papers in the industry mostly triangular corrugation plate type heat recharger used. In triangular corrugation plate type heat exchanger outlet temperature is not maintain. Take a practical reading of triangular corrugation plate type heat exchanger and CFD analysis of triangular corrugation plate type heat exchanger, And compare the practical reading and CFD result of triangular corrugation plate type heat exchanger , both are almost the same with minor error, Now study the sinusoidal corrugation plate type heat exchanger and CFD analysis of sinusoidal corrugation plate type heat exchanger , compare the practical reading of triangular corrugation plate type heat exchanger , CFD analysis of triangular corrugation plate type heat exchanger and CFD analysis result of sinusoidal corrugation plate type heat exchanger, the sinusoidal corrugation type plate type heat exchanger gives batter results as compare to triangular corrugation plate type heat exchanger.*

Keywords**— *Sinusoidal corrugation*, *Plate at plate type Heat Exchanger, Geometry of wall, Numerical analysis, Triangular corrugated wall.***

I. INTRODUCTION

Heat transfer enhancement with less pressure drop in heat exchanger devices is the very crucial phenomena in the thermal engineering. It has a lot of application in Heat exchangers, Process industries Condenser and evaporators, Thermal power plants Air conditioning systems and so on. The main problem in the heat industries is overheating which causes the failure of the system and various heat losses which cause to reduce the efficiency of the system in bulk amount. So that effective cooling is the great requirement of industries now a day. For cooling, generally a heat exchanger is used to transfer the waste heat from the hot fluid to cold fluid. Cooling is one of the applications of heat-exchanger. Other application of heat exchanger is to increase the system efficiency. For example, in thermal power plant, heat exchanger is used as super heater, condenser, feed water heater, air pre-heater and so on. In a heat exchangers, there are two major parameters one is heat transfer rate and other is the pressure drop across the heat exchanger (if it is high then more power require to pump the fluid).Therefore, for heat transfer enhancement, one should keep in mind that the pressure drop in a heat exchanger is very crucial parameter. Heat transfer is directly proportional to the surface area and the temperature difference. While temperature difference is restricted, another way to get maximum heat transfer is to change the wall geometry such that it will give maximum surface area as well as minimum pressure drop.

II. LITERATURE REVIEW

Many researcher studies on to the subject plate heat exchanger for improving its heat transfer rate hot fluid to cold fluid. As per the below literature survey we get some conclusion and research gap.

1. Veli Ozbolat Nehir, Tokgoz, Besir Sahin, IJMAIMME, Vol.7, No: 10(2013) :-In this paper the governing continuity, momentum and energy equation solved by SIMPLE Technique and Wavy surfaces operate as turbulence promoters to increase the heat transfer, In corrugated heat exchanger Nusselt number is high at duct throats.
2. Numerical Investigation of the Effect of Geometrical Shape of Plate Heat Transfer Efficiency Hamed Sanei, Mojammad, IJMAIMME,Vol.10, No.5,(2016):- The wonders are concentrated by changing the shape and size of the divider geometry and catch the variety of qualities (such temperature, pressure) along the channel is likewise contemplated. In this investigation, it is seen that warmth move improvement increments with the addition of the adequacy.

It is discovered that warmth move upgrade is most extreme for trapezoidal creased channel. It is likewise acquired that pressure misfortune is least with sinusoidal ridged channel. The primary focal point of the work was worried about hydrodynamic and warm examination of the plate heat exchanger channel with sinusoidal crease.

3. Design and analysis of plate heat exchanger with co2 and R134 as working fluids, T K S Sai Krishna, S G Rajasekhar, C pravarakhya., IJMET, Vol 4, Issue 4, July-August (2013):- In this paper plate heat exchanger performed CFD analysis in ANSYS software. The analysis stated that when the of the thickness of the plates decreases then the heat transfer rate increases and if the number of the plate increases then the outlet temperature difference of the fluid increased.

4. Modelling of fluid flow in 2D triangular, sinusoidal , and square corrugated channels, Abdulbasit G.A , Abdulsayid, IJCMNMME, Vol 6, No11(2012):- In this paper, work on the thermals analysis of three corrugated plate 1. Triangular, 2.sinusoidal, 3.square Reynolds number is function of the flow velocity, it is observed for triangular corrugated channel that if the flow velocity increase 125% the pressure drop increases 233.3%, and pressure drop increases 17.5%in the triangular model compared to in sinusoidal model , For the same Reynolds number friction factor high for square corrugated plate and low for sinusoidal corrugated plate.

5. Computer Aided Design CFD analysis of plate Heat exchanger, Dnyaneshwar B. Sapkal, Samir J. Deshmukh, Rucha R. Kolherkar, IJIERE, Vol 2, special issue 1 MEPCON (2015):-In this paper study of modelling a copper plate heat exchanger for milk pasteurization in a food industry using high temperature for a short time . And also compare with mild steel plate heat exchanger. Result obtained the total volume in use by M.S .material plate heat exchanger is 0.153 m3, while the volume of the copper plate heat exchanger is 0.02721m3 using copper material .total saving volume is 82.16%.When the use the copper plate heat exchanger in place of M.S material then the less material required in copper plate heat exchanger . But material cost is high.

6. Experimental Analysis of Heat Transfer Rate in Corrugated Plate Heat Exchanger Using Nano fluid in Milk Pasteurization Process , Ajinkya , K.Tamilselvan, B.Sivabalan, R.Prakash, M.Manojprasath, A.Mahabubadsha , Volume-4, Issue-5, May(2017) :-In This research paper focused on the heat transfer analysis of corrugated plate heat exchanger using Nano fluid in milk pasteurization process. The main advantage of using corrugated PHE in this work is that it has high heat transfer area. By using corrugated (sinusoidal) structure in heat transfer plates fouling will be reduced considerably. To get efficient heat transfer rate counter flow arrangements are made in this work.

III. PROBLEM DEFINITION

All In Industry when water temperature is high pass out PHE than Drive system(at limit value) is cut off and all system is shut down so much of time and money is west in some time. Because heat transfer rate is less and pressure drop is large at plate side. Overall Production decrease and Net profit decrease. And its solution is “CFD AND NUMERICAL ANALYSIS OF THE HEAT TRANSFER ENHANCEMENT IN CORRUGATED PLATE TYPE HEAT EXCHANGER”.

IV. OBJECTIVES

- To develop a CFD model in ANSYS using plate type heat exchanger (with triangular corrugation) and estimate pressure drop, outlet temperature and rate of heat transfer.
- To conduct experiments on plate type heat exchanger (with triangular corrugation), and measured pressure drop and outlet temperature. Validated the results of CFD with experimental results.(calculate error between two results).
- To estimate outlet temperatures, pressure drop and rate of heat transfer for plate type heat changer (with sinusoidal corrugation) using CFD model developed in ANSYS.
- To Compare the CFD results of plate type heat changer (with sinusoidal corrugation) with existing design (with triangular corrugation) and also consider error (occur in above problem).

V. EXPERIMENTAL AND CFD ANALYSIS OF EXISTING SETUP(MODEL)

Typical capacities:

1. Liquid flow rate:
   Up to 250 gpm, depending on media, permitted pressure drop and temperature program.
2. Standard materials
   (a) Frame plate:
   Mild steel, painted
   (b) Nozzles:
   Flange: Stainless steel,
   Lined: Stainless steel,
   Pipe: Stainless steel
   (c) Plates:
   Stainless steel AISI 316
   Titanium (M6M only)
   (d) Gaskets:
   Nitrile, EPDM

The setup employed for this experiment:

- A stainless steel plate heat exchanger with a facility to measure inlet and outlet temperature of hot and cold fluid with an accuracy of 0.1 °C.
- The plates are corrugated (triangular), There are a total of 14 plates making 15 chambers for the fluid transport– eight for the cold fluid and Seven for the hot fluid.
- The total heat transfer area available is equal to that of the number of plates (14). (Assignment: Measure the components of the plate heat exchanger).
- The cold fluid used here is water and the hot fluid is DM water. (TASK: Determine the dependence of both the fluids' properties–viscosity, thermal conductivity, and specific heat–with temperature in the range 40–80 °C).
- A treated steel protected tank with a radiator to go about as a store for the hot liquid. Hot liquid course siphon with a speed control potentiometer.
- Cold fluid inlet from the water supply taps.
- Four temperature sensors at the inlet and outlet points for each of the two fluids. The hot-fluid inlet thermometer is also a thermostat control, which controls the heater connected to the reservoir by a simple relay mechanism. And Rota meters for fluid flow measurements.

PHE Dimension of existing setup:

Height of Plate H = 800m m ,

Width of Plate W = 300 cm

Gap between two plates b = 3 mm

Number to plates N = 14

External wall height h: 920 mm

External wall width w: 320 mm

Figure 5.1 existing setup

Obs. No.	Pressure (Kg/cm^2)	Hot Fluid Temperature (C)		Cold Fluid Temperature (C)	
		Inlet (T1)	Outlet (T2)	Inlet (t1)	Outlet (t2)
1	2.8	32 °c	26	20 °c	29
2	2.5	31 °c	24	22°c	28
3	2.8	30 °c	24	23°c	27
4	2.4	33 °c	26	22 °c	28

Table 5.1 Observation reading from setup.

CFD analysis of plate (triangular) type heat exchanger:

Input parameter at hot fluid and cold fluid sides:

For hot fluid

- Temperature : 32^0C
- Density: 987071 kg/m^3
- Dynamic viscosity: 0.00055985 Ns/m^2
- Specific heat: 4181.04 J/kg K
- Thermal conductivity: 0.6424 W/mK

For cold fluid **Mass flow rate0.017kg/sec**

- Temperature inlet: 20^0C
- Density: 992.22 kg/m^3
- Dynamic viscosity: 0.0006532 Ns/m^2
- Specific heat: 4178.5 J/kg K
- Thermal conductivity: 0.6305 W/m K

Modeling:

After performing simple calculation, the modeling has been performed on the Creo 2.0 version and then after the analysis work has been performed on the ANSYS version.

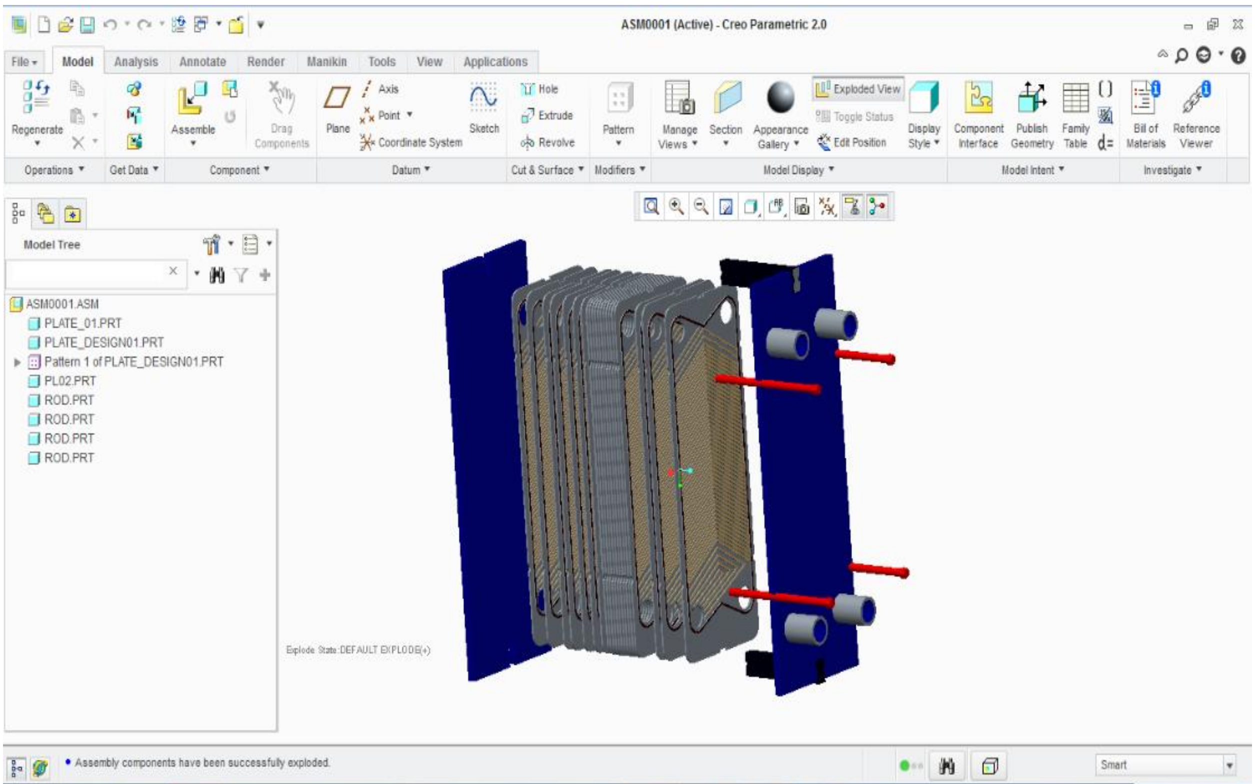

Figure 5.2 CDF Analysis of triangular corrugated plates.

Comparison between Practical Reading and Analysis Result:

	Experiment Data and CFD date				
Obs. No.	**Pressure(Kg/cm2)**	**Hot Fluid Temperature (C)**		**Cold Fluid Temperature (C)**	
		Inlet (T1)	**Outlet (T2)**	**Inlet (t1)**	**Outlet (t2)**
1	2.8	32 °c	26	20 °c	29
	CFD Result				
1	2.8	32	25.99	20	28.40
	Error between Practical And CFD Result				
	-	-	0.038 %	-	2.068 %

Table 5.2 comparison between practical reading and analysis results.

Validation:

- Compare experimental result and CDF results.
- the difference between experimental result.
- And CFD result for outlet is minimum; the error between them is minimum.
- This worth is taken by temperature test at Specified areas. From ANSYS result and practical reading we can conclude that ANSYS result is in good agreement with the practical reading.
- This solid model reflects the practical set up and can be used further for different analysis.(With Minimum Error).
- From the above explanation it can be concluded CFD result is validate.
- And also the author (Ajinkya : Experimental Analysis of Heat Transfer Rate in Corrugated Plate Heat Exchanger) clearly say that:
  1. The main advantage of using corrugated PHE in this work is that it has high heat transfer area.
  2. By using corrugated (sinusoidal) structure in heat transfer plates fouling will be reduced considerably.
- Also in corrugated plate (sinusoidal) structure low friction and high turbulence occur.

VI. NEW DESIGN CONCEPT(SINUSOUDAL CORRUGATED PLATE)

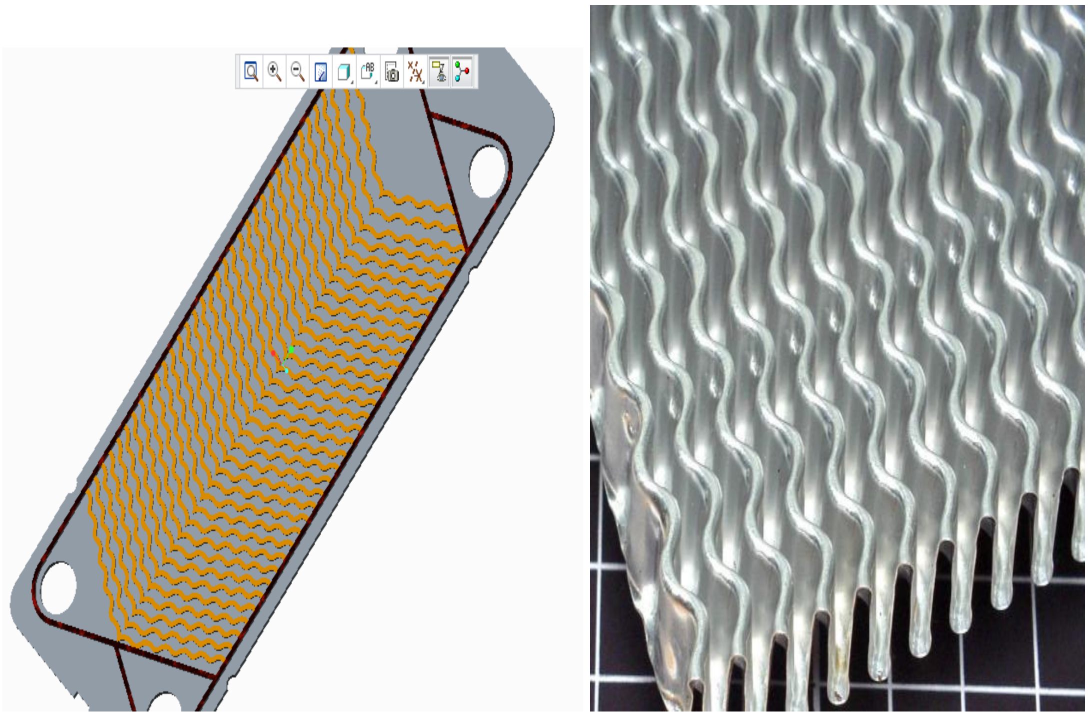

Figure 6.1 New Design Concepts

The profile of the sinusoidal channel :

$$S(x) = \frac{H_{min}}{2} + a \sin \frac{2\pi x}{L_w}$$

Figure 6.2 profile of sinusoidal

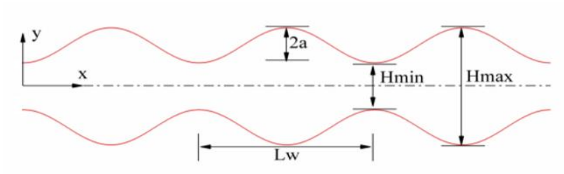

Figure 6.3 Schematic diagram of the channel

- L_w= Wave length,
- a= Wave amplitude,
- H_{min} = Min. spacing,
- H_{max}=Max. Spacing.

Geometrical configurations for three models:

The value of H_{min}/H_{max} for

- MODEL R1: 0.3
- MODEL R2: 0.4
- MODEL R3: 0.5

COMPARISON BETWEEN EXISTING DESIGN AND NEW CONCEPT DESIGN:

Obs. No.	Pressure (Kg/cm^2)	Hot Fluid Temperature (C)		Cold Fluid Temperature (C)	
		Inlet (T1)	Outlet (T2)	Inlet (t1)	Outlet (t2)
1	2.8	32 °c	26	20 °c	29
	CFD Result				
1	2.8	32	25.99	20	28.40
R1	2.8	32	25.2	20	30
R2	2.8	32	22.5	20	29.3
R3	2.8	32	24.3	20	28

Table 6.1 Comparison between existing design and new concept design.

Comparison between existing design and new concept design

(A). compare experimental result and CDF results

- The error between experimental reading (for existing design, triangular corrugated plate) and CDF result (For existing design, triangular corrugated plate) for Hot fluid outlet temperature is 0.038%,[0.01 ^{0}C](it is very low).
- The error between experimental reading (for existing design, triangular corrugated plate) and CDF result (For existing design, triangular corrugated plate) for Cold fluid outlet temperature is 2.068%, [0.6 ^{0}C](it is also min value) .
- This solid model reflects the practical set up and can be used further for different analysis. (With Minimum Error).

(B). New Design concept:

- Consider three different models R1 and R2 and R3 with different ratio of H_{min} and $H_{max.}$
- Above table result clearly say that maximum beneficially model is R2.
- For R2 model, Outlet temperature for hot fluid is 22.5 ^{0}C (benefit of 3.5 ^{0}C) and Outlet temperature for Cold fluid is 29.5 ^{0}C.

(C). Consider error in New Design

- Above clearly mention that error occur between experimental and CFD results at outlet temperature of hot fluid and outlet temperature of cold fluid , this error also consider for new concept design (consider high value safety purpose).
- So consider value of error at outlet temperature of hot fluid is 1 % and for cold fluid at outlet temperature is 2.2 %.
- That means value of outlet temperature for hot fluid is varies [22.5 +/ - 0.225 ^{0}C] and outlet temperature for cold fluid is varies(29.3 +/- 0.6446 ^{0}C).

(D) Benefit in New design

The outlet temperature for new design at hot fluid is (3.5 ^{0}C with minimum error) less as compare to outlet temperature for hot fluid in existing design.

VII. CONCLUSIONS

- Although **compact heat exchangers with corrugated plates offer many advant**ages compared to conventional heat exchangers, their main drawback is the absence of a general design method.
- The error between experimental reading (for existing design, triangular corrugated plate) and CDF result(For existing design , triangular corrugated plate) for Hot fluid outlet temperature is 0.038%,[0.01 ^{0}C](it is very low) and error between experimental reading (for existing design , triangular corrugated plate) and CDF result(For existing design , triangular corrugated plate) for Cold fluid outlet temperature is 2.068%,[0.6 ^{0}C](it is also min value).
- From the above analysis say that the plate type heat exchanger with sinusoidal corrugation are more beneficial as compare to triangular corrugation with respect to heat transfer rate.
- Also in plate type heat exchanger with sinusoidal, the pressure loss is less in compare to plate type heat exchanger with triangular corrugation.
- Due to less pressure loss in plate type heat exchanger with sinusoidal corrugation ,its help is decreases in pumping power.
- In the plate type heat exchanger with sinusoidal, more turbulent effect occur as compare to the flat plate type heat exchanger, these help to increase the heat transfer rate.
- Here above analysis, the material of plate does not change over analysis but if copper replace in place of steel then heat transfer rate increases for same size of heat exchanger ,but for same heat transfer size of copper plate heat exchanger decreases means copper heat exchanger is more compact as compare to steel plate heat exchanger.

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