# ANALYSIS OF HELICALCUM PINFIN HEAT EXCHANGER

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**ABSTRACT** :

In this investigation, augmented surfaces have been achieved with pinfin,helical(20X60) cum pinfin,

helical(20x20) cum pinfin strategically located in a pattern along the tube of a concentric tube heat exchanger with the increased area on the tube side.Augmented surfaces to increasing the amount of heat transfer with a consequent increase in the area.In this analysis to modify the inner tube of double pipe heat exchanger using pinfin and helical with pinfin tube.The concentric tube heat exchanger is design from creo software . In this design the inner tubes consider as the cold fluid and outer tube is hot fluid. Here In this study the properties of hot and cold fluid from data hand book at corresponding temperatures. analysis of designs are done in ansys cfx. from this cfx calculation the amount of heat transfer at laminar flow and at turbulent flow. and in each case three massflow rates are run both in cold fluid and hot fluid.among the all cases the mxmimum amount of heat transferred is achieved in turbulent flow helical(20x20) with pinfin heat exchanger hot m1=650 kg/h, coldm1=1100kg/h. by finally the enhanced helcal(20x20) and pinfin tube is compare with the other cases analysis the results.

## INTRODUCTION:

### HEAT EXCHANGER

A heat exchanger is a device that used to transfer thermal energy between two or more fluids, between a solid surface and a fluid, at different temperature. In a heat exchanger, there are usually no external heat and work interaction. Typical applications involve heating or cooling of a fluid stream of concern and evaluation or condensation of single or multi component fluid stream. In other application, the objective may be to recover or rejected heat, or sterilize, or control a process fluid. In few heat exchangers, the fluids exchanging heat are in direct contact. In most of heat exchangers, exchanges heat transfer between fluids through a separating wall or into and out of a wall in a transient manner. Fluid of many heat exchangers, are separating by a heat transfer surface, and ideally, they do not mix with each other. Such exchangers are referred to as direct transfer type, or simply recuperate. Other type heat exchanger in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface are referred to as indirect transfer type, or simply regenerators.

Such exchangers usually have fluid leakage from one fluid stream to other, due to pressure differences value switching.

Industrial application of heat exchanger is shell and tube exchangers, automobile radiators, condensers, evaporator, air pre-heaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger. There could be internal thermal energy sources in the exchangers such as in electric heaters and nuclear fuel elements. Combustion and chemical reaction may take place within the exchanger, such as in boilers, fired heaters, and fluidized bed exchanger. Mechanical device may be used in some exchanger such as in scraped surface exchanger, agitated vessels, and stirred tank reactors. Heat transfer in the separating wall of a recuperator generally takes place by conduction.

However, in a heat pipe heat exchanger, the heat pipe not only acts as a separating wall, but also facilitates the transfer of heat by condensation, evaporation, and conduction of the working fluid inside the heat pipe. In general, if the fluids are immiscible, the separating wall may be eliminated, and the interface between the fluid replace a heat transfer surface, as in a direct contact heat exchanger.

**MODELING OF HEAT EXCHANGER** :

Three different Heat Exchangers are modelled in 3D as per the standard dimensions of automobile thermoelectric generator using CRE 3.0 software as shown in Fig 5.1, Fig 5.2,Fig 5.3

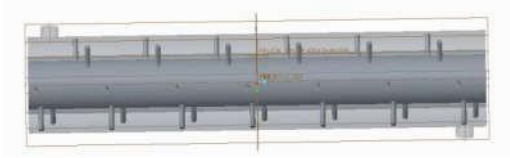


fig.1 pin finned heat exchanger

fig.2 helical and pin finned heat exchanger 20x60

fig.3 helical and pin finned heat exchanger 20x20

dimensions of the above geometries are given below:

Inner tube:

1. inner diameter - 48 mm
2. outer diameter - 50 mm
3. length of the tube - 520mm

Outer tube:

1. inner diameter - 90 mm
2. length of the tube - 520mm

3. inlet and out let tubes diameter - 20mm

helical fin:

rectangular section - 20×70 sq.mm

pitch of the helix - 85mm

pin fin:

pin diameter- 6mm

height of the pin - 20mm

pitch of the helix for pins - 85mm

**MATHEMATICAL MODELLING**

**PROPERTIES OF FLUIDS:**

**HOT FLUID AT 353K**

$c_p$ =4178.25 J/Kgk

$\dot{\rho}$ =994.5 Kg/m3

v=0.64805 mm2/s

α=0.15131mm2/s

pr=4.274

k=0.6513w/mk

5.1.2 COLD FLUID AT 300K

$c_p$ =4195 J/Kgk

$\dot{\rho}$ =974 Kg/m3

v=0.364 mm2/s

α=0.1636 mm2/s

pr = 2.22

k=0.6687 w/mk

$$q = \varepsilon C_{min} (T_{h1} - T_{c1})$$

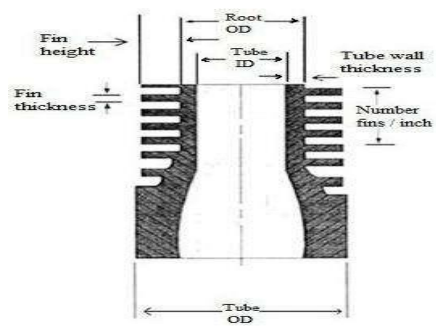
$$\varepsilon = \frac{2}{(1+c^*) + (1+c^{*2})^{0.5} \coth\left(\frac{NTU}{2} (1+c^{*2})^{0.5}\right)}$$

5.2 FORMULAS AND CALCULATIONS

The heat transfer rate and thermal effectiveness of a fin heat exchanger type as shown in

Figures 1 and 2, as follows

Here, q is the heat transfer rate, ε is the effectiveness, Cmin is the minimum thermal capacity of the hot and cold fluids (W/K), Th1 and Tc1 are the temperatures of the entering hot and cold fluids, respectively, $C^*$ is the thermal capacity rate and NTU is the number of thermal units. Some of these terms can be evaluated as follows .



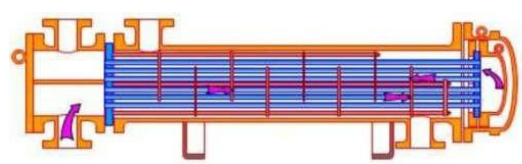



**Figure 4.** Schematic illustration of a radial l ow-fin tube [22].

We introduce ATot as the total external surface area of a finned tube heat exchanger and Uo
as the overall heat transfer coefficient. These can be expressed as follows [22]:

$$A_{Tot} = A_{fins} + A_{pirim}$$

Apirim = 0.0807808 m2
A fins = ∏dl Nt = 0.012571 m2
Atotal= 0.093226566 m2
Rdi = 0.0000821
Rdo= 0.0017540

$$U_o = \left[ \frac{A_{Tot}}{h_i A_i} + \frac{R_{Di} . A_{Tot}}{A_i} + \frac{A_{Tot} . \ln \frac{d_o}{d_i}}{2\pi . k_{tube} . L} + \frac{1}{h_o . \eta_w} + \frac{R_{Do}}{\eta_w} \right]^{-1}$$

Here, L, Nt, di, do, RDi, RDo, Kw, r2c, r1 and nf are tube Length, number of tubes, inside and outside diameters of the tube, tube and shell side fouling resistances, thermal conductivity of tube wall;
corrected fin radius, external radius of root tube and number of fins per unit length of tube, respectively. Also, Ai denotes the internal surface area of the tube, where

$$A_i = \pi d_i L N_t = 0.0390706$$

In the above relations, Ψ is a parameter in the equation for efficiency of annular fins, τ is the fin thickness and k is the thermal conductivity.

The fin temperature can be evaluated following the approach described below.
The tube side heat transfer coefficient hi is calculated as follows [24–26]:

$$h_i = \left(\frac{k_t}{d_i}\right) 0.116 \left(Re_t^{2/3} - 125\right) Pr_t^{1/3} \left(1 + \left(\frac{d_i}{L}\right)^{2/3}\right) \left(\frac{\mu}{\mu_w}\right)^{0.14} \quad \text{for } Re_t > 10^4 \tag{14}$$

$$h_i = \left(\frac{k_t}{d_i}\right) 0.027\, Re_T^{0.8}\, Pr_t^{0.4} \left(\frac{\mu}{\mu_w}\right)^{0.14} \quad \text{for } 2100 < Re_t < 10^4 \tag{15}$$

$$h_i = \left(\frac{k_t}{d_i}\right) 1.86 \left(\frac{Re_T \; Pr\, d}{L}\right)^{1/3} \left(\frac{\mu}{\mu_w}\right)^{0.14} \quad \text{for } Re_t < 2100 \tag{16}$$

The above equation is acceptable for $\left(\frac{Re_t \, Pr_t \, d_i}{L}\right)^{\frac{1}{3}} \left(\frac{\mu}{\mu_w}\right)^{0.14} > 2$, whereas for $\left(\frac{Re_t \, Pr_t \, d_i}{L}\right)^{\frac{1}{3}} \; \_ \; ^{0.14}$

$$h_i = 3.66 \frac{k_t}{d_i} \tag{17}$$

Here, kt, Prt, μ and μw are the tube inside fluid thermal conduction coefficient, the tube side Prandtl number, the viscosity and fluid viscosity evaluated at average temperature of tube wall. Also, the tube side Reynolds number (Ret) can be evaluated as follows [22]:

$$e_t = \frac{4\, \dot{m}_t \left(\frac{n_p}{N_t}\right)}{\pi . d_i . \mu}$$

where mt is the mass flow rate and np is the number of tube passes.

the shell-side heat transfer coefficient

$$h_o = j_H \left(\frac{K}{D_e}\right) Pr^{\frac{1}{3}} \left(\frac{m}{m_w}\right)^{0.14}$$

where JH and De are the modified Colburn factor for the shell-side heat transfer and the equivalent diameter, respectively. These can be evaluated as follows [22,25]:

$$j_H = 0.5\left(1 + \frac{B}{Ds}\right) \times \left(0.08\, Re_s^{0.6821} + 0.7\, Re_s^{0.1772}\right)$$

Re(tube side)=1.2576x10^(4)

Hi=6.6760085x10^5w/m2k, Re(shell side) = 7.204756x10^3

Jh = 18.8020, Ho = 1.26577 x10^5 w/m2k

Ψ = 0.02825121, M =765.705, ηf =0.06227,

ηW = 0.8726.

$U_o$ = 6682.6137 w/m2k, NTU=0.822,

ε = 2.7206

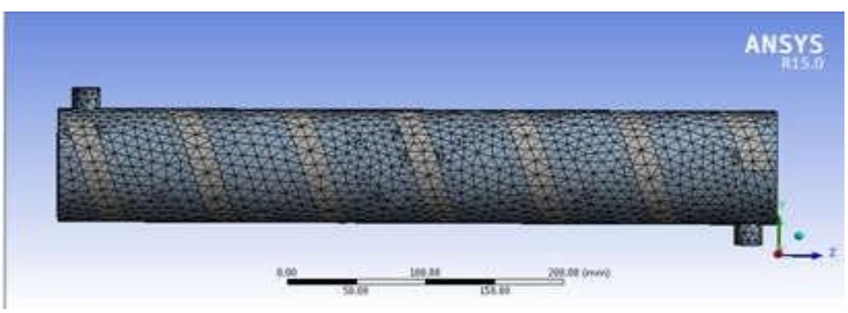
q = 2995.74w

## MESH GENERATION

The second step mesh generation constitutes one of the most important steps during the pre-process stage after the definition of the domain geometry. CFD requires the subdivision of the domain into a number of smaller, no overlapping sub domain in order to solver the flow physics within the domain geometry that has been created, while meshing geometry, care has been taken that, it should be free from skewness, for faster convergence, give result are appropriate. Mesh directly affects the result, finer is the mesh better will be the result obtained. Fineness in the mesh produces limitation to memory responsible for heat transfer. Hence other part of geometry can be meshed with coarser mesh.

## MESHING

initially default mesh setting with fine element has been taken and the inflation was applied at the interfaces with 10 layers at each interface




## BOUNDARY CONDITIONS

Cold inlet temperature – 300.65 K

Mass flow rate of cold fluid -1100 kg

Hot inlet temperature – 353.15 k

Mass flow rate of hot fluid – 650 kg/hr

**RESULTS AND DISCUSSION**

MASS FLOW RATES

As the heat is being transferred to cold fluid from hot water, the temperature of hot water decreases. since our concentration is on amount of heat recovered from hot water, the comparisons are made based on the hot side properties. In this analysis we consider the two flow rates laminar and Turbulent And each flow three mass flow rates as shown in table:

| SI.NO | FLOW TYPE | MASS FLOW RATES | | | | | |
|---|---|---|---|---|---|---|---|
| | | HOT FLUID (Kg/h) | | | COLD FLUID (Kg/h) | | |
| | | M1 | M2 | M3 | M1 | M2 | M3 |
| 1 | LAMINAR | 207 | 171 | 135 | 201 | 165 | 129 |
| 2 | TURBULENT | 650 | 470 | 290 | 1100 | 920 | 740 |

Two flow types and three massflow rates applied to the three types of Heat Exchangers : PIN FIN, HELICAL with PINFIN(20X60), HELICAL with PINFIN(20X20).

| S.NO. | SITUATION | HOT FLUID MASS FLOW RATE KG/H | COLD FLUID MASS FLOW RATE KG/H |
|---|---|---|---|
| 1 | PINFIN HEAT EXCHANGER WITH LAMINAR FLOW | 207 | 201 |
| 2 | PINFIN HEAT EXCHANGER WITH LAMINAR FLOW | 171 | 165 |
| 3 | PINFIN HEAT EXCHANGER WITH LAMINAR FLOW | 135 | 129 |
| 4 | PINFIN HEAT EXCHANGER WITH TURBULNT FLOW | 650 | 1100 |
| 5 | PINFIN HEAT EXCHANGER WITH TURBULNT FLOW | 470 | 920 |
| 6 | PINFIN HEAT EXCHANGER WITH TURBULNT FLOW | 290 | 740 |

| | | | |
|---|---|---|---|
| 7 | HELICAL(20X60)WITH PINFIN HEAT EXCHANGER LAMINAR FLOW | 207 | 201 |
| 8 | HELICAL(20X60)WITH PINFIN HEAT EXCHANGER LAMINAR FLOW | 171 | 165 |
| 9 | HELICAL(20X60)WITH PINFIN HEAT EXCHANGER LAMINAR FLOW | 135 | 129 |
| 10 | HELICAL(20X60)WITH PINFIN HEAT EXCHANGER TURBULENT FLOW | 650 | 1100 |
| 11 | HELICAL(20X60)WITH PINFIN HEAT EXCHANGER TURBULENT FLOW | 470 | 920 |
| 12 | HELICAL(20X60)WITH PINFIN HEAT EXCHANGER TURBULENT FLOW | 290 | 740 |
| 13 | HELICAL(20X20)WITH PINFIN HEAT EXCHANGER LAMINAR FLOW | 207 | 201 |
| 14 | HELICAL(20X20)WITH PINFIN HEAT EXCHANGER LAMINAR FLOW | 171 | 165 |
| 15 | HELICAL(20X20)WITH PINFIN HEAT EXCHANGER LAMINAR FLOW | 135 | 129 |
| 16 | HELICAL(20X20)WITH PINFIN HEAT EXCHANGER TURBULENT FLOW | 650 | 1100 |
| 17 | HELICAL(20X20)WITH PINFIN HEAT EXCHANGER TURBULENT FLOW | 470 | 920 |
| 18 | HELICAL(20X20)WITH PINFIN HEAT EXCHANGER TURBULENT FLOW | 290 | 740 |

**CONTOUR RESULTS**

PIN FIN HEAT EXCHANGER: Maximum amount of heat transfer at turbulent low pinfin heat exchanger with hot m1=650 kg/h, cold m1=1100 kg/h

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**TEMPERATURE**

HELICAL(20X60)WITH PINFIN HEAT EXCHANGER Maximun amount of heat transferred condition is

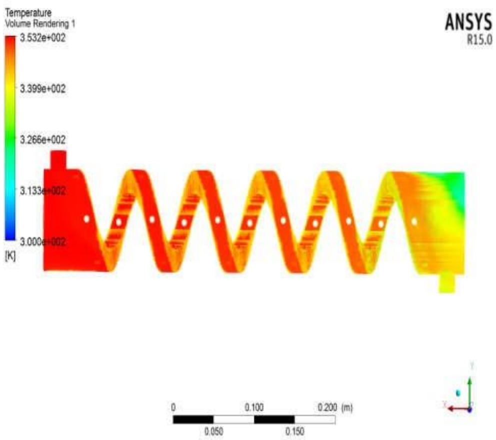



fig.6 Temperature contour

Maximum amount of heat transferred at turbulentlow helical(20x20) with pinfin heat exchanger with hotm1=650kg/h,coldm1=1100kg/h.

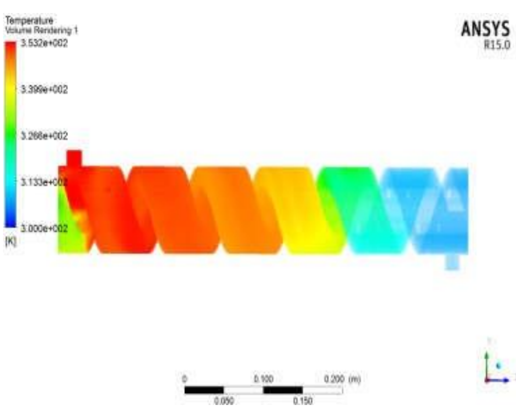



Fig.8 temperature contour

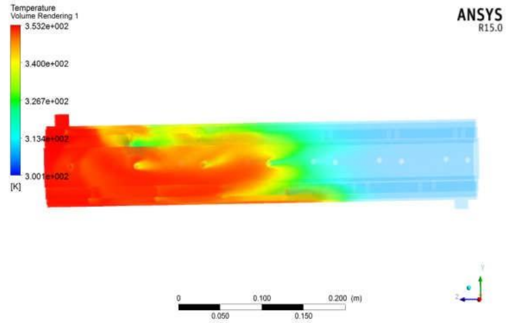



Fig.5 TEMPERATURE CONTOUR

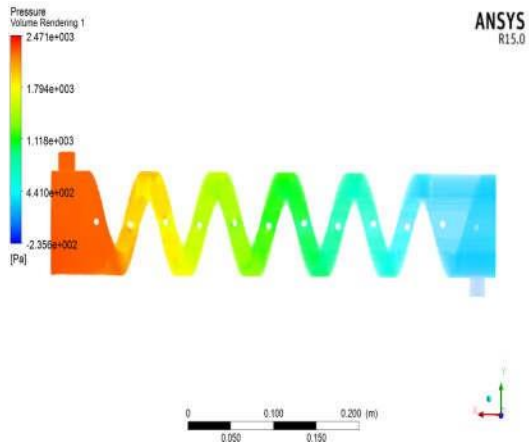



Fig.7 pressure contour

HELICAL(20X20) WITH PINFIN HEAT EXCHANGER

**PRESSURE**

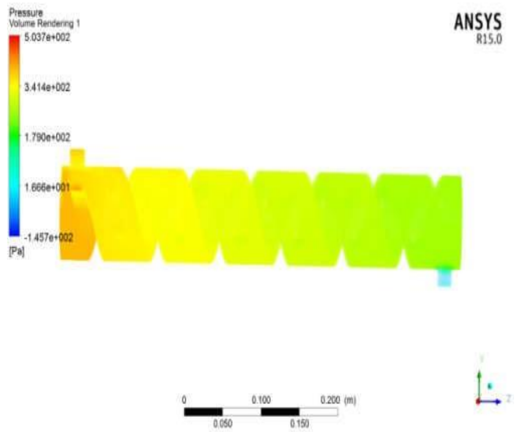



Fig.9 pressure contour

| S NO. | HOT FLIUID INLET (K) | HOT FLUID OUTLET (K) | TEMP ERATURE DIFFE RENCE (ΔT) | AMOUNT OF HEAT TRANSFRED (MC ΔT) |
|---|---|---|---|---|
| CASE1 | 353 | 310 | 43 | 10397.211 |
| CASE2 | 353 | 311 | 42 | 8393.515 |
| CASE3 | 353 | 312 | 41 | 6473.7198 |
| CASE4 | 353 | 308 | 45 | 34084.4589 |
| CASE5 | 353 | 309 | 44 | 24098.0268 |
| CASE6 | 353 | 310 | 43 | 14531.094 |
| CASE7 | 353 | 336 | 17 | 4110.525 |
| CASE8 | 353 | 338 | 15 | 2997.684 |
| CASE9 | 353 | 339 | 14 | 2210.538 |
| CASE10 | 353 | 333 | 20 | 15148.648 |
| CASE11 | 353 | 334 | 19 | 10405.965 |
| CASE12 | 353 | 335 | 18 | 6082.7835 |
| CASE13 | 353 | 307.8 | 45.2 | 10929.161 |
| CASE14 | 353 | 308 | 45 | 8993.0522 |

| | | | | |
|---|---|---|---|---|
| | | | | |
| CASE15 | 353 | 308.4 | 44.6 | 7042.13 |
| CASE16 | 353 | 307 | 46 | 34841.891 |
| CASE17 | 353 | 307.4 | 45.6 | 24974.31 |
| CASE18 | 353 | 308 | 45 | 15206.9589 |

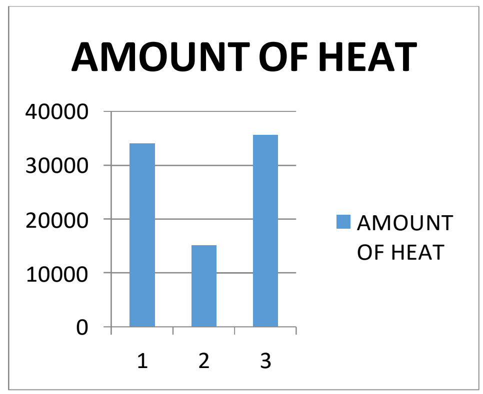
**VALIDATION**

For pinfin : Amount of heat transferred(theoratically)

= 29495.74w

Amount of heat transferred (by analysis(cfx)) = 34084.458 w

percentage of error =13.4%




1.pinfin 2.helical(20x60)

Fig.11 maximum amount of heat comparison from three exchangers

**GRAPHS**

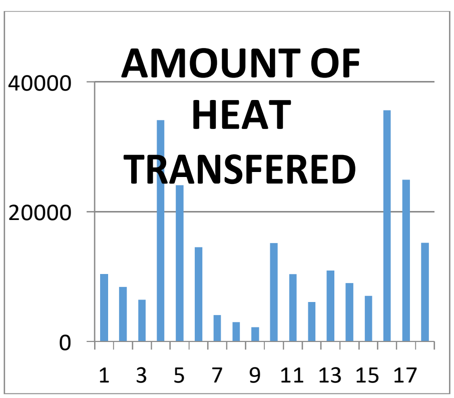



Fig.10 comparison of amount of heat in all cases

**CONCLUSION AND FUTURE SCOPE**

1. Heat transfer rate is more in case of helical(20x20) with pin finned heat exchanger i.e Maximum amount of heat transferred at turbulentlow helical(20x20) with pinfin heat exchanger with hotm1=650kg/h,coldm1=1100kg/h when compared to other

**FUTURE SCOPE**

Applications of heat exchangers are increasing as the industrial sector is growing day by day. So, the scope for the development of heat exchangers is increasing as demand for the compact heat exchangers is increasing exponentially. research programs are conducted in different fields like material science, nano technology, general physics etc. New discoveries are changing the performance of heat exchangers. for example ceramic heat exchangers can withstand high temperatures than metallic ones. Different geometries of tubes or ducts wll change the performance of heat exchangers. we can also change the working fluids with different staichiometric proportions to improve the performance of heat exchangers.

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