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REVIEW ON HEAT TRANSFER ENHANCEMENT IN HELICAL TUBE HEAT EXCHANGER

Sanyog Kumar[a, 1] , **Dr. A.R. Jaurker**[b]
[1]*Department of Mechanical Engineering, Jabalpur Engineering College, Jabalpur, Madhya Pradesh 482011, India*

ABSTRACT

Various heat transfer enhancement techniques are using at present in industries. This paper focus on various enhancement techniques in heat exchangers. These techniques may be active or passive. Some common methods are to make pipe helical, insertion of baffles, attachments of fins and use of nanofluids etc. after reviewing various techniques it can be concluded that helical pipe is always advantageous than straight pipe. Now further research can be done if this helical pipe could be modified.

KEYWORDS - ***Heat exchanger, Helical coil, Nano fluid, Eccentric***

I. INTRODUCTION

Heat exchanger is a thermal plant component used for exchanging heat between two fluids. Different techniques are using in present scenario for making energy efficient device. Maximum utilization of energy at minimum surface area and cost is the prime requirement. So, designing of compact heat exchanger is the critical task. For this different methods are using in present time. These are active method, passive method and combine method. In active method external power is used such as vibrations, pumping power etc. in active method no external power is used but instead of it, inner surfaces of heat exchangers are made helical, corrugated etc. in combine method both active and passive methods are used.

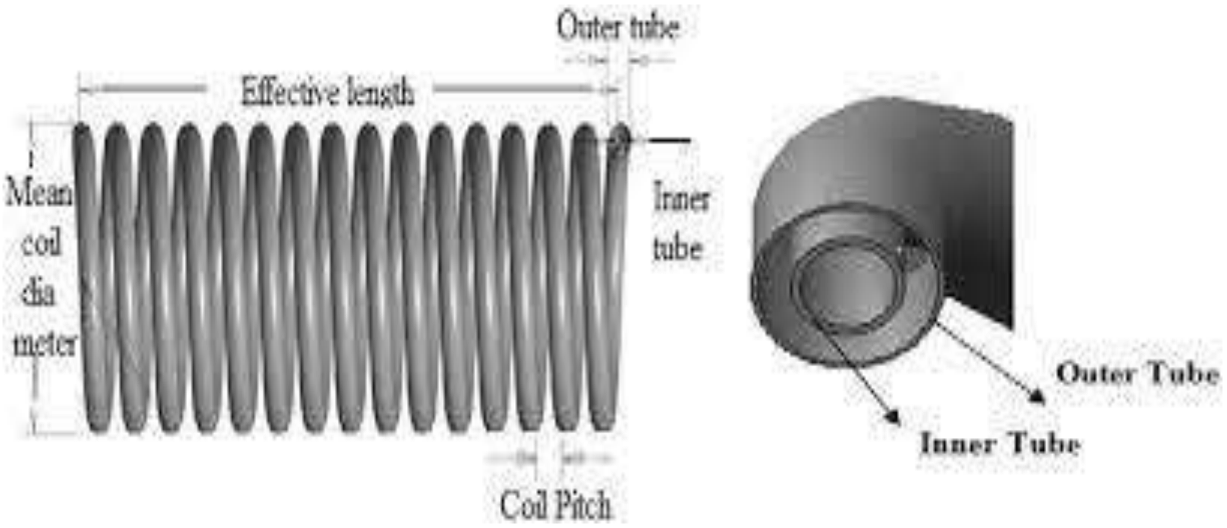


Fig. 1

II. LITERATURE REVIEW

Enhanced heat transfer at minimum surface area is required. For this purpose, many design variation is introduced in the heat exchangers.

M. Farman et al. [1] – analyzed thermal performance enhancement in a helical tube heat exchanger by adding twisting shape along with helical shape. Results are compared between helical tube and twisted helical tube heat exchanger; it is found that Nusselt no. is increased in twisted helical tube as compare to helical tube. Further a parametric analysis is also done, which show that helical dia. has highest impact on heat transfer then twist pitch and then helical pitch.

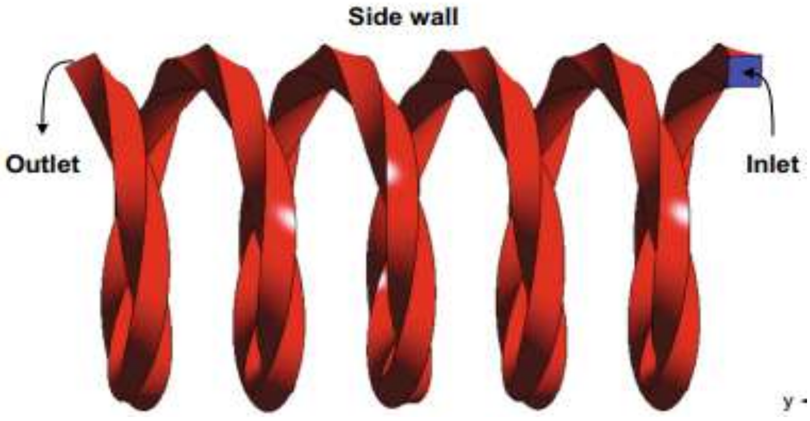
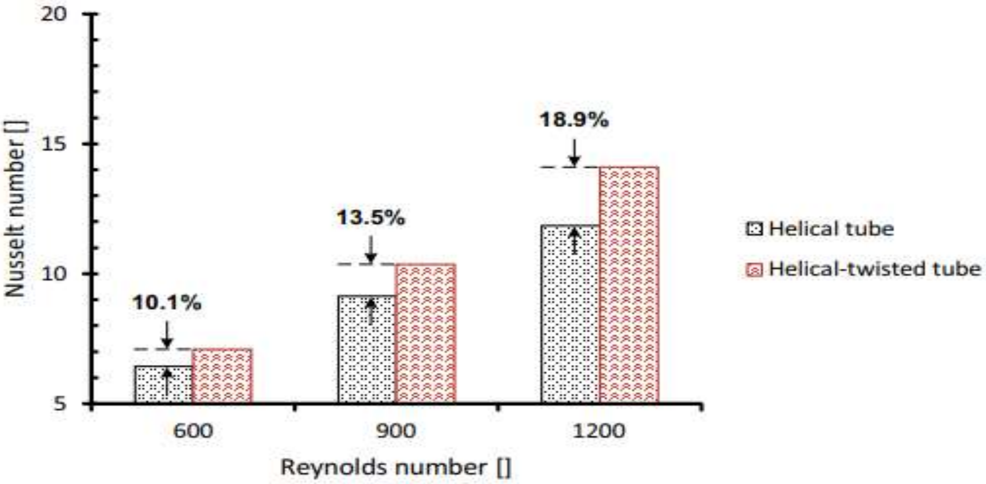


Fig. 2 Geometry of helical tube with twisted shape



Demba Ndiaye et al. [2] – Investigated the heat transfer performance in double tube helical coil heat exchanger with corrugation at the inner tube. Refrigerant is used to flow in the annulus side between two tubes and the water is flowing in the inner tube. Results are compared between helical coil tube with corrugation and without corrugation.

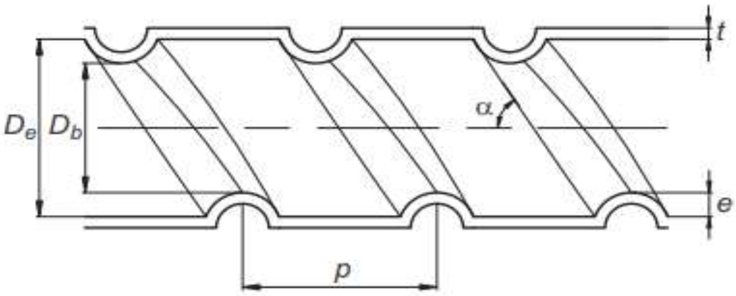


Fig. 3 Geometry of corrugated inner tube

Re	Helical tube without corrugation	Helical tube with corrugation
600	70	78
800	83	89
1000	89	93
1400	94	101
1600	101	107

Gangapathy V. [3] – Analysed the thermal performance enhancement by adding extended surface at the outer surface of a heat exchanger. These extended surfaces are fins which increase the outer surface area and hence heat transfer.

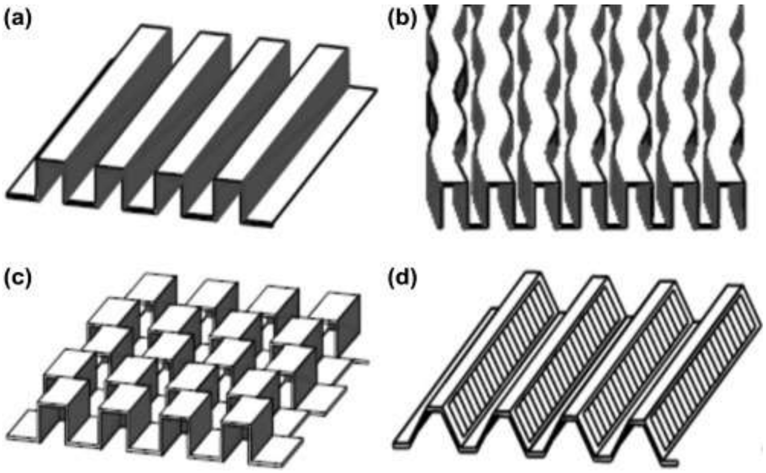


Fig. 4 Different shapes of fins

Shilling R. [4] – Studied the effect of twisting, corrugation and helical shape on the straight tube heat exchangers. Further results are compared between straight tube and twisting tube, corrugated tube, helical tube. Results show that modifications in the geometry always beneficial for heat transfer than straight tube.

Vander Ploeg [5] – Found the effect of baffles on thermal performance. Baffles are geometrical structures adding in the heat exchanger. By adding baffles turbulence is created due to disturbance in the direction of the flow due to this collision between atoms increase and hence heat transfer increase. The other effect of it is that pressure drop also increased.

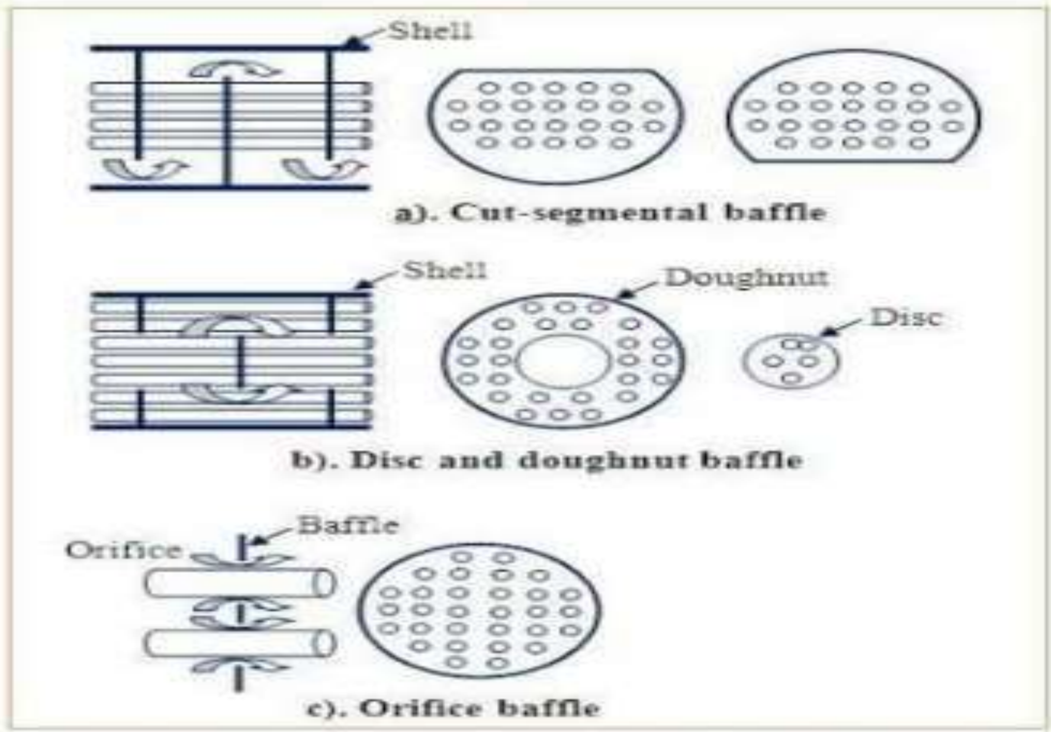


Fig. 5

A.R. Sajadi et al. [6] - Nanofluids can also be used as a heat transfer enhancement source. Nanofluid is a mixture of suspended nano particles into the base fluid such as water. Due to suspended particles both heat transfer conductivity and pressure drop increases. TiO2/water Nano fluids gave higher Nu than water. Higher Ø of nanoparticles would increase thermal conductivity, thus increasing heat transfer rate.

E. Gokul Nathan et al. [7] – Study about the effect of nano fluids on the heat transfer in the helical coil heat exchanger. Results show that by adding nanoparticles (Al2O3, SiO2, CuO etc.) in the base fluid (H2O) thermal conductivity of the mixture increases which further increased the heat transfer. The other effect of these solid particles is that it creates obstacle in the direction of flow which further increase the pressure drop.

N.D. shirgeral et al. [8] – Analysis about comparison between straight and helical coil tube heat exchanger and found that Helical coils are beneficial over straight tubes due to their compactness. Helical shape produces centrifugal force which in turn results in increment in turbulence. Thus, increases in heat transfer.
variation of overall heat transfer coefficient U (w/m^2-K) when mass flow rate inside the tube is 50 LPH. For various mass flow rate (m)

m (LPH)	U for straight tube parallel flow	U for straight tube counter flow	U for helical tube parallel flow	U for helical tube counter flow
30	120	162	143	160
50	160	164	180	210
70	143	200	209	218
85	160	185	219	224
100	180	215	227	245

Shubham Mittal et al. [9] – Analysis about comparison of heat transfer between double tube helical coil and straight tube and found that both heat transfer and friction factor is more in helical coil than straight tube due to curvature effect. These curvature effect create the secondary flow in the perpendicular direction of the axial flow. Combine effect of these two flows increase the heat transfer and friction factor.

Vahid safari et al. [10] – studied about the effect of fin shape and eccentricity of tube on melting behaviour of phase change material inside shell and helical tube heat exchanger (HX). Two unfinned heat exchangers with concentric and eccentric heat transfer tubes and six other HXs with different arrangements of straight and different shapes of fins are added. Results show that unfinned HXs with eccentric tube have less melting time compare to concentric tube HX.

Comparison of heat transfer coefficient (h) for concentric and eccentric shell and tube Heat exchanger at different temperature

T (˚C)	h (w/m^2-K) for concentric tube	h for eccentric tube
75	30	38
85	34	40
95	40	48

Comparison of heat transfer (q) for concentric and eccentric shell and tube Heat exchanger at different temperature

T (˚C)	q (w) for concentric tube	q for eccentric tube
75	18	24
85	22	29
95	28	35

Shima Akar et al. [11] – Studied about the effects of eccentricity of helical tubes on Nu, pressure loss and performance evaluation index. A model is made with helical screw tape insert at the inner side of the tube. Results show that on increasing the eccentricity both heat transfer and pressure drop increase. But increment in heat transfer is more than pressure drop increment.

Effect of eccentricity (e) on Nu at Re = 8000

e	Nu
0	80
0.5	86
2	100
3.5	110

Effect of eccentricity (e) on f at Re = 8000

e	f
0	0.04
0.5	0.042
2	0.043
3.5	0.045

Soheil Akbari et al. [12] – Studied about Effects of nanofluid volume concentration (Ø) and different cross-sections of tube on thermal performance of horizontal spiral-coil. Water-graphene nanoplatelet/platinum hybrid nanofluid is used. Different geometries including rectangle, elliptic, trapezoid and circle is selected as tube cross-sections. Results show that changes in heat transfer coefficient (h) at lower mass flow rate does not depend on flow cross-section. By increasing Ø, the highest Nu is achieved for elliptical cross-section. Surfaces with angular corners create greater velocity gradient in comparison with surfaces of curved corners and this behaviour produces higher pressure loss. Also, by increasing mass flow rate (m), the heat transfer between hot surface and cooling fluid is increased.

A. Fouda et al. [13] - Analysed the effect of operating and geometrical variables of the coil on the inner and outer side Nu, h, pumping power (P), effectiveness, and thermal performance index. No. of inner tubes (N) and outer coil inclination angle (β) is considered as geometrical parameter. Results show that on increasing N and β, both Nu and f increases. On increasing De, Nu increases but f decreases.

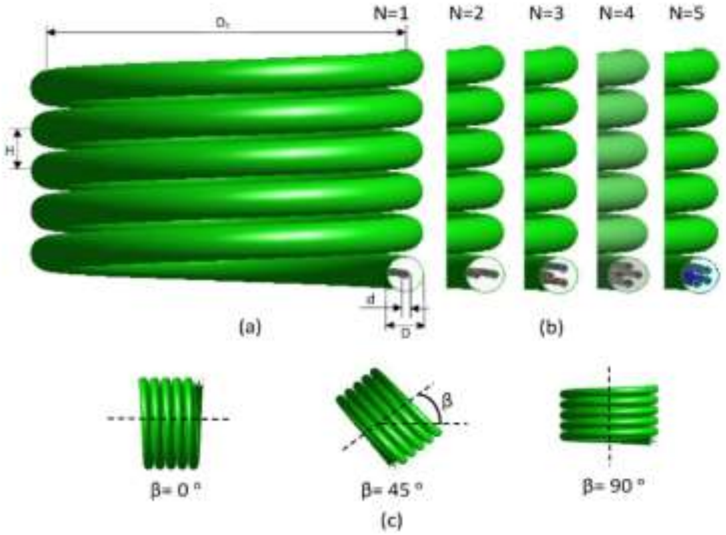


Fig. 6

Effect of De on Nu, f at N= 3, β= 0°

De	Nu
1250	58
1500	62
1750	69
2000	75
2250	81

De	f
1250	0.031
1500	0.029
1750	0.027
2000	0.026
2250	0.025

Effect of N on Nu at De = 2000

N	Nu
1	62
2	63
3	63
4	62
5	61

Effect of β on Nu at N = 1

β	Nu
0	62
45	42
90	59

P.C. Mukesh Kumar et al. [14] – Studied about the thermal performance of a helically coiled tube heat exchanger handling Al2O3 / water nanofluid. The effect of nanoparticle volume concentration (Ø) and De, on Nu and friction factor is studied. Results show that on increasing De, Nu increases but f decreases. On increasing Ø both Nu and f increases.

$$De=Re(d_h/D)^{0.5}$$
$$Re=(\rho v d_h)/\mu$$
$$Nu=hd_e/k$$
$$f=(dp*d_h*2)/(\rho*v^2*L)$$

where, d_h = hydraulic dia., d_e = equivalent dia., Re = Reynolds no., ρ = density (Kg/m^3)
k = Thermal conductivity (w/m-K), f = friction factor

Effect of Ø on Nu at De = 2000

Ø	Nu
0.1	70
0.4	78
0.8	90

Effect of Ø on f at De = 2000

Ø	f
0.1	0.0341
0.4	0.041
0.8	0.0478

Yuan et al. [15] – In this study a new mathematical approach differential evaluation algorithm (DEV) is used for optimization of design parameters of tube in tube helical coil heat exchanger. First changes in Nusselt no. and friction factor with respect to Reynolds no. and coil pitch is investigated numerically. Then these results are validated with k-ϵ standard, realisable and RNG model. Results show that RNG model shows least deviation with DEV results. Then generic algorithm (GA) approach is also used for comparing the numerical results. On the basis of comparison DEV is more accurate than GA. Results indicate that Reynolds no. affect Nusselt no. and friction factor more than coil pitch. So based on above study we find Reynolds no. as an important variable.

J. Rennie et al. [16] – Two heat exchangers of both parallel flow and counter flow type are studied experimentally in this work. Mass flow rate in the inner tube side and in the annulus, side is changed between 100 – 900 cm^3/min and outside temp. of both hot fluid and cold fluid is measured. After this Nusselt no. in both inner side and annulus side is calculated. It is found that counter flow heat exchanger has higher heat transfer rate as compare to parallel flow heat exchanger. Following formulas are used in this work

When a fluid flows in the annulus then it is convenient to express h and f by the equivalent diameter d_e. d_e is four times hydraulic radius. The hydraulic radius is obtained as the ratio of the flow area to the wetted perimeter. For a fluid flowing in annulus, flow area is $\pi/4(d^2_{o,inner} - d^2_{i,outer})$ but the wetted perimeters for heat transfer and pressure drops are different. For heat transfer

$d_e = (d^2_{oi} - d^2_{io}) / d_{io}$

d_{oi} = inner dia. of outer tube, d_{io} = outer dia. of inner tube

In pressure-drop measurement, friction is not only due to the resistance of the outer pipe but is also by the outer surface of the inner pipe. The total wetted perimeter is $\pi\ (d_{o,inner} - d_{i,outer})$ so the hydraulic dia. is given by

$d_h = (d_{io} - d_{oi})$

H.K. Dawood et al. [17] – Studied the variation of Nusselt no. in the range of Reynold no. Re (200-1000) and volume concentration of nano fluid Ø (0-4%). Al2O3, CuO, SiO2 and ZnO / EG (ethylene glycol) based nano fluid with different nanoparticle sizes are used for analysis. On increasing Re and Ø, Nu increases. While with increasing nanoparticle size Nu decreases. SiO2-EG nanofluid has the highest Nusselt number, followed by Al2O3-EG, ZnO-EG, CuO-EG, and lastly pure ethylene glycol.

The thermophysical properties of different nanoparticles and different base fluids at T = 300 K

Thermo p -hysical properties	**Al_2O_3**	**CuO**	**SiO_2**	**ZnO**	**Glycerine**	**Engine oil**	**EG**
ρ (Kg/m^3)	3970	6500	2200	5600	1259.9	884.1	1114.4
Cp (J/Kg-K)	765	535.6	703	495.2	2427	1909	2415
k (w/m-K)	40	20	1.2	13	0.286	0.145	0.252
µ (N-m/sec)	-	-	-	-	0.799	0.486	0.0157

Won S. Chang et al. [18] – In this paper study shows that in a gas turbine compressed air from compressor needs to be cooled otherwise it will melt the blade surface. There are two options for cooling the air one is, to use high melting point material for turbine blade second is, introduce thermal management system. To use higher melting point material such as titanium is very costly, so the only option is thermal management system. Now there are two types of thermal management system air to air and fuel to air. Results show that fuel-to-air heat exchanger system have the greatest capacity for enhancing engine performance while reducing dependency on advanced materials. Weight of an air-to-air system is very sensitive to potential increases in cooling flow requirements.

A.N. Dravid et al. [19] – This paper investigates the effect of secondary fluid motion on laminar flow in a helical coil tube. This paper gives the relation of local Nu in the form of De and Pr.

$$Nu = [0.65(De^{0.5})+0.76]Pr^{0.175}$$

Nu = Nusselt no., De = dean no., Pr = prendelt no.
This relation is valid for Pr in the range of (5-175)

fuel	Pr
water	5
n- amyl acetate	15
n- butanol	35
n- amyl alcohol	55
Ethylene glycol	175

In helical coil tube due to curvature effect secondary flow in the direction of axial flow is produced, which causes turbulence in the flow. So due to this reason heat transfer is increased in the helical tube as compare to straight tube.

Aly [20] – In this paper water based Al_2O_3 nano fluid is used as a working fluid in double concentric tube heat exchanger. Nano particle in the volume concentration of 0.5%, 1% and 2% and mass flow rate 2-5LPM and 10-25LPM in the tube side and annulus side is flowing. Coil dia. 0.18, 0.24 and 0.3m Results show that at the same Re or De, h increases by increasing the coil diameter and Ø. Also, f increases with increase in curvature ratio and pressure drop is negligible with increasing Ø. This paper also gives some corelations

Correlations	conditions
(1) $f = fs + 0.03\varrho^{0.5}$	$4500 < Re < 10^5$
$f_s = 0.3164Re^{-0.25}$	
(2) $f = 0.304Re^{-0.25} + 0.029\varrho^{0.5}$	$300 > Re\varrho^2 > 0.034$
(3) $f = 0.02985 + 75.89[0.5-atan\left(\frac{De-39.88}{77.56}\right)/\pi]\varrho 1.45$	$35 < De < 20000$
$f_s = (1.8\log_{10}Re - 1.5)^{-2}$	
(4) $Nu_s = \frac{PrRe(\frac{fs}{8})}{1+12.7(\frac{fs}{8})\hat{}0.5}[1 + (d_h/L)^{2/3}]$	$10000 < Re < 1000000$
(5) $Nu = \frac{PrRe(\frac{f}{8})}{1+12.7(\frac{f}{8})\hat{}0.5}$	$Re > 22000$

f_s = friction factor for straight tube, f = friction factor for helical tube, ϱ = curvature ratio = d_h/

III. CONCLUSION

1. Helical coil heat exchanger is better than straight tube heat exchanger.
2. By adding baffles, fins and twist geometry on the straight tube heat transfer enhances.
3. To use nano fluids is also a good choice for heat transfer enhancement.
4. Eccentricity is always beneficial for both straight and helical tube heat exchanger.
5. By changing geometrical structure such as increasing coil dia., no. of inner tubes and modified the model by shifting outer tube at different inclination angle are also used for heat transfer enhancement.

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