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Numerical Analysis and Comparison of Various Cross Sections of Heat Pipes in Heat Exchanger

Gadipelly Bhaskar[1], K.V. Narasimha Rao[2], M. Udaya Kumar[3]

Abstract

The present work describes about numerical analysis of heat pipe with different cross sections such as L-shape, U-shape, wave and spring configurations. The effect of various configurations of heat pipe plate exchanger are examined by considering temperatures, velocities, pressure depressions. The numerical values of Reynolds number, Nusselt number, heat transfer were calculated at different velocities. The outcome of numerical analysis found that it influences fluid flow and pressure depression. Hence, the most important of the current exertion is to improve warmth transmit coefficient, which leads to enhance the efficacy of heat exchanger. Consequently, the present analysis is conceded for heat pipe among different shapes using hot and cold working fluids under Laminar and disorderly flow regimes at varied temperature and velocity conditions. Mathematical analysis presented and found that spring type heat pipe plate exchanger shows better heat transfer performance.

Keywords: Heat pipe, Heat exchanger, Numerical analysis, Reynolds number, Laminar & Turbulent flow, Heat transfer.

INTRODUCTION

Heat exchangers are significant engineering devices in numerous industries since the effectiveness and economy of the method mostly depend on the concert of the heat exchangers. Enrichment in the recital may result in the lessening in the size of the heat exchangers a preset size can give an amplified heat transfer rate, it potency also provide a lesson in warmth difference between the process fluids enabling able deployment of thermodynamic ease of use.

Ahmed H N Mudhafa et al [1] numerically investigated the enrichment of warmth concert of segment alter in power storage space system and accomplished that Segment change material is solidifying by forty-one percentage when the customized webbed tube heat exchanger compares to webbed tube heat exchanger.

P.Samruaisin, Changcharen et al [2] analyzed and accomplished commonly spaced quadruple warped tapes defer lessen warmth transmit and cause low pressure losses compared to full-length tape.

XiaoyaLiu et al [3] studied and concluded that, the outcome of warmth transfer enrichment under given pumping power. The consequences indicated that the confined convective warmth transmit coefficient enhances with the incorporation of the novel warped tapes due to increase of the velocity close to wall and thickness decline of thermal boundary layer. They accomplished that Coaxial cross twisted tapes (CCTTs) increase the warmth transfer in tubes.

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Chirag Maradivya et al [4] This paper concludes the warmth transmit augmentation occurred in all cases because of lessening in the stream sectional area, an amplify in turbulent concentration and also improve in tangential stream by applying various inserts. Which leads to warmth transmit development considerably.

Wei Yun et al [5] explored the outcome of the turbulators on to the Pressure depression, warmth transmits distinctiveness in a round tube investigate in the course of mathematical simulations. The findings revealed that warmth transmit rate in a round tube section inserted turbulators is assorted in between 1.25 – 2.02 more than the plain tube.

Rajiva L Mahanty et al [6] studied the variant of frictional depression, warmth transmits in round, oblique tubes. These investigations performed a range of pitch ratio in the sort of 1.24 to 1.86. Reynold's number is varied in between one hundred to two thousand. The final result is warmth transmit coefficient, pressure depressions are steadily reduced even as enhancing pitch to diameter proportion.

Shyy Woei Chang, Kuo-Chang Yu [7] explored the result of spirally twisting springs in warmth exchanger. The outcome was thermal recital of warmth exchanger is amplified with spirally wrapped spring type insert.

Amnart Bonloi et al [8] observed the impact of flow angle of V type wavy shield and warmth transmit in warmth exchanger mathematically between the Reynold's number 2900–10,500. The best result was found that at an angle 20 degree and Reynold's number 3000 the thermal performance factor is observed 2.08 for V type upstream case.

J.P.Meyar, and Abolarin [9] explored on warped tube in a rounded tube at alter conditions of heat flux. It was concluded that transition stream region was influencing by different twisted ratios.

Y Xu MD [10] explored effect of obstruction and pitch ratios, different angles in heat pipe under steady heat flux condition. Reynold's number varied from 5900 to 33,500. The utmost warmth enrichment attained pitch proportion is equal to 2.4 Obstruction proportion is 0.10.

Suvnjan Bhatachary et al [11] observed the result of warped strip at an assortment angle in solar heater. The final result expressed at 18degree angle gives highest warmth transfer.

S Rashidi et al [12] focused on warmth and fluid stream characteristics of square cutting warped strip insert in warmth exchanger. The utmost efficiency of warmth exchanger with square cut warped strip insert is equal to 38 percentages.

Nemat Mashoofi et al [13] found axial perforated warped strip attained lessen pressure drop. It helps to enhance efficiency of warmth exchanger.

Zahra Hajabdollahi et al. [14] has studied the impact of pipe inserted with warped strip on the best possible propose fin-and-tube warmth exchanger. Finally, accomplished with the purpose of the wrapped tape on the pipe side outcome in operate amid the warmth transfer and frictional drop. Therefore, efficacy and the total yearly cost resulted in optimization concurrently.

Anastasia Stamation et al. [15] revealed that thermal energy storage method adopted for high level of compactness, and implementation of the charging and discharging progression at definite steady warmth levels.

Parkpoom Sriromreun [16] discussed that effect of Z shaped baffle in rectangular path. These are located on crown wall of pipe warmth exchanger to obtain co-rotating vortex strips which control stream disorder intensity. Reynold's number is varied from 4400 to 20400. Baffle leaning with 45 degrees provide greatest warmth transfer.

Smith Eiamsa-ard et.al [17] studied that the primary category is connected with ill-advised warmth exchanger access arrangement, the secondary category of segment to-entry stream mal-distribution occurred in a remarkably slighter warmth exchanger brought concerning by dissimilar fabricate resiliencies.

Sompol Skullong et.al [18] considered stream conflict and thermal description in a tube warmth exchanger attach with staggered-winglet perforate strip. The experimentation was conducted under steady heat-flux for disorderly flow system, Reynold's number varied from 4,180 to 26,000. The greatest concert is achieved as 1.71 with obstruction ratio is equal to 0.15, pitch ratio is equal to one at Reynold's number is equal to 4180.

Pongjet Promovonge, et.al [19] discussed the result of delta-wing strip insert applied as vortex generator in pipe warmth exchanger. These insert are positioned in the direction of forward-wing with inclined angle of thirty, forty, and sixty degrees and pitch ratio are 0.5,1.0,1.5,2.0 and 2.5. The outcome of the experiment reveals that delta wing strip provide uppermost thermal augmentation.

Orhan Keklikcioglu et.al [20] focused effect of wrapped spiral inserts in rounded tube warmth exchanger. The inserts are similar measurement lengthwise positioned in the period of one millimeter and two millimeter space starting the inside wall tube of pitch ratio = one, Two and Three. Experiments were performed varied Reynolds numbers from 3,429 to 26,663. The maximum performance was obtained 1.82 for a Reynold's number 3429.This is owing to laminar periphery stratum disorder.

In the present numerical analysis the following equations are used.

Heat transfer coefficient $h = Q/A\ (T_{sur}-T_{bulk})$ (1.1)

Heat transfer rate $Q = m\ c_p(T_{out}-T_{inlet})$ (1.2)

Mass flow rate $m = \rho x A x V$ (1.3)

Nusselt number $Nu = (hD)/k$ (1.4)

Theoretical Nusselt number $Nu_{theoretical} = 0.023(Re)^{0.8}(0.7)^{0.4}$ (1.5)

Reynolds number $Re = (VD)/\nu$ (1.6)

friction Factor $(f_t) = (0.79 \ln Re-1.64)^{-2}$ (1.7)

OBJECTIVES

- To examine warmth, transmit coefficient, pressure drop of heat pipe under uniform heat flux condition with water and hot fluid as working medium.
- To calculate pressure drop, warmth transmits coefficient of heat pipe with different geometries.
- To compute Nusselt number at dissimilar velocities of uniform heat pipe with various cross sections.
- To compare the outcome achieved through Numerical analysis of various cross sections of pipes.
- To equivalence all the findings and obtain inferences from the outcomes.

Case 1: Uniform heat pipe (hot fluid and cold fluid)

Velocity (V) = 0.3 m/sec
Cross sectional area of heat pipe = $7.85\times10^{-5}\ m^2$
Mass flow rate (m) = $\rho\ X\ A\ X\ V$ = 986.7X 7.85×10^{-5} X0.3 = 0.0232kg/sec
Specific heat (C_p) = 4187 J/kg K

Surface area of the plain pipe (A_s) = 1m^2
Heat transfer rate (Q) = m $C_p(T_0-T_i)$ = 0.0232x4187(16) = 1556.7 W
Heat transfer coefficient (h) = Q/(A_s (Ts-Tb))= 1556.7/ (1*(12)) = 129.7W/m^2 K
Reynolds number (Re) = $(VD_h)/\nu$ = (0.3X 0.01)/(0.53X10^{-6}) = 5660.4
Nusselt number (NU_{th}) = $0.023(Re)^{0.8}(Pr)^{0.4}$ = $0.023(5660.4)^{0.8}(3.35)^{0.4}$ = 37.5

FIGURES AND TABLES

The Table 1 values are represented at different velocities from 0.3 m/sec to 0.8 m/sec of uniform, L, U shape heat pipes. It has been observed that Nusselt number of U-shape heat pipe is more compared to L and uniform heat pipes due to geometrical shape of the pipe configuration.

Table 1. Comparison of Nusselt number and Reynolds number values of Uniform heat pipe with L and U shape heat pipes.

S.N.	Velocity (V) (m/sec)	Reynolds number (Re)	Nusselt number (Nu) uniform pipe	Nusselt number (Nu) Lpipe	Nusseltnumber (Nu)Upipe
1	0.3	5660.4	37.5	39.3	41.2
2	0.4	7547.2	47.2	49.6	50.6
3	0.5	9433.96	56.4	57.4	58.9
4	0.6	11320.7	65.3	68.5	70.5
5	0.7	13207.5	73.85	74.7	75.8
6	0.8	15094.3	82.2	84.6	85.7

Table 2. Comparison of Nusselt number and Reynolds number values of Uniform heat pipe with wave and spiral shape heat pipes.

S.N.	Velocity (V) (m/sec)	Reynolds number (Re)	Nusselt number (Nu) uniform pipe	Nusseltnumber (Nu)wave pipe	Nusselt number (Nu) spiral pipe
1	0.3	5660.4	37.5	43.6	46.7
2	0.4	7547.2	47.2	52.8	55.7
3	0.5	9433.96	56.4	59.9	63.5
4	0.6	11320.7	65.3	72.6	75.8
5	0.7	13207.5	73.85	77.9	81.5
6	0.8	15094.3	82.2	87.9	90.2

The Table 2 explained that warmness is enhanced from entrance to exodus, it occurs because of fluid stream is uninterruptedly rotate each bend of the pipe. The variance of first in- last out temperatures are high and it has been observed that warmth transmit is amplified for the velocity of0.8 meters/second. Nusselt number and frictional resistance are analyzed by using standard equations.

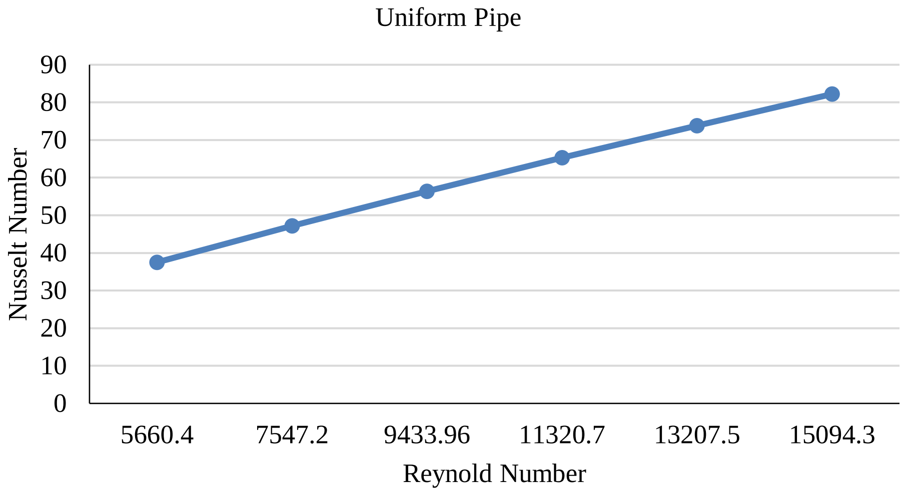

Figure 1. Variation of Nusselt number with Reynold number for Uniform heat pipe.

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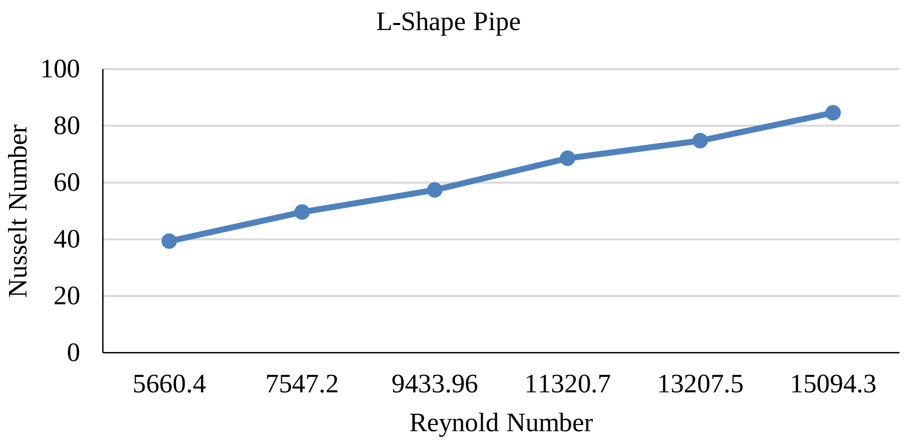

Figure 2. Variation of Nusselt number with Reynold number for L-shape heat pipe.

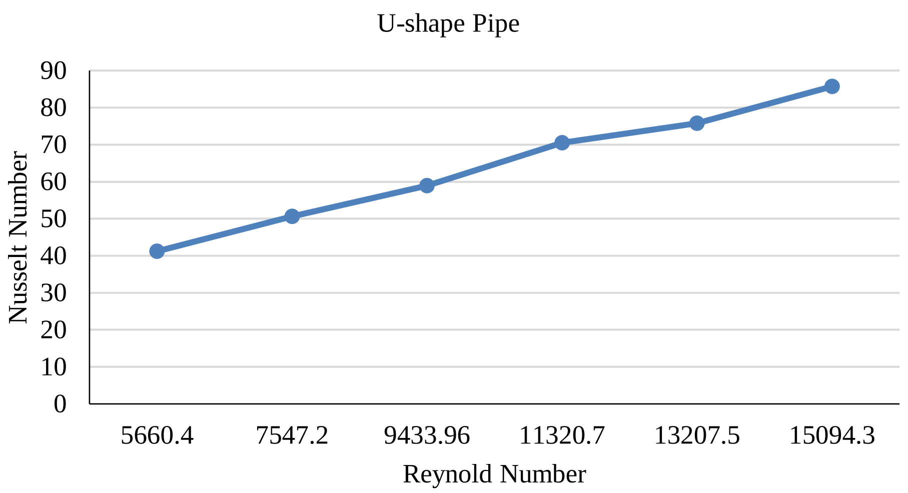

Figure 3. Variation of Nusselt number with Reynold number for U-shape heat pipe.

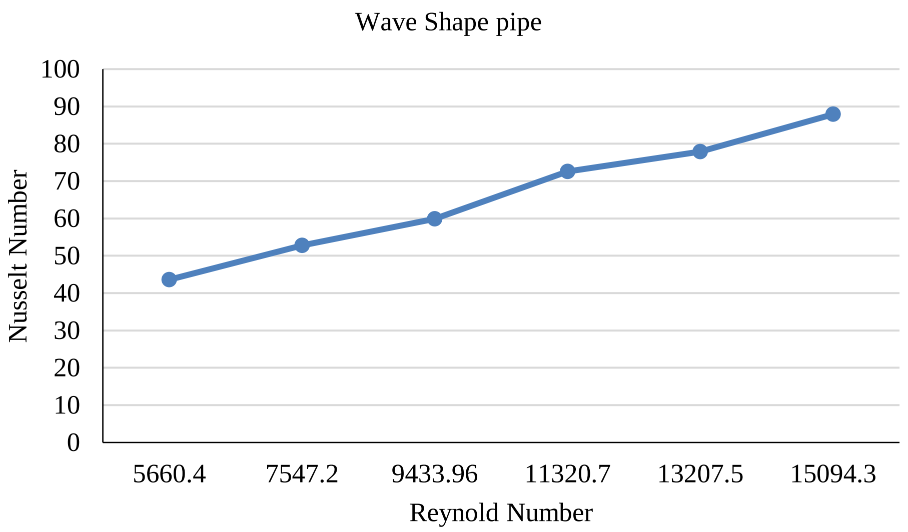

Figure 4. Nusselt number with Reynold number for Wave-shape heat Pipe.

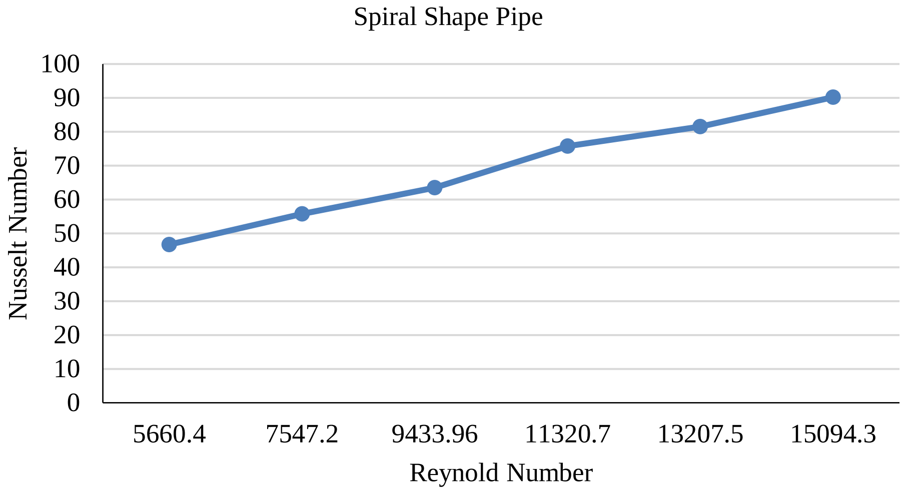

Figure 5. Nusselt Number with Reynold Number for Spiral-shape heat pipe.

The Figures 1-5 are explaining the variations of Reynolds number with Nusselt number of different configurations of heat pipe.

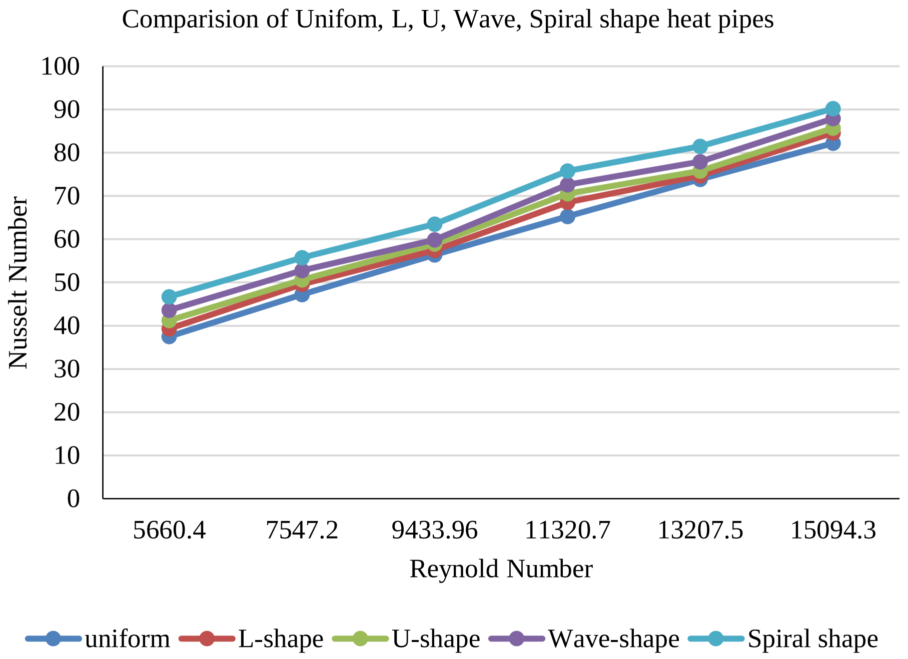

Figure 6. The graph shows the variation Nusselt number with Reynold number for different heat pipes.

In the Figure 6, it has been observed that Spiral shape heat pipe produces utmost heat transfer enhancement at 15094.3 Reynolds number, 0.8 m/sec velocity. It happens because of fluid flow molecules are properly mixed in this region.

CONCLUSIONS

Theoretical Nusselt number of spiral shape heat pipe is maximum at a velocity of 0.8 meters /second i.e. 90.2. This happens to be due to larger blockage ratio offers maximum stream movement, which provide stronger turbulent flow concentration, leads to devastation of thermal frontier layer, it helps to augmentation of heat movement in the object.

- The optimum heat flux found for the spiral pipe when compare with the other pipe configurations. This indicates temperature difference is maximum at the spiral pipe only.
- Finally, it is observed that Spiral shape heat pipe gives better heat transfer enhancement than other heat pipes configurations.

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