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Augmentation of Heat Transfer Using Twisted Tube Heat Exchanger

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Abstract: *Various techniques for improving the heat transfer are referred to as heat enhancement techniques. Heat exchanger with these techniques is called augmented heat exchanger. The objective is to reduce capital cost, power cost, maintenance cost and space. Twisted tube is a passive technique to enhance the heat transfer. Present twisted tubes are used for long and straight passage tubes. We experimentally investigated the fully developed laminar convective heat transfer and friction factor characteristics in a plain tube and fitted with twist tubes. Experiments were conducted within range of 1200□Re □ 2800.Experiments are performed for Reynolds number ranging from laminar to turbulent. Heat transfer without twisted tube is compared with heat transfer with twisted tube. The experimental results reveal that use of twisted tube leads to increase in heat transfer. Nusselt Number increase with increase in Reynolds Number. Twisted tube is inserted into the flow to provide redevelopment of the boundary layer, to increase the heat transfer surface area and to cause enhancement of heat transfer by increasing the turbulence or rapid mixing. Therefore, a more compact and economic heat exchanger with low lower operation costs can be obtained.*

I.INTRODUCTION

A heat exchanger is a device facilitating the convective heat transfer of fluid inside the Tubes and is extensively used in many engineering applications, such as thermal power plants, chemical processing plants, air conditioning equipment, refrigerator and radiators for automobiles. Today, attempts have been made to decrease the amount and rate of heat exchanger. In general, heat exchanger flow arrangement can be divided into two. One is parallel flow arrangement where both the hot and cold streams enter the heat exchanger at the same end and travel to the opposite end in parallel streams. Energy is transfer along the length from the hot to the cold fluid so the outlet temperature asymptotically approaches one another. The other is counter flow where the two streams enter at opposite ends of the heat exchanger and flow in opposite directions. Temperatures within the two streams tend to approach one another in a nearly linear fashion resulting in a much more uniform heating pattern.Parallel flow results in rapid initial rates of heat exchanger but rates rapidly decreases as the temperature of the two streams approach one another. Counter flow provides for relative uniform temperature difference and consequently, leads towards relatively uniform heat rates throughout the length of the unit. Various techniques have been described in literature to enhance heat transfer rate in heat exchangers. In most of the past studies the friction factor was correlated to Reynolds number. In some applications, such as air liquefaction process, crude oil transport over large distance involve large diameter pipe demanding large amount of pumping power. Determination of accurate friction factor is essential for such devices. Experimental setup has been fabricated and a series of experiments conducted to know the friction factor and Nusselt number variation with Reynolds number.

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Anyone who wants to use a heat exchanger faces a fundamental challenge fully defining the problem to be solved. Which requires an understanding of the thermodynamic and transport properties of fluids? Such knowledge can be combined with some simple calculations to define a specific heat transfer problem and select an appropriate heat exchanger.

Heat Enhancement Techniques

Heat transfer enhancement, augmentation or intensification deals with the improvement of thermo hydraulic performance of heat exchangers. Different enhancement techniques have been identified which can be broadly classified as passive and active techniques. They generally use surface or geometrical modifications to the flow channel, or incorporate an insert, material, or additional device.

How to increase heat transfer coefficient at internal channel flows (in pipes)?

1. Artificial wall roughness, porous wall
2. Fins, grooves, dimples
3. Inserts (static mixers, twisted tape, wire mesh, invertors)
4. Centrifugal forces (coiled tubes, bends)
5. Vibration, ultrasound, nanoparticles

Artificial wall roughness, porous wall

Heat transfer can be increased by a modification of wall such that the heat transfer surface is extended (fins, dimples), and the thermal boundary layer is disrupted (for example by vortices generated at protrusions or dimples).

Inserts (Static Mixers, Twisted Tape, Wire Mesh, Invertors)

Inserts (static mixers, twisted tape) extend heat transfer surface (as far as a good thermal contact with pipe wall is ensured) and generate secondary flows diminishing thermal boundary layer. Inserts are effective first of all in laminar flow regime (PEC is highest at low Re), but heat transfer enhancement in turbulent regime is also significant.
Wire coils disrupt thermal boundary layer (suitable for laminar flows), wire mesh affects the main flow and is effective in turbulent flows. Advantage: Tiny wire at wall has only small effect upon pressure drop.

Heat-Exchangers - Use of Fins

For a given LMTD the only way of increasing heat transfer rates in a heat-exchanger is to increase the surface area. One way of achieving this is through the use of extended or finned surfaces. With Liquid /Gas HX's very often the heat transfer coefficient on the liquid side is much greater than that on the gas side. Fins would then be used on the gas side so that the resistance to heat transfer was approximately the same on both sides.

Twisted tube heat exchanger

Heat transfer enhancement is one of fastest growing areas of heat transfer technology. In fact many techniques are available for improvement of various modes of heat transfer. Second generation enhancement technology is already common in the process industry. Brown fintube's recent research and development program is an effort to advance third generation of heat transfer enhancement technology, twisted tube exchangers. A twisted tube is a passive heat transfer enhancement device, generally classified in a swirl-flow device category. Swirl-flow devices consist of variety of geometrical flow arrangement that produce forced vortex fluid motion in confined flows. The enhancement of all the cases occurs primarily due to fluid agitation and mixing induced by swirl flow.

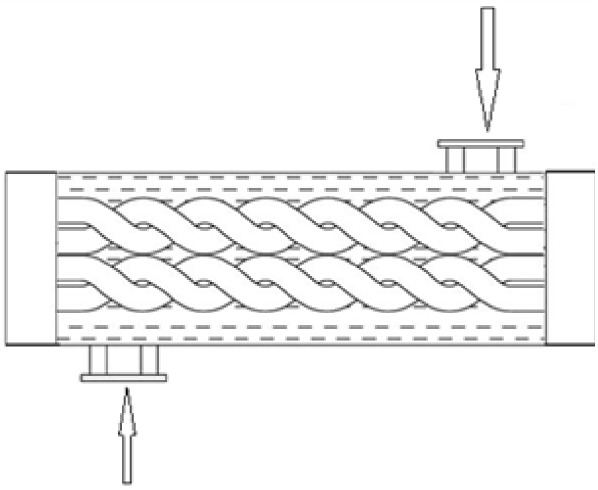

Fig-1: Twisted tube heat exchanger

II.LITERATURE REVIEW

For decades many of the wire coiled employed for augmentation of laminar or turbulent flow heat transfer have been reported and discussed however, few researches for coiled wire inserts have been found in comparison with those for twisted tape inserts. This has been noticed from the work Shoji at al or Garcia et al coiled wires are of practical interest, and therefore, their date are required to extend the use of this technique. Some investigation to be conducted to determine the effect of the coiled wire on the heat transfer and the friction factor for a long time . Enhancement of heat transfer by using several coiled wire inserts, base on energy analysis was investigated by Prasad and Shen . Correlations for friction factor and heat transfer coefficient for turbulent flow in internally augmented tubes were proposed by ravigururajan and bergles. Agarwal et al experimentally investigated heat transfer augmentation by using coiled wire inserts during forced convection condensation of R-22 inside a horizontal tube. Inaba and Ozaki presented the tubulant flow induced by using a coiled wire enhances heat transfer even downstream of the coiled wire. Kim et al investigated the flow pattern, void fraction and slug rise velocity on counter current two phase flow in a vertical round tube with coiled wire inserts. They observed that the slug rise velocity and void friction in a vertical round tube is higher for a coiled wire insert than that in a smooth tube.

Rahai et al. Experimentally investigated the influences of wire coil pitch spacing on the mixing enhancement of a turbulent jet from a Bunsen burner. Heat transfer enhancement of flowing water in a tube with flow drag reduction additives by inserting wire coils was presented by Inaba and Haruki . Rahai and Wong investigated turbulent jets from round tubes with coil inserts. Yakut and Sahin examined the heat transfer and friction loss by placing coiled wire twisted tubes in a tube in addition to the shedding frequencies and amplitudes of vortices produced by coiled wire twisted tubes, including a coupling of flow and acoustic structures. The conjugate heat transfer and thermal stress in a tube with coiled wire inserted under uniform and constant wall heat a chemical filled with high conductivity porous material subjected to oscillating flow is new and effective method of cooling electronic devices.

Mehmet sozen (Mehmet sozen et al, 1996) [26] numerically studied the enhanced heat transfer in round tubes filled with rolled copper mesh at Reynolds number range of 5000-19000 with water as the energy transport fluid and the tube being subjected to uniform heat flux, they reported up to ten fold increase in heat transfer coefficient with brazed porous inserts relative to plain tube at the expense of highly increased pressure drop. Paisarn Naphon (Paisarn Naphon et al., 2006)[27] had experimentally investigated the heat transfer characteristics and the pressure drop in horizontal double pipes with twisted tape insert. The results obtained from the tube with twisted insert are compared with those without twisted tape. Liao. Q (Liao. Q et al., 2001)[28] carried out experiments to study the heat transfer and friction characteristics for water, ethylene glycol and ISOVG46 turbine oil flowing inside four tubes with three dimensional internal extended surfaces and copper continuous or segmented twisted tape inserts within Prandtl number range from 5.5 to 590 and Reynolds numbers from 80 to 50,000. They found that for laminar flow of VG46 turbine oil, the average Stanton number could be enhanced up to 5.8times with friction factor increase of 6.5fold compared to plain tube. Betul Ayhan Sarac (Betul Ayhan Sarac et al., 2007)[29] conducted experiments to investigate heat transfer and pressure drop characteristics of a decaying swirl flow by the insertion of vortex generators in a horizontal pipe at Reynolds numbers ranging from 5000 to 30000. They observed that the Nusselt number increases ranging from 18% to 163% compared to smooth pipe. Experimental investigation on heat transfer and friction factor characteristics of circular tube fitted with right-left helical screw inserts of equal length and unequal length of different twist ratios was done by (Sivashanmugam et al., 2007)[30]. They observed that heat transfer coefficient enhancement for right left helical screw inserts is higher than that for straight helical twist for a given twist ratio. A maximum performance ratio of 2.97 was obtained by helical screw inserts. Heat transfer, friction factor and enhancement efficiency characteristics in a circular tube fitted with conical ring twisted tubes and a twisted-tape swirl generator were investigated experimentally by Promvonge (Promvonge et al., 2007)[31]. Air was used as test fluid. Reynolds number varied from 6000 to 26000. The average heat transfer rates from using both the conical-ring and twisted tape for twist ratios 3.75 and 7.5, respectively are found to be 367% and 350% over the plain tube. The effect of two tube insert wire coil and wire mesh on the heat transfer enhancement, pressure drop and mineral salts fouling mitigation in tube of a heat exchanger were investigated experimentally (Pahlavanzadeh H. et al., 2007) with water as working fluid. The heat transfer rate averagely increased by 22-28% for wire coil and 163 - 174% for wire mesh over a plain tube value depending on the type of tube insert, density of wire torsion and flow velocity. Pressure drop also increased substantially by 46% for wire coil and 500% for wire mesh. As Bogdan I. Pavel (Bogdan I. Pavel et al., 2004) carried out their work in a pipe with porous inserts in laminar and turbulent region with Reynolds number ranging from 1000-4500, the present work has been done similar lines but in turbulent region (Re number range of 7,000-14,000) as most of the flow problems in industrial heat exchangers involve turbulent flow region.

III.EXPERIMENTAL APPARATUS AND METHODS

The set up consists of:

a) Double pipe heat exchanger
b) Cold and hot water supply
c) Rota meters to measure flow rate
d) Thermometers to measure temperatures

A double pipe heat exchanger with provision to permit cold water in the annulus in opposite directions is available. Hot water from the geyser flow through the inner tubes, the heat transfer takes place across the wall of the inner tube. The cold water in the annulus is made to flow in the direction of the hot fluid, which is the parallel flow. There is a provision to record temperature at the inlet and outlet location.

Simple Heat Exchanger

In simple heat exchanger, the hot water flow in the inner tube and cold in the outer tube. The flow here is laminar, the temperature are recorded at hot inlet and outlet, cold inlet and outlet.

Technical Data:

a) Inner tube is constructed from copper, Dia: 6.3mm(4 tubes)
b) Outer tube is constructed from galvanised iron, Dia: 50mm
c) The heat transfer section is 1700mm long approximately.
d) Pitch is equal to 0.25 m

Fig-2: Simple Heat Exchanger

Working condition of heat exchanger

Fig-3: Working condition of heat working condition of heat exchanger.

Exchanger Procedure:

1. Configure the experiment for parallel flow heat exchanger operation such as ON the heating elements to heats the fluids.
2. Set the requested cold water mass flow rate M_c to 2 lpm constant.

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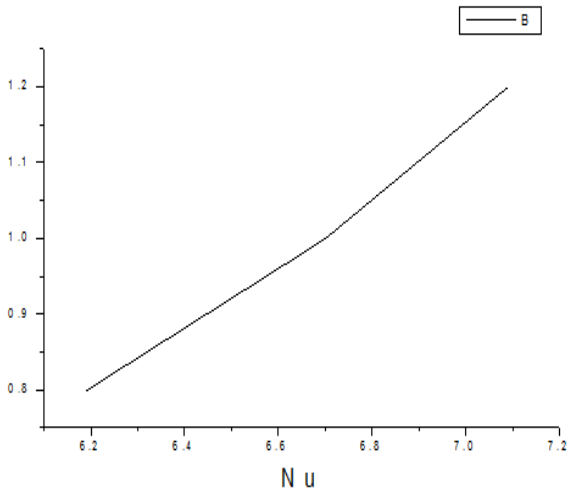
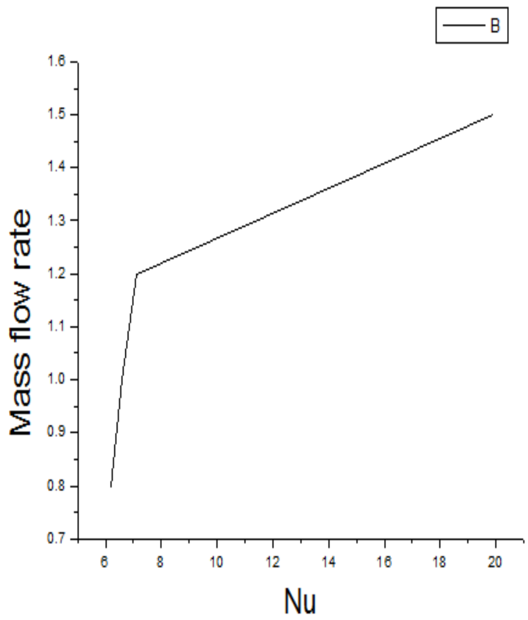
3. Initially set the hot water mass flow rate M_h to 0.8 lmp. Wait until 5 minutes before the four temperature readings are recorded.
4. Repeat this for mass flow rate, M_h of 1, 1.2, 1.5 etc for hot water. Record the temperature reading in the table.
5. Repeat this as above and record the temperature in the table.
6. After finish up the experiment, turn off the heating elements, close the valve for hot and cold wat

IV.RESULTS AND DISCUSSION

6.1 Comparison of mass flow rate with nusselt number For parallel and counter flow





Counter parallel

6.2 Comparison of nusselt number with Reynolds number for parallel and counter flow

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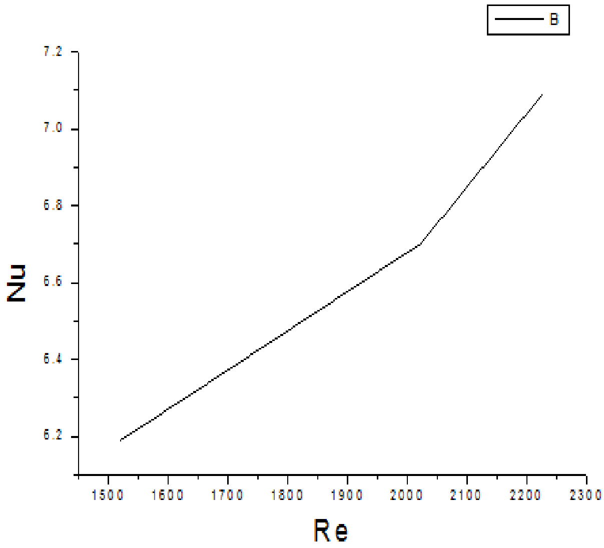
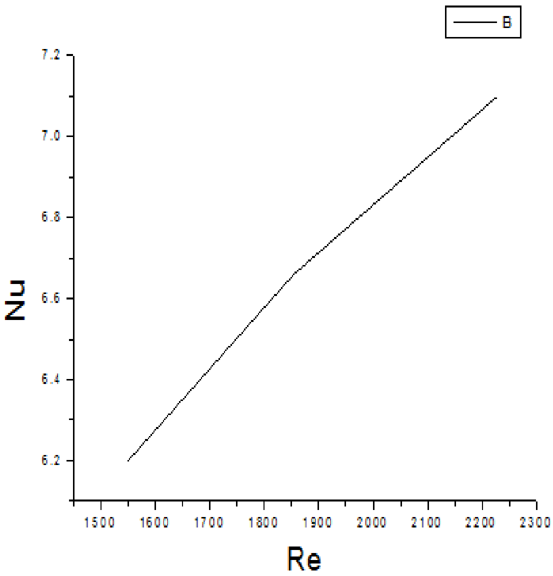
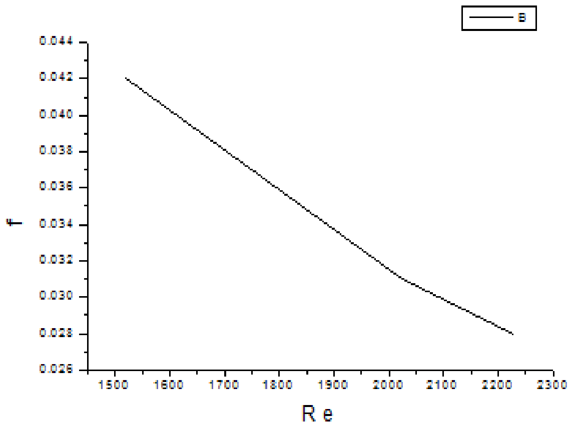
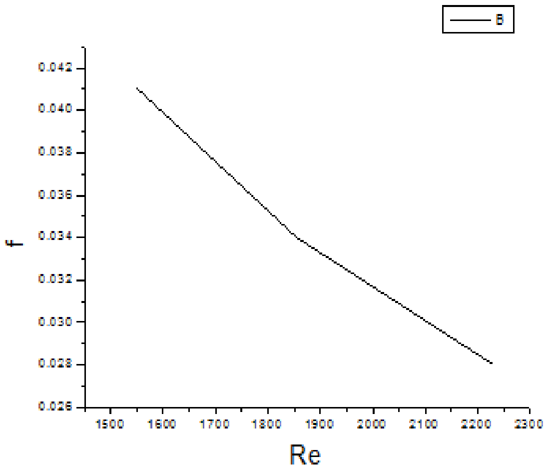




Counter **parallel**

6.2 Comparison of friction factor with Reynolds number for parallel and counter flow





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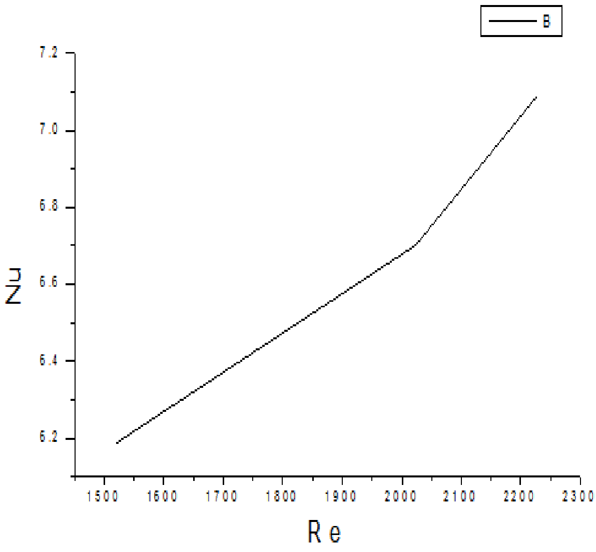
6.3 Comparison of nusselt number with Reynolds number for parallel and counter flow



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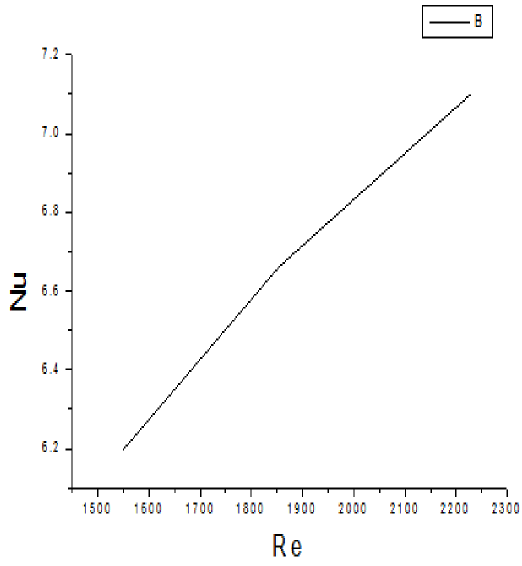
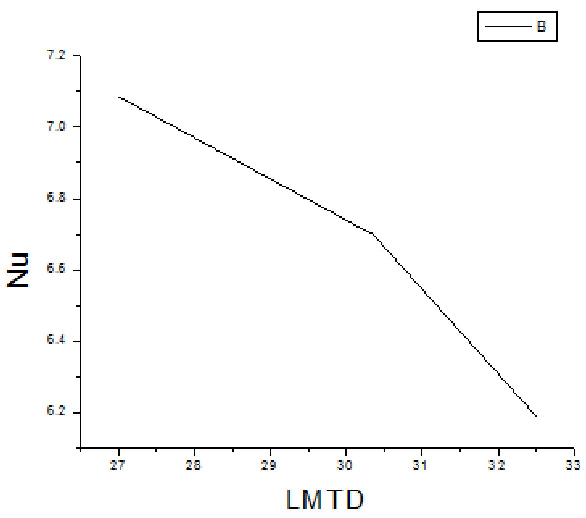


parallel

6.5Comparison of nusselt number with LMDT For parallel and counter flow



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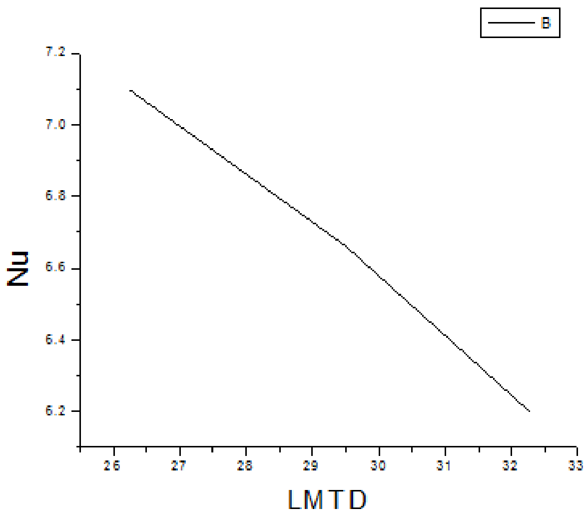

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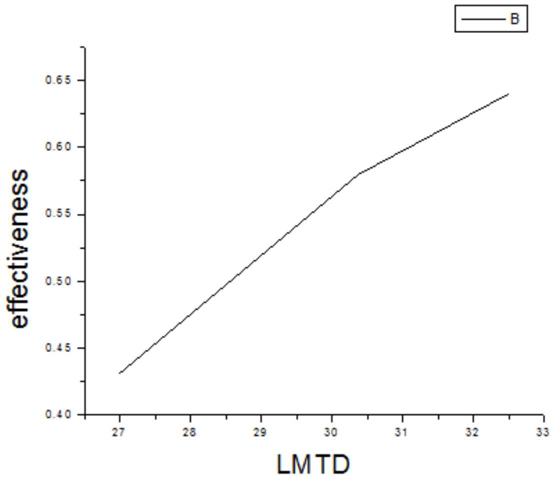
December 2017

6.6 Comparison of effectiveness with LMDT For parallel and counter flow



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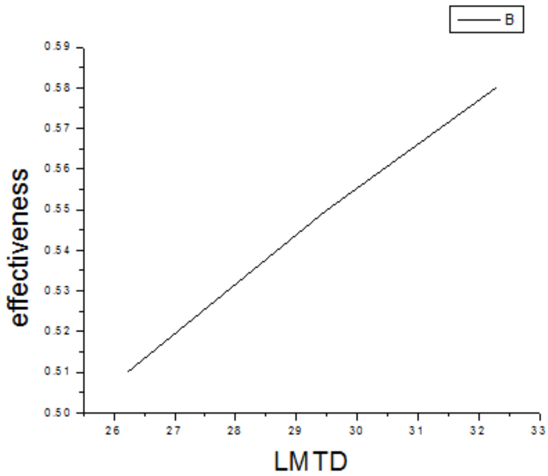
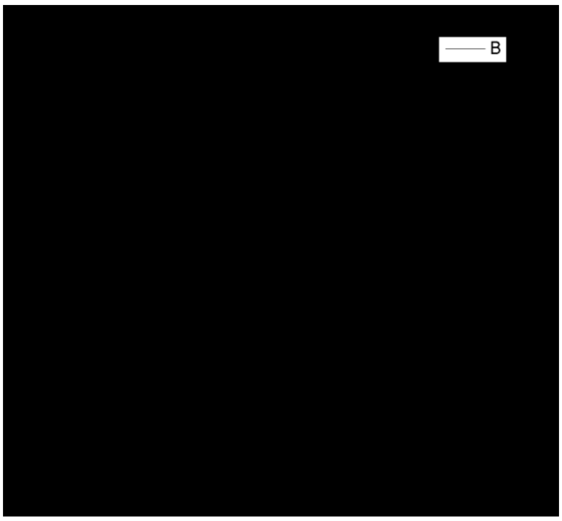
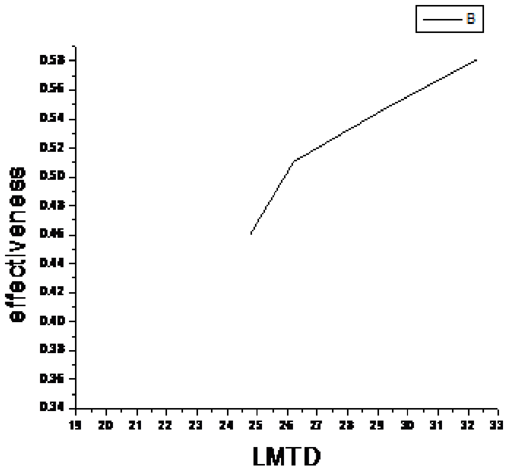


parallel

6.7 Comparison of effectiveness with LMDT With and without twisted tube



Without Twisted Tubes



with Twisted Tubes

Comparison of Effectiveness

S.No	with Twisted tube	without Twisted tube
1	0.58	0.35
2	0.55	0.4
3	0.43	0.42
4	0.37	0.3

CONCLUSIONS:

The important conclusions are drawn from this experimental investigations are as follows

1. Experiment was performed to investigate heat transfer characteristics with twisted copper tube
2. Use of twisted tube causes high heat transfer augmentation
3. In present investigation, effectiveness is 0.37 to 0.64

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AUTHOR's PROFILE

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