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Heat Transfer Enhancement in A Circular Tube Havingintegral Helical Swirl and Fitted with Twisted-Tape

A Dasthahir[1], K P Harshavardhan[2]

[1,2]Assistant Professor, Department of Mechanical Engineering, Karpagam Institute of Technology, Coimbatore, Tamilnadu, India

Abstract: *Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long term performance and the economic aspect of the equipment. Whenever inserts are used for the heat transfer enhancement, along with the increase in the heat transfer rate, the pressure drop also increases. This increase in pressure drop increases the pumping cost. Therefore any augmentation device should optimize between the benefits due to the increased heat transfer coefficient and the higher cost involved because of the increased frictional losses. The present paper includes various heat transfer augmentation techniques.*

1.0 INTRODUCTION

Heat exchangers have several industrial and engineering applications. The design Procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term Performance and the economic aspect of the equipment. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. Techniques for heat transfer augmentation are relevant to several engineering applications. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. Furthermore, sometimes there is a need for miniaturization of a heat exchanger in specific applications, such as space application, through an augmentation of heat transfer. For example, a heat exchanger for an ocean thermal energy conversion (OTEC) plant requires a heat transfer surface area of the order of 10000 m2/MW. Therefore, an increase in the efficiency of the heat exchanger through an augmentation technique may result in a considerable saving in the material cost. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow (breaking the viscous and thermal boundary layers), but in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an

Existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years and are discussed in the following sections.

1.1 Augmentation Techniques

They are broadly classified into three different categories:

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1. Passive Techniques
2. Active Techniques
3. Compound Techniques

1.1.1 Passive Techniques

These techniques do not require any direct input of external Power; rather they use it from the system itself which ultimately leads to an increase in fluid pressure drop. They generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior except for extended surfaces.

1.1.2 Active Techniques

In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer.

1.1.3 Compound Techniques

When any two or more of these techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement.

2.0 Methods and Methodology

These are the devices inserted into the flow channel to improve energy transport at the heated surface indirectly. The displaced inserts mix the main flow in addition to that in the wall region. Displaced wire coil insert (Figure 3.2) is not attached to the wall of the tube. These devices periodically mix the gross flow structure but not affecting the main flow significantly.

Fig 1 Displaced wire coil insert

2.1 Swirl Flow Devices

These devices (Figure3.3) include a number of geometrical arrangements or tube inserts for forced flow that create rotating or secondary flow. Full length twisted tape inserts or inlet vortex generator and axial coil inserts with a screw type winding are some examples of swirl flow devices.

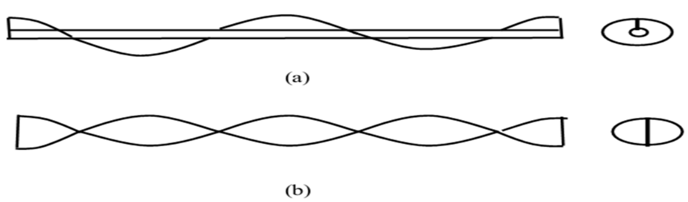

Figure 2 Swirl flow devices

2.2 Vortex Generator

One of the most important passive techniques to augment the heat transfer is the use of vortex generators. Transverse vortex generators produce vortices, whose axis is transverse to the main flow direction, whereas, the longitudinal vortex generators generate vortices whose axis is parallel to the main flow direction. It has been found that longitudinal vortex generators are more suitable than the transverse vortex generators when the heat transfer augmentation with pressure drop is an important consideration. The

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longitudinal vortices behind a slender aerodynamic object have been investigated for many years. Longitudinal vortices are found to persist for more than 100 protrusion heights downstream.

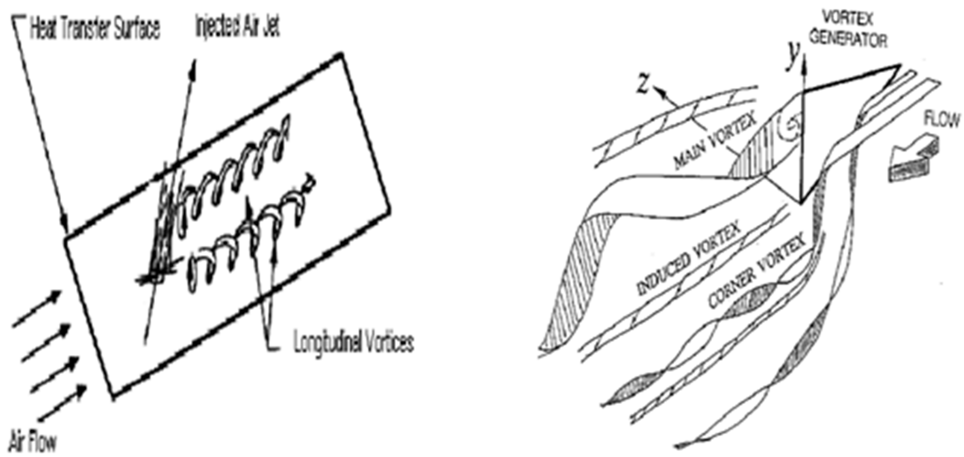


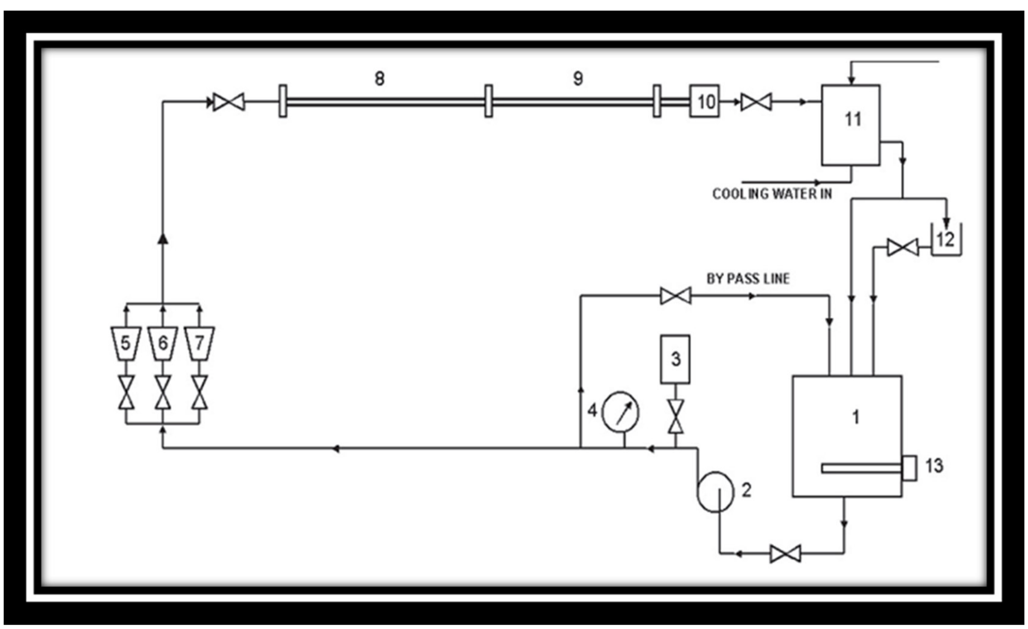
Fig 3 Vortex Generator

2.3 Experimental Setup

2.3.1 Introduction

In this chapter, a description of the experimental setup is presented with a Discussion of the experimental procedure

2.3.2 Proposed Experimental Setup Lay Out



1. Reservoir
2. Pump
3. Accumulator
4. Pressure gauge
5. Roto meter
6. Calming section
7. Test section

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8. Mixing chamber
9. Heat exchanger
10. Weighing section
11. Heater

2.4 Operating Procedure and Details

2.4.1 Labout the Inserts

The insert used for the experiment are twisted aluminium angles and stainless steel twisted tapes. While much literature can be found about passive heat transfer augmentation using twisted tapes as mentioned earlier, twisted aluminium angles are a new kind of insert where no such experiments have been done thus giving us ample room for experimental studies.

The present work deals with finding the friction factor and the heat transfer coefficient for the twisted angles with twist ratios and twisted tapes with twist and comparing those results with that of smooth tube and among themselves.

2.4.2 Fabrication of Inserts

Four angle tapes with varying twist ratios were fabricated as shown in fig 4 to fig 9 The end portions of the fabricated tapes were cut and drilled to join the tapes by thin high tension wires. Three tapes with the same twist ratio and twist in the same direction were joined to give a length of around 2.95 m, which was sufficient for the heat exchanger used for the experimental study. The twisted tapes are shown in fig 4to fig 9

2.4.3 Proposed Twist Tapes Figures

Fig 4

Fig 5

Fig 6

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Fig 7

Fig 8

Fig 9

2.5 Calibration Table for Large Rota Meter

	Observation1			Observation2			Observation3			
Rotameter Reading (kg/hr)	Wt (kg)	Time (sec)	m (kg/s)	Wt (kg)	Time (sec)	m (kg/s)	Wt. (kg)	Time (sec)	m (kg/s)	Average m
300	10.5	130	0.0808	10.2	127	0.0803	10.2	127	0.0803	0.0805
350	10.4	111	0.0937	10.4	109	0.0954	10.2	107	0.0953	0.0948
400	10.3	94	0.1096	10.3	93	0.1107	10.5	97	0.1082	0.1095
500	10.4	75	0.1387	10.7	78	0.1372	10.4	76	0.1368	0.1376
600	10.4	63	0.1651	10.6	64	0.1656	10.7	64	0.1672	0.1660
700	10.6	53	0.2000	10.4	53	0.1962	10.6	53	0.2000	0.1987
800	10.6	47	0.2255	10.8	46	0.2348	10.4	47	0.2213	0.2272
900	10.5	41	0.2561	10.6	42	0.2524	10.8	43	0.2512	0.2532
1000	10.7	39	0.2744	10.5	37	0.2838	10.5	37	0.2838	0.2806
1100	10.8	36	0.3000	10.7	37	0.2892	10.5	34	0.3088	0.2993
1200	10.6	33	0.3212	10.3	31	0.3323	10.8	33	0.3273	0.3269
1250	10.5	30	0.3500	10.7	31	0.3452	10.4	30	0.3467	0.3473

Table 1 2.6 Calibration Table for Small Rotameter

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	Observation1			Observation2			Observation3			
Rotameter Reading (lpm)	Wt (kg)	Time (sec)	m (kg/s)	Wt (kg)	Time (sec)	m (kg/s)	Wt. (kg)	Time (sec)	m (kg/s)	Average m
1	12	749	0.0160	10.7	655	0.0163	10.4	635	0.0164	0.0162
2	10.4	317	0.0328	10.6	322	0.0329	10.3	313	0.0329	0.0329
3	10.2	205	0.0498	10.2	205	0.0498	10.4	211	0.0493	0.0496
4	10.2	154	0.0662	10.2	155	0.0658	10.5	156	0.0673	0.0664
5	11.6	145	0.0800	10.0	124	0.0806	10.6	132	0.0803	0.0803

Table 2

Chapter – 5

Conclusion

In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation.

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