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Heat transfer augmentation using twisted tape inserts: A review

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ABSTRACT

Heat transfer enhancement is an important matter of concern for energy conservation and also beneficial from economic point of view. The use of passive devices like twisted tapes, roughness elements, wires inserts etc. are effective methods of heat transfer augmentation. Many research studies on different types of twisted tapes geometries to increase heat transfer rate have been carried out. Also, several correlations were developed to determine heat transfer and friction factor for twisted tape inserts. In the present study, a review on work done in the area of heat transfer augmentation using twisted tapes has been carried out. Previous experimental and numerical studies on various types of twisted tapes (based on the literature survey) were discussed. These studies reveal that the future research in the area of twisted tapes will bring more development in the heat exchanger systems. The optimum shape for twisted tapes can also be developed based on maximisation of heat transfer and minimisation of friction factor regarding fluid used in the system.

Contents

1. Introduction

Efficient heat transfer system is one of the important requirements in energy conservation [1]. The enhancement of heat transfer leads to augmentation of high heat flux. Apart from this, enhancement in heat transfer rate also leads to several advantages like reduction of heat exchanger size and temperature driving force etc. The reduced size of heat exchanger is quite important from economic point of view whereas reduction of temperature driving force leads to increase second law efficiency and minimisation of entropy generation or minimum energy destruction. In addition to this, high heat transfer rate is beneficial due to the fact that heat exchanger can be operated at low velocity and gives considerably higher heat transfer coefficient. Consequently, low operating pressure drop is achieved and operating cost is considerably reduced. In order to improve the efficiency of heat exchangers, it is very important to improve thermal contact and decrease the pumping power. These benefits associated with heat transfer enhancement forces to explore different techniques/methods to improve thermal performance of heat exchangers.

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Nomenclature

D	Tube diameter
f	Friction factor
e	Wire diameter
H	Pitch
Dh	Hydraulic diameter of the duct
c	Non-dimensional twisted tape centre clearance = C/D
C	Twisted tape centre clearance
Nu	Nusselt Number
Reax	Reynolds number based on axial velocity
Ra	Rayleigh number
Gz	Graetz number = m cp/kL
P	Wetted perimeter
Sw	Swirl parameter
Pr	Prandtl Number
Re	Reynolds Number
S	Spacer length
y	Twist ratio of twisted tape (H/D)
Y	Twist ratio of twisted tape (H/D)
h	Heat transfer coefficient
Bo	Boiling Number (q/g λ)
q	Heat Flux
g	Acceleration due to gravity

Greek symbols

μ	Dynamic viscosity
μ_b	Dynamic viscosity at bulk fluid temperature
μ_w	Dynamic viscosity at duct wall temperature
η	Thermal performance factor
θ	Corrugation angle
λ	Latent heat
ϕ	Volume concentration of nanoparticles (%)

Heat exchangers are commonly used in almost all areas of industrial activities. The concept of heat transfer enhancement is quite important and useful in power, process, refrigeration, air conditioning, automotive industries etc. In addition to this, heat transfer enhancement techniques are also becoming an important matter of interest in electronics cooling, solar heat collectors, micro chemical processing compact heat exchanger design etc. [2]. As the time progress, the matter of heat transfer enhancement has become more vital in all industrial applications. Generally, heat transfer enhancement techniques may be classified into three main classes i.e., active, passive and compound methods (Fig. 1). In active method, external power is used for heat transfer enhancement. It seems an easy method in several applications however it is quite complex from design point of view. That is why it is of limited use due to external power requirements. Apart from active methods, there is no involvement of external power supply in passive methods of heat transfer enhancement. Passive methods utilise energy within the system which leads to increase fluid pressure drop [3]. The use of special surface geometry gives high thermal performance as compared to plain surface. Twisted tapes, wire coils, dimples, ribs, fins, micro fins etc. are different passive devices which are used to enhance heat transfer rate. Also, tube with longitudinal inserts is also an effective passive method of heat transfer enhancement [4]. Passive techniques are associated with the use of modifications in surfaces and geometries in a flow channel with the help of inserts. Earlier, it was very difficult to work with complex geometries due to their fabrication constraints but with the advancement in manufacturing technology it is now quite possible to apply new geometries in heat transfer enhancement techniques. Compound heat transfer method is a hybrid technique which involves the use of both active and passive methods. The method is quite complex and have limited applications. Bergles [5] has presented a review on different types of developed convective heat transfer enhancement techniques. Different types of effective heat transfer techniques for various heat transfer modes were summarised. Also compound heat transfer enhancement techniques were discussed which involves simultaneous use of several techniques to enhance heat transfer rate and considered them as fourth generation heat transfer technology.

The use of twisted tape inserts is one of the important passive methods of heat transfer enhancement. Twisted tapes are generally the metallic strips which are twisted in some specific shape and dimensions and inserted across the flow. They are also considered as swirl flow devices and act as turbulators used to impart swirl flow which leads to the increase in heat transfer coefficient. Pitch and twist ratio are the important parameters used to study the performance of twisted tapes. Pitch of a twisted tape is the length between two points on a plane, parallel to the axis of the tape whereas twist ratio of a twisted tape is the ratio of pitch to inside diameter of the tube. Several experimental and numerical studies have been carried out by various scientists and researchers on heat transfer augmentation using twisted tapes. Some reviews have been also reported on twisted tapes however it is still need to summarise all previous works and latest techniques and modification in geometries required to increase the performance of twisted tapes. In the present paper an attempt has been carried out to review various analytical, experimental and numerical studies done on twisted tapes. Almost all previous works carried out on different types of twisted tape geometries for heat transfer enhancement in all applications; are included in this paper. Also studies carried out using twisted tapes with nanofluids are included in the review.

2. Heat transfer enhancement using twisted tapes

Heat transfer augmentation is always an important matter of concern since the enhancement of heat transfer rate leads to increase the performance of system which is quite important in various heat transfer applications. Twisted tapes are well known heat transfer enhancement devices and several correlations of heat transfer and pressure drop have been developed for different types of twisted tapes. The enhancement of heat transfer is obtained by developing swirl flow of the tube side fluid, which gives high velocities near boundary and fluid mixing and consequently high heat transfer coefficient. In heat transfer systems equipped with twisted tapes, the heat transfer and pressure drop

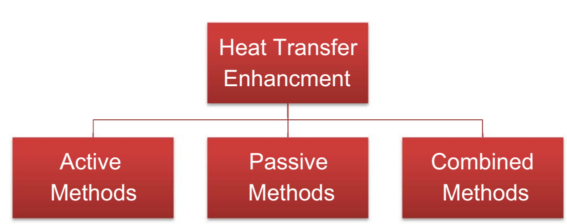

Fig. 1. Methods of heat transfer enhancement.