Renewable and Sustainable Energy Reviews 53 (2016) 433–449

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A comparative review of self-rotating and stationary twisted tape inserts in heat exchanger

Cancan Zhang [a], Dingbiao Wang [a,*], Kun Ren [b], Yong Han [a], Youjian Zhu [a], Xu Peng [a], Jing Deng [a], Xiying Zhang [a]

[a] School of Chemical and Energy Engineering, Zheng Zhou University, Zheng Zhou 450001, China
[b] North China University of Water Resources and Electric Power, Zheng Zhou 450001, China

ARTICLE INFO

Article history:
Received 10 April 2015
Received in revised form
15 May 2015
Accepted 21 August 2015

Keywords:
Heat transfer
Friction factor
Twisted tape
Self-rotating
Stationary

ABSTRACT

Heat transfer enhancement techniques are popularly used in various engineering applications such as heat exchanger, air conditioning, chemical reactors and refrigeration systems. Twisted tape is one of the most important passive techniques, which has been proved to disturb the flow fluid in tube and then strengthen the heat transfer efficiency. This paper conducted comprehensive and comparative review on experimental and numerical works taken by researchers on self-rotating and stationary twisted tapes. It is found that the heat transfer enhancement and the function of online anti-scaling and descaling in tube can be obtained with the self-rotating twisted tapes. Meanwhile, the tube with self-rotating twisted tapes gives the lower pressure drop. Both heat transfer coefficient and friction factor increase with the decreasing of twisted ratio. The twisted tapes combined with different modified techniques are the new development directions of heat transfer enhancement. The appropriate twisted tape modification is necessary for heat transfer enhancement with pressure loss penalty at a reasonable level.

Contents

* Corresponding author.
E-mail addresses: zhangwu8887@126.com (C. Zhang), wangdb@zzu.edu.cn (D. Wang), renkun_keyan@126.com (K. Ren), erichanyong@163.com (Y. Han), yuzhu01@hotmail.com (Y. Zhu), lanyuanxiansheng@126.com (X. Peng), dengjingy@163.com (J. Deng), xyzhang2009@163.com (X. Zhang).

http://dx.doi.org/10.1016/j.rser.2015.08.048
1364-0321/

Nomenclature

a^*	clearance ratio of the twisted tape, dimensionless
B	thickness of twisted tape, m
C	distance between inner wall of the tube and twisted tape insert, m
d_e	characteristic length, m
d_s	diameter of semicircle groove, m
D	the inner diameter of the tube, m
D_P	diameter of perforated, m
D_R	diameter ratio, dimensionless
D_S	serration depth, m
D_V	depth of V cut, m
D_W	depth of wing cut, m
e	the rib height, m
f	friction factor, dimensionless
h	the convective heat transfer coefficient, W m^{-2} K^{-1}
H	the half-length of twisted pitch, m
L	length of the tube, m
L_A	alternate length, m
L_C	pitch length of circular-ring tabulators, m
n	rotate speed, m s^{-1}
N	the number of regular spaced twisted tape, dimensionless
Nu	Nusselt number, dimensionless
ΔP	pressure drop, Pa
PR	pitch ratio of dimple
Re	Reynolds number, dimensionless
R_B	winglet blockage ratio, dimensionless
R_C	pitch ratio of converging section and diverging section, dimensionless
R_P	perforation pitch ratio, dimensionless
R_S	free space ratio, dimensionless
S_P	spaced-pitch length of perforated, m
S_S	the distance between two semicircle groove, m
T	temperature, K
W_P	width of peripheral cut, m
W_S	serration width, m
W_V	width of V cut, m

Greek symbols

β	angle of attack, degree
λ	thermal conductivity, W m^{-1} K^{-1}
δ	twisted tape pitch ratio, dimensionless
μ	dynamic viscosity, kg m^{-1} s^{-1}
ρ	density, kg m^3
η	thermal performance factor, dimensionless

Subscripts

w	tube wall
T	tube inserted with twisted tape
0	plain tube

1. Introduction

The consumption of oil, gas and coal in the final energy causes the global warming and pollutant emission. More efficient engines with less waste heat are being developed. As a general device, the heat exchanger plays an important role in the recovery process, air conditioning, refrigeration systems, and thermal power plants [1–5], etc. The performance of the heat exchanger influences system efficiency as well as its cost. Therefore it is important to enhance the heat transfer performance to achieve sustainable energy development.

In general, heat transfer augmentation methods can be classified into three broad categories: active, passive and compound methods [6]. The active method involves some external power input for the enhancement of heat transfer. On the contrary, the passive method can enhance the heat transfer by using modified surfaces or geometries such as rough surfaces, extended surfaces, tube inserts, etc. As the name implies, the compound method combines the passive method with the active method. To achieve an optimal heat transfer rate at an economic pumping power, the passive method is popularly used. As one of the passive method techniques, tube inserts technology has been widely used in the heat exchanger such as twisted tape, helical spring [7], ribs [8], conical nozzle, and conical ring [9–11], etc. The tube inserts can be divided into two broad categories: stationary and self-rotating. The stationary inserts have the relatively fixed position in plain tube. The self-rotating inserts are defined as such inserts which can automatically rotate while the fluid flows through the tube. The self-rotating inserts can strengthen the heat transfer efficiency and achieve the on-line anti-scaling and descaling effect.

As one of the major tube inserts, twisted tape can improve heat transfer rate, which has been widely studied by many scholars and popularly used for heat exchangers. Although literatures [12,13] comprehensively review the thermal performance twisted tape in heat exchangers, the thermal and anti-fouling performance of self-rotating twisted tape will be focused in the present paper. The findings provide useful references for future development of twisted tape. The present review is organized as follows: main categories of twisted tape, the main heat transfer enhancing mechanism and performance evaluation parameters are introduced in Sections 2–4, respectively. Sections 5 and 6 present the developments of self-rotating and stationary twisted tapes, respectively. The discussion and conclusion are drawn according to the previous reviews and analysis in Sections 7 and 8, respectively.

2. Main categories of twisted tapes

Large numbers of experimental and numerical work have been carried out by researchers and engineers to study the thermo-hydraulic performance of various twisted tapes from the 1960s onwards. Twisted tape can be manufactured in a variety of forms by suitable techniques using the aluminum, copper, steel or polymer plastic. It can be applied in various areas in certain conditions. Firstly, it is indispensable to define some important parameters used in this report to facilitate understanding and discussing the characteristics of twisted tape. Fig. 1 shows the sketch map of typical twisted tape. The basic parameter for twisted tape is twist ratio. The twist ratio is defined as follows: