Case Studies in Thermal Engineering 9 (2017) 79–89

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

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

Enhancement of heat transfer in six-start spirally corrugated tubes

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ARTICLE INFO

Keywords:
Enhancement of heat transfer
Spirally corrugated tube
Six–starts
Friction factor

ABSTRACT

The utilization of corrugation for improvement in heat transfer is increasingly becoming interesting recently due to its combined advantages such as extended surfaces, turbulators as well as roughness. This study employed the use of both numerical as well as experimental settings on the water flowing at lower Reynolds numbers in a corrugated tubes with spiral shape to evaluate the performance of heat in a newly designed corrugation style profile. The total performance of the heat for the corrugation tubes were determined and the mathematical information generated from both the Nusselt number and the factors of friction were equated with those of the experimentally generated outcome for both standard smooth as well as the corrugated tubes. Analysis of the dat generated revealed improvements in heat transfer ranges of (2.4–3.7) times those 0btained from the smooth tubes with significant increase in the friction factors of (1.7–2.3) times those of the smooth tubes. Based on the findings of study, it was concluded that for extended period and extensive range use, tubes with severity index values at 36.364×10^{-3} could produce better heat performance (1.8–3.4) at Reynolds numbers ranging from 100 to 1300. This was an indication that the geometric expression with spiral corrugation profile could significantly enhance the efficiency of heat transfer with significantly increased friction factors.

1. Introduction

Optimal heat transfer could be obtained by fundamental techniques. These include the passive, active and the compound techniques [1]. While modifications on surfaces, insert or additive are required in the passive technique: an external source is essential in the active technique. The compound technique, as indicated by the name, involve the mixture of either the previous main techniques (passive and active) or it's neither active nor passive but somewhat amid the two techniques, as can be seen in vibrated flow (active) using corrugated tubes (passive) or in electrostatic fields (which is active) using nano-fluids (which is passive) [2]. However, owing to the overwhelming degree in the loss of energy in addition to the quest for small sizes and more economical enhanced thermal transfer device, these 3 techniques have been employed in thermal exchangers and other applications that are relatively related [3]. The main reason for employing heat transfer enhanced techniques is for cutting costs as well as for practical purposes. The major roles of corrugations is for enhancing the secondary re-circulation flows, via induction of the component the radial velocities as well as the mixing of the flow layer. These techniques have been widely utilized in recent heat exchangers [4]. The outcome generated from the surface area modifications or the manipulations of heat transfers, which has been demonstrated to induce swirls or spirally flowing patterns has attracted increasing interests [5]. Additionally, corrugation enhances heat transfer owing to the existence of mixing fluids generated through separations and re-attachments [6]. In an experimental study conducted recently on water and SiO_2 flow in a single plain tube having 5 tubes corrugated at varying height and pitch in corrugation tubes [7] to determine the effect of nano-fluids and corrugations on the rate of heat transfers and pressure drops. The authors of the said experiment reported by increasing the corrugation heights with a corresponding reduction in corrugation pitch could lead to enhancement in heat transfers and consequently causing intensified effects on the nano-particles of the heat transfers. In spirally

http://dx.doi.org/10.1016/j.csite.2017.01.001
Received 25 December 2016; Accepted 3 January 2017
Available online 03 January 2017

Nomenclature

C_p	Heat Capacity at Constant Pressure
D	Tube inside Diameter
E	Error
e	Roughness Height
f	Friction Factor
F_s	Safety Factor
GCI	Grid Independence Index
Gz	Graetz Number
h	Heat Transfer Coefficient
k	Thermal Conductivity
L	Tube Length
m	Slope
Nu	Nusselt Number
P	Pressure
p	Pitch of Corrugation
Pr	Prandtl Number
q''	Heat Flux Per Unit Area
r	Refinement Ratio
Re	Reynolds Number
T	Temperature
u	Fluid Velocity
x	Axial Direction

Greek symbols

μ	Dynamic Viscosity
ν	Kinematic Viscosity of The Fluid
ρ	Density of Fluid
φ	Severity Index, $\varphi=e^2/(pD_n)$
η	Thermal Efficiency

Subscripts

*	Dimensionless
b	Bore
B	Bulk
c	Corrugated
en	Envelope
in	Inlet
n	Nominal
s	Smooth
x	Local

corrugated tube, the flowing of water were also investigated experimentally for the purpose of evaluating characteristic effect of corrugation on lowering pressure and heat transfers at Reynolds number ranging from 17×10^3 to 58×10^3 with the tubes having p (corrugation pitch) of 10 mm and e (corrugation height) of 0.8 mm. The authors of the said study reported that the friction factors ranged from 4 to 5 times greater compared to those from smooth tubes, and the total heat performance of the corrugation tubes was 1.27 greater compared to those from plain tubes [8]. Laminar flowing oils on circular ducts of axial corrugations which are fixed with center-cleared tape that was twisted at Reynolds numbers ranging from 2×10^2 to 8×10^3 has been experimentally investigated [9] determine the friction factors and Nusselt numbers in tubes with p/e=2.0437–5.6481. The findings of these authors revealed that the center-cleared tape that was twisted and axial corrugations produced superior performance compared to those individually used through specific values of center-clearance. Additionally, the increase in the range of heat transfers were in the range of 15–30% consistent pumping power, with a decline ranging from 15% to 25% pumping power for consistent thermal duty. Fluids flowing at Reynolds number ranging from 10^6 to 10^8 in corrugation tubes having p/D=0.886–1.158 and e/D=0.0572–0.0267 has been also investigated [10]. The authors of the said study documented that corrugation heights have significant effects on enhancement of heat transfers, and increasing the corrugation heights consequently lead to reduction in Nusselt number when the Reynolds number is below the vital limits. However, increasing the corrugation heights could be beneficial in improving heat transfers if the Reynolds number is above the vital limits. Flowing of water through corrugation tube of 0.103≤e/D≤0.148 and 0.462≤p/D≤0.270 at Reynolds numbers ranging from 10^3 to 10^5 was studied in a previous experiment [11] for the determination of friction factor. In the said

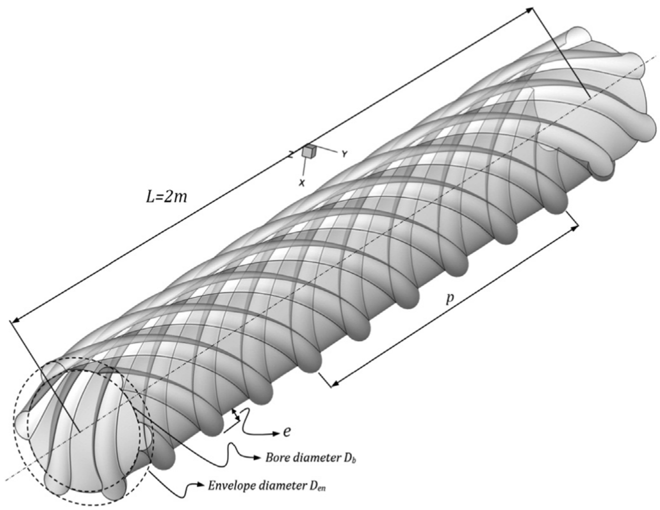

Fig. 1. Six–starts spirally corrugated tube.