Convective Heat Transfers Inside Tubes

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Abstract **-** Among the swirl flow devices, Twisted Tape inserts increases the heat transfer coefficients with relatively small increase in the pressure drop. A CFD investigation on enhancement of turbulent flow heat transfer with twisted tape inserts in a horizontal tube under forced convection with air flowing inside is carried out using ANSYS FLUENT. Influences of the tube with short-length twisted tape inserts at several tape-length ratios (LR=0.29, 0.43, 0.57 and 1.0 (full-length tape) on the heat transfer (Nu), friction factor (f) and thermal enhancement factor characteristics have been investigated through CFD approach. The effect of Reynolds number and tape-length ratios on the heat transfer coefficient and friction factor have been studied for (Re = 4000–20,000). It is found that the tube with shortlength twisted tape (LR=0.57) provides the better thermal enhancement factor (TEF=1.032) for the studied range of Reynolds number and hence can be employed for heat transfer augmentation.

KEY WORD-: CNC, depth of cut, surface roughness, MRR (Material Removal Rate), Taguchi method, ANOVA.

INTRODUCTION

HEAT EXCHANGER

A heat exchanger may be defined as equipment, which transfers the energy from a hot fluid to a cold fluid with maximum rate and minimum investment and running cost. Heat transfer augmentation techniques are needed in heat exchanger systems to enhance heat transfer rate and improve their thermal performance.

Heat Transfer Augmentation

The importance of increasing the thermal performance of heat exchangers has caused development and use of many techniques termed as heat transfer enhancement. These methods augment convective heat transfer by reducing the thermal resistance in a heat exchanger. Utilize of augmentation techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop. To reach high heat transfer rate while taking care of the augment pumping power, various techniques have been presented in recent decade. Recently, swirl flow devices have widely been used for increasing the convective heat transfer in various industries.

Increases in heat transfer due to surface treatment can be brought about by increased turbulence, increased surface area, improved mixing, or flow swirl. These effects generally result in an increase in pressure drop along with the increase in heat transfer. The associated increase in pumping work is almost always greater than the increase in heat transfer relative to a smooth (untreated) heat transfer surface of the same nominal (base) heat transfer area, but heat transfer enhancement is gaining industrial importance because it gives one the opportunity to: 1. Reduce the heat transfer surface area required for a given application and thus reduce the heat exchanger size and cost. 2. Increase the heat duty of the exchanger. 3. Permit closer approach temperatures. All of these can be visualized from the expression for heat duty for a heat exchanger, Eq. $Q = UA\ (LMTD)$ Any enhancement technique that increases the heat transfer coefficient also increases the overall heat transfer coefficient U. Therefore, one can either reduce the heat transfer area A, increase the heat duty Q, or decrease the temperature difference LMTD for fixed Q and LMTD, fixed A and LMTD, or fixed Q and A, respectively. Enhancement can also be used to prevent overheating of heat transfer surfaces in systems with a fixed heat generation rate. In any practical application, a complete analysis is required to determine the economic benefit of enhancement. Such an analysis must include a possible increased first-cost because of the enhancement, increased heat exchanger heat transfer performance, the effect on operating costs (especially a potential increase in pumping power because of roughness, turbulence promoters, and swirl devices) and maintenance costs. A major practical concern in industrial applications is the increased fouling of the heat exchange surface caused by the enhancement.

Computational Fluid Dynamics

Computational fluid dynamics (CFD), which has been around for many years, is a powerful numerical technique for solving industrial fluid flow problems. CFD calculation involves the use of a computational grid where the governing equations describing fluid flow—the continuity equation and the set of the Navier – Stokes equations, and any additional conservation equations such as energy balance are solved across each grid cell by means of an iterative procedure in order to predict the profiles of velocity, temperature, shear, pressure, and other parameters. The early applications of CFD can be found in the automotive, aerospace and nuclear industries.

INTRODUCTION TO ANSYS FLUENT

FLUENT is a computational fluid dynamics (CFD) software package to simulate fluid flow and heat transfer in complex geometries. It uses the finite-volume method to solve the governing equations for mass, impulse and energy transfer. It provides the capability to use different physical models such as incompressible or compressible, viscous or non-viscous, laminar or turbulent, etc. Geometry and grid generation is done using GAMBIT which is the pre-processor bundled with FLUENT.

Literature review

An experimental investigation for a solar water heater with twisted tape inserts having twist pitch to tube was studied by Kumar and Prasad. They found that twisted-tapes generate turbulence superimposed with swirlness inside the flow tube and consequently result in enhanced heat transfer. Decreasing the values of twist ratio leads to increasing values of heat transfer rate and the pressure drop.

Influence of helical tapes inserted in a tube on heat transfer enhancement was studied experimentally by Eiamsa-ard and Promvonge (Fig. 2.1). They showed that the maximum mean Nusselt number may be increased by 160% for the full-length helical tape with centered-rod, 150% for the full-length helical tape without rod and 145% for the regularlyspaced helical tape, s ¼ 0.5, in comparison with the plain tube

RESULTS AND DISCUSSIONS

Heat transfer augmentation with twisted tape is given extreme importance due to its applicability in various industrial applications. Most of the studies have addressed to the fluid flow and heat transfer characteristics in tubes with twisted tape inserts on the basis of experimental investigations, but the numerical simulations are scarce. The present computational work is made on heat transfer enhancement for air inside the horizontal tube in the presence of twisted tape inserts. Numerical study is done using CFD approach. The aim of the current study is to report details of the turbulence modelling to help in understanding of the behaviours of the swirl flows for tube fitted with the twisted tapes in comparison with those for a plain tube. The effects of tape length ratio and Reynolds number on heat transfer and flow friction characteristics in a cylindrical tube having twisted tape inserts are presented below. The results have been compared with those obtained in case of smooth tube operating under similar operating conditions to discuss the enhancement in heat transfer and friction factor on account of twisted tape inserts.

Influences of the tube with short-length twisted tape inserts at several tape-length ratios (LR=0.29, 0.43, 0.57 and 1.0 (full-length tape)) on the heat transfer (Nu), friction factor (f) and thermal enhancement factor characteristics have been investigated through CFD approach. The effect of Reynolds number and tape-length ratios on the heat transfer coefficient and friction factor have been studied. Computational investigation has been carried out in medium Reynolds number flow (Re = 4000–20,000). The following conclusions are drawn from present analysis: Insertion of twisted tape in a tube provides a simple passive technique for enhancing the convective heat transfer by producing swirl into the bulk flow and by disrupting the boundary layer at the tube surface. However, the increase in friction is seemed to be the penalty of the technique. Thus, tube with twisted tape insert is frequently used in heat exchanger systems because of it low cost, less maintenance and compact.

REFRENCES

[1] Eiamsa-ard S, ThianpongCh, Eiamsa-ardPetpices, PromvongePongjet. Convective heat transfer in a circular tube with short-length twisted tape insert. IntCommun Heat Mass Transf 2009; 36:365–71.

[2] Bergles AE. Techniques to augment heat transfer. In: Rosenhow WM, editor. Handbook of heat transfer applications. New York: McGraw-Hill; 1985 [Chapter 3].

[3] Bergles AE, Webb RL. Guide to the literature on convection heat transfer augmentation. Adv Enhanced Heat Transfer 1985; 43:81–9.

[4] Manglik RM, Bergles AE. Heat transfer and pressure drop correlations for twisted tape inserts in isothermal tubes: Part II—Transition and turbulent flows. Trans ASME J Heat Transfer 1992; 202: 99–106.

[5] Manglik, RM, Bergles AE. Heat transfer and pressure drop correlations for twisted tape insert in isothermal tubes. Part 1: laminar flows. Trans. ASME, J. Heat Transfer 1993; 116: 881–889.

[6] Kumar A, Prasad BN. Investigation of twisted tape inserted solar water heaters-heat transfer, friction factor and thermal performance results. Renew Energy 2000; 19:379–98.

[7] Eiamsa-ard S, Promvonge P. Enhancement of heat transfer in a tube with regularly spaced helical tape swirl generators. Sol Energy 2005; 78:483–94.

[8] Raj Kumar Yadav. Using CFD Tools Heat Exchanger Design: A Review. Recent Trends in Fluid Mechanics. 2017; 4(3): 26–28p.

[9] Raj Kumar Yadav. Parametric Optimization of Waste Plastic Fuel Parameters. Journal of Thermal Engineering and Applications. 2017; 4(3): 26–30p.