Presentation of Novel Tube to Enhance Crude Oil Fouling in Heat Exchangers

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ABSTRACT

The objective of the research is to represent a novel arrangement of plain tube for heat transfer coefficient enhancement.

Experiments handled in stainless steel_316 tube without roughness and hot crude oil is circulated in constant heat flux condition in the related set up. Pressure drop is measured in this set up and compared with pressure drop in a smooth tube with the same operating conditions.

Heat transfer coefficient is one of essential parameter for design of heat transfer equipments and in this experimental work this is investigated for an Iranian crude oil in the plain tube. Heat transfer coefficient in plain tube is higher than other commercial enhanced tubes. Plain tube improves the performance of heat transfer equipments and also optimizes the size of the mentioned devices. Consequently this type is advantageous in Energy and cost saving.

Keywords: Energy and cost saving; Plain tube; Heat transfer; Set up.

Introduction

Heat transfer equipments are devices that are commonly used to transfer heat between two or more fluids with different temperatures. They are used in a wide variety of applications such as refrigeration and air-conditioning systems, power engineering and other thermal processing plants. Besides the performance of the heat exchanger being improved, the techniques of heat transfer enhancement optimize the size of these equipments.

There are a number of techniques to augment or enhance heat transfer. These techniques may be conveniently divided into three classes: passive, active and compound techniques. Table-1 shows a brief summery of these methods. Passive techniques require no direct application of external power, whereas active techniques need an external activator/power supply to bring about the enhancement. Compound techniques involve a combination of techniques, namely two or more of the active or passive techniques may be utilized simultaneously to produce an enhancement that is bigger than the techniques operating separately [1].

Enhanced Tubes

The subject of enhanced heat transfer tubes has grown to the stage so that it is of serious interest for a whole range of industries [2]. The air-conditioning and refrigeration as well as automotive industry routinely use enhanced heat transfer tubes in their heat exchangers. The substantial development of low-finned and double enhanced tubes over the years is shown in Fig. 1. Several enhanced tubes have been tested by using hydrocarbons, including low-fin tubes and re-entrant cavities structured tubes [3].

A Novel arrangement of plain enhanced tube

Helical tubes and three dimensional roughness tubes are 2 famous types of enhanced tubes to augment heat transfer in heat exchangers. Although studies show the benefits of 3D roughness tubes such as increasing flow turbulence and heat transfer coefficient, there is not a unique equation to define the heat transfer parameters for all of types of these tubes. Considering this, authors investigate about the new proposed plain tube to find heat transfer factors.

Despite pressure drop increasing enhances heat transfer coefficient, this may creates some operational problems in industries. Inner arrangement of such tubes should be designed to augment heat transfer coefficient without any malfunctions. The plain arrangement prepares high heat transfer coefficient for smooth pipes and also experimental results show the fraction of obtained pressure drop of this tube over the pressure drop of current smooth pipe is 1.41. This fraction is relatively low comparison with reported values for the other rough tubes. A pattern of very small conical holes in plain used in this experiment is shown in Fig-2.

Turbulence is increased by two different size of conical roughness. Moreover between each four large cones there are two smaller cones which divide this gap into three equal steps. Information about some properties is Presented in Table-2.

Used set up in this work

A sample of crude oil circulates in a stainless steel_316 plain tube and is heated by constant heat flux which emerges to the main test section. The main plain tube section is a small 3D enhanced tube with truncated cone roughness and is insulated externally. Total Pressure drop is measured with a U-tube manometer and the inlet pressure is measured by a pressure gauge. The tube characteristics are listed in Table 3. The oil is re- circulated by a centrifugal pump and flow rate is controlled by a flow meter. The inlet

pressure of the oil is 5.5 KPa. Avoiding Erosion corrosion and crevice corrosion, because of turbulence, the used plain tube and oil tank are made of stainless steel-316. To hence heat transfer, a new arrangement of truncated cone roughness is examined in this test in turbulent regime of crude oil. This type is introduced in Table.2 and is shown in fig.2 schematically. A sample of Iranian crude oil is used in this apparatus and some of its specifications at 142°C are in Table 4. It is declared that viscosity is the most important property which may be changed by temperature.

Although many correlations for friction factor in smooth tubes have been presented, the friction factor correlations for three dimensional roughness tubes are scarce.

$$f = 0.1432\,\mathrm{Re}^{(-0.1147)} \qquad \text{Eq-1}$$

This friction factor is used in shear stress parameter.

$$\tau = f\,\frac{\rho u^2}{2} \qquad \text{Eq-2}$$

Results and Discussion

Measurements are occurred every five days. Using experimental data of overall heat transfer coefficient, it is possible to calculate heat transfer coefficient. Roughness existence in tube caused flow to be turbulent. In addition also the experiment was handled by high flow rate and then in high Reynolds number, friction factor is an important parameter to augment heat transfer and also in heat transfer coefficient calculation Physical properties of fluid and its operational condition affect heat transfer coefficient. There is a power correlation to show this relation. Table 5 compares some of items like cost and heat flux between the proposed plain and the current types; cost analysis is in late 2010.

Conclusion

The study points out that the novel arrangement of plain tube to enhance heat transfer coefficient and augments rate of heat

Transfer in laboratory scale rough tube contains an Iranian crude oil. To aim this purpose an experimental apparatus is built. This set up contains a novel arrangement of conical 3D plain tube which is equipped with pressure, flow and temperature gauge instruments, centrifugal pump, storage tank. The novel tube is emerged by constant heat flux and the fluid flow regime is turbulent and the pipe segment is insulated. Experimental results show the fraction of obtained pressure drop of this tube over the pressure drop of current smooth pipes is 1.41. Although studies show the benefits of plain tubes such as increasing flow turbulence and heat transfer coefficient, there is not a unique equation to define the heat transfer parameters for all types of these tubes.

References

1. Karsli,S.,Yilmaz,M.,Comaki,O., *The effect of internal surface modification on flow instabilities in forced convection boiling in a Horizontal tube*: submitted to International Journal of Heat and Fluid Flow, (2002),776-791.
2. Ngo, T.L., Kato, Y., Nikitin, K., Tsuzuki,K N,. *New printed circuit heat exchanger with S-shaped .ns for hot water supplier*: submitted to Experimental Thermal and Fluid Science , (2006) 811–819.
3.Jamialahmadi,M., Müller-Steinhagen, H., *Heat Exchanger Fouling and Cleaning in the Dihydrate Process for the Production of Phosphoric Acid* : submitted to Chemical. Engineering Research and Design (2007) 245-255.
4. Kho, T., Müller-Steenhagen H., *An Experimental and Numerical Investigation of Heat Transfer and Fluid Flow in Flat Plate Heat Exchangers.* Submitted to Chemical. Engineering Research and Design (1999) 124-130.
5.Perry,J. H.,1963. *Chemical Engineers Handbook*, Section 10-7, Forth Edition, McGraw Hill Publication.

Fig.1.Samples of enhanced tubes. [1]

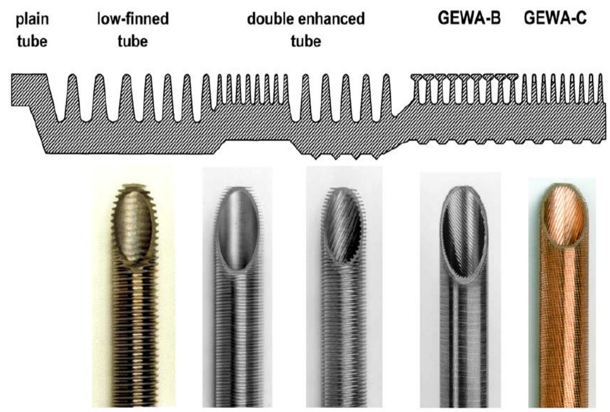

Fig.2. The proposed arrangement of truncated cone enhanced tube

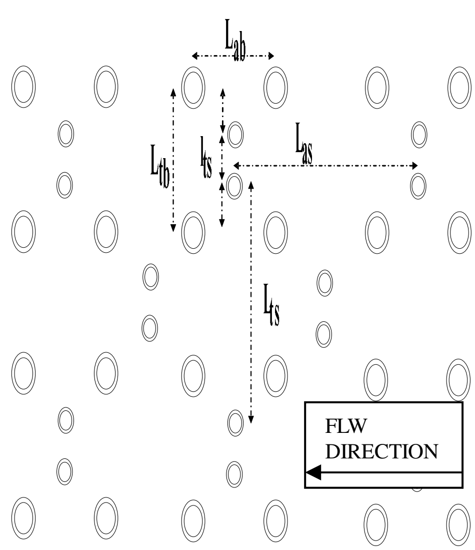

Table 1. Introduction of some heat transfer enhancement techniques, related to (Bergles and Webb, 1985; Reay, 1991; Ohadi et al., 1996) reference.

Passive techniques	**Active techniques**
Treated surfaces	Mechanical aids
Rough surfaces	Surface vibration
Extended surfaces	Fluid vibration
Displaced enhancement devices	Electrostatic/electro-hydrodynamic
Swirl flow devices	Suction /injection
Surface tension devices	Jet impingement
Additives	
	Induced flow
	Rotation

Table. 2. Specifications of new plain arrangement, and the other current ones.

Tube	Di (mm)	ε / d_i	L_{ab} / ε_b	L_{tb} / ε_b	L_{as} / ε_s	L_{ts} / ε_s	l_{ts} / ε_s
FS3D	50	0.028	7.16	7.16	28.65	23.89	4.77
TC3[2]	17.32	0.024	3.95	7.21	------	------	------
TC2[2]	17.32	0.022	8.16	8.16	------	------	------
TC1[2]	17. 60	0.029	6.08	6.08	------	------	------

Table .3. Used small roughness in plain tube information.

Type	**Length (m)**	**Diameter (m)**	**Thickness (m)**
3D-truncated cone tube	2	0.05	0.002

Type	Viscosity (kg/ms)	Heat Capacity (J/kgK)	Conductivity (w/mK)	Density $(kg/m^3$
Crud Oil	0.00987	2717.204	0.13836	868

Table. 4.Some of oil Specifications. @ 142°C.

Table .5. Summary of economic benefits of the Proposed plain tube and Current smooth tubes.

Item	Current smooth th tube	Proposed plain tube
Fabrication cost, $\frac{\$}{m}$	15	17
Fouling rate	nill	0.88
Ratio of total heat transfer coefficient, $\left(\frac{U}{U_p}\right)$	1	1.90
Ratio of heat flux, $\frac{Q''}{Q''_p}$	1	2.78
Cost per unit of energy production,$	1	0.3484
Cost Saving,$	0	0.6516