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Research Paper

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Assessment of Passive Augmentation Technique in Circular Tube side CMC/Water Process Fluid using Twisted Tape

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Abstract— Heat exchangers are used in processes to recover the heat between two process fluids in industries like chemical, petrochemical, food, beverages, thermal, etc. Influence of Heat transfer augmentation technique (passive) on heat transfer; pressure drop and thermal performance characteristics under laminar flow condition is reported. In the present paper; Carboxymethyl Cellulose (CMC) having a concentration of 0.02 % with tap water as a process fluid has been studied. The experimental values for parameters as friction factor, Reynolds number along with mass flow rate ranges between 0.02 kg/sec to 0.033 kg/sec tube side fluid. The study of heat transfer augmentation technique; passive technique using twisted tape having twist ratio Y = 4.3. This passive technique affects the heat transfer coefficient, pressure drop, friction factor, and Reynolds number. From experimental work, it was observed that for twisted tape; a higher heat transfer coefficient and higher pressure drop and hence higher friction factor has been obtained when compared with a smooth tube.

Keywords— Carboxymethyl Cellulose, Coefficient of Heat Transfer, Friction factor, Passive augmentation, Twist tape

I. INTRODUCTION

Bhuiya et. al. [1] have done experimentation on heat transfer and friction factor characteristics of flow through a circular tube in the turbulent region with different porosities twisted tape. Yasser Aldali et. al. [2] studied heat transfer and pressure drop for laminar flow in an inner circular tube with considering twist ratio and tape thickness of twist tape insert. S. Lui. et. al. [3] has done a comprehensive review regarding the heat transfer enhancement technique in the pipe heat exchanger by forming passive augmentation. A Comparative experiment works on twisted tape with different configuration and geometry that have been discussed. In addition, they discussed the impact of wire coil, wings, swirl flow, fins and conical ring on heat transfer thermal performance factor. S. Eiamsa et. al. [4] investigated the thermal performance of tube heat exchanger equipped with coupling twisted tape (co-coupling and counter coupling) configuration and the effect of coupling width ratio and twist ratio on the thermal performance of exchanger. Bodius Salam et. al. [5] carried experimentation on tube side water fluid in turbulent flow using a circular tube fitted with rectangular cut twisted tape insert. Heat transfer coefficient, enhancement efficiency, and friction factor have been investigated. Sompol Skullong et. al. [6] studied experimentally on coupled co-twisted tape with V-shaped ribs into the edges having the same twist ratio (TR = 4). The work is done in a round tube by V-ribs twist tape insertion a vertex generator in turbulent flow and fluid as air examined. Tegun Hady Ariwibawo [7] studied the performance of the hairpin heat exchanger with twisted tape to effectiveness on heat transfer coefficient and heat load. P. V. Durga Prasad [8] investigated the U-tube heat exchanger having Al_2O_3/ water nano-fluid with the insertion of trapezoidal cut twisted tape experimentation. S. Eiamsa-ard et. al. [9] reported the influence of perforated helical twisted tape on heat transfer, thermal performance and friction characteristics under a uniform heat flux condition.

II. RELATED WORK

J. P. Meyer and S. M. Abolarin [10] studied the heat transfer and pressure drop with twisted tape insert and square edged inlet in the transitional flow regime for a circular tube. They have experimented with Reynolds number between ranges of 400 to 11400 along with different twist ratios. S. Bhattacharyya et. al. [11] presented numerical friction factor and Nusselt number data to heat transfer enhancement of laminar flow. A square channel fitted with angular cut wavy tape used as swirl flow.

III. METHODOLOGY

Why CMC?
CMC (Carboxy Methyl Cellulose) is also used as a thickening agent, for example, in the oil-drilling industry as an ingredient of drilling mud, where it acts as a viscosity

modifier and water retention agent. CMC have many applications as follows,

- Thickening agent
- Viscosity modifier
- Stabilizer

Also, used as a soil suspension polymer in detergents and lubricants in artificial tears.

Table 1: Applications of CMC in the major field of industry [13]

Industry	Paper	Cosmetics	Detergents	Textiles	Foods
Function	Water binder	Suspension aid, Thickener	Soil anti-redeposition aid	Thickener, Water binder	Inhibit ice crystal growth
Application	Internal additive	Toothpaste	Laundry	dye , Printing paste	Frozen desserts

The rheological properties of these solutions are measured and have reported seeing table 2. No specific experimental investigations related to the use of CMC-water solutions as an attempt to imitating the luminal fluid in debris flows kind of phenomena. In particular:

(i) Employed CMC concentration helps to attain accurate viscosity values.
(ii) CMC-water solution's rheological behaviour is slightly pseudo-plastic and thus approximate to the Newtonian association for low rates of deformation [12].

Analysis is done at TKCP, Warananagar, analytical instrumentation laboratory & CMC properties as follows,

Table 2: Basic properties of CMC solution 0.02%

Parameter	Minimum	Maximum	Average
Viscosity (Pa.s)	2.7440	332.8952	23.4013
Torque (m Nm)	23.7152	31.0583	29.7480
Speed (1/min)	0.2150	33.3260	16.8268
Shear Stress (Pa)	214.7174	281.2014	269.3386
Shear Rate (1/s)	0.6450	99.9780	50.4803
Kinematic Viscosity (cP)	0.0027	0.3329	0.0234
Density (g/cm3)	1.0000	1.0000	1.0000

Table 3: Double pipe heat exchanger design specifications

Specification	Inner Pipe, mm	Outer Pipe, mm
L	100	76
Do	15	25
Di	13	23
Material of construction	Cu	PVC

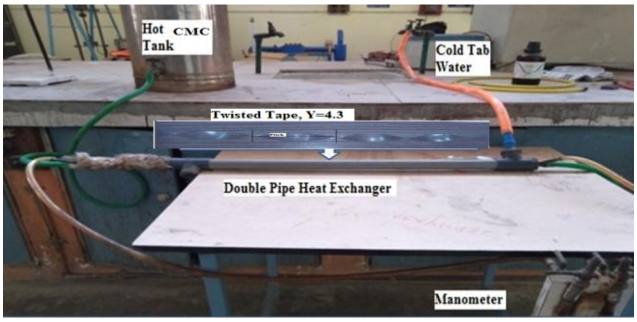

Figure 1. Laboratory scale DPHE with hot & cold fluid source with twisted tape

Figure 2. Sample of CMC solution with different concentrations

Table 4: Design specifications for twisted tape

Thickness	2 mm
Length	90 cm
Material of construction	Mild steel
Width	1.2 cm
Twist ratio (Y)	4.3

The twisted tape of twist ratio 4.3 was inserted in the inner pipe of the double pipe heat exchanger. The inner pipe of DPHE is connected to the container containing CMC at 60° C and the annulus of DPHE is directly connected to tap water. The annulus ha pressure tapping to which orifice is connected.

IV. RESULTS AND DISCUSSION

The above Figure 3 shows the variation of friction factor (F_{exp}) with Reynolds Number for Smooth tube, twisted tape (Y = 4.3). A higher degree of swirl is created as the twist ratio decreases; leads to higher pressure drop & friction factor. In the case of twisted tape (Y = 4.3) a much higher friction factor is observed because of an increase in the degree of turbulence created by the respective tapes.

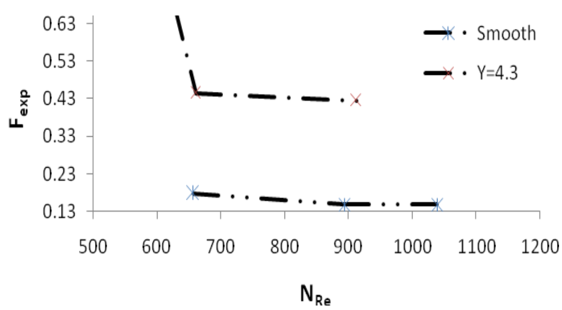

Figure 3. Reynolds number vs. Friction factor with concentration 0.02 %

From the above figure 4 it is shows that the variation of heat transfer coefficient (Ui) with Reynolds Number for Smooth tube, twisted tape (Y = 4.3) As the twist ratio (Y) decreases, a higher degree of swirl is created leads to increase turbulence and the heat transfer coefficient increases. In the case of twisted tape (Y = 4.3) a much higher heat transfer coefficient is observed because of an increase in the degree of secondary flow created which disturbs the entire thermal boundary layer & hence the heat transfer coefficient increases the twist ratio decreases.

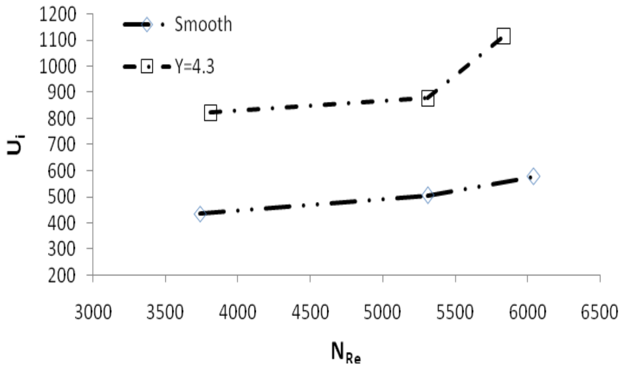

Figure 4. Reynolds number vs. Heat Transfer Coefficient with 0.02 %

V. CONCLUSION AND FUTURE SCOPE

As the application, CMC in many industries needs to recover the waste by applying the augmentation technique. The passive heat transfer augmentation technique has very beneficial using twisted tape with ratio Y = 4.3. The friction factor and heat transfer coefficient have enhanced in DPHE from tube side CMC solution to annulus side fluid.

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Nomenclature

Y	Twist ratio, dimensionless
U_i	Overall heat transfer coefficient, [W/m2 K]
f_{exp}	Friction factor, dimensionless
N_{Re}	Reynolds number, dimensionless
L	Length, [mm]
Do	Outer diameter, [mm]
Di	Inner diameter, [mm]

Author's Profile

Mr. P. B. Dehankar pursed Bachelor of Engineering from Pune University of Pune in 2009 and Master of Technology from Babasaheb Ambedkar Technological University Lonere Raigad in year 2011. He is currently pursuing Ph.D. and currently working as Assistant Professor in Department of Chemical Engineering, Tatyasaheb Kore Institute of Engineering & Technology, Warananagar, Shivaji University, Kolhapur since 2013. He has published more than 10 research papers in reputed international journals including Thomson Reuters (SCI & Web of Science) and conferences and it's also available online. His main research work focuses on augmentation in heat transfer, heat exchanger networking, advenced waste water techniques. He has 8 years of teaching experience and 1 year of Research Experience.

