Chapter

Assessment of Augmentation Techniques to Intensify Heat Transmission Power

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Abstract

The heat exchanger detects heat between two processes of liquids in the chemical, petrochemical, food, beverage, and hot metals, and so on. Although the required heat transfer calculations and pressure reductions are achieved with a two-pipeline temperature switch (DPHE), the optimization of the heat transfer parameter is used to measure laboratory test settings. This will allow you to build a DPHE model with twisted tapes and mimic the ASPEN PLUS and work it out by trying to scale the lab that has already been produced and standardized for DPHE. Parameter values for this study range from 0.02 kg / sec −0.033 kg / sec as suspension, pressure reduction, and Reynolds numbers. Also to study the mechanism of increased heat transfer by the use of twisted tape with Y1 = 4.3 and Y2 = 7.7 deviations. They are trying to compare the results of a mathematical model with simulation. This mode of inactivity has the effect of equilibrium heat transfer, pressure drop, the collision factor, and the number Reynolds. We tested the modeling and simulation effects and tried to measure the 4 input parameters of the two output parameters: cold flow rate, hot flow rate, cold and cold temperatures. DPHE, therefore, confirmed the flow rates of weight between 0.02–0.07 kg/s with experiments and simulations performed by Aspen Plus.

Keywords: modeling, simulation, DPHE, twist tape, ASPEN PLUS

1. Introduction

Heat exchangers have many applications in industry and engineering. The process of building a heat exchanger is somewhat difficult because, apart from problems such as long-term operation and the economic side of the equipment, careful study of the rate of heat transfer and pressure drop pressure is required. The biggest problem in building a heat exchanger is to make the equipment compact [1], with less pumping power reaching a higher transmission rate. In a variety of technological applications, **Figure 1**, heat transfer techniques are compatible. The high cost of energy and materials in recent years has led to a concerted effort to produce more efficient heat exchange equipment. In addition, for special applications such as space use, a reduction in temperature is sometimes required by increasing the heat transfer. While changes in fluid flow (viscosity breakage and thermal boundary layers) can increase the heat transfer rate, the pumping capacity in this process can increase significantly and ultimately the cost of pumping. Therefore, many

Figure 1.
The idea of a model.

techniques have been developed to obtain the required amount of heat transfer to an existing heat exchanger with low-cost pumping power. A process model is a set of statistics that allows us to predict the performance of a chemical process system.

Increasing heat transfer, which leads to energy and cost savings, is of paramount importance to academics. In the field of processes and engineering, there are many devices used to transfer heat to stations. With many additional strategies, conventional exchanges are developed with an emphasis on various types of site improvement [2, 3]. Extra fixtures can help to increase the heat transfer rate and the unwanted increase in conflicts with one or more of the following:

- Disruption and disruption of energy levels.
- The heat transfer area is increased.
- Generate rotating/rotating/secondary flow.

2. Objectives

1. Developing a DPHE model.
2. To conduct a DPHE test to validate the model.
3. The use of the results comparison software.

Enhanced surfaces can generally be used for three purposes,

a. The pumping power required for the heat transfer process should be reduced.

b. Increase the heat exchanger's total UA value.

c. Creating model equations for hot and cold fluid output temperature.

In any case, a greater UA value can be used,

- To achieve a greater heat change at the fixed temperature of the fluid inflow, or
- Reduces the mean heat exchange temperature differential by increasing thermodynamic process efficiency that might lead to operational costs being saved.

3. Motivation

For many years efforts have been made to create more heat exchangers using various methods to improve heat transfer. Due to the increasing demand for the industry in terms of heat exchange devices, however, they are lower in design and

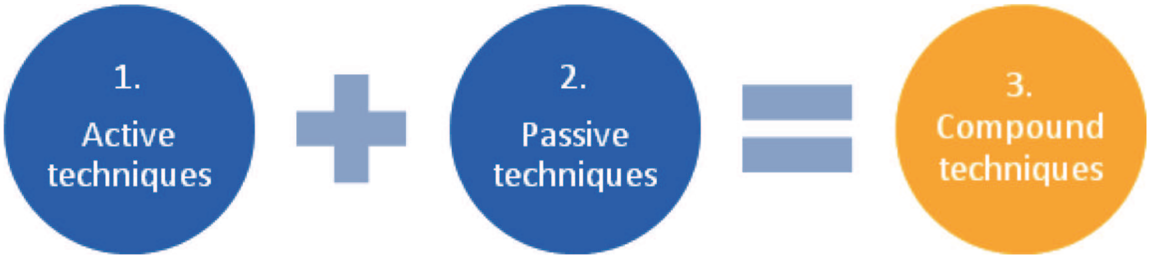

Figure 2.
Types of augmentation techniques.

operation than conventional heat exchange devices; advanced heat transfer studies **Figure 2** have become more effective in recent years. Energy-saving and energy consumption also provide a significant incentive for new development processes. It is important that heat exchangers are cohesive and lightweight when building cooling systems for cars and spacecraft. Additional devices are also required for high-temperature power switches (i.e. air-cooled condensers, nuclear fuel rods). This and many other uses have led to the production of various improved heat exchangers.

More heat transfer is greatly increased by retransmission or redistribution of flow to improve efficiency,

- Axial Reynolds number
- Shortcut flow area
- It means speed
- Temperature gradient near the wall of the tube

4. Methodology

Existing enhancement techniques can be broadly classified into three different categories:

1. Active Techniques: some external power to improve the heat transfer rate in the heat exchanger is appropriate for that process. This method is no more complicated than the synthetic and complex method, for example, machinery, surface vibration, liquid vibration, etc.

2. Passive Techniques: The flux pattern changes in this method only with systemic power available without external power. This change causes the layer of temperature disturbances and pressure to decrease to improve the heat transfer rate of the heat exchangers e.g. heavy face, swirl flow, etc.

3. Compound Techniques: An effective and practical process is used in this approach. Complex technology is a complex that raises the pressure and decreases, for example, an empty tube with twisted tape, a water tube, and so on.

5. Observations from literature review

Twisted tape installation mixes the flow of quantities well and is thus superior to any other installation in laminar flux, as heat resistance is not restricted from laminar flow [4] to a small area near the wall. But the performance of twisted tape

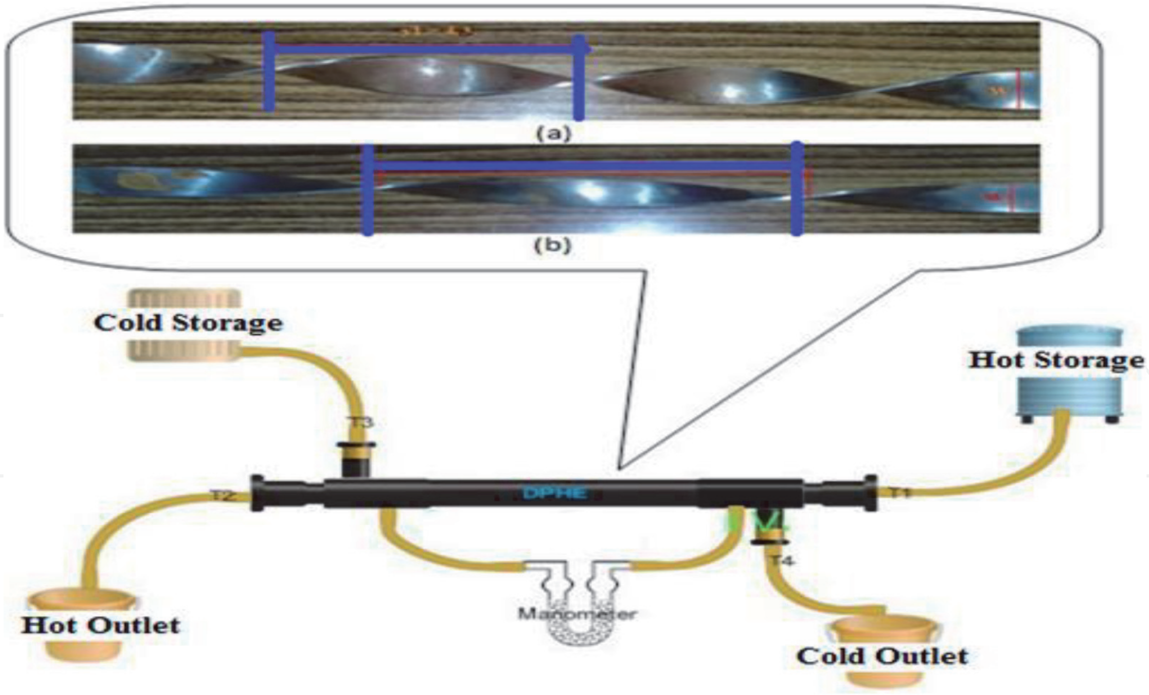

Figure 3.
Experimental DPHE setup with twisted tape.

depends on the fluid parameters such as Prandtl number. Due to its flexible volume, the length of a twisted band **Figure 3(a)** and **(b)** is better than the length of a full band. Twisted tape can be used effectively to increase heat transfer when designing small heat exchanges **Figure 3** for laminar flow.

Turbulent flow [5] twist tape works well up to a certain level of Reynolds but not beyond the wide range of Reynolds. The twisted tape does not work in a turbulent flow compared to a wind turbine due to the drop in pressure drop. So the performance of hot rolled tape is not very good compared to the turbulent flow wire coil. It can therefore be proved that in a turbulent environment a wire spool is a good choice. However, short twisted tapestry offers better hydrothermal performance compared to long and twisted tapestry.

6. Selection and choice of process

The selected process consists of a liquid flow, e.g. water through a double body temperature. The heat exchanger has a lot of industrial and engineering performance. An accurate study of heat transfer rate and pressure reduction and performance and economic aspect of heat exchange equipment is required in the development of a heat exchange process [6–8]. The pressure drop increases when the input is used to increase the heat transfer and the heat transfer rate. As the pressure decreases, pumping costs are high [9–12]. It is also very important that the pressure drop does not exceed a certain amount when using the insert to install a heat transfer system.

7. Mathematical modeling

7.1 Hypothesis

To expand the mathematical model, we look at this simple idea to do the following:

- Merchant performance in a consistent state government.
- Transmission of heat to the environment is ignored.
- HE is considered to be a system with illuminated parameters.
- Two flows in the liquid phase and does not change the phase.

7.2 Modeling equations

By taking heat balance of hot & cold fluid, we get,

$$Q_h Cp_h\ (T_1 - T_2) = Q_c Cp_c\ (T_4 - T_3) \quad (1)$$

$$Q_h Cp_h\ (T_1 - T_2) = U\ A\Delta T_{lm} \quad (2)$$

$$Q_h Cp_h\ (T_1 - T_2) = \frac{U\ A\ \{\ (T_1 - T_4) - (T_2 - T_3)\}}{\ln\ \frac{(T_1 - T_4)}{(T_2 - T_3)}} \quad (3)$$

The heat exchanger's mathematical model has been constructed, and it includes a heat balance equation for the two material fluxes Qh and Qc, as well as an expression for transferred heat flow **Table 1**. The overall heat exchange coefficient, U, has a standard expression as the overall HTC, which may be given by Eq. (4), for the heat flow transported in the heat exchanger.

$$U = \frac{1}{\left\{ \left(\frac{1}{h_i}\right) \left(\frac{d_e}{d_i}\right) + \left(\frac{d_e}{2k}\right) \ln \left(\frac{d_e}{d_i}\right) + \ \left(\frac{1}{h_o}\right) \right\}} \quad (4)$$

7.3 Solving of the mathematical model

Eq. (1) represents a system of two non-linear equations with two variables having the form,

$$f_1\ (T_2, T_4) = 0,\ \ f_2\ (T_2, T_4) = 0 \quad (5)$$

$$f_1 = Q_h Cp_h\ (T_1 - T_2)\ \ - Q_c Cp_c\ (T_4 - T_3) \quad (6)$$

$$f_2 = \{Q_h Cp_h\ (T_1 - T_2)\}\ \ - \left\{ \frac{U\ A\ \{\ (T_1 - T_4) - (T_2 - T_3)\ \}}{\ln\ \frac{(T_1 - T_4)}{(T_2 - T_3)}} \right\} \quad (7)$$

The equation's unknown variables (4), the hot fluid's T2 outlet temperature, and the cold fluid's T4 outlet temperature, are also the heat exchanger's output variables. The expressions of the functions f1 and f2 of the Eq. (5) are defined by the relations (6) and (7).

T1° C	T2° C	T3° C	T4° C	Nre	U W/m^2 K
70	49.25	29	38	11936.60	169.37
60	47.48	29	37	13433.33	171.65
55	45.1	29	35	13602.49	172.51

Table 1.
Experimental parameters.

We can get solutions from two methods,

- Jacobean matrix
- Newton–Raphson method

The Jacobean matrix associated with the linear Eq. (5) is given by,

$$J(X) = \begin{bmatrix} \frac{\partial f_1}{\partial T_2} & \frac{\partial f_1}{\partial T_4} \\ \frac{\partial f_2}{\partial T_2} & \frac{\partial f_2}{\partial T_4} \end{bmatrix} \quad (8)$$

$$\frac{\partial f_1}{\partial T_2} = -Q_h Cp_h \quad (9)$$

$$\frac{\partial f_1}{\partial T_4} = -Q_c Cp_c \quad (10)$$

$$\frac{\partial f_2}{\partial T_2} = -Q_h Cp_h - \left\{ \frac{[U\,A\,\{\,(T_1 - T_4) - (T_4 - T_3)\,\}]\left[\frac{(T_1-T_4)}{(T_2-T_3)}\right]^2}{\ln\left[\frac{(T_1-T_4)}{(T_2-T_3)}\right]^2} \right\} \quad (11)$$

7.4 Example a certain amount when using the insert to install a heat transfer system

Assuming, Temperature T1 = 70°C and T3 = 29°C; μ at 70̊ C = 0.0004101 Pa ses; k = 0.62136 W/m K; de = 0.0280 m; di = 0.013 m;
Cp = 4186 J/kg K.
Apply Eq. (5)

$$h_i = \frac{j^H\,k}{d_i\,\left(C_p\,\frac{\mu}{k}\right)^{1/3}}$$

$$h_o = \frac{j^H\,k}{d_e\,\left(C_p\,\frac{\mu}{k}\right)^{1/3}}$$

$$N_{re} = \frac{d_i\,v\,\rho}{\mu}$$

$$v = \frac{Q}{A}$$

By using Eqs. (1), (2) and (3) and substituting all above calculated values we get,

$$\dot{m}\;C_p\;\Delta T_{|hot} = \dot{m}\;C_p\;\Delta T_{|cold}$$

T2 = 190.35–4.15 T4

$$\dot{m}\;C_p\;(T_1 - T_2) = U\,A\Delta T_{lm}$$

By substituting value of T2 from Eq. (1)

$$f(T_4) - \frac{(70 - T_4) - (161.35 - 4.15\,T_4)}{\ln(70 - T_4) - \ln(161.35 - 4.15\,T_4)} - 66.15\,T_4 + 1918.07$$

From trial and error method,
T4 = 38° C.
From Eq. (1), substituting T4.
T2 = 49.25° C.

8. Results of mathematical model

8.1 About the inserts

Mild steel twisted tapes were utilized as inserts in the experiment **Table 2**. The purpose of this study is to determine the friction factor and heat transfer coefficient for twisted tape with a twist ratio of (Y1 = 4.3, Y2 = 7.7) and compare them to those of a smooth tube.

Twist ratio 1 = 4.3.
Twist ratio 2 = 7.7.
Twisted tape thickness = 0.002 m.
Twisted tape length = 0.90 m.
Twist width = 0.012 m.

8.2 Simulation

Simulation means the equation through the use of software mathematical tools. Chemical engineering requires a process simulation to solve difficulties associated with process design, process analysis control, and much more, in the actual world a chemical process is defined in a process fluid sheet.

What is Process Simulation/Analysis?

The analysis/simulation is designed to model and predict how the process is performed. In any performance test, the process must be broken down into fragments (e.g. units). Process factors are predicted by analytical strategies (e.g. flow rates, tracks, temperatures, pressures, features, equipment size, etc.) Mathematical models, dynamic correlations, and process simulation tools include these strategies (e.g. ASPEN Plus). In order to predict and validate performance, process analysis may include the use of test methods. As a result, we obtain the installation process and the flow process during the process simulation and are required to predict the results of the process **Figure 4**. ASPEN Plus is the focus of the lab. It is computer-assisted software that predicts process performance (e.g., broadcast parameters, operating conditions, and machine sizes, and uses basic

Inner pipe ID	0.013 m
Inner pipe OD	0.015 m
Outer pipe ID	0.023 m
Outer pipe OD	0.025 m
MOC of tube	Cu
MOC outer pipe	PVC
Heat transfer length	0.90 m
Outer pipe length	0.76 m

Table 2.
Specification of experiment setup.

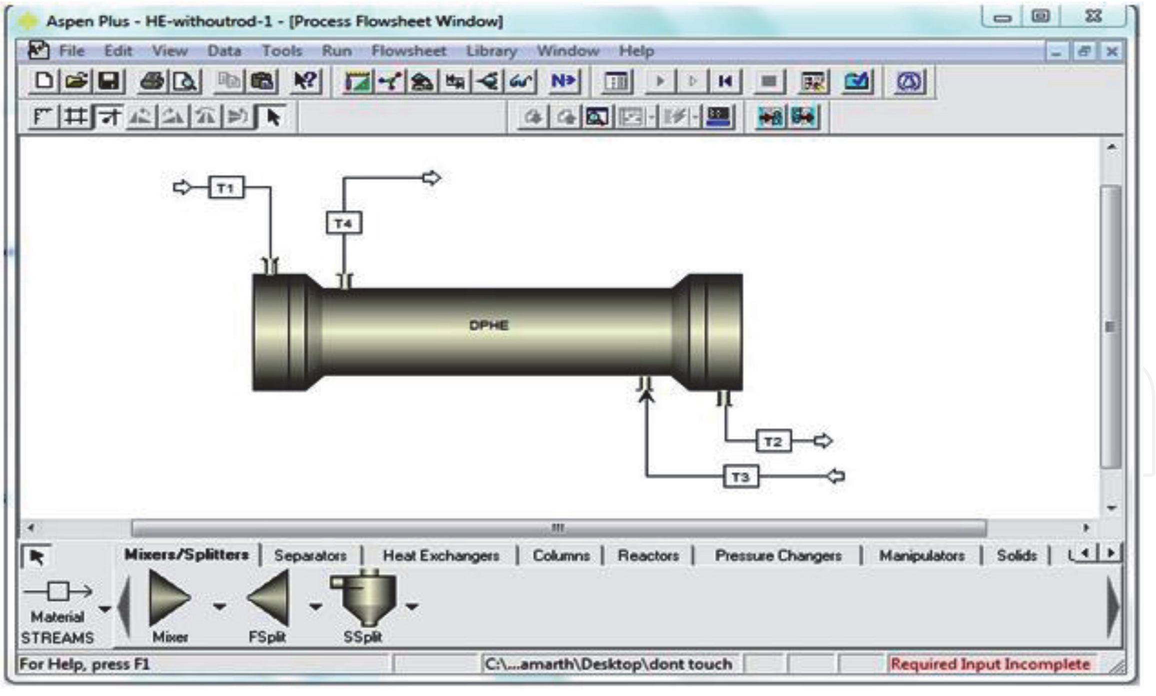

Figure 4.
DPHE with inlet and outlet streams.

physical coordinates (e.g., material and power balances, thermodynamic equilibrium, and measurement).

Computer-assisted simulation has various benefits:

- Allows designers to easily evaluate and provide information on integrated water systems integration.
- It can be integrated to achieve a complete integrated design and integration process.
- Reduces testing and expansion efforts.
- Flexibility and awareness of the process are assessed by answering the questions of "what if?"
- Modeling process and understanding process performance in bulk.

9. Result and discussion

9.1 Final result

At DPHE, the set results were confirmed by experimental work on mathematical models **Tables 3** and **4**. **Figures 5** and **6** shows that, in comparison with the test values for the full total result, a larger 4°C rating was obtained for the mathematical model due to a few manual errors.

Mathematical model analysis and test function are shown in **Figures 7** and **8**. The test consists of a smooth tube with a torsioned tube Y1 = 4.3 and Y2 = 7.7 without installation and installation. Recovery of heat from hot and cold liquids increases as **Table 5** temperature differences increase. Extreme heat transfer from

T2° C	T4° C	U W/m^2 K
49.25	38	169.37
47.48	37	171.65
45.1	35	172.51

Table 3.
Theoretical values for temperatures and heat transfer coefficient.

Smooth tube			Y_1 = 4.3			Y_2 = 7.7		
T2	**T4**	**U**	**T2**	**T4**	**U**	**T2**	**T4**	**U**
55	35	1849.002	56	39	2941.53	55	39	2456.17
51	34	2505.59	48	34	3762.55	50	33	2859.64

Table 4.
Experimental values of heat transfer coefficient for smooth and twist tape.

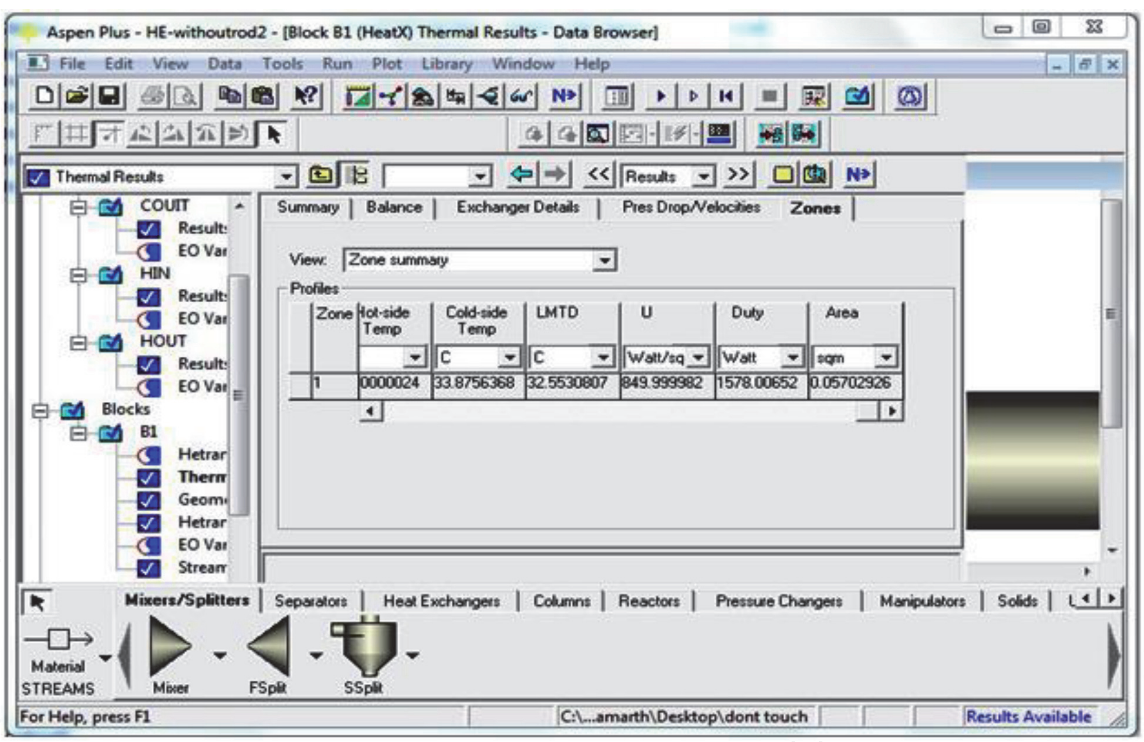

Figure 5.
Thermal results in plane tube simulation.

hot and cold liquids is used in the form of heat transfer. It was noted that the 6°C of the twist ration Y1 = 4.3 and the 4°C of the twist ratio Y2 = 7.7 as the comparable smooth tube was increased using twist-tape.

Figure 9 translates that, the conflict decreased as the snumber of Reynolds increased. Therefore, when twisted tapes with different twist ratios are shown in 4.3 and 7.7 a device that is more important than a smooth tab is used. The heat transfer coefficient with a twist ratio of 4.3 rather than a 7.7 twist ratio. Therefore, the ratio of the contraction of the pulsating tap and the sugar is very smooth to 4.3 twist ratio and then 7.7.

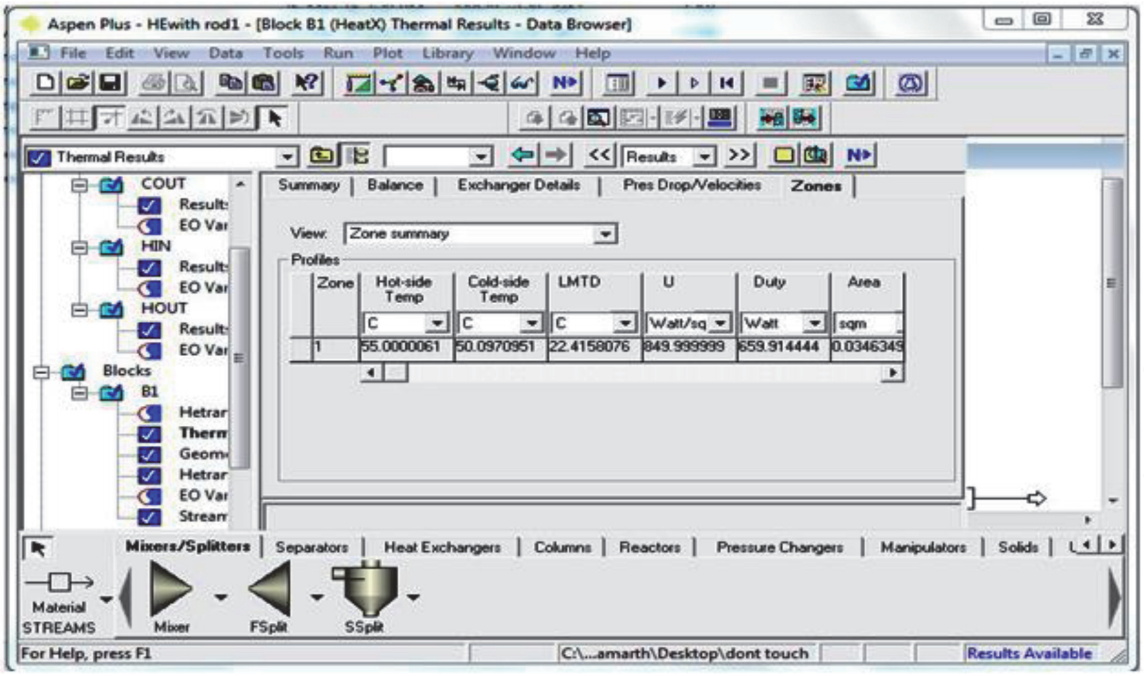

Figure 6.
Thermal results in tube with tape simulation.

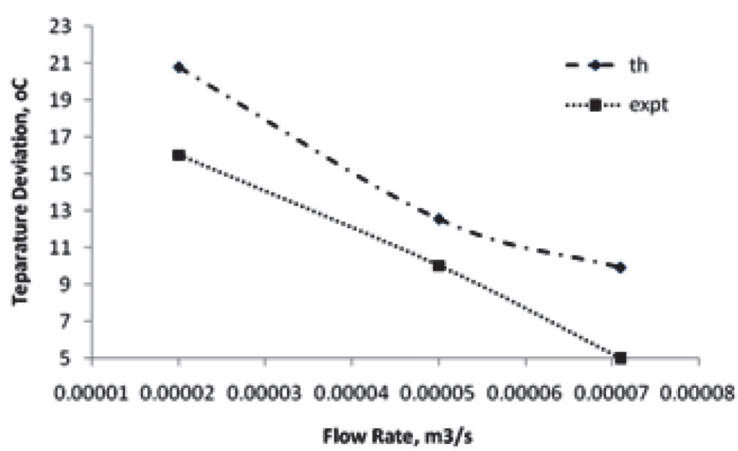

Figure 7.
Comparison between mathematical model and experimental work.

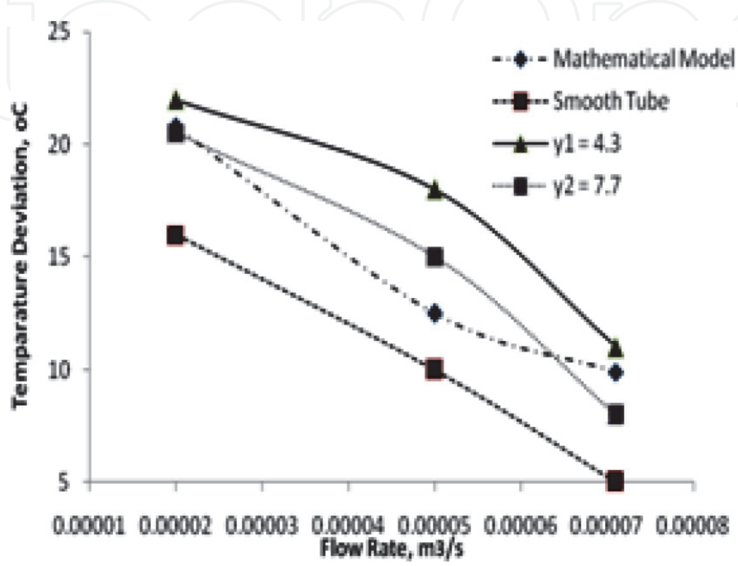

Figure 8.
Comparison between mathematical model and experimental work for smooth tube, twisted tape having twist ration (Y1 = 4.3 & Y2 = 7.7).

Flow rate	Model			Smooth tube			Y_1 = 4.3			Y_2 = 7.7		
	T1	T2	ΔT	T1	T2	Δt	T1	T2	ΔT	T1	T2	ΔT
0.00002	70	49.25	20.75	74	58	16	71	49	22	70	49.5	20.5
0.00005	60	47.48	12.52	65	55	10	63	45	18	62	47	15
0.000071	55	45.1	9.9	56	51	5	59	48	11	60	52	8

Table 5.
Comparison of temperature difference.

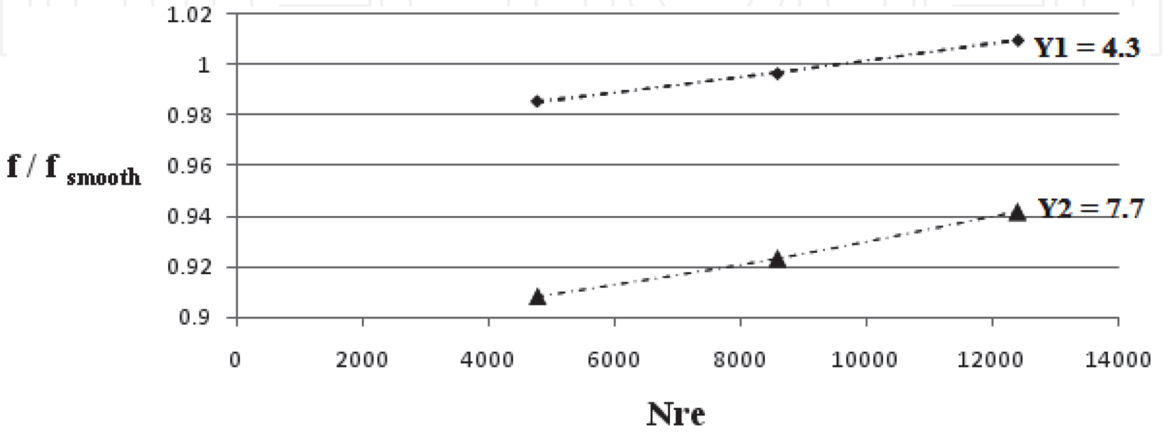

Figure 9.
Friction factor ratios vs. Nre for theoretical and experimental values.

10. Conclusion

In this experiment, we find that with the introduction of a torn tape, the heat transfer rate increases. When the installation is installed in a flow-through station, the rate of heat transfer and pressure drop leads to a higher level of turbulence. By comparing experiments using open source tools, we get results similar to Aspen Plus.

The statistical model is validated by comparing the test values under the same operating conditions of the two output flow temperatures associated with the model. In the analysis of industrial vendors in the cleaning areas, a mathematical model and algorithm of its solution will be used.

Scope for Future Work

1. DPHE manufactured to compute temperature-related viscosity; for energy saving.

2. As a process of intensification approaching the green technology principle in the chemical industry.

Nomenclature

Ai	Inside heat transfer surface area, m^2
Ac	Cross-sectional area, m^2
Cp	Specific heat of fluid, J/kg K
Di	Inside diameter of the tube, m

fa	Fanning friction factor, dimensionless
f	Theoretical Fanning friction for smooth tube, dimensionless
Gz	Greatz number, dimensionless
h	Difference in level of CCl4 in the manometer, m
hi	Inside HTC, W/m^2 K
ho	Outside HTC, W/m^2 K
H	Linear distance of the tape for 180° rotation
k	Thermal conductivity of the fluid, W/m K
Lw	Heat transfer length, m
Lh	Pressure taping to pressure taping length, m
ΔTlm	Log mean temperature difference
$\dot{m}$	Mass flow rate, kg/s
Nu	Nusselt number
Pr	Prandtl number
ΔP	Pressure drop
Q	Heat transfer rate, W
Re	Reynolds number
T	Temperature in° C
Ui	Overall heat transfer coefficient, W/m2 K
v	Velocity of water, m/s
w	Width of the twisted tape
Wt	Weight of the water taken, kg
y	Twist ratio, dimensionless, H/d

Greek letters

ρ	Density of fluid, kg/m^3
μ	Dynamic viscosity of the fluid, Pa sec

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