THERMAL-HYDRAULIC OPTIMIZATION OF MULTI-PASS HEAT EXCHANGERS IN SOLIDWORKS

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Introduction

Heat can be transferred between two or more process fluids using a heat exchanger. Their main function is to either heat or cool elements [1–5]. Their efficiency directly impacts operational costs and energy consumption [6]. However, optimizing their performance, particularly in multi-pass configurations, remains a significant challenge. Despite advances in heat exchanger technology, there is a lack of comprehensive studies on the optimization of thermal hydraulic performance in vertical shell and tube heat exchangers with multiple passes [7]. Inefficient designs lead to substantial energy losses and increased operational costs [8, 9].

The purpose of this research is to investigate and enhance the thermal hydraulic performance of vertical shell and tube heat exchangers with multiple passes. Specifically, the primary objective is to evaluate and optimize the thermal hydraulic performance of the IRT-T vertical shell and tube heat exchanger by incorporating twisted tapes using solid work software.

SolidWorks thermal hydraulic analysis

SolidWorks thermal hydraulic analysis provides a detailed examination of the thermal and hydraulic characteristics of a system using SolidWorks software. Table 1 below outlines the boundary conditions used in the SolidWorks thermal hydraulic analysis of the vertical shell and tube heat exchanger. These parameters are crucial for determining the heat exchanger's overall thermal performance, as they directly impact the heat transfer rate and the fluid's physical properties and flow characteristics.

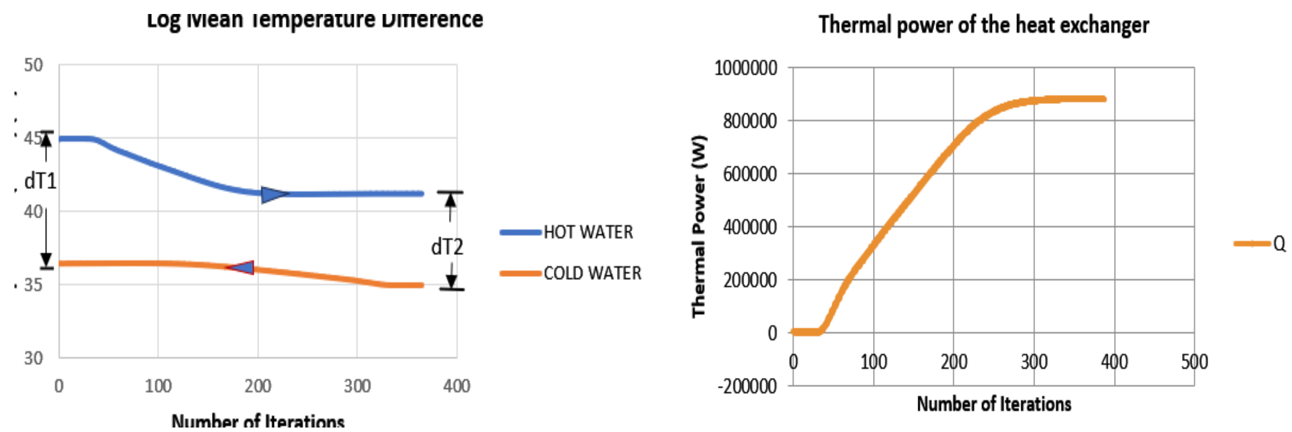
Table 1. Boundary conditions

	Cold Inlet	Cold Outlet	Hot Inlet	Hot outlet
Mass flow rate	136.3640	–	49.5250	–
Fully developed flow	Yes	–	Yes	–
Temperature	35 degrees	–	35 degrees	–
Environment pressure		400000Pa		400000Pa
Turbulence intensity and length Intensity:		2 %		2 %

Results and Discussion

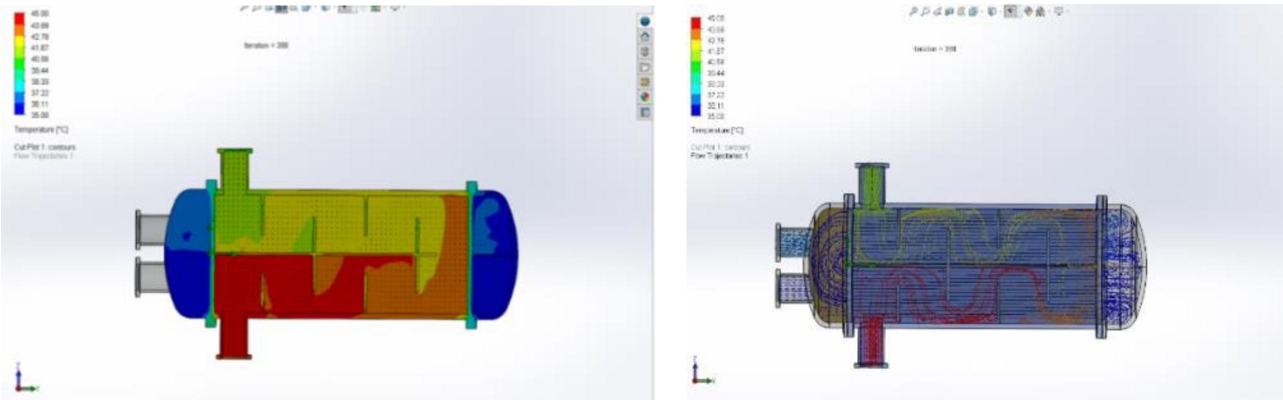
Table 2 presents the key analysis results from the SolidWorks thermal hydraulic simulation of the heat exchanger. These results are provided for two configurations: smooth tubes and tubes with twisted tape inserts. The comparison highlights the impact of twisted tape on thermal performance, with a slightly higher LMTD and thermal power observed for the twisted tape configuration.

The heat transfer performance analysis yields significant findings regarding the system's efficiency. The heat exchanger equipped with twisted tape inserts demonstrates superior performance, achieving a thermal power output of 0.8801 MW, compared to 0.8014 MW for the smooth tube configuration. This improved performance is attributed to the enhanced turbulence and mixing effects created by the twisted tape inserts. The Log Mean Temperature Difference (LMTD) also shows a slight improvement in the twisted tape configuration (7.36°C) compared to smooth tubes (7.31°C). This higher LMTD indicates greater heat transfer potential, contributing to the overall improved thermal performance of the twisted tape system. The analysis conclusively demonstrates that the incorporation of twisted tape inserts leads to measurable improvements in heat transfer efficiency. The above can be illustrated using fig. 1, *a*, *b*.

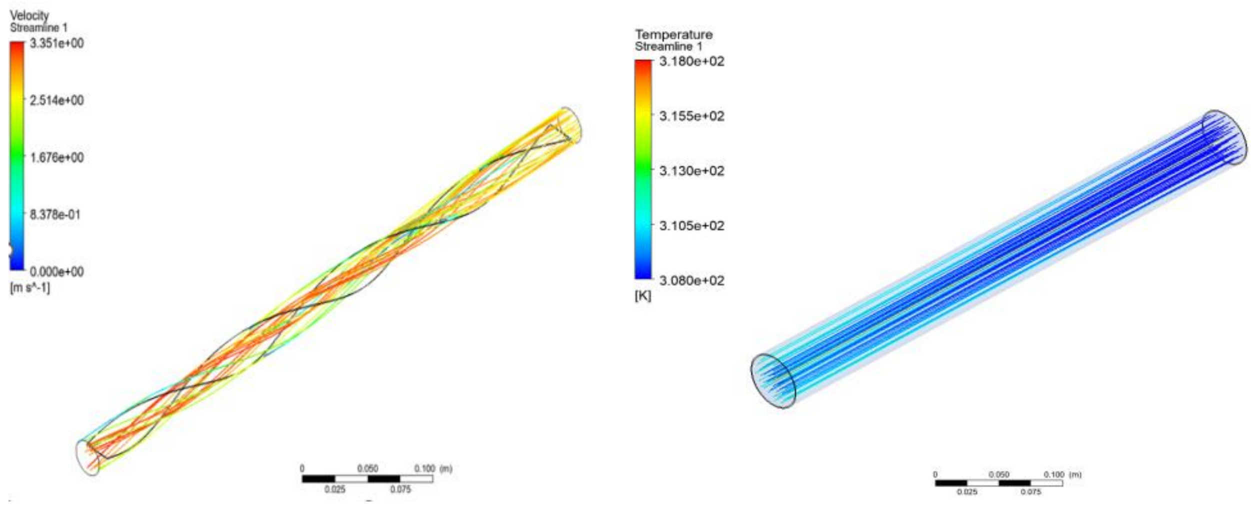


a *b*

Fig. 1. Temperature distribution of hot and cold fluids along the heat exchanger (a); overall heat transfer rate, indicating thermal exchange efficiency (b)



a *b*



c *d*

Fig. 2. Fluid flow patterns in twisted ribbon pipes to smooth pipes: a – Cut Plot Contours; b – Flow Trajectories; c – Fluid flow along tube with twisted tape; d – Fluid flow along smooth tube

Table 2. Analysis results

	Smooth tubes of 2.132 m		Tubes with twisted tapes and reduced length of 2.07 m	
Parameters	Unit	Value	Unit	Value
Cold Inlet Total Pressure	Pa	509543.99	Pa	509507.38
Cold Inlet Velocity	m/s	4.380	m/s	4.380
Cold Outlet Temperature	°C	36.41	°C	36.37
Cold Outlet Velocity	m/s	4.414	m/s	4.414
Hot Inlet Velocity	m/s	1.769	m/s	1.769
Hot Inlet Total Pressure	Pa	417240.41	Pa	417192.90
Hot Outlet Temperature	°C	41.17	°C	41.23
Hot Outlet Velocity	m/s	1.777	m/s	1.779
dTb	°C	6.17	°C	6.23
dTa	°C	8.59	°C	8.63
Q	W	801360.02	W	880056.92
LMTD	°C	7.31	°C	7.36

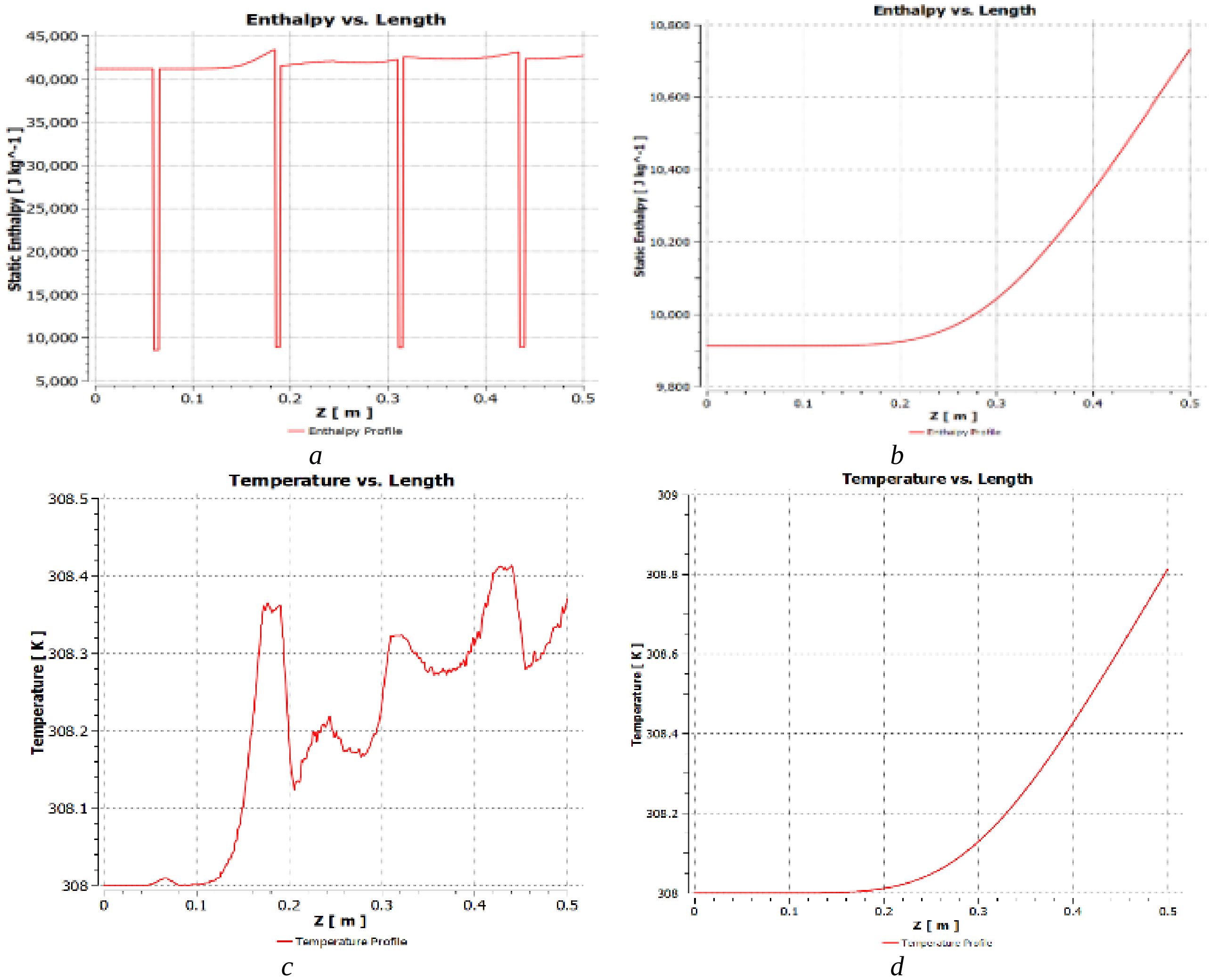


Fig. 3. Enthalpy and temperature distributions, respectively, along the tube length:
a – Enthalpy along tube with twisted tape; b – Enthalpy along smooth tube;
c – Temperature along tube with twisted tape; d – Temperature along smooth tube

Figure 2 compares fluid flow patterns in tubes with twisted tape to smooth tubes, showing how twisted tape induces a more turbulent and complex flow. The twisted tape creates secondary flows and increased mixing, enhancing heat transfer by disrupting the boundary layer more effectively than in smooth tubes, where flow remains more laminar. Figures 3 illustrate enthalpy and temperature distributions, respectively, along the tube length. In tubes with twisted tape, the enthalpy fluctuates due to the enhanced turbulence and varied flow patterns introduced by the tape's geometry, resulting in regions of higher and lower heat transfer efficiency. In contrast, enthalpy increases more steadily in smooth tubes, with less boundary layer disruption. The temperature profile in twisted-tape tubes also fluctuates more, reflecting the alternating regions of heat transfer efficiency, whereas smooth tubes display a gradual temperature rise as heat transfer reaches a steady state. Overall, twisted tape significantly improves thermal performance compared to smooth tubes by enhancing turbulence and fluid mixing.

Conclusion

In conclusion, incorporating twisted tape in tubes significantly enhances thermal performance compared to smooth tubes. The twisted tape's design induces secondary flows and turbulence, which disrupt the boundary layer, increase mixing, and lead to higher heat transfer coefficients. This results in fluctuating enthalpy and temperature profiles, indicating regions of enhanced heat transfer. Smooth tubes, by contrast, show a more uniform flow and gradual heat transfer. Overall, twisted tape is an effective technique for optimizing heat transfer efficiency in heat exchangers.

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ДРОБЛЕНИЕ КАПЕЛЬ ВОДОУГОЛЬНОГО ТОПЛИВА В ПОТОКЕ ВОЗДУХА

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Возможность внедрения в энергетику водоугольного топлива обоснована многими работами, например [1]. Результаты работы [2] по сжиганию ВУТ позволяют утверждать, что при сжигании такого вида топлива, дымовые газы содержат значительно меньше оксидов серы и азота. В работе [3] показано, что, при сжигании ВУТ, эффективность теплопередачи от продуктов сгорания такого топлива к теплоносителю значительно выше, чем при применении угля.