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Effect of Thermal and Hydrodynamic Corrosion-Erosion of Solid Particles in Shell and Tube Heat Exchanger

Nur Dayana Irdina Depikalasben[1], Normayati Nordin[1]*

[1] *1Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: mayati@uthm.edu.my
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Abstract

The corrosion attack frequently leads to the failure of the initial tube rows in shell and tube heat exchangers (STHE) utilised within the oil and gas sectors. There are several contributing factors that can lead to this occurrence, such as elevated temperature, inadequate flow distribution, and excessive velocity. The implementation of helical baffles is anticipated to enhance the flow characteristics upon entering the shell, thereby reducing the adverse impacts of corrosion. The research presented here investigates what takes place when helical baffles are installed and recommend the optimal configuration for carrying out such an implementation. There was some consideration given to STHE, with HVGO (Heavy Vacuum Oil Gas) proposed as the potential working fluid. According to the results of CFD simulations carried out in ANSYS FLUENT 2023, it was discovered that the first tube rows were being attacked by corrosion. Therefore, helical baffles of the appropriate size may be used to reduce the influence that corrosion has on the tube, which will result in the tube having a longer lifespan.

1. Introduction

Heat exchangers are critical components in many industries and processes because they transfer heat from one fluid to another. These fluids can be corrosive to heat exchangers, which are typically formed of metal. Corrosion failures of heat exchangers are widespread, and corrosion frequently results in costly maintenance or repair costs. (Faes,2019). In the case of erosion, erosion is a big issue in many industrial operations, particularly heat exchangers that use saltwater for cooling and oil and gas producing facilities. It causes serious damage to various flow routes, resulting in frequent failure of various equipment and greater maintenance costs, as well as the loss of important production time.

When particles have substantial velocity towards the walls of heat exchanger tubes in shell and tube heat exchangers, the erosion mechanism might take the form of direct impingement erosion. (Habib, 2005). With Shell and Tube Heat Exchangers (STHE), the oil and gas sector faces issues relating to crude oil supply and quality. Corrosion in STHE diminishes their efficiency, resulting in a variety of problems. To overcome this, excellent practises must be followed while selecting materials, developing the device, and using it, especially in corrosive situations. Furthermore, preventative measures such as wear-resistant impingement plates or angle tube protectors can be used to shield the sensitive sections around the shell. The objectives are to conduct a numerical investigation into the impact of thermal and hydrodynamics on solid particle corrosion-erosion in shell and tube heat exchangers and to determine the optimal configuration and operating conditions for shell and tube heat exchangers to prevent solid particle corrosion-erosion.

This study also attempts to develop a CFD simulation of erosion in shell and tube heat exchangers in order to better understand the corrosion and identify the heat transfer involved.

2. Methodology

The case study requires creating a Solidworks model of the shell-and-tube heat exchanger and configuring Fluent simulation in ANSYS FLUENT 2023.

2.1 Modelling STHE

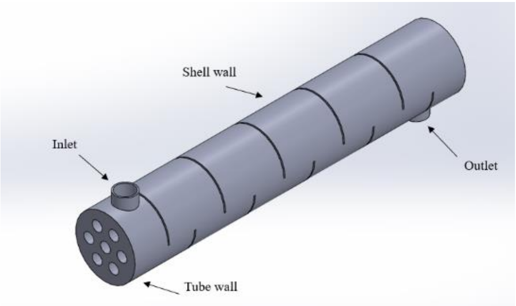
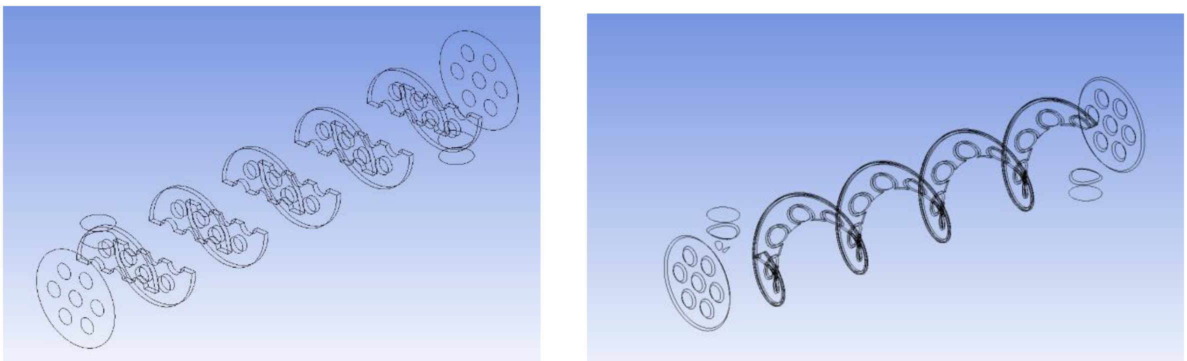


Fig. 1 *STHE model in isometric view in Solidworks*

Table 1 *Design parameter of Shell and Tube Heat Exchanger*

Parameter	Value
STHE length, L (mm)	500
Nozzle diameter, D (mm)	30
Number of tubes	7
Shell diameter (mm)	90
Tube pitch, P_t (mm)	25
Tube diameter, D (mm)	15
Tube layout	Triangular 30°
Number of baffles	10
Baffle cut (%)	25
Central baffle spacing, B (mm)	41.50

2.2 Geometry and mesh STHE in ANSYS FLUENT



a) b)

Fig. 2 *STHE geometry a) Straight baffle b) Helical baffle*

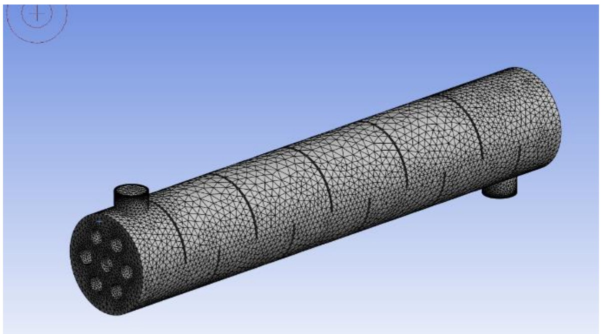


Fig. 3 *Meshing model in isometric view*

2.3 Settings of solver and boundary conditions

Inlets were described as mass flow rate inlets, and outputs as pressure outlets. HVGO was the shell side.

Table 2 *HVGO Fluid properties*

Parameter	Value
Thermal Conductivity, (W/m.K)	0.124
Density, ρ (kg/m^3)	744.5
Dynamic Viscosity, μ (kg/m. s)	1.645×10^{-5}
Capacity Heat, C_p (J/kg.K)	2878

Table 3 *Boundary conditions*

	BC Type	Shell (HVGO)
Inlet	Mass flow rate inlet, m (kg/s)	0.5
Outlet	Pressure outlet, Pa	0
Wall	Shell wall, W/m^2	No heat flux
Capacity Heat, C_p (J/kg.K)	Tube wall, K	500

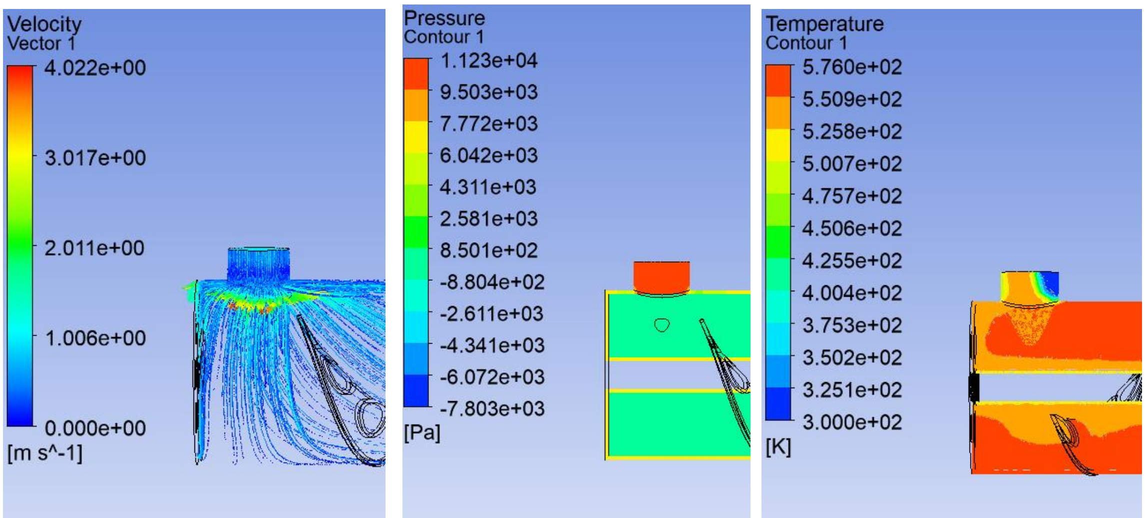
3. Results and Discussion

The results of the CFD simulation have provided conclusive evidence that corrosion took place within the STHE as a direct result of the flow of its shell dispersion. The results of the pressure drop and output temperature have been taken into consideration in Table 4 for optimization.

Table 4 *Output STHE result*

Parameter	Result
Outlet temperature, (K)	525.091
Pressure drops, (kPa)	1194.233

It is evident that the implementation of a helical baffle in Figure 4 (a) effectively interferes with the higher velocity arising from the inner nozzle, thereby extending the lifespan of the tube. The design featuring fine holes offers superior flow distribution due to its minimal presence of stagnant flow areas near the nozzle. For pressure in Figure 4 (b), the design of the helical diverter effects the fluid pressure on the shell's side. The pressure is highest in the interior orifice. After colliding with the plate, the helical baffle will allow the fluid to rebound. It increases the reduction of pressure. Next, according to the Figure 4 (c), the design of the helical baffles in the Shell and Tube Heat Exchanger (STHE) has a negligible impact on the temperature fluctuation. The greater temperature is one factor that contributes to the occurrence of corrosion.



a) **b)** **c)**

Fig. 4 *a) Velocity vector b) Pressure contour c) Temperature contour*

The parameters of pressu``re drop and outlet temperature were utilized in this study to evaluate the performance of the Shell and Tube Heat Exchanger (STHE). In essence, the primary objective of the fine holes design was to fulfil the minimum requirements necessary for mitigating the occurrence of corrosion. The simulated results were compared with those of a previous study in order to analyze the pattern and accuracy of the developed model. The findings pertaining to pressure head loss in this study exhibited a high degree of similarity to those observed in the previous study. Therefore, this study can be deemed successful.

Table 5 *Performance comparison between the straight and helical baffle*

	Straight baffle	Helical baffle
Outlet temperature, (K)	525.091	415.340
Pressure drops, (Pa)	1194.233	1195.835

4. Conclusions

Optimizing the flow speeds and paying close attention to temperature differences and thermal gradients can help reduce the thermal loads that cause rusting to happen faster. These results show how important it is to use a whole-system method that includes both design and operation practices to make sure that shell-and-tube heat exchangers will last and work well even when solid particles are corroding them. These results show how important it is to look at both temperature and hydrodynamic factors when figuring out how likely it is that rust and erosion will happen in shell-and-tube heat exchangers. As a whole, the findings of this work add to a fuller knowledge of the complex interplay between thermal and hydrodynamic parameters and the effect these factors have on the corrosion-erosion of solid particles in shell and tube heat exchangers. The insights that were gathered from this research can serve as the foundation for future work that is targeted at designing designs for heat exchangers that are more resilient and efficient while also reducing the danger of corrosion-erosion.

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