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Impacts of Fins on The Heat Transfer Characteristics in A Shell and Cone-Shaped Coil Heat Exchanger

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Abstract
In shell-and-coil heat exchangers, cone coils are a more effective choice for better heat transfer than plain cone coils because they have a bigger surface area and create more turbulence, which increases the heat transfer rate. This study uses numerical analysis to assess the effects of using two different fins (numbers two and three) attached to the outside of a "cone-shaped coil tube in a shell-and-coil tube heat exchanger" while taking different cold water entry velocities into account. The finite volume approach-based numerical simulations are carried out using ANSYS Fluent. The numerical results obtained showed that the heat transmission is increased when the fins are attached to the cone coil's outside surface. There are five instances in this research, with two or three fins attached to the cone coil's outer surface and cold-water input velocities of 1.4 and 1.0 m/s. Based on all scenarios' numerical findings, the most optimal case was taken into consideration. Both case 3, and case 5 show the beast result in terms of rate of heat transfer and outlet temperature of cold water respectively. Case 3 shows that the maximum rate of heat transfer of 0.47W and case 5 shows that the maximum cold water outlet temperature of 311.17 K.

Keywords; Heat transfer, Shell and tube heat exchanger, shell and cone coil heat exchanger, Temperature, Computational fluid analysis

INTRODUCTION

There are several reasons why the performance of shell and tube heat exchangers has to be enhanced, one of which is to increase energy efficiency. Efficient use of energy reduces operational expenses and has a negligible impact on the environment. Optimising industrial processes, increasing productivity and reliability, and reducing wasteful heat transfer are all outcomes of increased efficiency [1]. By reducing the frequency of maintenance and downtime, this enhancement leads to significant cost savings. Further, it safeguards the heat exchanger's integrity and reduces corrosion and fouling, extending the equipment's lifetime [2]. Businesses may avoid penalties and improve their sustainable image by using efficient heat exchangers, which also help them comply with tight energy and environmental rules [3]. More efficient and durable market solutions are the end result of investments in performance improvements, which fuel innovation and competitiveness. A heat exchanger with a shell and coil tube design has a better heat transfer coefficient than one with only a shell and tube design because of the larger surface area and enhanced turbulence [4]. Its coiled form allows for a smaller device with effective temperature gradients and maximises the driving force for heat transfer. In addition to enhancing thermal performance generally and avoiding hot or cold spots, the coil design guarantees equal distribution of flow [5]. By reducing fouling, the created turbulence helps maintain ongoing better thermal efficiency. Shell and coil tube heat exchangers are more efficient and effective in heat transmission because of these advantages [6].

To effectively transfer thermal energy from one fluid to another, a heat exchanger is an essential equipment utilised in many different industries and applications [7]. Energy recovery, heating, and cooling all rely on it. A heat exchanger's principal role is to separate several fluids physically so that heat may be transferred between them [8]. This ensures the fluids remain separate throughout the thermal energy exchange, which reduces the risk of contamination [9]. A large number of industries make use of heat exchangers, including those dealing with heating, ventilation, and air conditioning (HVAC), electricity production, chemical processing, refrigeration, and manufacturing [10]. Various kinds and combinations are available to meet individual needs; their design and operation are based on fluid mechanics and thermodynamics [11].

The medium to be heated or cooled is housed in a single tube in a shell and tube heat exchanger. The "shell" encases this and houses the fluid responsible for heating or cooling the initial medium [12]. Counterflow, parallel flow, and cross flow are three types of shell and tube heat exchangers. The optimal method relies on the medium being chilled or heated [13]. Before making a recommendation for a heat exchanger, we carefully consider the intended use and desired outcomes to determine the best kind to meet those needs. Heat exchangers with tubes and shells are designed using exact technical specifications and powerful computer tools [14]. Crucial components of these devices are "the shell, shell cover, tubes, channel, tube sheet, baffles, nozzles, and channel cover". The design and production standards for shell and tube heat exchangers are governed by the "Tubular Exchanger Manufacturers Association" (TEMA). Before making a shell-and-tube heat exchanger, the manufacturers need to provide a lot of important details [15]. The physical properties of the materials being processed, as well as parameters like as flow rates, input and output temperatures, the pressure levels, the pressure drops, the pipe dimensions, and shell diameter are all part of this [16]. To guarantee the manufacturing of a heat exchanger that satisfies the particular requirements of the application, comprehensive technical specifications are required in addition to these basic elements [17].

Several research have concentrated on altering the geometry, materials, and tube configurations to enhance the efficiency of "shell and tube heat exchangers". For instance, Hashemi Karouei et al. (2024) [4] examined how changing the shell and tube's inlet and outlet configurations, as well as geometrical elements like pitch, affected the efficiency of heat transfer. However, there hasn't been much research done on enhancing the heat transfer capabilities of "shell and tube heat exchangers" by adding fins to the exterior of the tube. The effectiveness of fins in shell as well as "conical coil heat exchangers" is not well understood, despite the fact that they are known to improve heat transfer by increasing surface area. In order to close this gap, this work uses numerical simulations to examine how fin attachments affect a shell & conical coil heat exchanger's thermal performance with the goal of optimising its heat transfer properties.

RESEARCH METHODOLOGY

Governing equation

The following provides an accurate and correct approach for numerically simulating fluid flow while taking into account the influence of turbulence, which is the most important aspect in flow modelling.

“Mass conservation equation”

$$\frac{\partial}{\partial X_i}(u_i) = 0$$

“Momentum conservation equation”

$$\frac{\partial}{\partial X_j}(u_i u_j) = -\frac{1}{\rho}\frac{\partial P}{\partial X_i} + \mu\frac{\partial^2 u_i}{\partial X_j{}^2} - \frac{\partial}{\partial X_j}\left(\overline{\acute{u}_i \acute{u}_j}\right)$$

The Reynolds stresses are represented as $-\rho\overline{\acute{u}_i \acute{u}_j}$, where $\acute{u}_i$ and $\acute{u}_j$ are the varying elements of the velocity in directions i and j. Using the "Boussinesq approximation", which makes the assumption that the Reynolds stresses may be connected to the mean velocity gradients in the following way, these terms are modelled:

$$-\rho\overline{\acute{u}_i \acute{u}_j} = \mu_t\left(\frac{\partial u_i}{\partial X_j} + \frac{\partial u_j}{\partial X_i}\right) - \frac{2}{3}\rho k \delta_{ij}$$

Additionally, the "k-ε turbulence model" defines the turbulent viscosity as follows:

$$\mu_t = C_\mu \frac{\rho k^2}{\varepsilon}$$

Thus, the following is the final momentum equation with turbulent viscosity:

$$\frac{\partial}{\partial X_j}(u_i u_j) = -\frac{1}{\rho}\frac{\partial P}{\partial X_i} + \frac{\partial}{\partial X_j}\left[(v + v_t)\left(\frac{\partial u_i}{\partial X_j}\right)\right]$$

The turbulence kinetic energy and turbulence dissipation rate differential transfer equations provide the following direct values for "k and ε in the k-ε turbulence model":

$$\frac{\partial(u_i k)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\left(v + \frac{v_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + \frac{P_k}{\rho} - \varepsilon$$

$$\frac{\partial(u_i \varepsilon)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\left(v + \frac{v_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + \frac{\varepsilon}{k}\left(C_{\varepsilon 1}\frac{P_k}{\rho} - C_{\varepsilon 2}\varepsilon\right)$$

where Pk is as follows: Pk is the turbulence caused by viscous forces.

$$P_k = \mu_t\left(\frac{\partial u_i}{\partial X_j} + \frac{\partial u_j}{\partial X_i}\right)\frac{\partial u_i}{\partial X_j}$$

The constant coefficients of this turbulence model are, respectively, "0.09, 1.44, 1.92, 1.0, and 1.3" for Cμ, Cε1, Cε2, σk, and σε.

"Energy equation"

$$\rho u_j \frac{\partial T}{\partial X_J} = \frac{\partial}{\partial X_J}\left[\left(\lambda + \frac{\mu_t}{\sigma_t}\right)\frac{\partial T}{\partial X_J}\right]$$

In this case, σt, or Turbulent Prandtl number, equals 0.9.

Performance analysis equation

Reynolds number

$$Re = \frac{\rho u D_H}{\mu}$$

$$D_H = \frac{4A}{P_w}$$

Friction factor

$$f = 2\Delta P \frac{D_H}{L}\frac{1}{\rho u^2}$$

Rate of heat transfer

$$\dot{Q} = \dot{m} C_p (T_{inlet} - T_{outlet})$$

Computational model

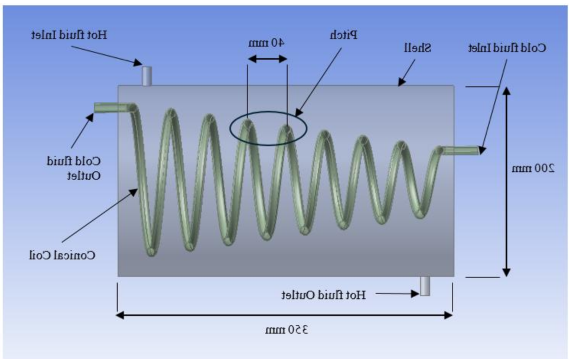
Figure 1-3 illustrate that the dimension and position of the inlet and outlet of shell and conical coil. Figure 1 illustrate the shell and conical coil heat exchanger with simple coil having a pitch of 40 mm, shell diameter and length of 200 mm, and 350 mm, respectively. Inner and outer diameter of the conical coil is 8 mm, and 10 mm, respectively show in table 1. Attach 2 fins in the outer surface of the conical coil with 180 degree angle with each, having heigh of 4 mm from the outer surface and 1 mm thickness, show in the figure 2. Attach 3 fins in the outer surface of the conical coil at angle of 120 degree with each fins, having a height of 6 mm from the outer surface of the conical coil and thickness of 1 mm show in the figure 3. Dimension of fins use in design 2 and design 3 mention in table 2.

Table 1 General geometry description

Sections	Parameter	Units	Value
Cone coil	Angle of the cone coil	Degree	8
	Cone inner tube diameter	mm	8
	Cone outer tube diameter	mm	10
	Cone coil diameter	mm	64
	Coil pitch	mm	40
Shell	Shell diameter	mm	200
	Shell length	mm	350

Table 2 fins dimension in design 2 and design 3

Parameter	Unit	Design 2- 2 fins in conical coil	Design 3 – 3 fins in conical coil
Height	mm	4	6
Thickness	mm	1	1
Angle between each fin	Degree	180	120



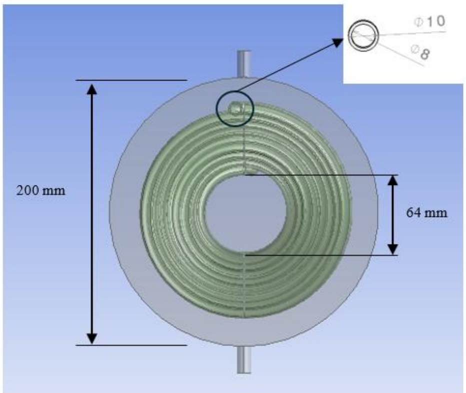
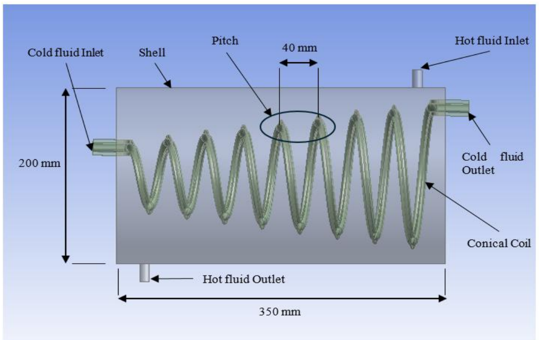


Figure 1 Design 1 – simple conical coil (shell and conical coil heat exchanger with simple coil) [4]



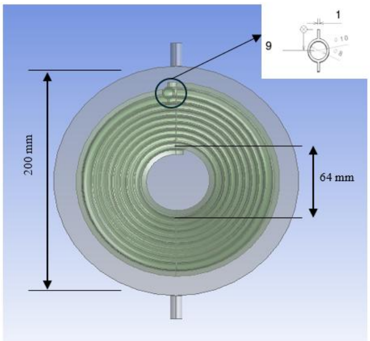
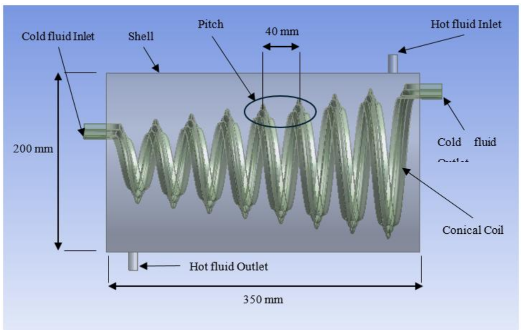


Figure 2 Design 2 – 2 fins in conical coil (shell and conical coil heat exchanger with 2 fins in conical coil outer surface)



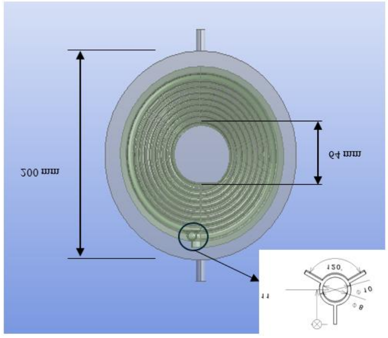


Figure 3 Design 3 – 3 fins in conical coil (shell and conical coil heat exchanger with 3 fins in conical coil outer surface)

Mesh generation

Meshes are made to discretise the physical domain into smaller subdomains (elements) in order to make it easier to compute the PDEs ("partial differential equations") that govern the physical characteristics of fluid flow. The element has triangular forms and measures 90 mm for the shell domain and 100 mm for the other. In all of the computational models under investigation, this process constitutes a significant number of elements and nodes (for more information, see table 3). Figure 4 displays the computational model created from the mesh.

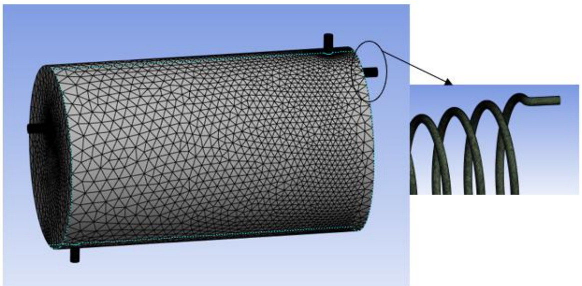


Figure 4 Mesh representation in shell and conical coil heat exchanger

Table 3 Mesh details

Design	Elements	Nodes
Design1 – simple coil	2626589	539491
Design 2 = 2 fins conical coil	3203569	696958
Design – 3 fins conical coil	3409466	767001

Numerical condition

"The finite volume method (FVM)"-based commercial CFD code was used in the mathematical calculations. For the steady-state situation, the analysis was used. Both coil and shell sections' fluid flow regime was regarded as turbulence, and the turbulence model used is k-ε. Water makes up the HTF on the hot side (shell) and the one on the cold side (conical coil). To run the simulation, ANSYS FLUENT 23 is used. The equations for "mass, momentum, and energy conservation" are discretised in the second-order upwind method. The connection of pressure and velocity is provided by the SIMPLE approach. Every gradient is assessed employing the Green-Gauss cell-based technique. The 10− 6 convergence criterion is used to each equation's residuals.

Boundary condition

In the shell and cone shape coil tube heat exchanger the working fluid as water is flowing in both the shell and cone shape tube. Cold water flow in the cone shape coil tube with inlet velocity of 1.4 m/s and 1.0 m/s and inlet temperature of 309 K. Hot water flow in the shell with inlet velocity and temperature of 0.19 m/s, and 325 K respectively. The conical coil allows cold water to flow in the opposite direction as the shell. The fluid flow is incompressible for both shell and cone shape coil tube. The system was considered well-insulated, with no environmental heat loss. The thermos-physical properties of working fluid (water) is mention is table 4. Boundary condition is mention is table 5 for shell and cone shape coil.

Table 4 Thermo-physical properties of water (working fluid)

Properties	Unit	Water	Coil
Density	$(kg.m^{-3})$	998.2	8978
Specific heat	$(J.kg^{-1}.K^{-1})$	4.182	381.0
Thermal conductivity	$(W.m^{-1}.K^{-1})$	0.6	387.6
Viscosity	$(Pa.s)$	0.001003	-

Table 5 Boundary condition

Parameter	Unit	Value
Cold water inlet velocity	m/s	1.4 and 1.0
Cold water inlet temperature	K	309
Hot water inlet velocity	m/s	0.19
Hot water inlet temperature	K	325
Turbulence model		k-ε (standard)

Case description

The study focused on enhancing the heat transfer in the shell and conical coil heat exchanger. To address this issue modified the conical coil by attaching the fins in the outer surface of the conical coil. After that consider the variation in the inlet velocity of cold water (fluid). Table 6 illustrate the scenarios consider for this study.

Table 6 Various cases description

Cases notation	Design of shell and conical coil heat exchanger	Inlet velocity of cold water
Case 1	Design 1 – simple conical coil	1.4 m/s
Case 2	Design 2 – 2 fins attach in the conical coil	1.4 m/s
Case 3	Design 3 – 3 fins attach in the conical coil	1.4 m/s
Case 4	Design 2 – 2 fins attach in the conical coil	1.0 m/s
Case 5	Design 3 – 3 fins attach in the conical coil	1.0 m/s

Validation

It is crucial to compare "the geometry and boundary conditions" with earlier studies in order to guarantee the numerical model's correctness. An 8-degree cone-shaped tube was used to construct "the shell and conical coil heat exchanger's" geometry. The conical coil measures 200 mm in diameter with an outside diameter of 10 mm, a pitch of 40 mm, and an internal diameter of 8 mm. For the simulation, hot water flows inside the shell at 325 K, and cold water flows inside the conical coil at 309 K. The inlet velocities of cold and hot water are 1.4 m/s and 0.19 m/s, respectively. The validation process involved comparing the present simulated results with the results of Hashemi Karouei et al. (2024) [4]. The boundary conditions and geometric parameters were applied consistently to ensure reliability. Analysing the temperature contours of the "conical coil heat exchanger" and the shell revealed a high degree of consistency between the two datasets. A comparison of the friction factors from the current simulation and the previous study showed negligible differences, confirming the accuracy of the computational model. These findings support the study's numerical methodology and provide assurance that it can reliably forecast "the shell and conical coil heat exchangers" heat transfer properties in comparable circumstances. This validation ensures that subsequent simulations and analyses can be conducted with reliability.

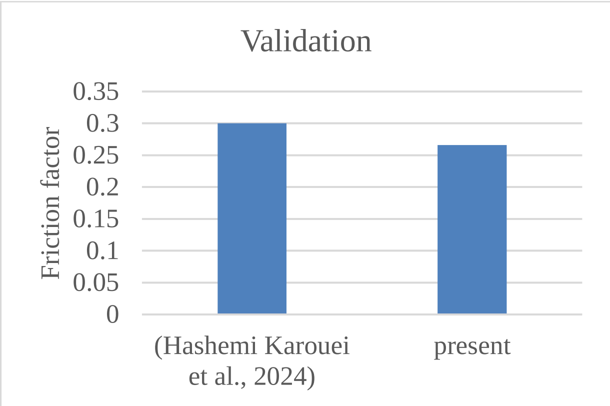
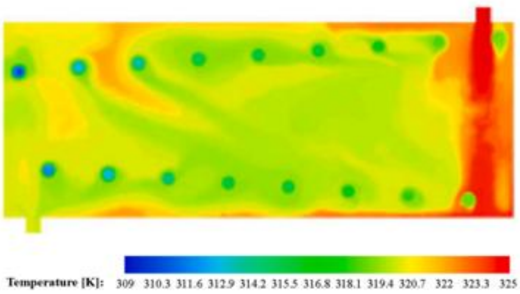
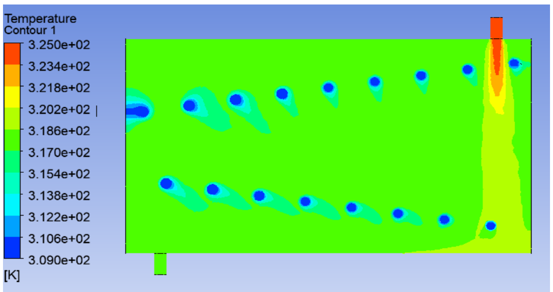


Figure 5 Validation graph



(a) Temperature contour of [4]



(b) Temperature contour of present simulation

Figure 6 Temperature contour validation

RESULT AND DISCUSSION

Temperature contour

The hot water and cold water temperature contours at "the shell and conical coil heat exchanger's" midsection are shown in Figures 7. These cases analyze the heat transfer mechanism under varying conditions. Cases 1 to 3 involve a cold water inlet velocity of 1.4 m/s, while Cases 4 and 5 reduce the cold water inlet velocity to 1.0 m/s. Both the hot and cold water have input temperatures of 325 K and 309 K, respectively. Heat transfer occurs as the hot water inside the shell transfers thermal energy to the cold water flowing through the conical coil, driven by the temperature gradient between the two fluids.

Because the conical coil's outer surface has a smaller heat transfer surface area, the heat transmission in Case 1 (Figure 7) is constrained. To enhance heat transfer, fins are introduced in subsequent cases. The surface area accessible for heat exchange is increased in Case 2 by attaching two fins to the outside surface of the conical coil at 180° intervals. By arranging the fins in this way, the hot water may be more efficiently transferred to the cold water via convective heat transfer. In Case 3, three fins are attached at 120° intervals, further enhancing the heat transfer compared to Case 1, as the additional fins provide more contact area for heat exchange.

Cases 4 and 5 explore the effect of reducing the cold water inlet velocity to 1.0 m/s. The lower velocity allows the cold water to remain in the conical coil for a longer duration, increasing the contact time with the hot water. The cold water's exit temperature rises as a result of improved convective heat transfer. The fluids are able to transmit heat to one another by convection, which happens when the layers of fluid are in motion, and conduction, which happens when heat is transferred over the fins and coil wall. This energy exchange is driven by the temperature differential between cold and hot water, which is consistent with the second rule of thermodynamics, which says that heat moves from a hotter area to a colder one.

The temperature differential between the two fluids controls the heat transmission between hot and cold water, which mostly happens via conduction and convection. The hot water in the shell transfers energy to the outer surface of the conical coil through convection, driven by fluid motion. Convection carries this energy to the inner layer of the coil, from whence it is transmitted to the cold water passing through the coil. By increasing the surface area (e.g., by adding fins) and reducing the cold water velocity, the contact area and time for heat exchange are maximized, leading to improved thermal performance.

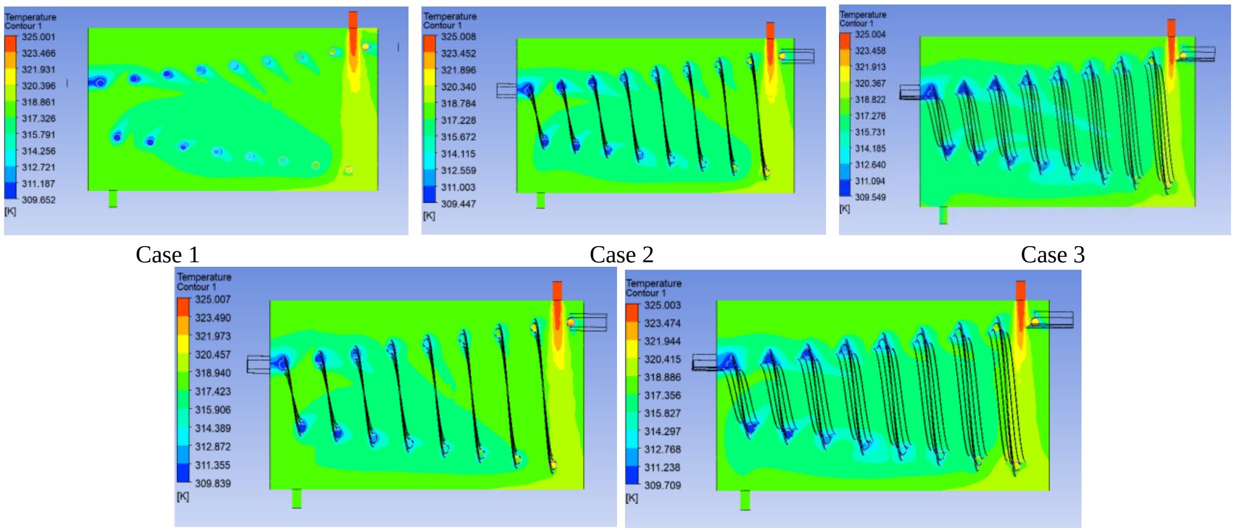


Figure 7 Temperature contour in all cases

Outlet temperature

To demonstrate how "the conical coil heat exchanger's" thermal performance is affected by variations in cold water velocity and the addition of fins, Figures 8 & 9 compare the temperatures of the hot and cold water that exits the heat exchanger in each scenario. The findings show that when fins are attached, the temperature of the hot water leaves the system rises and the temperature of the cold water leaves the system drops. Additionally, reducing the cold water velocity further affects the heat transfer process, leading to variations in the outlet temperatures of both fluids.

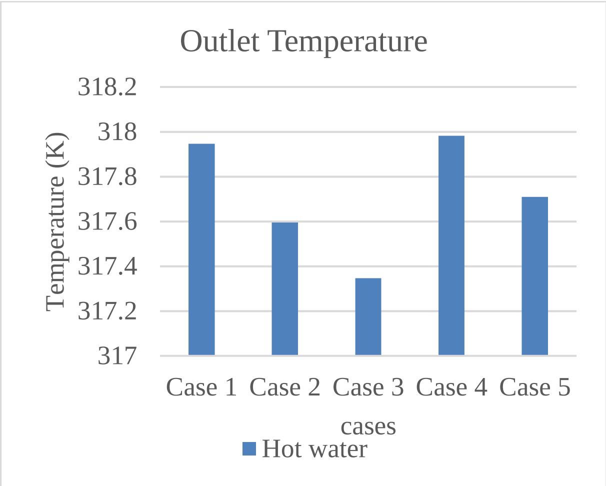
Cases 2 and 3 include fins that are connected to the conical coil's outside, therefore increasing the surface area available for heat transmission. Better conduction of heat from hot to cold water is made possible by the larger surface area. As a result, the outlet temperature of the hot water decreases, while the outlet temperature of the cold water rises. For example, in Case 3, which has three fins, the heat transfer is more effective compared to Case 2, which has two fins. Since more heat is transmitted to the cold water, this causes the hot water to exit at the lowest possible temperature in Case 3.

When the cold water velocity is reduced in Cases 4 and 5, the cold water spends more time inside the conical coil. This longer residence period raises the cold water's output temperature by allowing it to retain additional heat from the hot water. At the same time, the slower velocity reduces turbulence, which may slightly reduce the convective heat transfer rate. However, the overall extended contact time compensates for this, resulting in better heat absorption.

Interestingly, the outlet temperature of hot water in Cases 4 and 5 is slightly higher compared to Cases 2 and 3, even though the cold water velocity is lower. This is due to the fact that, even though the residence period is longer, the rate of heat extraction from the hot water is lowered due to the lower velocity of the cold water. As a result, less heat is transferred per unit time, leaving the hot water outlet temperature relatively higher than in Cases 2 and 3.

In both velocity conditions (1.4 m/s and 1.0 m/s), Case 5 exhibits the highest outlet temperature for cold water because it combines the effects of reduced velocity and enhanced heat transfer due to the fins. Case 3, on the other hand, gets hot water out at the lowest possible temperature because to its three fins' increased surface area and improved thermal conductivity, which maximise the heat transfer rate.

These variations highlight the interplay between flow velocity, heat transfer surface area, and thermal efficiency. While attaching fins enhances heat transfer, reducing cold water velocity allows for better heat absorption. In any case, the heat exchanger's thermal performance is dictated by the equilibrium of these parameters.



"Figure 8 Outlet temperature of hot water in all cases

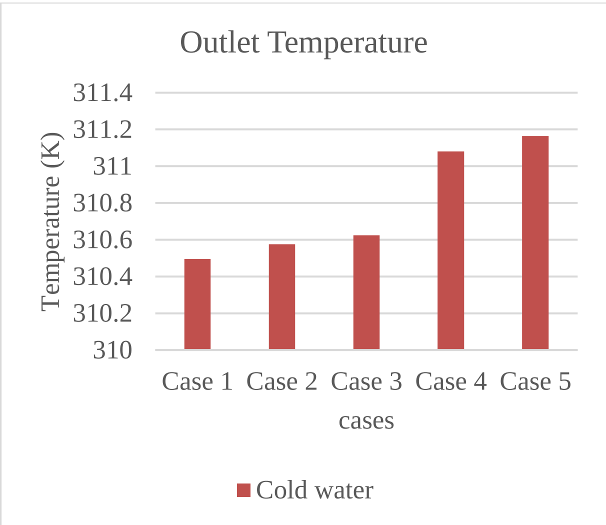


Figure 9 Outlet temperature of cold water in all cases"

Pressure contour

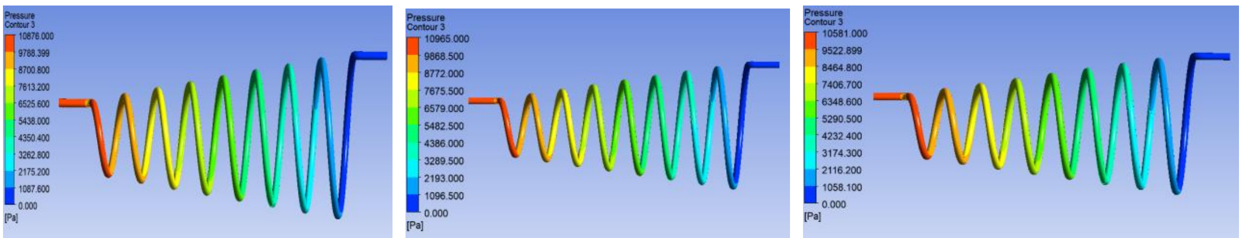
Figure 10 illustrate the pressure contours on the outer surface of the cold water domain for all cases, highlighting the variations in pressure caused by changes in geometry, surface area, and flow velocities. The results demonstrate that attaching fins and reducing the cold water velocity significantly influence the maximum pressure and pressure drop in both cold water and hot water domains.

Without fins and at a speed of 1.4 m/s, the cold water pressure in Case 1 may reach a maximum of 10,878 Pa. When two fins are added in Case 2, the surface area increases, enhancing heat transfer but also creating additional resistance to flow, resulting in a slightly higher maximum pressure of 10,965 Pa. However, in Case 3, attaching three fins improves flow uniformity by distributing the flow more evenly along the surface. This reduces turbulence and lowers the maximum pressure to 10,581 Pa, despite the increased surface area.

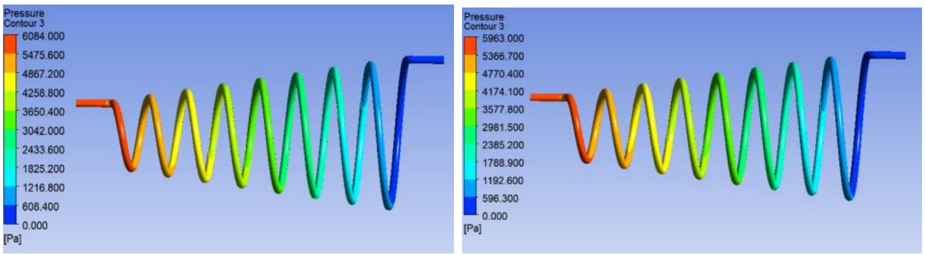
In Cases 4 and 5, where the cold water velocity is reduced to 1.0 m/s, the maximum pressure in the cold water decreases significantly to 6,084 Pa and 5,963 Pa, respectively. The reduction in velocity minimizes the dynamic pressure and the frictional resistance along the coil surface, leading to lower overall pressure levels.

Figure 11 highlight the average pressure drop in the cold and hot water domains, respectively. In the cold water domain, Case 5 exhibits the lowest pressure drop of 5,796.87 Pa due to the lower velocity, which reduces frictional and form drag along the conical coil's surface. Conversely, in the hot water domain, Case 3 has the lowest pressure drop of 38.41 Pa. This occurs because the addition of three fins in Case 3 creates a more uniform heat transfer and smoother flow distribution, reducing disturbances in the hot water domain.

Changes in geometry and flow conditions have a direct correlation to the fluctuation of pressure drop. Higher cold water velocities and fewer fins lead to greater turbulence and pressure drop, while lower velocities and optimized fin placement reduce flow resistance, promoting smoother and more efficient fluid motion. These results underscore the importance of balancing heat transfer performance with flow dynamics to achieve optimal heat exchanger design.



Case 1 Case 2 Case 3



Case 4 Case 5

Figure 10 Pressure contour in all cases

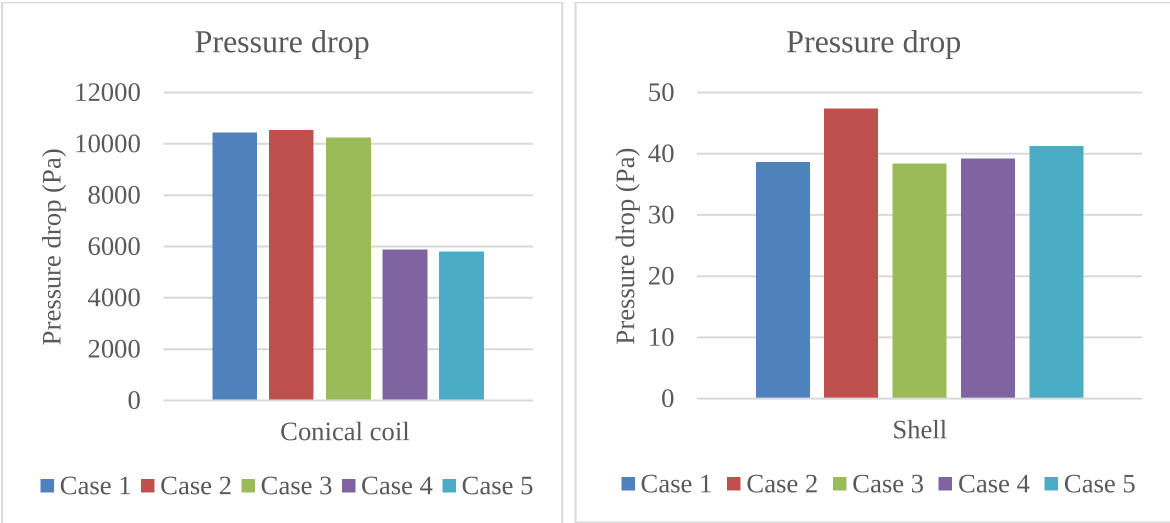


Figure 11 Pressure drop in Conical coil (Cold water) and shell (Hot water)"

Velocity streamline

Figure 12 depict the velocity behavior of cold and hot water in all cases, showing the impact of geometry modifications and flow velocities on the maximum velocity. At the conical coil's bends, especially at its two ends where the fluid flow changes directions, the maximum velocity is clearly seen. These regions experience higher velocity due to the curvature of the coil and the corresponding acceleration caused by the centrifugal forces acting on the flowing fluid.

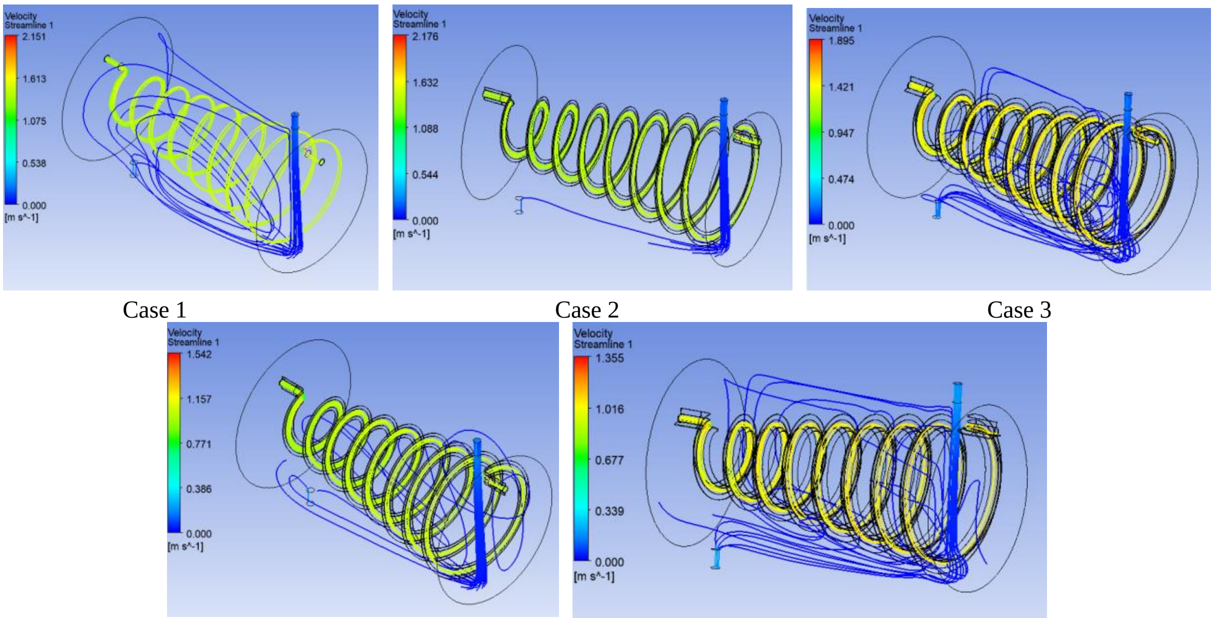
In Case 1, the conical coil has no fins, and the cold water inlet velocity is set at 1.4 m/s. At the coil's bends, the maximum velocity is 2.151 m/s, which is quite high due to the absence of extra resistance. In Case 2, where two fins are added, the increased surface area slightly enhances the resistance to flow, resulting in a marginal increase in flow velocity to 2.176 m/s at the bends as the water is forced to navigate around the added fins, creating localized flow acceleration.

In Case 3, three fins are attached, which distribute the flow more uniformly and reduce the turbulence near the coil's surface. This results in a reduction in maximum velocity to 1.895 m/s. The improved distribution ensures smoother flow around the coil, lowering peak velocities despite the additional surface area.

In Cases 4 and 5, the cold water inlet velocity is reduced to 1.0 m/s, significantly lowering the overall velocity throughout the system. In these cases, the maximum velocities at the bends are 1.542 m/s and 1.355 m/s, respectively. The reduced inlet velocity decreases the energy available to accelerate the water at the bends, minimizing the impact of centrifugal forces and resistance caused by the coil's geometry and the fins.

The hot water in the shell exhibits a more uniform velocity profile due to the relatively low inlet velocity (0.19 m/s) and the larger cross-sectional area of the shell, which promotes a steady flow. The variations in velocity within the hot water domain are minimal compared to the cold water domain and are primarily influenced by the heat exchanger's geometry and the arrangement of fins, which create minor flow disturbances.

Overall, the variation in maximum velocity across cases is influenced by the combination of inlet velocity, flow resistance introduced by fins, and the geometric constraints of the conical coil. Higher inlet velocities and fewer fins lead to higher peak velocities, while reduced velocities and optimized fin configurations result in smoother flow and lower maximum velocities. These findings highlight the trade-offs between flow dynamics and heat transfer performance in designing efficient heat exchangers.



Case 1 Case 2 Case 3

Case 4 Case 5

Figure 12 Velocity streamline in all cases

Rate of heat transfer

To demonstrate how fins and entrance velocities of cold water affect thermal performance, Figure 13 shows the rates of heat transfer for all situations. In order to increase "the rate of heat transfer", the data shows that fins attached to the conical coil's outside surface greatly increase the area that is used for heat exchange. This improvement occurs because the fins provide more surface for heat conduction and enhance the interaction between the cold water and the hot water, thereby facilitating greater thermal energy transfer.

Among the cases, Case 3 exhibits the highest rate of heat transfer, reaching a peak value of 0.47 W. The reason for this is because the conical coil is equipped with three fins that are set at 120 degrees apart. This arrangement maximises the surface area available for heat transmission. Improved convection and more consistent heat distribution are the results of Case 3's configured, which allows for more effective energy transfer between the hot and cold water.

But in Cases 4 and 5, the heat transfer rate drops because the cold water entry velocity is lower. Although reducing the cold water velocity increases its residence time within the conical coil, it also decreases turbulence, which is essential for enhancing convective heat transfer. Despite longer contact times, the total rate of heat transfer is lower when turbulence levels are low because the "convective heat transfer coefficient" is lower.

The results indicate a trade-off between velocity and thermal performance. The rate of heat transfer is improved and turbulence is increased when the cold water velocities are greater, as shown in Cases 2 and 3. On the other hand, reduced velocities (as in Cases 4 and 5) limit turbulence, which negatively impacts heat transfer efficiency, even though the cold water has more time to absorb heat.

Case 3's optimal fin design makes it the most effective, however adding fins generally increases the heat transfer rate. The heat transfer rate drops as the entrance velocity of cold water drops, highlighting the need to optimise the conical coil heat exchanger's performance by balancing the flow dynamics with fin design.

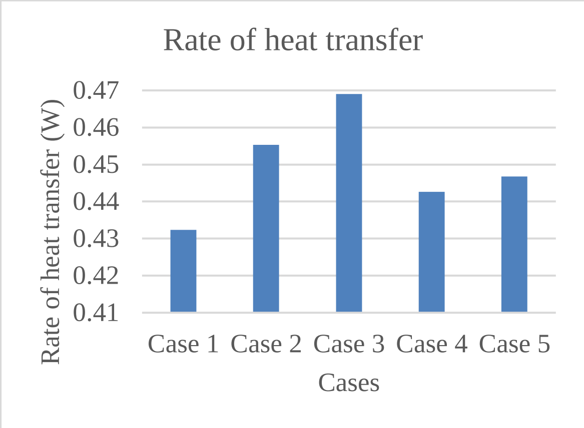


Figure 13 Rate of heat transfer in all cases

CONCLUSION

In this computational study, the impacts of con-shape coil tube attachments 2, and 3 to the outside surface of "a shell-and-coil heat exchanger" were investigated. The numerical computations were carried out using a commercial CFD tool that depends on the "finite volume approach". Two parts make up this task. In the first section, we reviewed three distinct coil configurations: the basic coil, the cone-shaped coil with two fins, and the cone-shaped coil with three fins. Part two looked at how two different velocities—1.4 m/s and 1.0 m/s—of cold water in a shell and a cone-shaped coil heat exchanger with two fins and three fins on the outside of the coil, respectively, affected the heat transfer. What follows are the numerical findings that were obtained.

- By attaching the fins in the outer surface of the cone coil increases the heat transfer.
- Case 3 and case 5 show the better result in terms of rate of heat transfer.
- Outlet temperature of 317.35 K of hot water is minimum in case 3, and in this case outlet temperature of 310.62 K of cold water.
- Case 5 shows the maximum cold water outlet temperature of 311.17 K and hot water outlet temperature of 317.71 K.
- Rate of heat transfer in case 3, and case 5 is 0.47 W and 0.45 W respectively.

FUTURE SCOPE

The future scope of enhancing the performance of shell and cone coil heat exchangers lies in exploring innovative design modifications and advanced materials. Changing the cone coil material to high thermal conductivity alloys or composite materials can significantly improve heat transfer efficiency. Altering the coil configuration, such as varying the cone angle, pitch, or diameter, can optimize flow dynamics and heat exchange. Investigating the impact of different working fluid velocities can help identify optimal operating conditions. Incorporating nanoparticles into the working fluid can enhance its thermal conductivity, leading to improved heat transfer rates. Attaching fins of varying shapes (e.g., rectangular, triangular, or curved) on the outer surface of the cone coil can increase the heat transfer surface area and efficiency. Adding baffles in the shell can redirect the flow, improve turbulence, and enhance overall heat transfer performance. These advancements offer promising opportunities to further optimize shell and cone coil heat exchangers for diverse industrial applications.

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