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An Investigation on Concurrent and Countercurrent Heat Transfer Performance in a Double Pipe Helical Coil Heat Exchanger Using CFD

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Abstract – Traditional heat exchangers present a significant space constraint in industrial settings. This research investigates the potential of double-tube helical coils as a compact and efficient alternative. Helical coils offer a larger heat transfer area due to their twisted design, making them ideal for applications in food processing, power generation, and beyond. Computational Fluid Dynamics (CFD) software is employed to analyse fluid flow within the inner and outer tubes. Copper, known for its excellent heat conductivity, is chosen as the material for both tubes. Water, a readily available coolant, will flow through the innertube. By leveraging the capabilities of ANSYS Fluent, the total heat transfer emanating from the exchanger walls will be comprehensively analysed. This research aims to optimize the performance of double-tube helical coils. And compare the results obtained in both software and an experimental setup of the same. By investigating different flow arrangements, we seek to unlock greater efficiency in industrial heat transfer, paving the way for a more sustainable future.

***Key Words*:** Mesh. Boolean, Wire frame view, Thermocouple, Logarithmic Mean temperature Difference (LMTD), HVAC (Heating, Ventilation and Air Conditioning).

1.INTRODUCTION

A heat exchanger is a device that facilitates the transfer of thermal energy between two or more fluids, within them mixing together. They are vital components in various industries for heating, ventilation, air conditioning (HVAC), refrigeration, power generation, chemical processing, and many other applications. Heat exchangers work on the fundamental principle of thermodynamics that dictates heat transfer from a high-temperature (hot fluid) to a low temperature (cold fluid). This design of heat exchangers maximizes the surface area for efficient heat transfer between the fluids. They also promote turbulence within the fluids for better contact. Heat transfer in exchangers occurs through conduction, convection, or radiation, or a combination of these.

The comparison between both experimental analysis and simulation analysis depicts the desired outcomes.

2. LITERATURE REVIEW

Helical Coil Heat Exchangers (HCHEs) have gained significant interest in HVAC applications due to their potential for improved heat transfer compared to traditional straight tube heat exchangers. Research has attributed this enhancement to secondary flows induced by centrifugal forces within the curved tubes of HCHEs. These secondary flows promote better mixing of the fluids, leading to increased heat transfer between the fluid and the tube wall. Studies have explored various parameters influencing HCHE performance, including curvature ratio, mass flow rate, coil geometry and meshing strategies in CFD simulations. For instance, investigation showed that an increase in curvature ratio and coil pitch lead to augmented heat transfer.

In conclusion, HCHEs offer a promising technology for enhancing heat transfer in HVAC systems. Their ability to generate secondary flows through curved tubes promotes better mixing and heat transfer, leading to improved system performance. Further research on optimizing HCHE design and CFD simulation techniques can contribute to significant advancements in energy efficiency and overall system performance in HVAC applications.

3. METHODOLOGY

Experimental Analysis:

Experimental Setup

Double helical coil heat exchangers prove to be a game changer for space constraint applications like airplanes and spacecraft their compact design achieved through the use of helical coils that promote efficient mixing of fluids surpasses the capabilities of traditional stride tube exchangers this study explored the effectiveness of this design by comparing the performance of a double helical coil heat exchanger in both concurrent and countercurrent flow configurations using antis simulation software the simulations were then validated against data from a physical experiment conforming the accuracy of the simulations and highlighting the potential for further optimization of this promising heat exchanger technology.

The experimental procedure follows the given below steps:

1. Power on the unit start cold water flow and set the exchanger to parallel flow activate the heater and direct hot water through the outer tubes.

2. Adjust flow rates for both hot and cold-water measure flow rates using jars and wait for study state.

3. Record hot or cold-water inlet or outlet temperatures and flow rates.

4. Repeat for different flow rates and hot water inlet temperature switch to counter flow configuration.

Dimensions

Helical Coil Dimensions	
Height	150mm
Mean diameter of coil	100mm
Inner diameter of inner pipe	6.3mm
Outer diameter of inner pipe	7.3mm
Inner diameter of outer pipe	12.7mm
Outer diameter of outer pipe	13.7mm
Thickness of each pipe	1mm
Number of turns	10

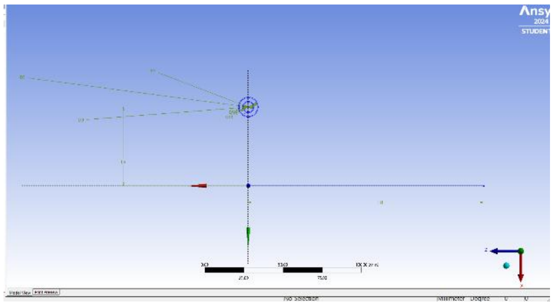
Simulation Work:

The design and simulation of a double helical coil heat exchanger involves crucial step designing the coil itself. This process defines key dimensions like pipe diameter, spacing contents, which influence the overall geometry. 2D sketches are created on separate planes to define the pipe's core section, followed by excluding the profile to generate the basic helical coil. Side pipes are then created and merged with the coil using Boolean operations.

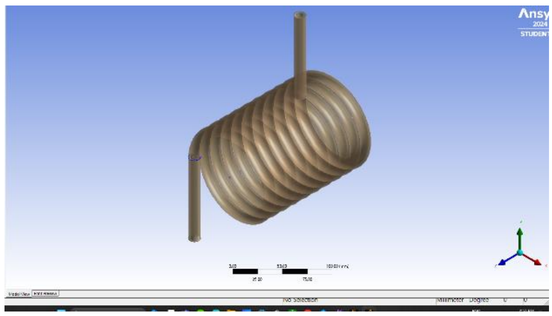
Finally, the design is named saved and updated mesh generation comes next the coil geometry is divided into smaller elements for numerical calculations. This starts with a course mesh to inspect for gaps followed by defining specific regions or refinement. Mesh element size and type are specified considering factors like complexity and accuracy. Once generated, the missed quality is evaluated for element ratios, skewness and orthogonal quality. Upon satisfaction, the mess is updated for further analysis.

Mesh Details

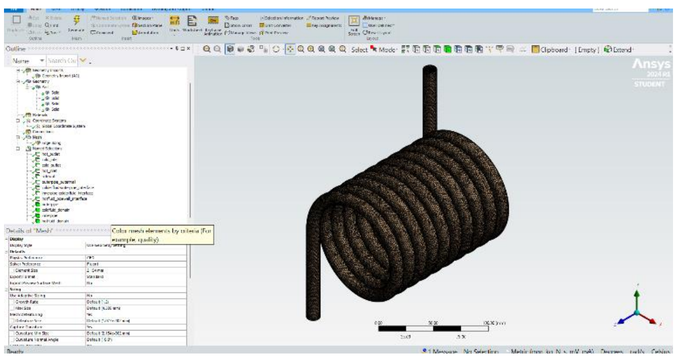
MESH DETAILS		
SL NO	Parameter	Ansys Fluent
1	Global Size Mesh	2.154mm
2	Surface Mesh Size	2.154mm
3	Curve Mesh Size	2.154mm
4	Mesh Type	Tetra-Hedral
5	Mesh Quality	Standard



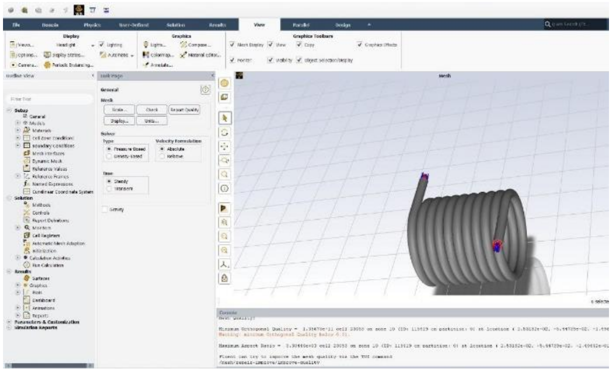
2D profile



Double Helical Coil



Meshing



Setup

4. RESULTS

Experimental Results:

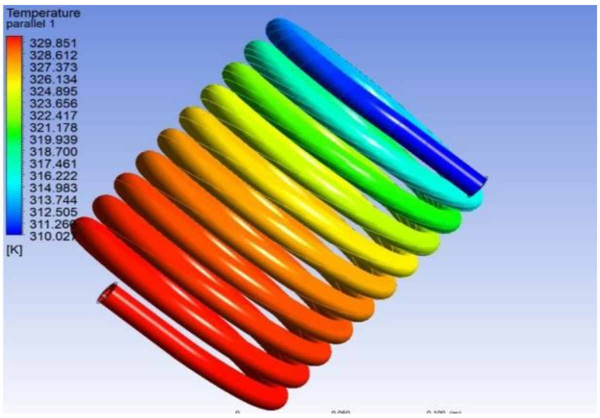
Flow rate in kg/s

Arrangement	Hot Water Flow Rate	Cold Water Flow Rate
Parallel Flow	0.0113	0.03
Counter Flow	0.04	0.03

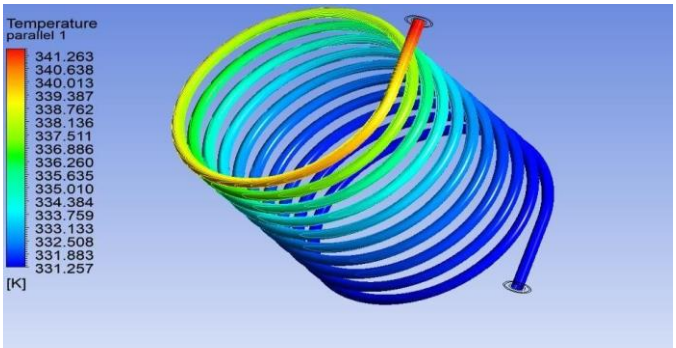
Temperatures

Arrangement	Temperature of Cold Water in K		Temperature of Hot Water in K	
	Inlet	Outlet	Inlet	Outlet
Parallel Flow	314	335	343	336
Counter Flow	311	326	330	316

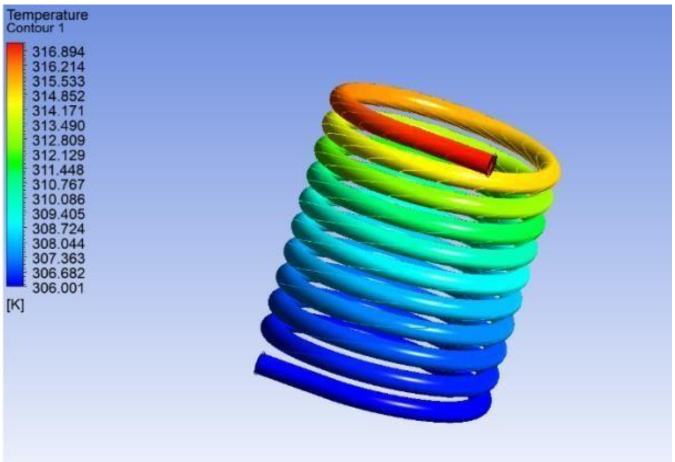
Simulation Results:



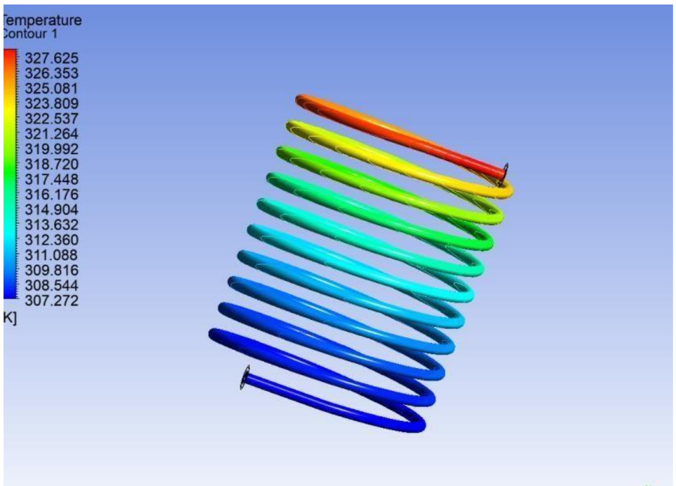
Cold Fluid interface (parallel flow)



Hot Fluid Interface (parallel flow)



Cold Fluid Interface (counter flow)



Hot Fluid Interface (counter flow)

Temperature

Arrangement	Temperature of Cold Water in K		Temperature of Hot Water in	
	Inlet	Outlet	Inlet	Outlet
Parallel Flow	310	330	341	331
Counter Flow	316	332	327	307

5. CONCLUSIONS

The study employed answers fluent, a computational fluid dynamics software package to analyze the heat transfer performance of a helical coil double pipe heat exchanger. These results were then compared with those obtained for a parallel flow configuration. The CFD simulations were validated against experimental data for various sources demonstrating good agreement within acceptable error limits. The analysis revealed a strong correlation between the simulation, results and the experimental data. In particular, we observed a constant cold water flow rate increasing the heat transfer rate.

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