

# Modeling and computational fluid dynamic analysis of twisted pipe heat exchanger

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## Abstract

When two or more fluids, a solid surface, or solid particles are in thermal contact with one another and have different temperatures, a heat exchanger may be used to transfer the enthalpy of the heat between the two or more media. Interactions between external heat and work are often absent in heat exchangers. Common uses include controlling the temperature of a fluid stream, preventing the evaporation or condensation of streams containing one or more components, and so forth. To improve the object's performance and heat transfer rate coefficient, this thesis models twisted tube heat exchangers using Solid Works and analyses them using static and computational fluid dynamics (CFD) boundary conditions. We employed nanoparticles, combined them with water in varying quantities, and then measured their effects on variables like pressure and

values for the input and exit temperatures (cold and hot), as well as the velocity and temperature parameters. The thesis concludes with the optimal mixing of nanoparticles to optimise performance, based on all these data.

## 1. Introduction

### HEAT EXCHANGERS

When two or more fluids, a solid surface, or solid particles are in thermal contact with one another and have different temperatures, a heat exchanger may be used to transfer the enthalpy of the heat between the two or more media. Interactions between external heat and work are often absent in heat exchangers. Common uses include controlling the temperature of a fluid stream, preventing the evaporation or condensation of streams containing one or more components, and so forth. The goal may be to sterilise, pasteurise, fractionate, distil, or recover or reject heat in other applications.

to direct the flow of a process fluid, crystallise it, or concentrate it. The fluids that transfer heat are in close proximity to one another in some heat exchangers. Fluids often undergo transitory heat

transfer into and out of a wall or via a dividing wall in most heat exchangers. Ideally, the fluids in a heat exchanger would not mix or leak; instead, they would be separated by a heat transfer surface. Direct transfer type, or just recuperate, describes these exchangers. On the other hand, regenerators or indirect transfer types of heat exchangers include the intermittent transfer of heat from hot to cold fluids via the storage and release of thermal energy through the exchanger's surface or matrix. Pressure divergences and matrix rotation/valve switching are common causes of fluid leakage in these exchangers. Cooling towers, air preheaters, evaporators, condensers, and shell-and-tube exchangers are some common types of heat exchangers. An example of a sensible heat exchanger would be one in which no fluid undergoes a phase transition. Similar to electric heaters and nuclear fuel components, the exchangers might include internal thermal energy sources.

## Zno Nanoparticles

Nanoparticles of zinc oxide (ZnO) are those with sizes less than 100 nanometers. Their strong catalytic activity and vast surface area make them ideal catalysts.

Various methods of synthesis determine the precise chemical and physical characteristics of zinc oxide nanoparticles. Laser ablation, electrochemical depositions, hydrothermal methods, sol-gel methods, thermal vapour deposition, combustion methods, ultrasound, microwave-assisted combustion method, two-step mechanochemical-thermal synthesis, anodization, co-precipitation, electrophoretic deposition, and precipitation processes utilising solution concentration, pH, and washing medium are some of the possible ways to produce ZnO nanoparticles. An energy gap of 3.37 eV is present in ZnO at ambient temperature, making it a wide-bandgap semiconductor.

## TWISTED PIPE HEAT EXCHANGER

### Heat transfer enhancement techniques

- One of the most dynamic subfields of heat transfer technology is heat transfer enhancement, which encompasses both active and passive methods for boosting heat transfer efficiency.
- A twisted tube is a common passive method that employs a certain design to create a swirl in the flow along the tube's sides.

Without baffles, the twisted tube heat exchanger is constructed of a bundle of tubes that are uniquely fashioned.

- A tubular heat exchanger with twisted tubes has the maximum attainable heat transfer coefficient.

Optimal turbulence and minimal pressure drop are achieved in uniform shell side flow by use of complicated interrupted swirl flow on the shell side.

- Turbulence, produced by swirl movement in a tube, enhances heat transmission. Achieving a high heat transfer performance is achieved by maintaining a turbulent flow.

### Literature Review

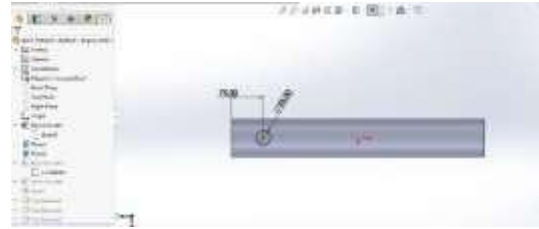
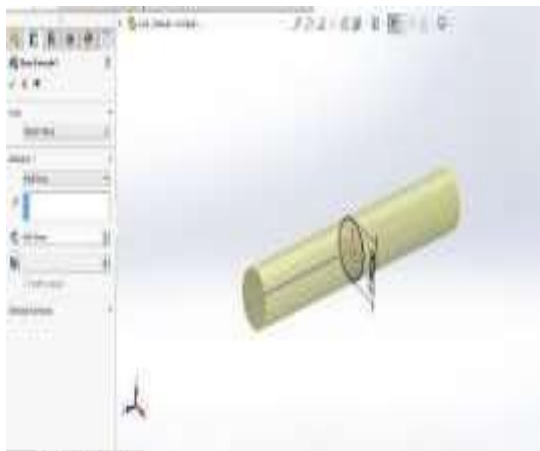
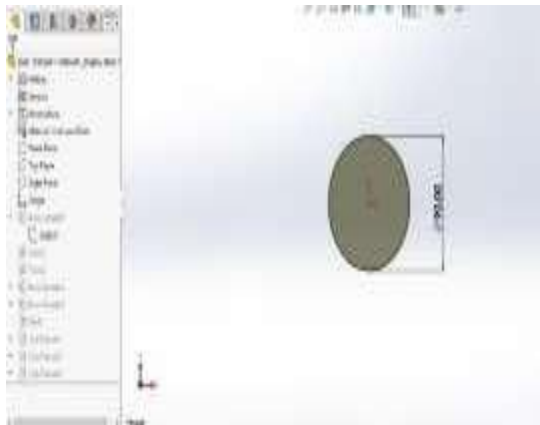
A great deal of research on passive heat transfer has made use of different insert and tube geometries. Here are the results of numerous researchers' investigations:

An experiment was carried out by Li Zhang, Sheng Yang, and colleagues [1] to examine the features of steam condensation heat transfer on horizontal twisted elliptical tubes (TETs) with varying geometrical parameters. At the steam saturation temperature of about 100.5 °C and with the wall subcooling ranging from approximately 2 °C to 14 °C, five distinct transverse experimental tubes (TETs) with varying structural properties were evaluated. The heat transfer coefficients for condensation are greater in a smooth round tube than in any of the TETs that were examined. The five TETs, numbered from 1 to 5, have enhancement factors ranging from 0.87 to 1.34. As the ellipticity of the tubes increases, so do the steam condensation heat transfer coefficients on the TETs. The TET No. 3 had the greatest condensation improvement of around 34% and the maximum ellipticity of 0.86. A decreased twist pitch resulted in a lower condensation heat transfer coefficient. Using a variety of structural factors, Sheng Yang, Hong Xu, and colleagues [2] conducted experimental investigations on the heat transfer and flow resistance properties of water flow inside twisted elliptical tubes (TETs). Impacts of structural factors of tubes (twist and aspect ratio)

(pitch) on how well TETs worked were examined. Both a lower twist pitch ( $S$ ) and a bigger tube aspect ratio ( $A/B$ ) improve the heat transfer performance, according to the experimental data.

When compared to the impact of tube aspect ratio on heat transfer performance, twist pitch stands out. A twisted oval tube heat exchanger's pressure drop, heat transfer, and shell-side and tube-side performance were experimentally evaluated by Xiang-hui Tan, Dong-sheng Zhu, and colleagues [3]. According to the results of the experiments, compared to a smooth round tube, a twisted oval tube has a larger pressure drop and heat transfer coefficient along its side. An analysis of the data reveals that twisted oval tube heat exchangers perform best when the shell flow rate is high and the tube flow rate is low.

**Designing process step by step**



**Static analysis results**

**Material selection**

**Steel**

Young's modulus: -  $2.0 \times 10^{11}$  Pa

Poisson ratio: 0.29

Density:  $7850 \text{ Kg/m}^3$

Yield strength: 250 Mpa

Thermal conductivity:  $60.5 \text{ w/m-k}$

**Steel-440C**

Young's modulus:-  $1.988 \times 10^{11}$  Pa

Poisson ratio:0.228

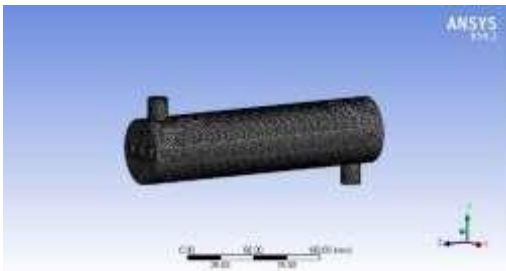
Density: 7800Kg/m<sup>3</sup>

Yield strength: 450 Mpa

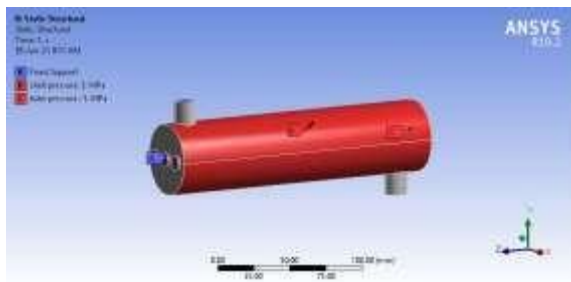
Thermal conductivity:24.2 w/m-k

### Meshing

After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.



### Boundary conditions



Static structural → supports → fixed support → inlet and outlet areas

Pressure → 3Mpa

After completion of boundary conditions here we have to check results by solving. Just click on solve option and select results like deformation, strain, stress and safety factor values for the object.

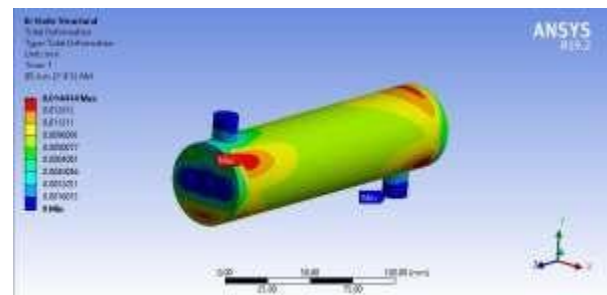
Solution → solve → deformation

Solution → solve → safety factor

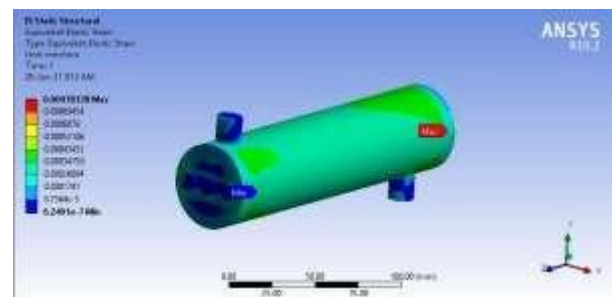
Solution → solve → stress

### Steel

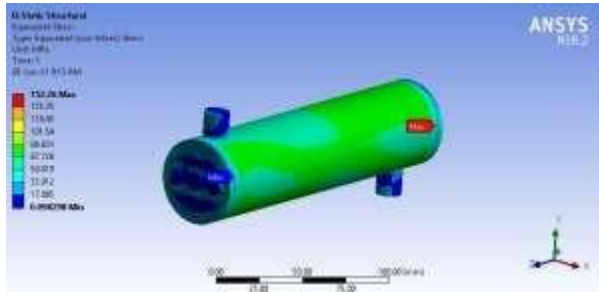
### Deformation



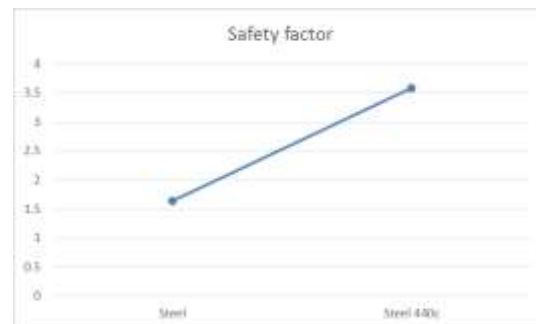
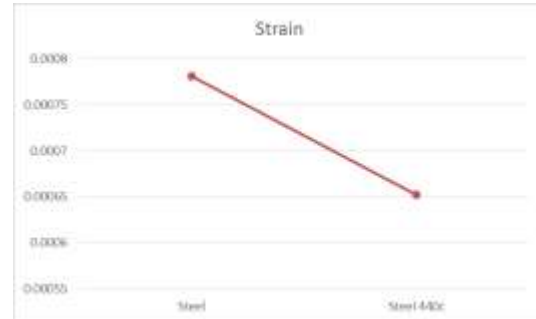
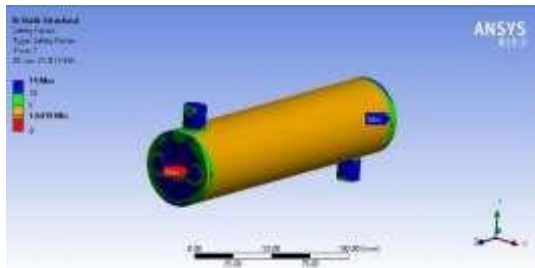
### Strain



### Stress



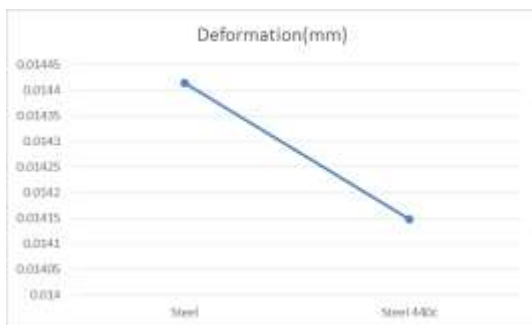
**Safety factor**



**Tables**

	Steel	Steel 440c
Deformation(mm)	0.014414	0.014148
Stress (Mpa)	152.26	125.56
Strain	0.00078128	0.00065197
Safety factor	1.6419	3.5841

**Graphs**



**Fluent analysis results**

**Water**

Density: 998.2 kg/m<sup>3</sup>

Specific heat: 4182 j/kg-k

Thermal conductivity: 0.6 w/m-k Viscosity:

0.001003 kg/m-s

**Water+ZNO0.1% Nano particles**

Density: 2052.42 kg/m<sup>3</sup>

Specific heat: 6354 j/kg-k

Thermal conductivity: 0.3215 w/m-k

Viscosity: 0.01445 kg/m-s

### Water+ZNO0.15% Nano particles

Density: 2068.78 kg/m<sup>3</sup>

Specific heat: 6368.12 j/kg-k

Thermal conductivity: 0.32255 w/m-k

Viscosity: 0.01485 kg/m-s

### Boundary conditions

Cold inlet temperature → 25°C

Hot inlet temperature → 55°C

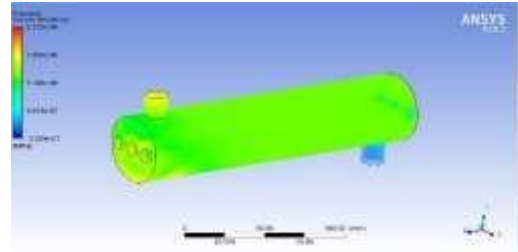
Cold mass flow rate → 0.166 kg/s

Hot mass flow rate → 0.08 kg/s

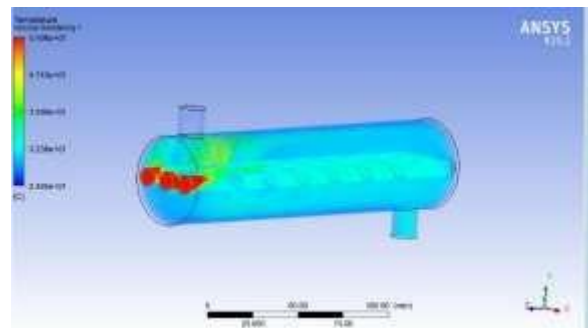
Assign cold water to cold domain, and hot water to hot domain, later on change cold domain with water + zno 0.1% nano particles, water + zno 0.15% nano particles.

## Water

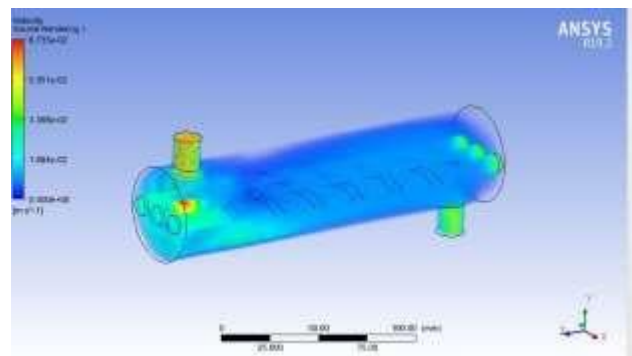
## Pressure



## Temperature

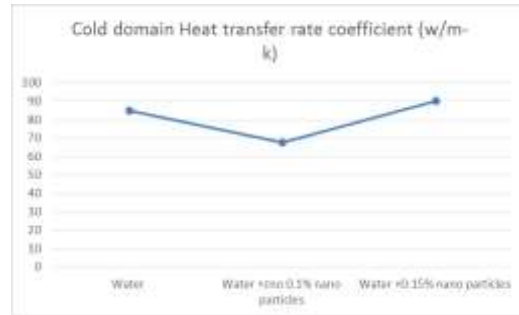


## Velocity

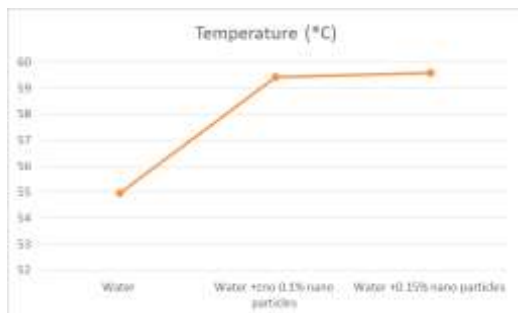
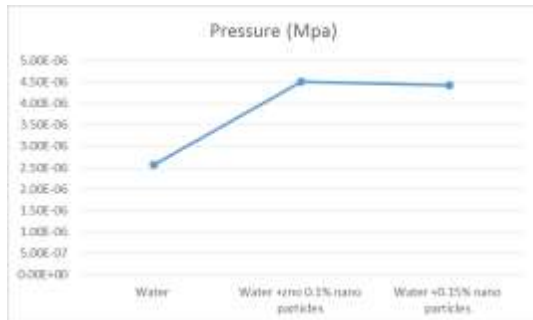


## Tables

	Water	Water +200 0.1% nano particles	Water +0.15% nano particles
Pressure (Mpa)	2.573e-6	4.505e-6	4.416e-6
Temperature (°C)	54.96	59.43	59.58
Velocity (m/s)	6.735e-2	8.009e-2	7.750e-2
Cold inlet temperature (K)	297.999	297.999	297.999
Cold outlet temperature (K)	305.36624	316.531	316.2758
hot inlet temperature (K)	327.999	327.999	327.999
Hot outlet temperature (K)	305.75661	301.70057	301.59381
Cold domain Heat transfer rate coefficient (w/m-k)	1810	1747.2	877.1
hot domain Heat transfer rate coefficient (w/m-k)	4663	4650	5064



## Graphs



## Improving Efficiency Increased heat transfer coefficient

- A greater tube side coefficient is the outcome of swirl flow's turbulence.
  - The shell side coefficient is optimised by combining uniform fluid distribution with intermittent swirl flow. tube-side heat transfer coefficient is 40% more
- Reduced pressure loss

Reducing the significant pressure drop associated with segmental baffles is achieved using the longitudinal swirl flow of twisted tube technology. Shorter in stature and with a reduced number of tubes, twisty tube heat exchangers are

allows for a reduced pressure drop on the side of

the tube. Vibration not detected

- A baffle-free design allows the fluid to flow from the shell side to the actual longitudinal direction.
- Twisted tube technology ensures that each tube is supported at several spots throughout its length.
- No more fretting or failure of the tube as a result of vibration. Less fouling
- Constant and uniform velocity
- No baffles to trap debris
- No dead areas for fouling to build.

- The temperature of the tube wall is controlled by the constant flow distribution.

## Conclusion

The twisted tube heat exchangers used in this thesis were modelled in Solid Works and subjected to static and computational fluid dynamics (CFD) boundary conditions for analysis. In order to improve the object's performance and heat transfer rate coefficient, ZNO Nano particles were mixed with water in varying concentrations (0.15% and 0.25%, respectively). The results included parameters for pressure, temperature, and velocity, as well as cold input and outlet temperatures.

on top of the heated input and output temperatures.

The findings of the computational fluid dynamics (CFD) study show that the

concentration of nanoparticles has a direct correlation with the rise in wall pressure; nonetheless, the static analysis shows that our item is safe up to 3Mpa of pressure. This means that the pressure values that rise with nanoparticle use are insignificant. In the end, the thesis states that the object's heat transfer coefficient may be improved compared to water by adding 0.15 percent zno to water, even if these pressure values are only applicable under yield limit circumstances.

### Performance calculations for inlet and outlet temperature values

- Water has 74.1%
- Water + 0.1 % znoparticles has 87.6%
- Water + 0.15 zno particles has 87.9%

Finally here object performance has been increasing from 74% to 88%, with the help of these Nano particles.

## References

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