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MODELLING AND CFD ANALYSIS OF TWISTED PIPE HEAT EXCHANGER

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ABSTRACT: A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single-or multi component fluid streams.

In this thesis twisted tube heat exchanger were modeling with the help of solid works tool and analyzing with static and cfd boundary conditions, to enhance the heat transfer rate coefficient and performance of the object here Nano particles were used, these Nano particles were mixed with water with different amount of percentages, and calculating results like pressure and temperature and velocity parameters, and also cold inlet and outlet temperature values, along with hot inlet and outlet temperature values. By knowing all these results, thesis conclude with optimum Nano particle mixture to improve the performance.

Tools were used:

CAD tool: Solid works

CFD tool: ANSYS workbench

1. Introduction

HEAT EXCHANGERS

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single-or multi component fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact.

NANO FLUID

A Nano fluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid.

Zno Nano particles

Zinc oxide nanoparticles are nanoparticles of zinc oxide (ZnO) that have diameters less than 100 nanometers. They have a large surface area relative to their size and high catalytic activity. The exact physical and chemical properties of zinc oxide nanoparticles depend on the different ways they are synthesized. Some possible ways to produce ZnOnano-particles are laser ablation, hydrothermal methods, electrochemical depositions, sol–gel method, chemical vapor deposition, thermal decomposition, combustion methods, ultrasound, microwave-assisted combustion method, two-step mechanochemical–thermal synthesis, anodization, co-precipitation, electrophoretic deposition, and precipitation processes using solution concentration, pH, and washing medium. ZnO is a wide-bandgap semiconductor with an energy gap of 3.37 eV at room temperature.

TWISTED PIPE HEAT EXCHANGER

Heat transfer enhancement techniques

- Heat transfer enhancement is one of the fastest growing areas of heat transfer technology.
- The technologies are classified into active and passive techniques depending on how the heat transfer performance is improved.
- A twisted tube is a typical passive technique that uses a specific geometry to induce swirl on the tube side flow.
- The twisted tube heat exchanger consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles.
- Twisted tube technology provide highest heat transfer coefficient possible in tubular heat exchanger.
- In uniform shell side flow the complex interrupted swirl flow on shell side maximizes turbulence while minimizing pressure drop.
- Swirl flow in tube creates turbulence to improve heat transfer.

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- By keeping the flow turbulent one secures a high heat transfer performance.

Literature Review

Number of investigations has been carried out by using various inserts and tube geometries for passive heat transfer. Investigations of various researchers and their findings are as follows:

Li Zhang, Sheng Yang et al. [1] conducted an experiment on condensation heat transfer characteristics of steam onhorizontal twisted elliptical tubes (TETs) with different geometrical parameters. A smooth circular tube, an elliptical tube (ET) and five TETs with different structure parameters were tested at the steam saturation temperature of around 100.5 ℃ with the wall subcooling from around 2 ℃ to 14 ℃. A smooth circular tube has higher condensation heat transfer coefficients than all the tested TETs. The enhancement factors of the five TETs from TET No. 1 to TET No. 5 range from 0.87 to 1.34. The condensation heat transfer coefficients of steam on the TETs increase with the rise in the tube ellipticity. The condensation enhancement of around 34% was the highest for the TET No. 3 with largest ellipticity of 0.86. The condensation heat transfer coefficient was lower for a smaller twist pitch. Sheng Yang, Hong Xu, et al. [2] experimentally investigated the heat transfer and flow resistance characteristics of water flow inside the twisted elliptical tubes (TETs) with different structural parameters. Effects of tube structural parameters (aspect ratio and twist pitch) on the performance of TETs were analyzed. Experimental results indicate that the heat transfer performance is better for both a larger tube aspect ratio (A/B) and a smaller twist pitch (S). The effect of twist pitch on heat transfer performance is more notable than that of tube aspect ratio. Xiang-hui Tan, Dong-sheng Zhu, et al. [3] studied that the tube side and shell side heat transfer and pressure drop performances of a twisted oval tube heat exchanger experimentally. Experimental study shows that the tube side heat transfer coefficient and pressure drop in a twisted oval tube are both higher than in a smooth round tube. The analyzing result shows that the twisted oval tube heat exchangers is preferred to work at low tube side flow rate an high shell side flow rate.

Designing process step by step

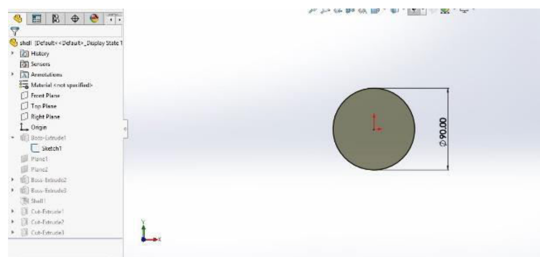

Fig no. 2.2 shell dia

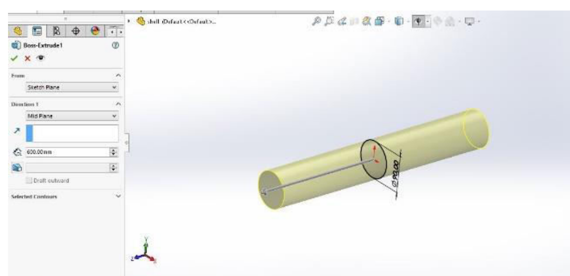

Fig no. 2.3 shell 3d

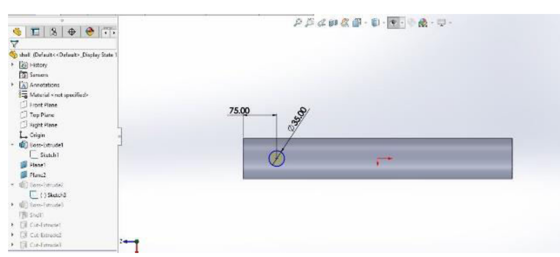

Fig no. 2.3 shell inlet design

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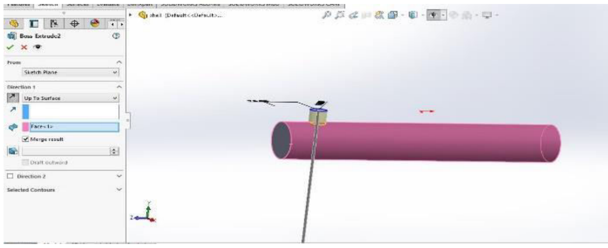


Fig no. 2.4 shell design 3d

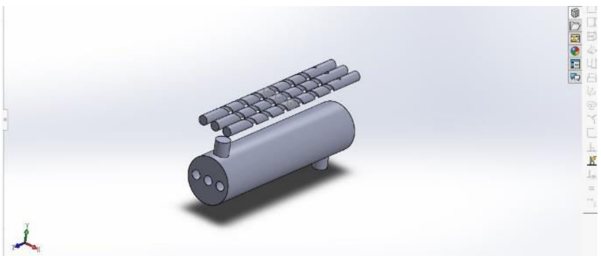


Fig no. 2.11 parts to be assembled

Fig no. Assembly of shell and twisted tubes

Static analysis results

Material selection

Steel

Young's modulus: - 2.0*10^11 Pa

Poison ratio: 0.29

Density: 7850 Kg/m^3

Yield strength: 250Mpa

Thermal conductivity: 60.5 w/m-k

Steel - 440C

Young's modulus:- 1.988*10^11 Pa

Poison ratio: 0.228

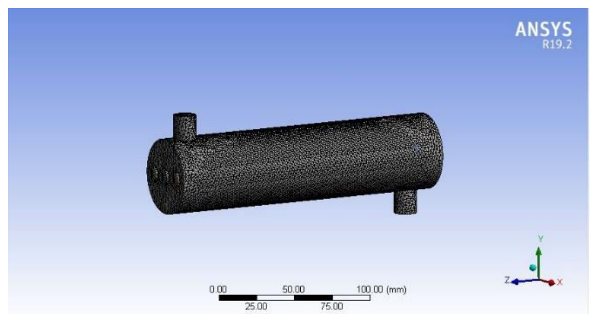
Density: 7800Kg/m^3

Yield strength: 450 Mpa

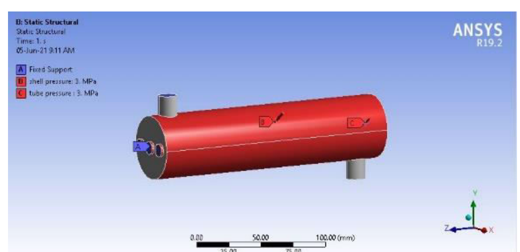
Thermal conductivity: 24.2 w/m-k

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

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results like deformation, strain, stress and safety factor values for the object.

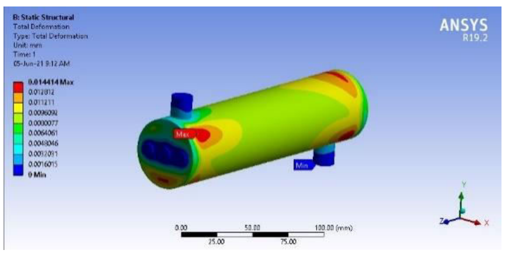
Solution→solve→deformation

Solution→solve→safety factor

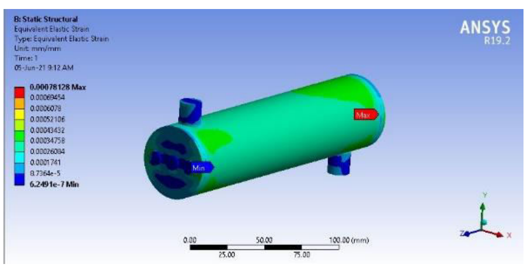
Solution→solve→stress

Steel

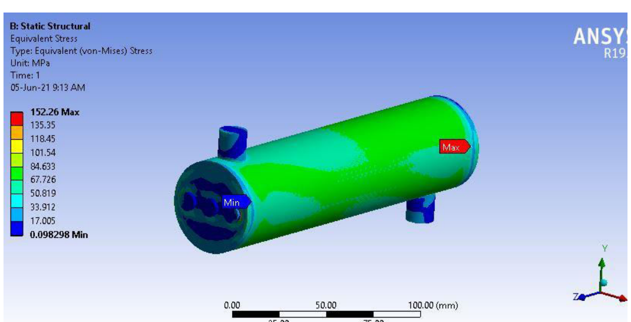
Deformation



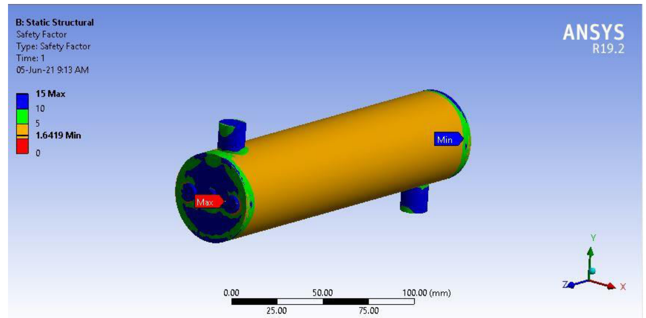
Strain



Stress



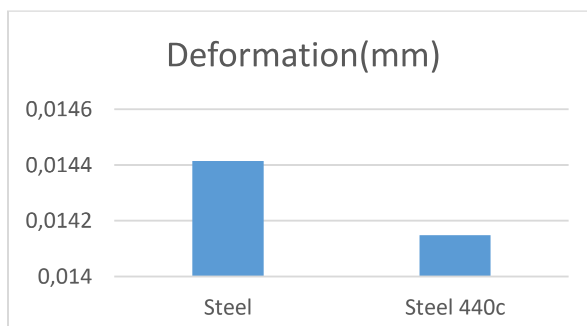
Safety factor



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



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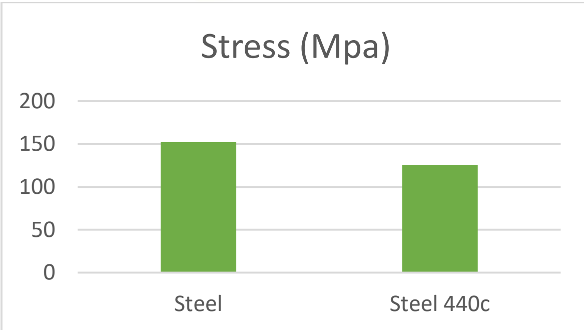
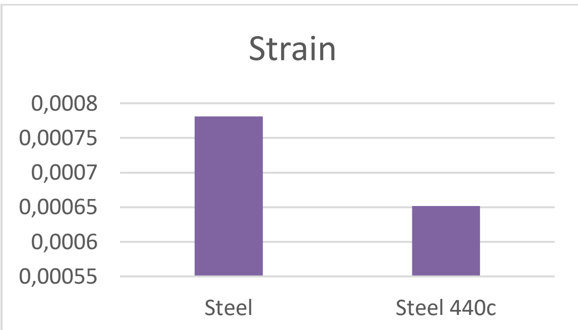
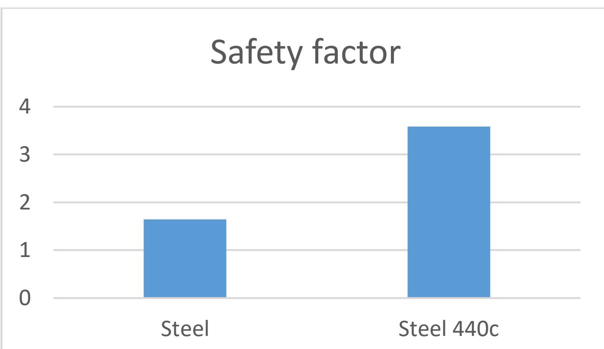






Fluent analysis results

Boundary conditions

Cold inlet temperature → 25*C

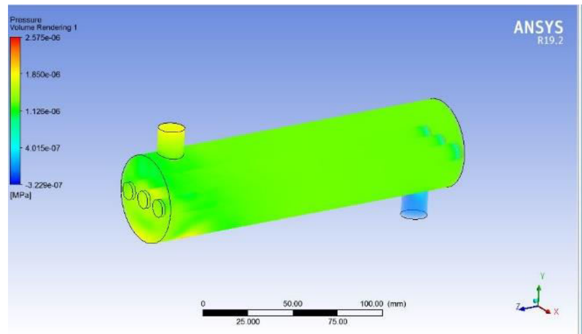
Hot inlet temperature → 55*

Cold mass flow rate → 0.166 kg/s

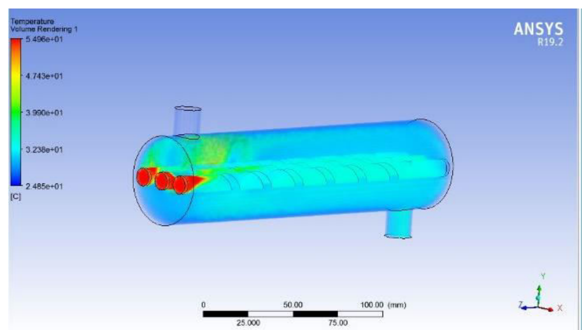
Hot mass flow rate → 0.08 kg/s

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.

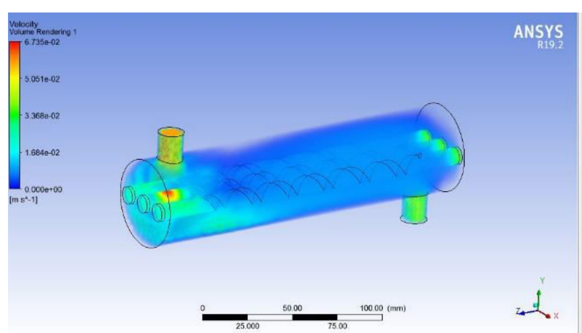
Pressure



Temperature



Velocity



Tables

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	Water	Water +zno 0.1% nano particles	Water +0.15% nano particles	Water +0.35% Nano particles
Pressure (Mpa)	2.575e-6	4.505e-6	4.416e-6	3.57e-6
Temperature (°C)	54.96	53.53	53.66	54.86
Velocity (m/s)	6.735e-2	8.009e-2	7.750e-2	5.258e-2
Cold inlet temperature (K)	297.999	297.999	297.999	297.999
Cold outlet temperature (K)	305.86624	316.531	316.2758	309.17655
hot inlet temperature (K)	327.999	327.999	327.999	327.999
Hot outlet temperature (K)	305.75061	301.70057	301.59581	307.65
Cold domain Heat transfer rate coefficient (w/m^2-k)	1810	1747.2	877.1	838.38
hot domain Heat transfer rate coefficient (w/m^2-k)	4663	4650	5064	3747.013

Improving Efficiency Increased heat transfer coefficient

•Swirl flow creates turbulence resulting in higher tube side coefficient.

• Uniform fluid distribution combined with interrupted swirl flow result in optimized shell side coefficient.

• 40% higher tube side heat transfer coefficient Lower pressure drop

• The longitudinal swirl flow of twisted tube technology reduces the high pressure drop associated with segmental baffles.

• Twisted tube heat exchanger are usually shorter in length and have fewer number of passes for a lower pressure drop on the tube side. No vibration

• Baffles free design directs shell side fluid to true longitudinal flow.

• Each tube using twisted tube technology is extensively supported at multiple contact points along its entire length.

• Tube fretting and failure due to vibration is eliminated. Reduced fouling

• Baffles free design eliminates dead spots where the fouling can occur.

• Velocity is constant and uniform.

• Constant flow distribution controls tube wall temperature

Conclusion

In this thesis twisted tube heat exchanger were modeling with the help of solid works tool and analyzing with static and cfd boundary conditions, to enhance the heat transfer rate coefficient and performance of the object here ZNO Nano particles were used, these Nano particles were mixed with water with different amount of 0.1 & 0.15%, 0.35%percentages, and calculating results like pressure and temperature and velocity parameters, and also cold inlet and outlet temperature values, along with hot inlet and outlet temperature values.

From cfd analysis results here it is observed that heat transfer rate coefficient values were increasing while increasing Nano particles concentration, and also it increases the pressure on walls, from static analysis results it is clear that our object is safe up to 3Mpa of pressure on it. So the pressure values which is increasing while using Nano particles is negligible. And these pressure values under yield limit conditions, only, finally thesis conclude with water +zno 0.15% Nano particles can increase the heat transfer coefficient of the object compare to water.

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Effectiveness calculations for inlet and outlet temperature values

- Water has 74.1%
- Water +0.1 % zno particles has 87.6%
- Water + 0.15 zno particles has 87.9%
- Water + 0.35 zno particles has 78.09%

Finally here object performance has been increasing from 74% to 88%, with the help of these Nano particles. And also effectiveness decreased for 0.35%, but the overall effectiveness is greater than water effectiveness value.

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