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Performance Analysis of Heat Exchanger Using Modeling and Analysis Software's

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ABSTRACT

A distinctive of heat exchanger design is the process of specifying a layout. Heat transfer area and pressure drops and examining regardless of if the assumed design fulfills all necessity or perhaps not. On this paper a basic method of improve the design of Shell Tube Heat Exchanger [STHE] through the use of Finite Element Analysis [FEA]. The FEA. The FEA of STHE works well for attaining optimization in design by protection against tube failure caused as a result of FEA. The reason why for design of STHE is always to improve the heat exchanger for more secure design. Standard design factors and design method will also be explained in this paper. In design computation HTRI software program is utilized to examine manually determined outcome.

KEY WORDS: Heat exchanger, pressure drop, heat transfer coefficient, LMTD, HTRI"(Heat Transfer Research Institute of USA),Finite Element Analysis [FEA],of Shell Tube Heat Exchanger [STHE].

I. INTRODUCTION

The science of thermodynamics deals with the quantitative transitions and rearrangements of energy as heat in bodies of matter. Heat transfer is the science that deals with the rate of exchange of heat between hot and cold bodies called the source and receiver. When one Kg of water is vaporized or condensed, the energy change in either process is identical. However, the rates at which either process proceeds is different, vaporization being much more rapid than condensation.

The major difference between thermodynamics and heat transfer is that the former deals with the relation between heat and other forms of energy, whereas the latter is concerned with the analysis of the rate of heat transfer. Thermodynamics deals with systems in equilibrium so it cannot be expected to predict quantitatively the rate of change in a process, which results from non-equilibrium states. Heat transfer is commonly associated with fluid dynamics and it also supplements the laws of thermodynamics by providing additional rules to establish energy transfer rates.

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Process heat transfer deals with the rates of heat exchange as they occur in the heat transfer equipment of the engineering process. This approach brings to better focus the importance of the temperature difference between the source and the receiver, which is, after all, the driving force whereby the transfer of heat is accomplished.

II. PRINCIPLES OF HEAT TRANSFER

The heat exchange process in a heat exchanger can be described by the principles of conduction, convection, and radiation.

A. Conduction

The process by which heat or electricity is directly transmitted through the material of substance, when there is difference of temperature or of electrical potential between adjoining regions, without movement of the material.

$$Q = -KA\ (d_t/d_x)$$

K= Coefficient of thermal conductivity

B Convection

Convection is heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it.

$$q = Q/A = h(T_s-T_m)$$

Where

q= heat flux at the wall in W/m^2
h = heat transfer coefficient in W/m^2 °c
T_s = surface temperature in °c
T_m = mean temperature in °c

C. Radiation

$Q= \sigma T_1^{\ 4}$
Where,
σ = Stefan-Boltzmann constant
T_1= Surface temperature in °Kelvin

III. CLASSIFICATION OF HEAT EXCHANGERS

A Classification based on working features:

The heat exchangers are mainly divided into three categories according to their working features

1. Closed type exchanger

2. Regenerators

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3. Open type exchangers or mixed type

1. Closed Type Exchanger

Closed type exchangers are those in which heat transfer occurs between two fluids, which do not mix, or physically in contact with each other. The fluids involved are separated from each one other by a pipe or a tube wall or any other surface, which may be involved in heat transfer path.

2. Regenerators

The regenerators are storage type heat exchangers. The heat transfer surface or elements are usually referred to as a matrix in the regenerator. Regenerators are exchangers in which a hot fluid, then a cold fluid, flows through same space alternatively with as little mixing as possible occurring between the two streams.

3. Open Type of Exchangers Or Mixed Type

Open type heat exchangers, as the name implies are devices where in the entering fluid stream flow into the open chamber and complete mixing of the two streams occurs. Hot and cold fluids entering such an exchange will leave as a single stream.

B. Classification based on fluid flow arrrangements

Mostly heat exchangers are classified on the basis of configuration of the fluid flow paths through the heat exchangers

1. Counter Flow Exchanger

In counter flow exchanger the two fluids flow parallel to each other but in opposite directions within the core. The counter flow arrangements are thermodynamically superior to any other flow arrangements. It is the most efficient flow arrangements for given overall thermal conductance (UA), fluid flow rates and inlet temperatures.

2. Parallel Flow Exchanger

In parallel flow exchanger the fluid streams enter together at one end, flow parallel to each other in the same direction and leave together at other end. This arrangement has lowest exchanger effectiveness among the single pass exchanger for given overall thermal conductance and fluid flow rates. In a parallel flow exchanger, a large temperature difference between inlet temperatures of hot and cold fluid exists at the inlet side, which may include high thermal

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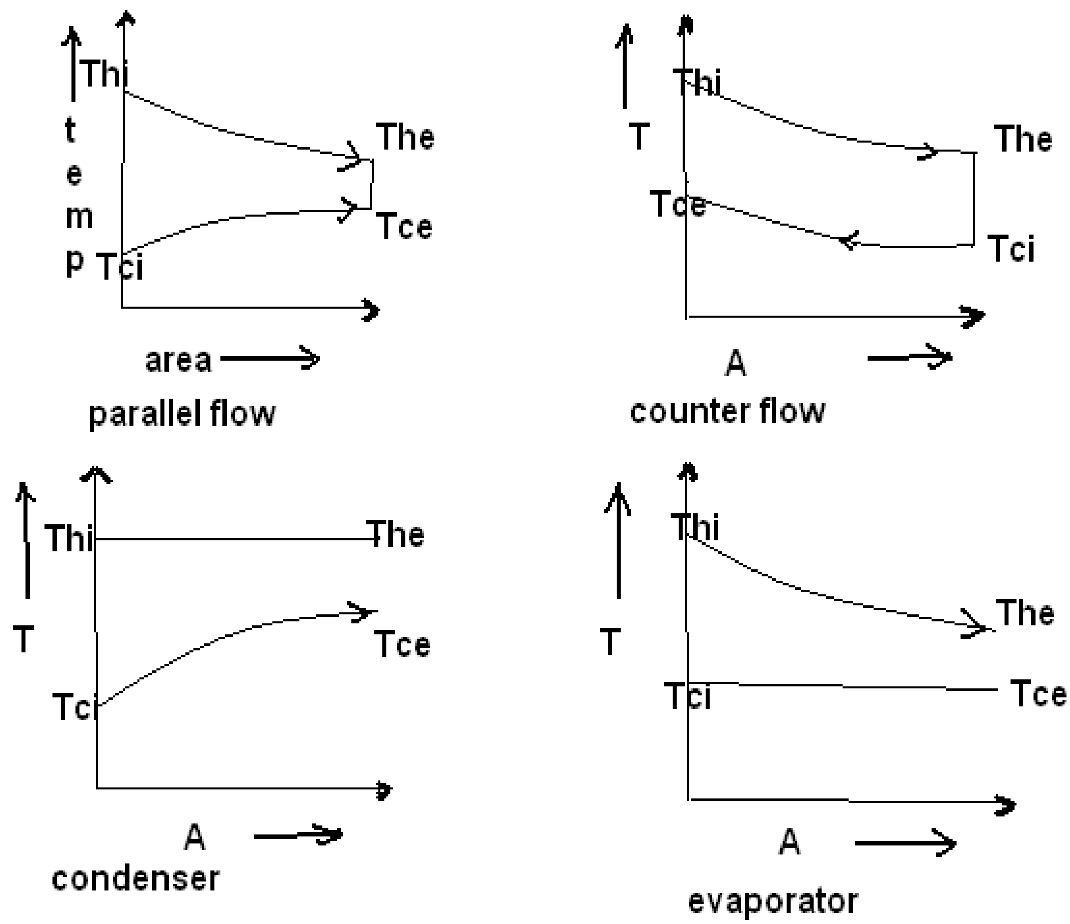
stresses in the exchanger wall at the inlet. This flow arrangement is not used for applications requiring high temperature effectiveness.

3. Cross Flow Exchanger

In this type of exchanger the fluids flow normal to each other. Thermodynamically, the effectiveness of the cross flow exchanger falls between the parallel and counter flow exchangers. This is one of the most common flow arrangements used for extended surface heat exchanger, because it greatly simplifies the header design at the exit of each fluid.

1.



IV. **TYPES OF HEAT EXCHANGERS**

C. Main types of heat exchangers:

1. Air Cooled Heat Exchanger

It is tubular heat transfer equipment in which ambient air passes over the tubes and thus acts as the cooling medium. Air is available in unlimited quantities compared to water. The airside fouling is frequent problem. But the heat transfer coefficient of air is less than that of water.

2. Plate Type Heat Exchanger

The plate type of heat exchanger consists of a thin rectangular metal sheet upon which a corrugated pattern has been formed by precision pressing. One side of each plate mounted on the frame and clamped together. The space between adjacent plates forms a flow channel. The cold and hot fluids flow through channels.

3. Shell And Tube Type Heat Exchanger

Shell and tube type heat exchangers are the most versatile and suitable for almost all applications, irrespective of duty, pressure and temperature. Shell and tube type exchanger consists of a cylindrical shell containing a nest of tubes that run parallel to the longitudinal axis of the shell and are attached to perforated flat plates called tube sheets at each end. There are a number of perforated plates, through which the tube passes called as baffles. This assembly of tubes and baffles is called a tube bundle and is held together by tie rods and spacer tubes.

D Selection of Heat Exchangers

The proper selection depends on several factors. They are:

- Heat transfer rate
- Cost
- Pumping power
- Size and weight
- Type
- Materials
- Tube expansion
- Tube to tube sheet joint
- Other considerations like toxic, expansive fluids, ease of service and low maintains cost

V. GENERAL DESIGN CONSIDERATIONS

For designing any water-cooled heat exchanger, several parameters are usually fixed. These parameters include heat duty, inlet and outlet process steam temperatures and ambient inlet temperature of water. The key variable parameter that controls the heat exchanger design is the cooling water flow rate. An increase in the cooling water flow rate increases the overall heat transfer coefficients and the mean temperature difference, thereby decreasing the size of the heat exchanger. The increase in water velocity also increases the waterside pressure drop through the exchanger, thus increasing the necessary pump capacity. Erosion problems, vibrations, flow stability and tube materials also restrict the velocity of water. While designing a heat exchanger, values of certain design parameters like number of tubes and water quantity are assumed initially. Therefore, a trial and error is required to find the optimum values of the design parameters. Sometimes, this may lead to too much iteration and thus the design becomes cumbersome. However, with the advent of personal computer this process is simplified. HTRI (Heat Transfer Research Institute of USA) has developed a powerful software package for designing heat exchangers with the help of which the designing becomes very simple and optimum. The thermal design involves the calculation of shell side and tube side heat transfer coefficients, heat transfer surface area and pressure drops on the shell side and tube side. The mechanical design involves the calculations of thickness of pressure parts of the heat exchanger such as the shell, channel, tube etc. to evaluate the rigidity of part under design pressures. The design of the heat exchanger is then modeled in PRO-Engineer and finally analyzed using ANSYS software.

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VI. RESULT AND DISCUSSIONS

The thermal and pressure drop calculations for a given heat exchanger are done using theoretical equations. These results are evaluated with the world-renowned software package for design of heat exchanger “HTRI”(Heat Transfer Research Institute of USA). This is shown in Table 1.The calculated results were found to be closely matching with program output values. Hence the heat balance and the provided heat transfer surface areas are matching with power plant requirements. In mechanical design, important minimum dimensions of different parts of the equipment to suit the design pressures and temperatures. The design standard ASME codes for pressure vessel constructions are used. The surface area required by calculations is adequately provided in the tube; the pressure drops calculated for the flows through the heat exchanger are within the permissible limits; the critical components have been designed for sufficient mechanical strength as per ASME .The performance of the given geometry is tabulated (Table 2,3,4) and graphically analyzed by varying the parameters (Fig 2,3,4). Hence, the present design of oil-to-water heat exchanger is in order. As the inlet temperature of water increases, LMTD decreases due to

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increase in surface area. (Fig.2) shows the variation. As the fouling factor increases over all heat transfer coefficient decreases as shown in (Fig.4).

S.NO	Pressure drop, Kg/cm^2				Overall heat transfer coefficient, Kcal/hr-m^2/^{0}C		
		Theoretical	**HTRI**	**% Error**	**Theoretical**	**HTRI**	**% Error**
1	Shell Side	0.336	0.335	0.29	244.9	249.035	1.68
2	Tube Side	0.2629	0.229	1.4			

TABLE.1

Comparison of pressure drop &overall heat transfer coefficient values with HTRI

TABLE.2

Variation of LMTD and surface area with water inlet temperature

Sample.no	Water inlet temp t_1 °C	LMTD °C	Area required mm^2	% Margin
1.	30	18.78	13.887	23.73
2.	31	17.76	14.684	17.01
3.	32	16.74	15.57	10.32
4.	33	15.72	16.586	3.59
5.	34	14.7	17.7	-3.10
6.	35	13.67	19.07	-9.90
7.	36	12.64	20.632	-16.0

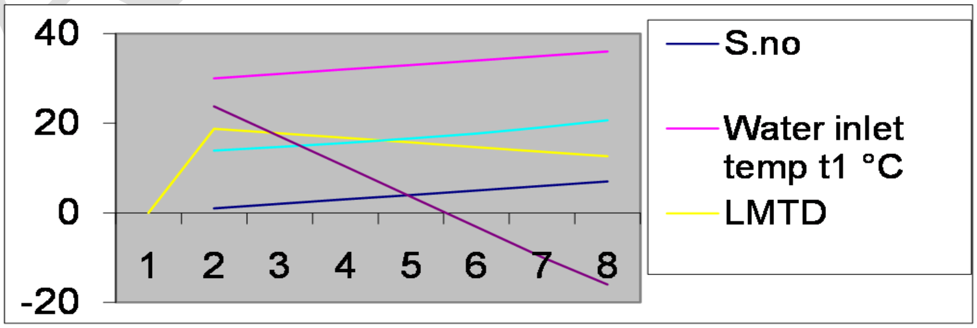

Fig.1 Variation of LMTD and surface area with water inlet temperature

TABLE.3

Variation of overall heat transfer coefficient with fouling factor of oil

S.no	Fouling factor of oil Hr-m^2-°c/kcal	Heat transfer coefficient of oil Kcal/hr-m^2-°C	Overall heat transfer coefficient Kcal/hr-m^2-°C
1.	0.0001	331.196	276.595
2.	0.0002	320.578	249.035
3.	0.0003	310.620	237.228
4.	0.0004	301.263	226.479

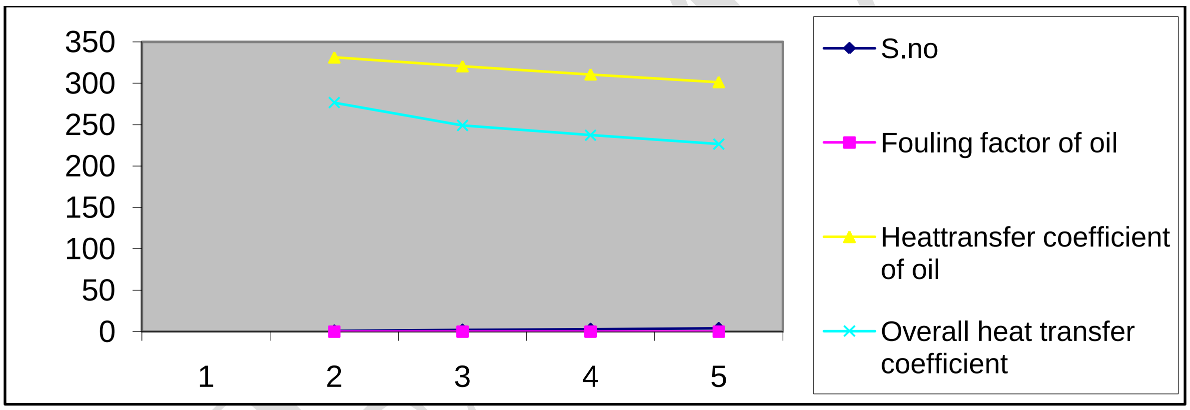

Fig.2 Variation of overall heat transfer coefficient with fouling factor of oil

TABLE.4

Variation of heat load and overall heat transfer coefficient with oil quantity

S.no	Oil quantity 1000 kg/ hr(m)	Heat load Q_s Kcal/hr	Reynolds No	Heat transfer coefficient of oil Kcal/hr-m^2-°C	Overall heat transfer coefficient Kcal/hr-m^2-°C
1.	11.0655	48760.513	154.83	273.898	219.971
2.	11.8032	52011.213	165.125	283.207	225.885
3.	12.5409	55261.914	175.472	292.274	231.616
4.	13.2766	58512.615	185.79	301.048	237.092
5.	14.0163	61763.331	196.119	309.572	242.347
6.	14.754	65014	209.873	320.578	249.035
7.	15.4917	68264.71	216.757	325.944	252.267
8.	16.2294	71515.419	227.085	333.831	256.966

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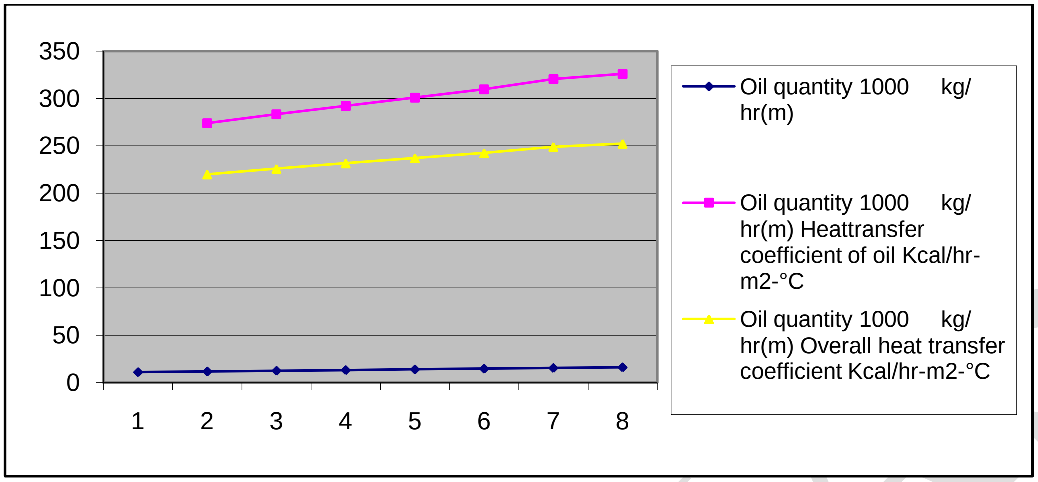


Fig.3 Variation of heat load and overall heat transfer coefficient with oil quantity

A.Modelling of Heat Exchanger Using Pro-E

Pro-Engineer is a parametric feature based package which is very flexible and versatile and hence is widely used .also it has an additional advantage of direct interface with a CNC machine. It is one of the very few design packages which incorporates a wide range of modules required by the industry like :

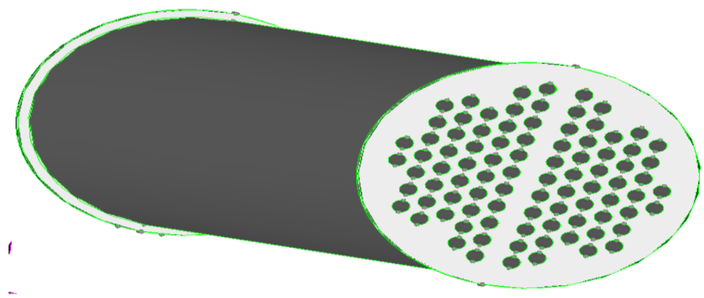
- Sketcher
- Part drawing
- Advanced part
- Assembly
- Manufacturing
- Sheet metal
- Surface
- Drawing

In the present project, the components of heat exchanger are modeled using part drawing features and then using assembly modules, the assembly of the heat exchanger is generated. The part drawing is a versatile module where in the whole heat exchanger can be modeled as a single unit as opposed to the assembly module where each part is modeled separately and finally assembled to get the required component using the various options available.

ISSN: 2349-3224 || www.ijaetmas.com || Volume 04 - Issue 09 || September-2017 || PP. 01-12

B. Geometric model

The geometric model of heat exchanger is shown below



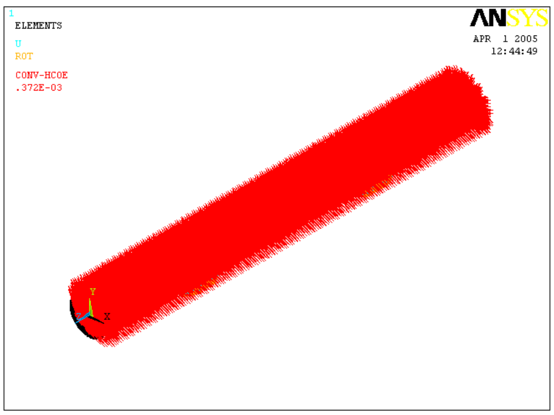


Fig.4 The finite element model of heat exchanger

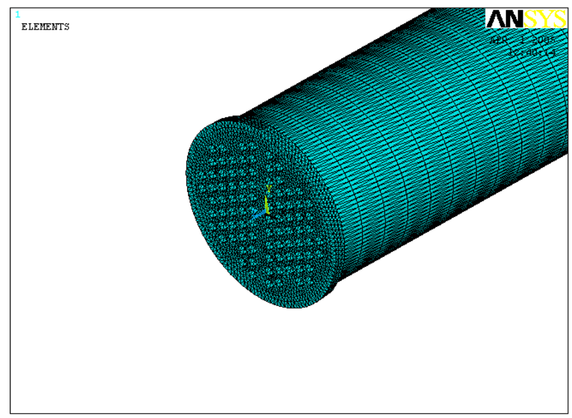


Fig.5 The thermal boundary conditions

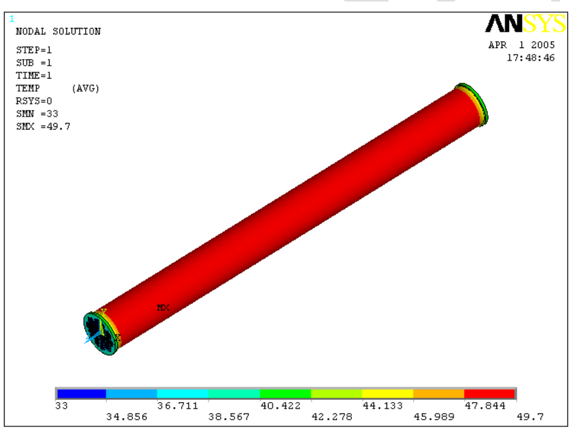


Fig.6 Nodal solution for Temperature Distribution Condition

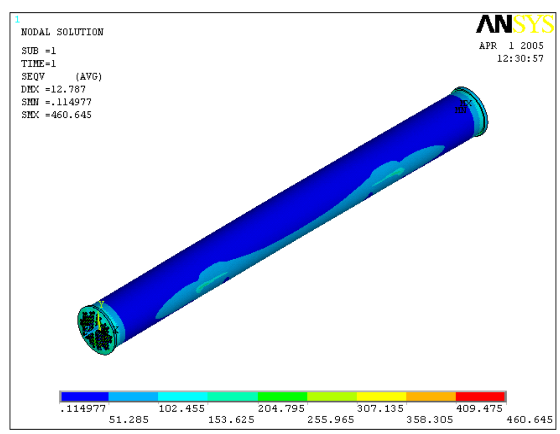


Fig.7 Nodal solution for Von Mises Stress

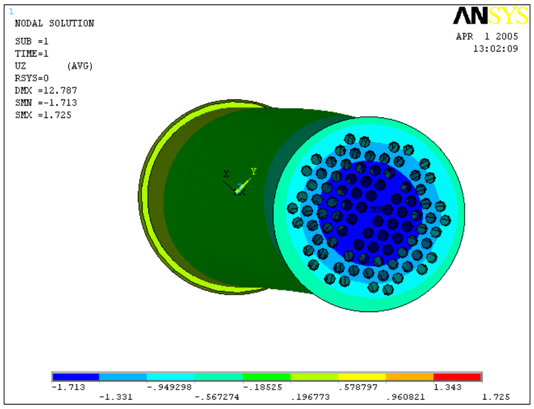


Fig.8 Nodal solution for Deformation in Z-direction

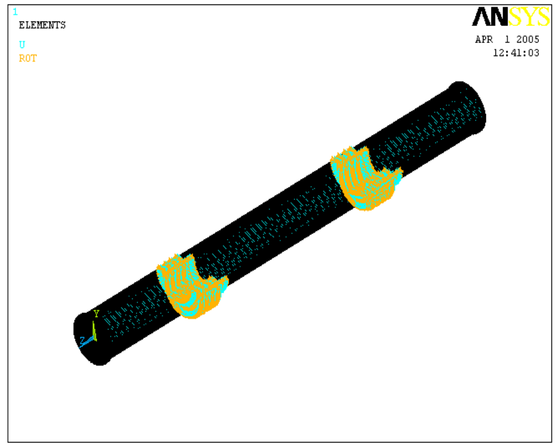


Fig.9 Nodal solution for Deformation in x-direction

VII. CONCLUSION

The thermal solution is coupled with structural analysis for the deflection and the stresses .the maximum displacement is observed **1.725mm** where as the maximum stresses is observe red to be **460.645 MPa**. The pressure drop values on shell side and tube side at the same time, overall heat transfer coefficient values are with a variation of **0.29%. 1.4%** and **1.68%** respectively and matching with the HTRI software. Variation of LMTD and surface area with water inlet temperature decreases and increases respectively and variation in overall heat transfer coefficient decreases with the increase of fouling factor of oil. As the quantity of oil is varied increasingly the heat load and the overall heat transfer coefficient also increases. From the theoretical modeling the convection heat transfer coefficients along with the bulk temperature and imposed as a boundary conditions to predict the temperature distribution in heat transfer analysis in both the shell and tube. The maximum Von Mises stress induced is **460.645Mpa**, which is less than allowable stress. Hence the design is safe based on the strength.

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