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Modeling and Analysis of Shell and Tube Heat Exchanger Tubes by Using Finite Element Analysis

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ABSTRACT

A computational study for the optimal design of heat exchangers (HX) used in a high temperature and high pressure system is presented. In present day shell and tube heat exchanger is the most common type heat exchanger widely used in oil refinery and other large chemical process, because it suits high pressure application.In the present attempt these tubes are modeled in modeling software CATIA by using a material Al2O3 and HIGH CARBON STEEL (AISI 1065) and their thermal analysis of the tubes is analyzed by using simulation software ANSYS. For the result the heat flux of Al2O3 is much more when compared to Stainless steel material.

INTRODUCTION

Heat exchangers are one of the mostly used equipment in the process industries. Heat exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense is known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements. Heat exchangers are of two types:

- Direct contact heat exchanger - Where both media between which heat is exchanged are in direct contact with each other.
- Indirect contact heat exchanger - Where both media are separated by a wall through which heat is transferred so that they never mix, indirect contact heat exchanger.

CLASSIFICATION OF HEAT EXCHANGERS

The transfer of heat from one fluid to another fluid is the most important task for most of the chemical industries. Of various applications, the main application of heat transfer is in designing of the heat transfer equipment for exchanging heat from one fluid to another. Such equipment designed for the efficient transfer of heat is called Heat Exchanger generally. Heat exchangers are generally distinguished depending on the transfer process occurring in them. The tube and shell exchangers are most widely used heat exchange equipment among various exchangers available. The common types of shell and tube exchangers are of two types.

Fixed tube-sheet exchanger (non-removable tube bundle): This design is the simplest and cheapest type of shell and tube exchanger design. In this type of exchangers, no relative movement between the shell and tube bundle is possible and the tube sheet is welded to the shell.

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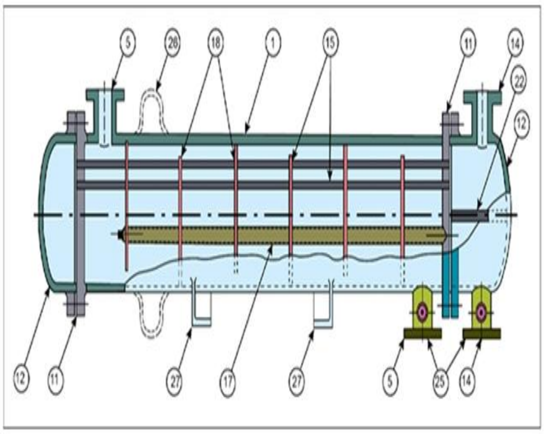
Removable tube bundle: This tube bundle may be removed for ease of cleaning and replacement. Removable tube bundle exchangers can be further categorized in floatinghead and U-tube exchanger.

Floating-head exchanger:

A stationery tube sheet is clamped with the shell flange in this floating head exchanger. The tubes expand into a freely ridingfloating tube or floating-head at the opposite end of the bundle. A floating head cover is bolted to the tube sheet and the entire bundle can be removed for cleaning and inspection of the inner design. This floating type exchanger is shown in Figure 3.2.

U-tube exchanger:

In this type of exchangers,the tubes which are bent in the form of a „U" and rolled back into the tube sheet are shown in the Figure 3.4. This means that it omits some tubes at the center of the tube bundledepending on the arrangement of the tube. The tubes expand freely towards the „U" bend end. The various constructional and operational advantages and disadvantages depending on applications of shell and tube exchangers.



Shell

Shell is the container for the shell fluid and the tube bundle is placed inside the shell. The Shell diameter is selected in such a way so that it gives a close fit of the tube bundle. The clearance between the tube bundle and inner shell wall depends on the type of exchanger. Shells are fabricated from standard steel pipe usually with satisfactory corrosion allowance. The shell thickness of 3/8 inch for the shell ID of 12-24 inch is satisfactorily used up to 300 psi of operating pressure.

Tube

Tube OD of ¾ and 1"" are generally used to design a compact heat exchanger. The most efficient condition for heat transfer is to have the maximum number of tubes in the shell to increase turbulence. The tube thickness should be enough to withstand the internal pressure along with the adequate corrosion allowance. The tube thickness is expressed in terms of BWG (Birmingham Wire Gauge) and true outside diameter (OD). The tube length of 6, 8, 12, 16, 20 and 24 ft are used preferably. The Longer tube reduces shell diameter but with the higher shell pressure drop. The Finned tubes are used when fluid with low heat transfer coefficient flows in the shell side. Stainless steel, brass, bronze, admiralty copper and alloys of nickel- copper are the tube materials widely used.

Tube material selection

The tube material should have good thermal conductivity for to transfer heat well. Because heat is transferred from a hot to a cold side through the tubes, there is a temperature difference through the width of the tubes. Because of the tendency of the tube material to thermally expand differently at various temperatures, thermal stresses occur during operation. This is in addition to any stress from high pressures from the fluids themselves. The tube material also should be compatible with both the shell and tube side fluids for long periods under the operating conditions (temperatures, pressures, pH, etc.) to minimize deterioration such as corrosion. All of these requirements call for careful selection of strong, thermally-conductive, corrosion-resistant, high quality tube materials, typically metals, including copper

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alloy, stainless steel, carbon steel, non-ferrous copper alloy, Inconel, nickel, Hastelloy and titanium. Fluoropolymers such asper fluoroalkoxalkane (PFA) and Fluorinated ethylene propylene (FEP) are also used to produce the tubing material due to their high resistance to extreme temperatures. Poor choice of tube material could result in a leak through a tube between the shell and tube sides causing fluid cross-contamination and possibly loss of pressure.

- Materials selection and compatibility between construction materials and working fluids are important issues, in particular with regard to corrosion and/or operation at elevated temperatures.
- Requirement for low cost, light weight, high conductivity, and goodjoining characteristics often leads to the selection of aluminium forthe heat transfer surface.
- On the other side, stainless steel is used for food processing orfluids that require corrosion resistance.
- In general, one of the selection criteria for exchanger materialdepends on the corrosiveness of the working fluid.
- A summary Table is provided as a reference forcorrosive and noncorrosiveenvironments

In this shell and tube heat exchanger design we considered two different materials.

HIGH CARBON STEEL (AISI 1065):

Properties	Metric	Imperial
Density	7.85 g/cm³	0.284 lb/in³

Mechanical Properties

The following table shows mechanical properties of cold drawn AISI 1065 carbon steel.

Properties	Metric	Imperial
Tensile strength, ultimate	635 MPa	92100 psi
Tensile strength, yield	490 MPa	71100 psi
Modulus of elasticity	300MPa	0.27-0.30
Bulk modulus (typical for steel)	140 GPa	20300 ksi
Shear modulus (typical for steel)	80 GPa	11600 ksi
Poissons ratio (typical for steel)	0.27-0.30	0.27-0.30

Aluminium Oxide (Al_2O_3)

Aluminium oxide is the one of the chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. Most commonly it is the occurring of several aluminium oxides, and specifically identified as aluminium(III) oxide. CommonlyAl_2O_3 called as alumina, and may also be called aloxide, aloxite, or alundum depending on their forms or applications.

Crystalline polymorphicα-Al2O3 phase it occurs commonly, in which it composes the mineral corundum, varieties of which form the precious gemstones ruby and sapphire. Al2O3 is significant in its use to produce aluminium metal, its hardness makes it as an abrasive, and as a refractory material owing to its high melting point.

Al_2O_3 has a relatively high thermal conductivity(30 Wm−1K−1) and has a low electrical resistivity for a ceramic material. In waterAluminium oxide is insoluble. In its most commonly occurring crystalline form, called corundum or α-aluminium oxide, its hardness makes it suitable for use as an abrasive and as a component in cutting tools.

Physical properties:

- Melting Range: 2551-2641°F
- Density: 0.291 lb/in³ (8.027 g/cm³)
- Modulus of Elasticity in Tension: 29.7 x 10^6 psi (205 GPa)
- Modulus of Shear: 11.7 x 10^6 psi (81 Gpa)
- Thermal Conductivity: 14-17 W/m · K
- Specific Heat: 490 J/kg °K

Mechanical Properties

- Yield Strength: 30,000 psi
- Ultimate Tensile Strength: 85,000 psi
- Percent Elongation in 2 inch: 32%
- Hardness: 246Brinell

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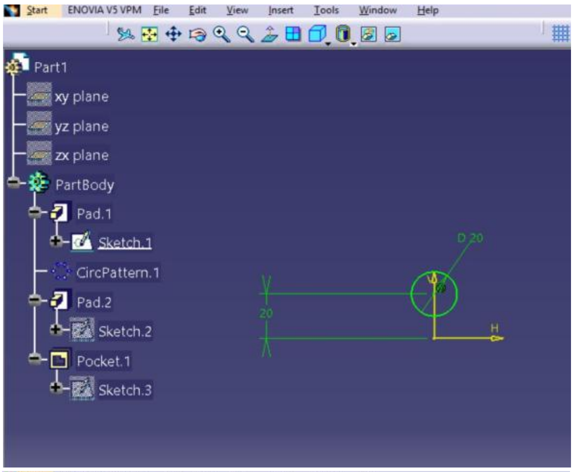

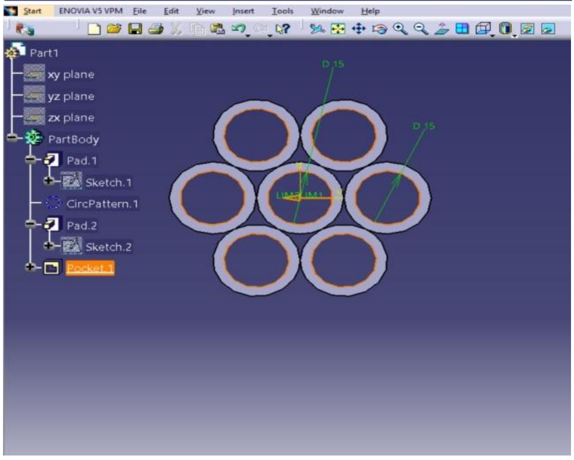

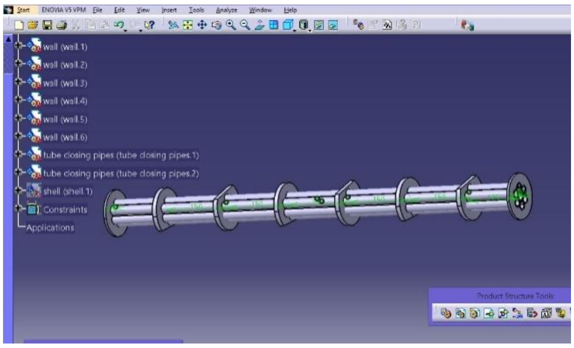

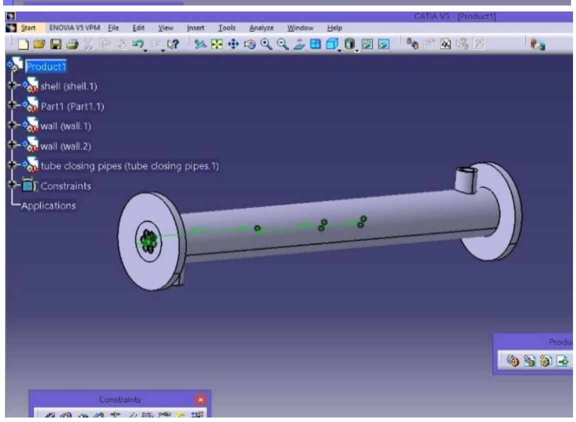

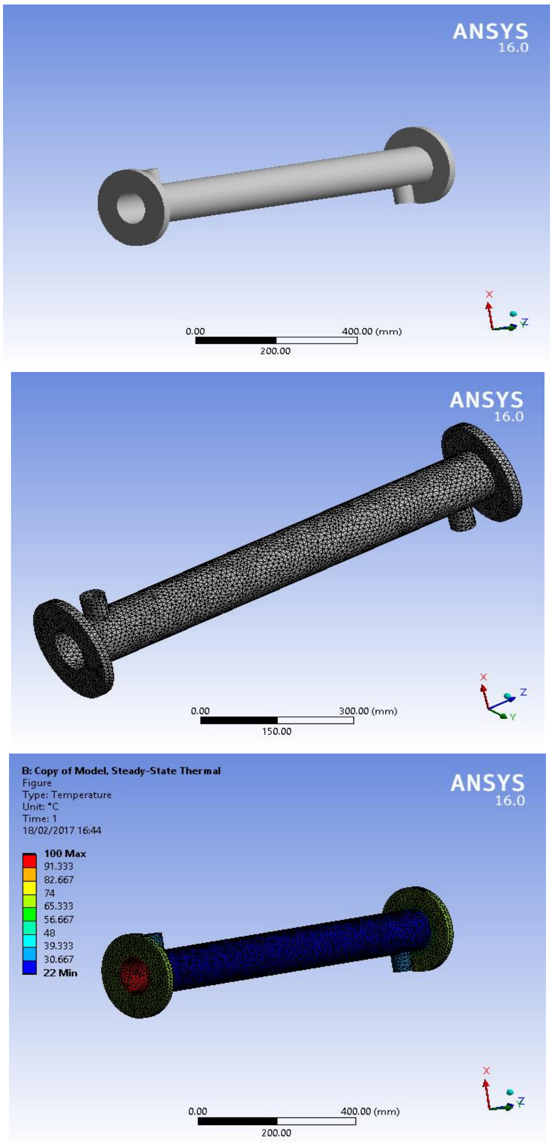

Figure 1: FOR HIGH CARBON STEEL

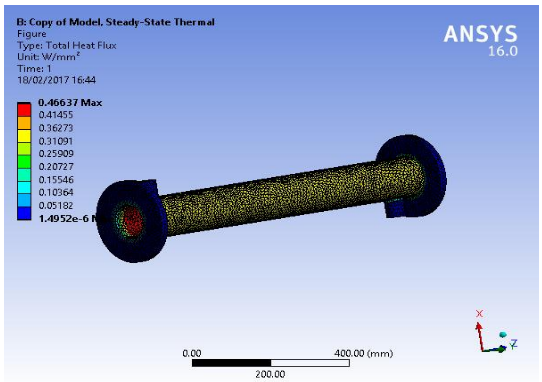

Figure 2: FOR HIGH CARBON STEEL TOTAL HEAT FLUX

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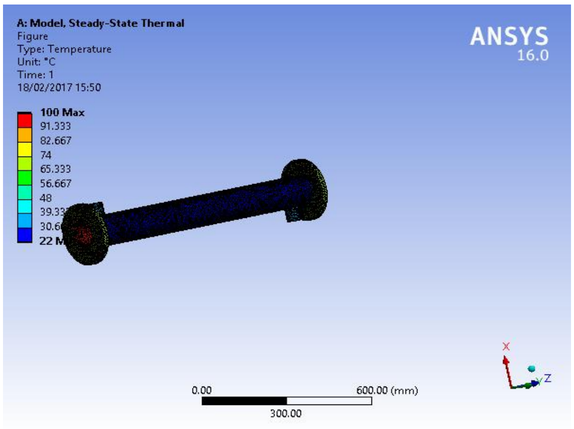

Figure 3: TEMPERATURE DIFFERENCE FOR ALUMINIUM OXIDE

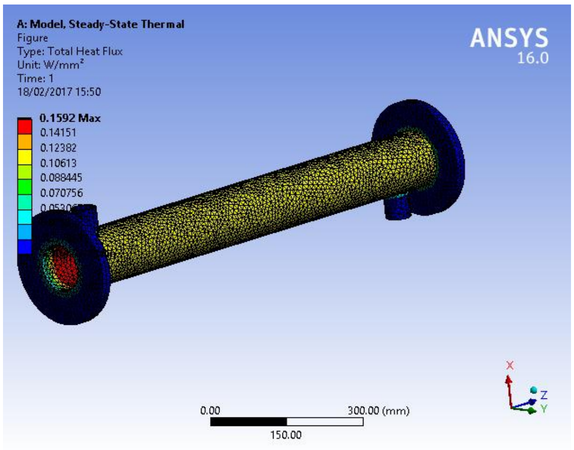

Figure 4:HEAT FLUX FOR ALUMINIUM OXIDE

CONCLUSION

Various analyses required to analysis for operating pressure loads and transient thermal analyses together with mechanical loads. The analyzing of Total Heat Flux using ANSYSon both materials HIGH CARBON STEEL (AISI 1065) and $Al_2O_3$the results are noted and the material having the good Heat Flux is $Al_2O_3$with 0.1592 W/mm^2 whereas steel has a maximum of 0.466W/mm^2 which makes aluminium preferred than steel and the material having good physical and mechanical properties. Aluminium oxide is more malleable and elastic than steel.Better to do analysis in realistic actual methods for both shell side and tube for to get optimum shell and tube heat exchanger.

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