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SCHEMATIC APPROACH ON SHELL AND TUBE HEAT EXCHANGER WITH CERAMIC COATING USING CFD APPROACH

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Abstract:

This project presents an attempt to optimize a shell and tube heat exchanger. Heat exchanger is a device used to transfer heat between two or more fluids. Of the various types of heat exchangers used in various industries, the shell and tube heat exchanger is probably the most versatile and widely used in most industrial sectors. This project captures the optimization of the total annual operating cost together with structural and CFD optimization Ceramic heat exchanger is one which can with stand high temperatures ranging from 600-1000oC .Ceramic heat exchanger has low material cost and also it can withstand high temperatures compared to metallic heat exchanger. Due to this reason it is important to predict the performance of ceramic heat exchanger, before it gets fabricated .In this project CFD analysis is performed on the ceramic heat exchanger having rectangular and circular ducts where aluminum nitride is used to predict and optimize various parameters like heat transfer rate and effectiveness.

Keywords **— Ceramic Heat Exchangers, Heat Transfer Rates, Effectiveness, ANYS.**

1.0 Introduction:

A Heat Exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. Heat Exchangers are useful in many engineering processes those in refrigerating and air-conditioning systems, power systems, food processing systems, chemical reactors and space or aeronautical applications. 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 of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements.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. A typical problem of process heat transfer is concerned with the quantities of heat to be transferred, the rates at which they may be transferred because of the natures of the bodies, the driving potential, the extent and arrangement of the surface separating the source and the receiver, and the amount of mechanical energy which may be expanded to facilitate the transfer.

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 for spacing the baffles.

Computational Fluid Dynamics (CFD):

CFD is a sophisticated computationally-based design and analysis technique. CFD software gives you the power to simulate flows of gases and liquids, heat and mass transfer, moving bodies, multiphase physics, chemical reaction, fluid-structure interaction and acoustics through computer modeling. This software can also build a virtual prototype of the system or device before can be apply to real-world physics and chemistry to the model, and the software will provide with images and data, which predict the performance of that design. Computational fluid dynamics (CFD) is useful in a wide variety of applications and use in industry. CFD is one of the branches of fluid mechanics that uses numerical methods and algorithm can be used to solve and analyses problems that involve fluid flows and also simulate the flow over a piping, vehicle or machinery. Computers are used to perform the millions of calculations required to simulate the interaction.

APPLICATION OF CFD:

CFD not just spans on chemical industry, but a wide range of industrial and nonindustrial application areas which is in below:

- Aerodynamics of aircraft and vehicle.
- Combustion in IC engines and gas turbine in power plant.
- Loads on offshore structure in marine engineering.
- Blood flows through arteries and vein in biomedical engineering.
- Weather prediction in meteorology.

- Flow inside rotating passages and diffusers in turbo-machinery.

2.0 Literature review:

Baydaa Rashid Ismael, drArunaKumari (2014) they are widely used in petroleum refineries, chemical plants, and petrochemical plants. The purpose of this thesis work is to design an Oil Cooler, especially for shell and tube heat exchange which is the majority type of liquid to liquid heat exchanger with baffle for induced turbulence and higher heat transfer coefficient. Modeling is done by using PRO-Engineer, and analysis carried out in General design consideration and design procedure are also illustrated in this thesis in design calculation; the and HTRI software are used. Within the project work the analysis are done for heat exchanger with baffle and without baffle also used four material for tubes (brass, nickel, carbon steel ,stainless steel) and observed the heat transfer rate is increased for heat exchanger with baffle and when we used brass material.

D.amruthavijay, p.snehalatha (2016) 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. A Heat Exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. 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.

P Sowjanya, M Ganesh Kumar (2016) Demand of world energy consumption is steadily growing due to development of industries and increase of population. However, fossil fuels most available at this time will be exhausted in near future. Moreover, the fossil fuels cause environmental pollution and global warming. Therefore, fuel cell systems become interested in energy market for alternative energy sourcesthe ceramic heat exchanger then to improve the heat transfer rate of ceramic heat exchanger A circular tubes where placed in place of rectangle duct a comparison is also made for rectangular duct and circular tube heat exchanger to show which gives better performance.

Mohammed Irshad , Mohammed Kaushar (2017) Shell and tube heat exchangers are the most common type of heat exchangers used in present scenario. Heat exchangers are widely used equipment in various industries such as power generation and transportation, refrigeration industry and chemical process industries because it suits high pressure application. Presented in this project is comparison for several shell- and- tube heat exchangers with segmental baffles. drop and heat transfer rate values are obtained. From the CFD

result it is observed that the heat exchanger without any shortcircuited flow has the higher heat transfer coefficient than the heat exchanger with leakage.

3.0 Methodology:

In the present project, the methodology used in the design of the heat exchanger is studied and presented. 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. In this system oil is taken as hot fluid and cold fluid is water.

Materials and methods:

Silicon Carbide, SiC Ceramic Properties Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramic s, and numerous high-performance applications.

Silicon Carbide Properties:

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus

General Silicon Carbide Information:

Silicon carbide is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon carbide is not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. Thermal conductivity coupled with low thermal expansion and high strength give this material exceptional thermal shock resistant qualities. Silicon carbide ceramic s with little or no grain boundary impurities maintains their strength to very high temperatures, approaching 1600°C with no strength loss. Chemical purity, resistance to chemical attack at temperature, and strength retention at high temperatures has made this material very popular as wafer tray supports and paddles in semiconductor furnaces.

Design parameters of the ceramic heat exchanger:

It was considered from the paper a theoretical analysis and cfd simulation on the ceramic monolith heat exchangerModeling of ceramic heat exchanger by using NX-CAD software. Create finite volume mesh for 3D model of ceramic heat exchanger by

using ANSYS ICEM CFD software and import into ANSYS FLUENT software. Perform flow analysis of ceramic heat exchanger using ANSYS Fluent software to determine the flow rate the 3D model of the ceramic heat exchanger is created using NX-CAD software from the 2D drawings. NX-CAD is the world's leading 3D product development solution. This software enables designers and engineers to bring better products to the market faster.

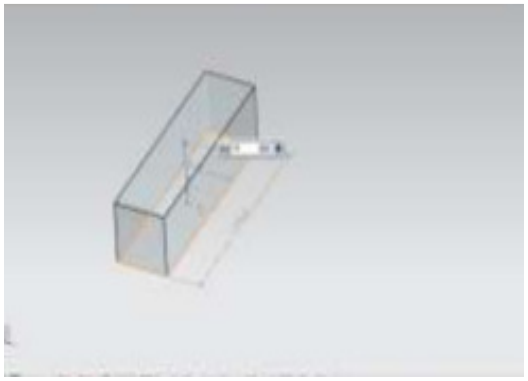


Figure: Generation of rectangle cube

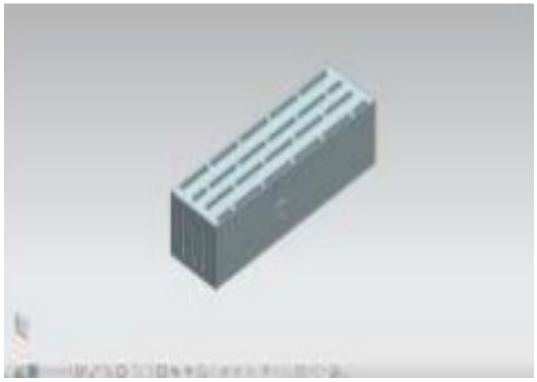


Figure: Final rectangle ceramic heat exchanger.

4.0 Flow analysis of ceramic heat exchanger:

CFD allows virtual experimentation and consequently optimization of parameters, such as fluids at different temperatures and wide range of operating boundary conditions. It is very attractive to industry as it saves both time and effort during the design process when compared to alongside traditional experimental methods. However, the degree of confidence in the results is dependent on many factors. In pre-processing stage, the ceramic heat exchanger was designed and meshed using edge and face meshing in order to take care of the sleekness, the figure of the ceramic heat exchanger is shown below. The domain was meshed by using tetrahedral meshing technique. For the flow analysis, the ceramic heat exchanger is generated in NX-CAD and mesh is created in the ICEM CFD software. The domain was meshed using tetrahedral meshing technique.

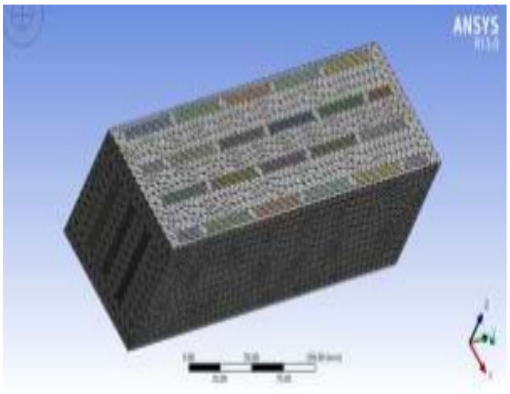


Figure: Mesh of rectangle tube heat exchanger

The CFX software comes with different boundary types which synchronize with the physical conditions. The CFX boundary model has been incorporated which uses "VELOCITY INLET' boundary types for fluid inlet. Flow velocity (5.02m/s) is given as inlet boundary condition for ceramic heat exchanger and temperature of 1123k is given as cool inlet boundary condition, temperature of 833k is given as hot inlet boundary condition.

Rectangular ceramic heat exchanger

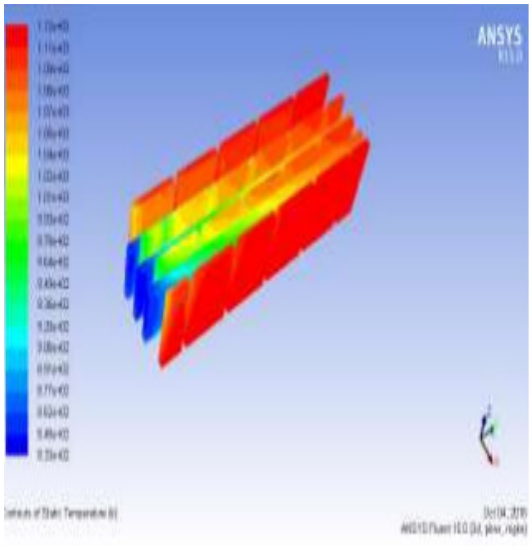


Figure: Overall heat exchanger after analysis

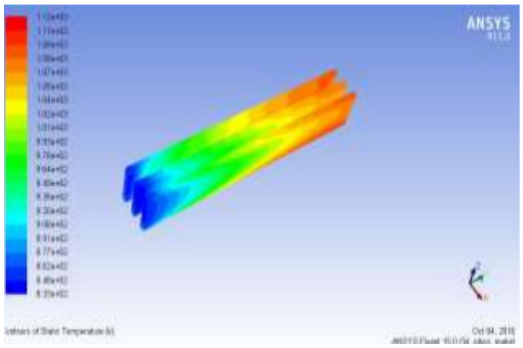


Figure: Temperature variation of heat exchanger

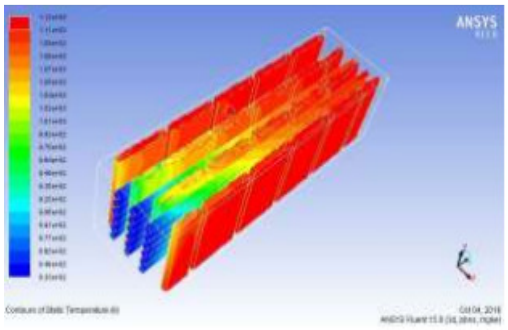


Figure:over allheat of Ceramic heat exchanger

Circular ceramic heat exchanger:

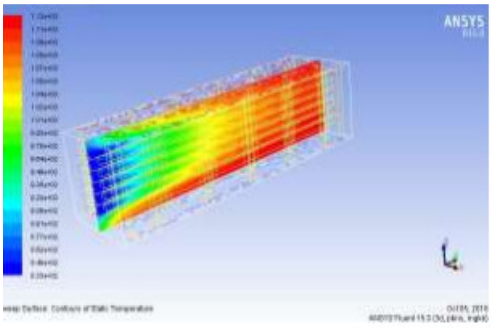


Figure: Sweep surface ceramic heat exchanger

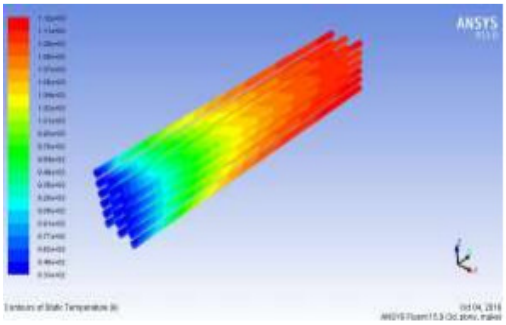


Figure: Temperature distribution in all circular pipes

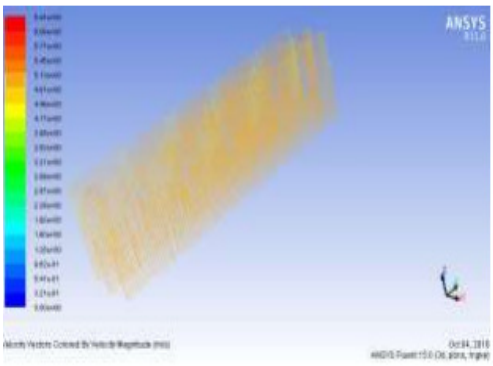
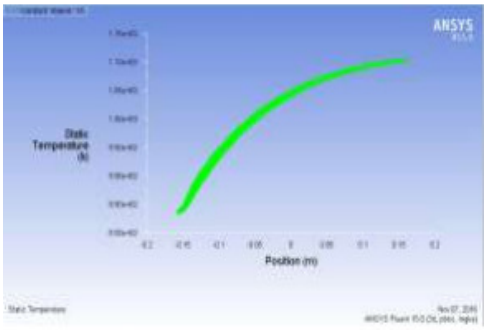
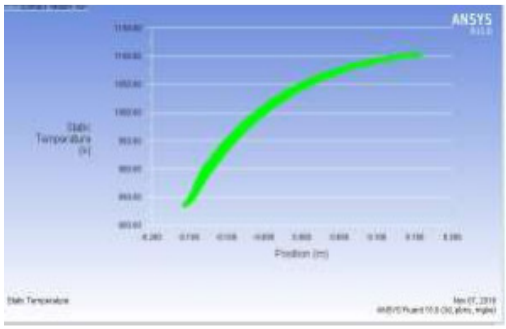


Figure: Velocity contours in circular ceramic heat exchanger



Graph: along length for circular ceramic heat exchanger



Graph: along length for rectangular ceramic heat exchanger

Conclusions:

In this project a 3D model of Ceramic heat exchanger is done. The generated 3-D model was imported into ANSYS CFD software using the Parasolid format and fluid flow analysis was done on Ceramic heat exchanger. Temperatures at cool air outlet are analyzed by performing fluid flow analysis of Ceramic heat exchanger for inlet velocity and inlet temperature boundary conditions. Optimization of model has been done to improve the heat exchange process.In this study simulation is carried out for hot exhaust ceramic core, and cold air in the ceramic heat exchanger then to improve the heat transfer rate of ceramic heat exchanger.A circular tubes where placed in place of rectangle duct a comparison is also made for rectangular duct and circular tube heat exchanger to show which gives better performance.

- Temperature variations has been analyzed by performing fluid flow analysis of rectangle slot ceramic heat exchanger is 978K for inlet temperature boundary conditions .And for circular slot ceramic heat exchanger is 964K.
- From the calculations the overall heat transfer rate of circular heat exchanger is 7times better than the rectangular heat exchanger.
- Hence optimization has been done to improve the efficiency. From the above results we observed that the modified ceramic heat exchanger is more efficient that original model.

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