Experimental Study on Double Pipe Heat Exchanger with Fin

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Abstract— Heat exchangers are a device that exchange the heat between two fluids of different temperatures that are separated by a solid wall. The temperature gradient, or the differences in temperature facilitate this transfer of heat. Transfer of heat happens by three principle means: radiation, conduction and convection. In the use of heat exchangers radiation does take place. However, in comparison to conduction and convection, radiation does not play a major role. Conduction occurs as the heat from the higher temperature fluid passes through the solid wall. The present work is based on industrial requirement. In the petroleum refinery after distillation different grade of oil comes out at different high temperature which comes in to a pump and supplied at required level. The heat exchanger data, temperature of hydrocarbon and required temperature rise of crude oil were Chosen. Therefore the objective of present work involves the study of refinery process and apply phenomena of heat transfer for aluminium material and different thickness for thermal design procedure of the counter flow heat exchanger. The inner pipe in which hot hydrocarbon flows and in outer annulus cold crude oil passes from opposite direction. The heat recovery from hot fluid is used to increase the temperature of cold fluid. Design was carried out based on the outlet temperature requirement of the cold fluid. With the help of computation fluid dynamics the study and unsteady simulation carried out for designed heat exchanger and based on the simulation results thermal analysis carried out.

Key words: Heat exchanger, Refinery process, Distillation, CFD analysis

I. INTRODUCTION

The double-pipe heat exchanger is one of the simplest types of heat exchangers. It is called a double-pipe exchanger because one fluid flows inside a pipe and the other fluid flows between that pipe and another pipe that surrounds the first. This is a concentric tube construction. Flow in a double-pipe heat exchanger can be co-current or counter-current. There are two flow configurations: co-current is when the flow of the two streams is in the same direction, counter current is when the flow of the streams is in opposite directions. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid [1-3]. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperates[4-6] . In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface or matrix are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/valve switching [7] . Heat transfer in the separating wall of a recuperate generally takes place by conduction. However, in a heat pipe heat exchanger, the heat pipe not only acts as a separating wall, but also facilitates the transfer of heat by condensation, evaporation, and conduction of the working fluid inside the heat pipe [8-9] . In general, if the fluids are immiscible, the separating wall may be eliminated, and the interface between the fluids replaces a heat transfer surface, as in a direct-contact heat exchanger. The double pipe heat exchanger is shown in fig 1.

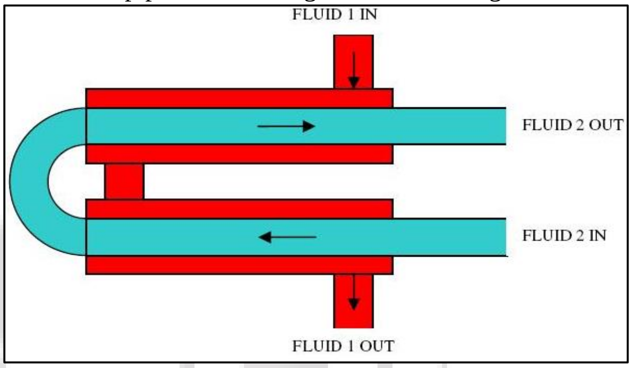

Fig. 1: Double pipe heat exchanger

Chemical resistance under operating conditions with regard to corrosive media, concentration, temperature, foreign substances, flow behavior etc. the rate of corrosion must be negligible over a prolonged period of time and the material must be resistant against other corrosion phenomenon, mechanical resistance i.e. strength and sufficient toughness at operating temperatures, no detrimental interference by the material on the process or on the products, easy supply of material with time permitted and in the time required.

II. REFINERY PROCESS

Refinery processes have developed in response to changing market demands for certain products. With the advent of the internal combustion engine the main task of refineries became the production of petrol. Distillation is the first step in the processing of crude oil and it takes place in a tall aluminium tower called a fractionation column. The inside of the column is divided at intervals by horizontal trays. The column is kept very hot at the bottom (the column is insulated) but as different hydrocarbons boil at different temperatures, the temperature gradually reduces towards the top, so that each tray is a little cooler than the one below. As the raw crude oil arriving contains quite a bit of water and salt, it is normally sent for salt removing first, in a piece of equipment called a desalter. Upstream the desalter, the crude is mixed with a water stream, typically about 4 - 6% on feed. Intense mixing takes place over a mixing valve and (optionally) as static mixer. The desalter, a large liquid full vessel, uses an electric field to separate the crude from the water droplets. The refinery process is shown in fig2.

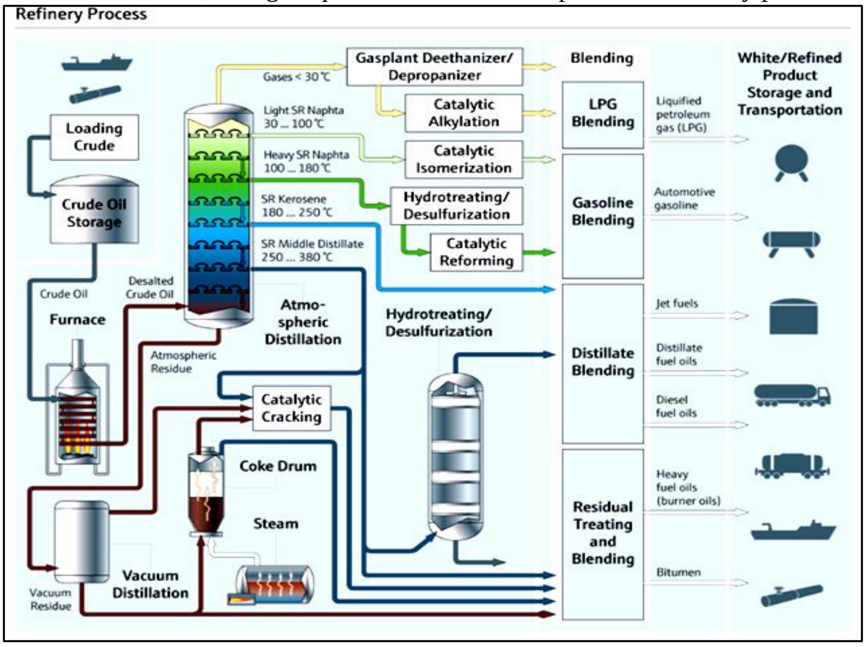

Fig. 2: Refinery process

III. DISTILLATION (FRACTIONATION)

Atmospheric distillation takes place in a distilling column at or near atmospheric pressure. The crude oil is heated to 350 - 400ºC and the vapour and liquid are piped into the distilling column. The liquid falls to the bottom and the vapour rises, passing through a series of perforated trays (sieve trays). Heavier hydrocarbons condense more quickly and settle on lower trays and lighter hydrocarbons remain as a vapour longer and condense on higher trays. Liquid fractions are drawn from the trays and removed. In this way the light gases, methane, ethane, propane and butane pass out the top of the column, petrol is formed in the top trays, kerosene and gas oils in the middle, and fuel oils at the bottom. Residue drawn of the bottom may be burned as fuel, processed into lubricating oils, waxes and bitumen or used as feedstock for cracking units. To recover additional heavy distillates from this residue, it may be piped to a second distillation column where the process is repeated under vacuum, called vacuum distillation. This allows heavy hydrocarbons with boiling points of 450oC and higher to be separated without them partly cracking into unwanted products such as coke and gas. The heavy distillates recovered by vacuum distillation can be converted into lubricating oils by a variety of processes. The most common of these is called solvent extraction. In one version of this process the heavy distillate is washed with a liquid which does not dissolve in it but which dissolves (and so extracts) the non-lubricating oil components out of it. Another version uses a liquid which does not dissolve in it but which causes the non-lubricating oil components to precipitate (as an extract) from it. Other processes exist which remove impurities by adsorption onto a highly porous solid or which remove any waxes that may be present by causing them to crystallize and precipitate out.

IV. MODEL DEVELOPMENT OF HEAT EXCHANGER

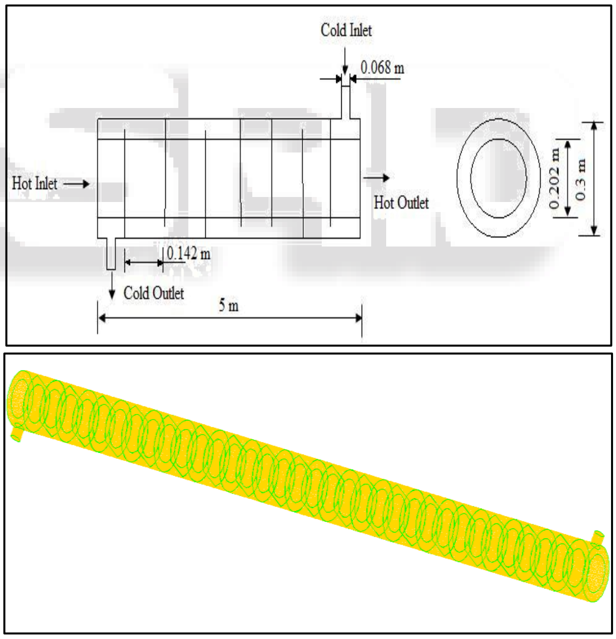

Fig. 3: Model heat exchanger

A. *Design Parameters*

1) *Shell Side*

- Type of fluid: crude oil.
- Inlet temperature =313k
- Outlet temperature =553k.
- Mass flow rate=0.320kg/s.
- Diameter of shell=0.3m.

2) *Tube Side*

- Type of fluid: diesel oil.
- Inlet temperature =618k
- Outlet temperature =?.
- Mass flow rate=145.6kg/s.
- Specific gravity=0.874

- Tube inside diameter =0.2027m.
- Tube outside diameter=0.2191m

V. Results and Discussion

The present work involves the Numerical analysis of the heat exchanger for aluminium material with varying fin thickness for cold fluid. Initially the simulation is carried out with mass flow rate 0.320 kg/s. The analysis carried out for aluminium, of different thickness range from 0.002m to 0.005m in the interval of 0.001m are and the simulations and results are discussed. These simulations are done as an attempt for analysis of heat transfer and flow phenomena in the shell side and tube side. The steady state and unsteady simulations are done with inlet conditions using turbulence model. The domain in the present study is quite a complex 3-D geometry, so it is quite diligent to present the flow physics in the whole domain for discussions. The 2-D planes are taken in the geometry for the discussions. The plane and line along with the whole geometry and the coordinate axes are shown in Fig 5.1. The Plane and line are taken along the length of the heat exchanger in the X-Y planes of constant Z-coordinate. Plane is taken in the centre of tubular section and a line is at 0.220m from an outlet of the section.

A. *Material Aluminum*

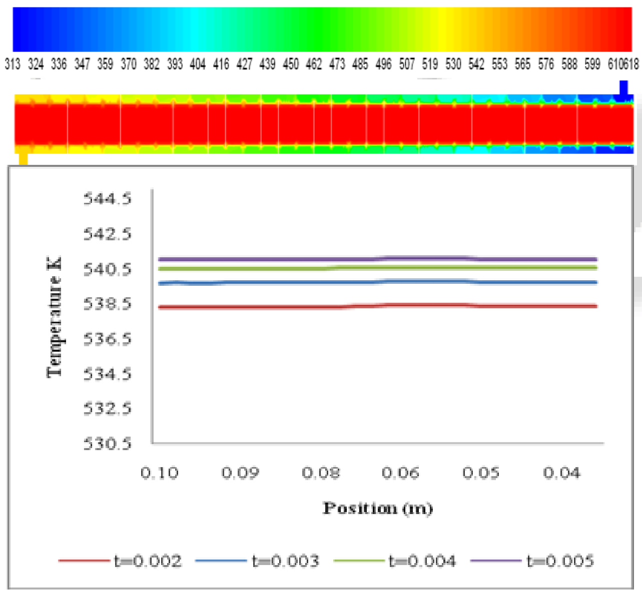

Fig. 4: Temperature variation across Outlet for varying Fin thickness.

B. *Summary of CFD analysis results*

Mass flow rates 0.320kg/s

Sr no	Thickness of fin (m)	Temp. (k)	Pressure (Pascal)	Vel(m/s)	Heat transfer (W)
1	0.002	538.39	37.7	0.14	176473.69
2	0.003	539.76	38	0.14	177524.04
3	0.004	540.55	38	0.14	178145.21
4	0.005	541.07	38	0.14	178549.9

Table 1: Variation of properties with different thickness aluminum

VI. Conclusions

Based on the analysis the following important conclusions are

- The temperature of the cold fluid at the outlet of the heat exchanger increases with increase the fin thickness.
- There is very minor changes occur in the pressure and velocity profile with increase of fin thickness and doesn't get much affected by varying thickness of fin and material of fin.
- The simulated outlet temperature is 543k which is very near to design outlet temperature 553k. there is less than 3% variation occurs in design value**.**

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