Thermal Design and Analysis of Shell And Tube Heat Exchanger With The Use Of Alumina (Al_2O_3) Nanoparticle

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Abstract--- In the last decades our world is been marked by questioning of Sustainability, Resource scarcity. To guarantee the safety of future generations, governments and industries share the common goal of environment preservation and rational energy expenditure. Heat exchangers perform an important role in heating, cooling and heat recovery. This project deals with design, and analysis of a Shell and Tube type condenser. But the main limitation of current exchangers is the poor heat transfer behaviour of common operating fluids, such as oil, glycols or water. To improve fluid heat transfer, the recent advent of nano fluids having high heat transfer nanoparticle suspensions in base fluids, has taken place. These have displayed substantial heat transfer performances. For the convective heat transfer study of a nano fluid, Alumina powder suspended in water with different volumetric concentration of nanoparticle is used. After extensive literature review, Kern approach for thermal design and TEMA design code is used for mechanical design and validated based on experimental data to find the effect of nanofluid in heat exchanger. The acquired results for the nanofluid are then compared to the matching data for base-water and to common theoretical correlations.

I. INTRODUCTION

Heat exchangers are devices in which heat is transfer from one fluid to another. The most commonly used type of heat exchanger is a shell and tube heat exchanger. Shell and tube heat exchangers are used extensively in engineering applications like power generations, refrigeration and air-conditioning, petrochemical industries etc. These heat exchangers can be designed for almost any capacity. The main purpose in the heat exchanger design is given task for heat transfer measurement to govern the overall cost of the heat exchanger. In condensers, the latent heat is given up by process fluid and then it is transferred to the cooling medium. Water or air is generally used as cooling medium in industry; here it is Nanofluid to increase the heat transfer capacity.

A. *Application Of Shell And Tube Heat Exchanger :*

The shell-and-tube heat exchanger is by far the most common type of heat exchanger used in industry. It can be fabricated from a wide range of materials both metallic and non-metallic. Design pressures range from full vacuum to 6,000 psi. Design temperatures range from 250°C to 800°C. Shell-and-tube heat exchangers can be used in almost all process heat transfer applications [1].

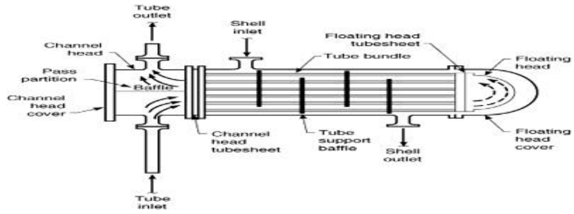

Fig.1.1: Shell and tube heat exchanger

The shell-and-tube design is more rugged than other types of heat exchangers. However, it may not be the most economical or most efficient selection especially for heat recovery applications or for highly viscous fluids. The heat exchanger will perform poorly with any temperature crosses unless multiple units in series are employed. Typical applications include condensers, re-boilers and process heaters and coolers.

II. NANOFLUID

Nanotechnology is the production and use of materials with purposely engineered features close to the atomic or molecular scale. Nanotechnology deals with putting things together tomby-atom and with structures so small they are invisible to the naked eye. It provides the ability to create materials, devices and systems with fundamentally new functions and properties. It is the use and manipulation of matter at a tiny scale. At this size, atoms and molecules work differently, and provide a variety of surprising and interesting uses.

The prefix of nanotechnology derives from "Nanos" – the Greek word for dwarf. A nanometer is a billionth of a meter, or to put it comparatively, about 1/80,000 of the diameter of a human hair. Although often referred to as the 'tiny science', nanotechnology does not simply mean very small structures and products. Nanoscale features are often incorporated into bulk materials and large surface area. When we talk about nanotechnology, there is possibility that we might minimize the size of current heat exchanger into a smaller size.

Table. 1 Summaries of experimental studies of nanofluids

Authors (year)	Nanoparticle material	Base fluid	Enhancement in K (vol. fraction)
Xuan and Li(1999)	Cu	Water	54% (5 vol. %)
Xie et al. (2002)	Al_2O_3	EG	30% (5 vol. %)
Hong et al. (2005)	Fe	EG	11.5% (0.55 vol. %)
Murshed et al.(2006)	Al_2O_3	Water	24% (5 vol. %)
Liu et al.(2006)	CuO	EG	23% (5 vol. %)
Lee et al.(2008)	Al_2O_3	Water	1.44% (0.3 vol. %)

Thermo Physical Properties Of Nanofluid: Experimental studies show that thermal conductivity of nanofluids depends on many factors such as particle volume fraction, particle material, particle size, particle shape, base fluid material, and temperature. The transport properties of nanofluid: dynamic thermal conductivity and viscosity are not only dependent on volume fraction of nanoparticle, also highly dependent on other parameters such as particle shape, size, and mixture combinations etc. Studies showed that the thermal conductivity as well as viscosity both increases by use of nanofluid compared to base fluid.

- Thermal conductivity
- Viscosity of nanofluid:
- Density of nanofluid
- Specific heat of nanofluid

III. Design Of Heat Exchanger

Design of a condenser is considered more complicated and interesting than a simple heat exchanger. But the design of desuperheater-condenser is more interesting because it includes both sensible and latent heat transfer. Desuperheating is basically a phenomenon where vapors undergo sensible cooling. Due to this reason, the heat transfer coefficient is lower for desuperheating.

There are different method is used for Design of shell and tube heat exchanger, Kern Method, Bell – Delaware, Will –Johnston method. It is concluded from literature review and expert opinion that Kern method is more suitable for the thermal design of condenser Kern provide methods for calculating shell-side pressure drop and heat transfer coefficient were those in which correlations were developed based on experimental data for typical heat exchangers[2]. This method provides higher values for the heat-transfer coefficient and pressure drop on the shell side.

A. Design Steps For Manual Design Of R22-Water Desuperheater-Condenser : For manual design of R22-Water Desuperheater-condenser, the following steps have been followed [3, 4]:

- Allocation of the fluids on shell side and tube side.
- Calculation of heat duty
- Calculation of water flow-rate.
- Selection of appropriate condenser geometry.
- Estimation of intermediate temperature based on condensation duty.
- Estimation of area required for desuper heating and condensation separately.
- Estimation of number of tubes and selection of number of tube passes.
- Calculation of shell diameter.
- Calculation of shell side and tube side heat transfer coefficients.
- Estimation of shell side and tube side pressure drop.

Table. 2:detail specification of shell and tube condensor

Type	Shell And Tube Type Condenser
Size	Shell:5mm thick, Tube: 19.05mm O.D
Material	Tube: Copper, Shell: Mild Steel
Capacity	10 TR
Shell Fluid	Refrigerant Gas : R-22
Tube Fluid	Water based Nanofluid (Water + Alumina)
No of Pass	Tube Side: 2 ,Shell Side:1
Inlet temp of R-22	120 ^{0}C
Outlet temp of R-22	52.70 ^{0}C
Inlet temp of Nanofluid	30 ^{0}C

Design Considerations: For designing the desuperheater-condenser, some points such as fluid allocation, tube layout and passes, baffle type etc. have been considered. Ammonia has been allocated to shell side. As water is the cooling medium, it is preferably routed through the tube side as it is more corrosive and fouling. A square tube layout has been selected, as ammonia service is corrosive and would require continuous cleaning lanes, which cannot be accommodated in triangular layout [5]. Six tube passes have been selected (as the optimum value), because at two and four passes, the tube side velocity comes out to be less than 1 m/s.

To avoid fouling, the tube side velocity should be kept greater than 1 m/s. Single segmental baffles with 250 mm of baffle spacing and 25 % baffle cut (optimized values) have been selected. Double segmental baffles or No-tubes-in window baffles can also be selected, but they give a slightly lower value of heat transfer coefficient and, % overdesign is also decreased [6, 7]. TEMA AES type exchanger has been selected. E-shell is the simplest in construction and also cheapest as compared to other shell types [1]. Standard correlations based on kern's method have been used for carrying out the manual theoretical calculations.

IV. Results And Discussions

Designing a heat exchanger is an art. So many parameters have to be taken care of, and for a good design, it is very necessary to analyse the effect of all the design parameters simultaneously. While designing a heat exchanger manually, it is very difficult to vary different parameters simultaneously and analyse the effect. Manual calculations become more of a trial and error loop.

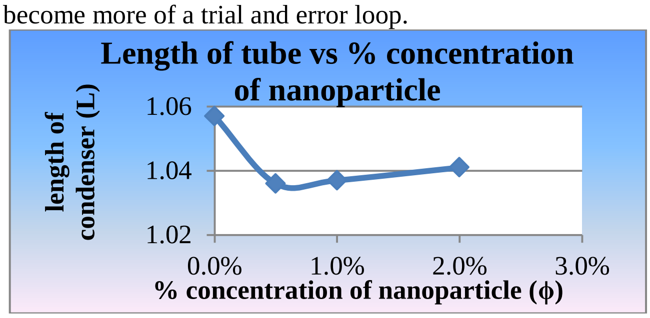

Fig.1.1 Condenser tube length vs % concentration of Nanoparticle

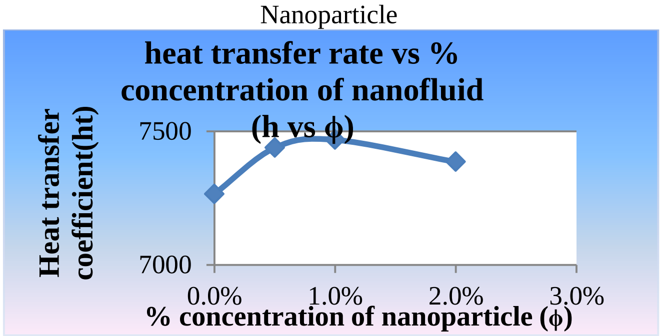

Fig.4.2 Heat transfer coefficient vs % concentration of nanoparticle

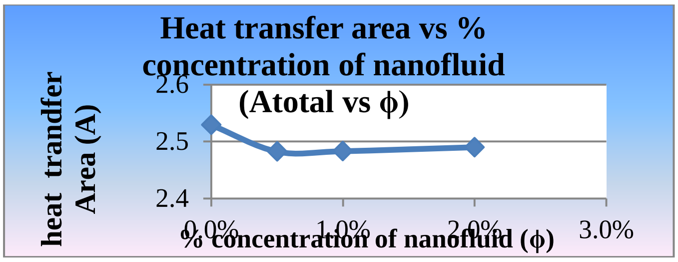

Fig. 4.3 Heat exchanger area vs % concentration of Nanoparticle

V. CONCUSION

By the numerical model it is found that Heat transfer rate increases by addition of nano particle in working medium (water) this phenomenon remains continuous up to certain level of saturation and then after heat transfer rate decreases by the further addition of Nanoparticle. Above phenomena mainly includes these parameters: density, specific heat, thermal conductivity and convective heat transfer coefficient. Results show that increase in density or concentration of Nanoparticle accompanied by reduction in specific heat of nanofluid and hence heat transfer rate must decreases with addition of Nanoparticle. But because of the high conductivity of Nanoparticle heat transfer increases.

After certain level of saturation heat transfer rate decrease by further addition of Nanoparticle. High concentration Nanoparticle results in viscous heat generation which reduces the capacity of outside heat absorption. So it is concluded from numerical model that high transfer rate may be achieved by nanofluid in place of conventional fluid.

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