

A Review on Shell & Tube Heat Exchanger Using Nanofluids for Enhancement of Thermal Conductivity

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ABSTRACT: A heat exchanger is a device that allows heat from a fluid (a liquid or a gas) to pass to a second one (another liquid or gas) without their mixing or direct contact. The efficiency of the heat exchanger depends directly on the heat transfer coefficient of the material. In this review paper a comparison of shell & tube heat exchanger with varied designs of tubes is done; with water and nanofluid as coolants. Nanofluids are suspensions of nanoparticles in base fluids. The convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature, due to increased surface area. And the variation in design of tube helps in improving the turbulence of flow and thereby improves heat transfer.

KEYWORDS: Nanoparticles, Nanofluids, Heat exchanger, Baffles, Copper oxide, Thermal conductivity, Conduction, Convection, Turbulence

I. INTRODUCTION

Heat exchanger is equipment where heat energy is transferred from a hot fluid to a cold fluid. The transfer of heat energy between the two fluids could be carried out:-

- (i) Either by direct mixing of the two fluids and the mixed fluids leaves at an intermediate temperature determined from the principles of conservation of energy (convection),
- (ii) Or by transmission through a wall separating the two fluids (conduction). The former types are called direct contact heat exchangers such as water cooling towers and jet condensers. The latter types are called regenerators, recuperator surface exchangers. Heat exchangers are widely used in automobiles as radiators, oil coolers etc, in chemical and process industries.

A mixture of nanoparticles suspended in a base liquid is called as nanofluid. The base fluid can be selected based on properties of nanoparticles and the nanofluid required. Water is widely used as the base fluid in most cases. When compared to conventional liquids nanofluids have many advantages like higher thermal conductivity, better flow, and pressure drop induced is very small, prevent sedimentation and high surface area. Increased thermal conductivity, increased heat transfer, and increased critical heat flux are the three important features of nanofluid which makes it a better coolant. From various researches it has been found that adding very small amount of nanoparticles to the base fluid can enhance thermal conductivity to large extend.

The concept of heat exchangers first developed by Lewis E. Grimes, Michael D. Rychener and Arthur W. Westerberg in the journal "The synthesis and evolution of networks of heat exchange that feature the minimum number of units", in 1981 [1]. The heat transfer rates of different materials were calculated, and the one with maximum advantage was selected by P. Rodriguez in his journal "Selection of Materials for Heat Exchangers", published in 1997 [2]. The use of nanofluids in heat exchanger, was studied and introduced by A. K. Singh in his journal "Thermal Conductivity of

Nanofluids”, published in 2008 [3]. All the subsequent papers, [4] [5] [6] [7] [8] were all pointed to the same direction supporting the context, which were used in analysing the various factors affecting heat exchangers.

The work in this review paper is divided into three different sections. The section 1 is about introduction to heat exchangers and nanofluids, section 2 deals with the discussion on analysis of two different designs of heat exchangers. And finally in section 3 conclusions about the variation in design and in fluid is explained.

Shell and Tube Heat Exchanger

In shell and tube heat exchanger one of the fluid flows through a bundle of tubes enclosed by a shell. The other fluid is forced through the shell and it flows over the outside of the tubes. Baffles are provided inside the shell which directs the flow through the shell. This type of arrangement is employed where reliability and heat transfer effectiveness are important. With the use of multiple tubes heat transfer rate is amply improved due to increased surface area. Tubes are made of materials with high thermal conductivity and heat transfer coefficient.

II. DISCUSSIONS

In this review paper we are comparing the heat transfer rate in two different designs of shell and tube heat exchangers. Comparison is made on the type of fluid flowing through the tube. Materials selection for making heat exchanger and the nanofluids are done with the help of journals mentioned.

The first design consists of shell and tube heat exchanger with straight tubes and second with curved tubes. The shell and tube are made of steel and copper respectively. The designs are created using SOLIDWORKS software, in different parts and were assembled. Baffles were also added in between for increasing the turbulence and to prevent vibration of tubes inside.

First step is the analysis of the heat exchangers in ANSYS software. The variation in the heat transfer of the two different designs with different fluids is taken into consideration. First, we create heat exchangers with both straight and curved tubes. Then analysis is to be done in the designs for finding thermal conductivity with water and nanofluid as coolants. The nanofluid selected is copper oxide (CuO) dispersed in water.

3D & 2D Designs of Heat Exchanger

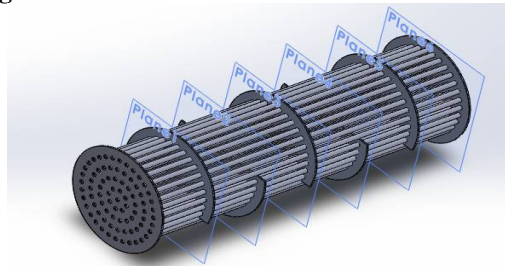


Fig. 1: 3D view of straight tube heat exchanger

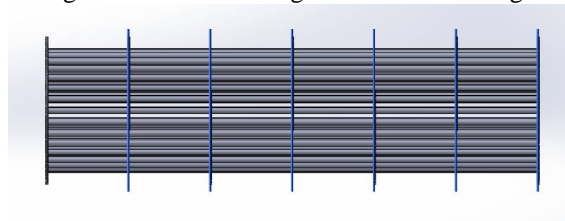


Fig. 2: 2D view of straight tube heat exchanger

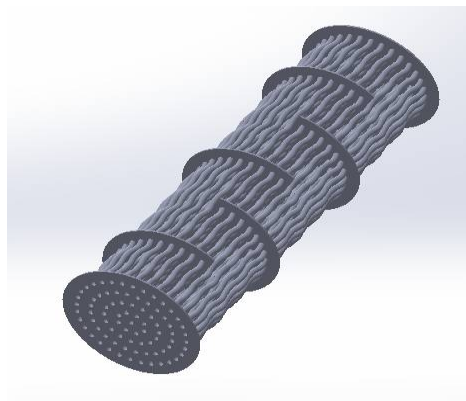


Fig. 3: 3D view of curved tube heat exchanger

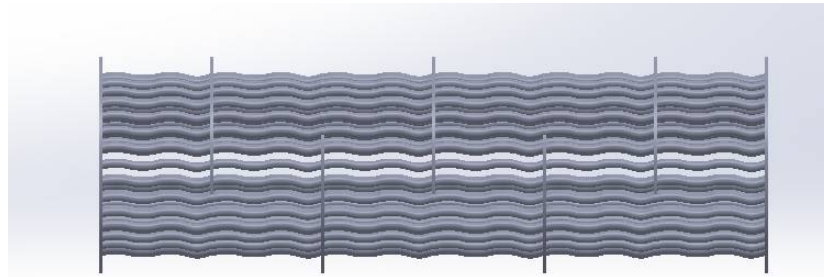


Fig. 4: 2D view of curved tube heat exchanger

Properties of Materials Used

Steel:-

The core material used for the synthesis of shell is steel, Stainless steel exchangers work well in a wide range of pH, which reduces maintenance cost than aluminium heat exchangers which have less range of pH. This necessitates the water in the boiler to be treated frequently with special chemicals to maintain an optimal pH. This regular maintenance required by aluminum boilers comes at an extra cost, which is eliminated by using stainless steel. The stainless steel exchanger is less vulnerable, durable and efficient. It does not need periodic maintenance and will not be replaced often.

Copper:-

The tubes of shell and tube heat exchanger are made of copper because thermal conductivity of copper is very high and as a result it allows fast heat transfer. The thermal conductivity of copper is 399 W/mK. Apart for thermal conductivity copper have many other properties that makes copper suitable for making tubes in heat exchangers. Copper has a good corrosion resistance, antimicrobial properties that prevent surface contamination, tensile strength and they are easy to fabricate and assemble.

Copper Oxide (CuO) nanofluid:-

The nanofluid used in this shell and tube heat exchanger is Copper Oxide (CuO) dispersed in water. CuO nanoparticles appear as a brownish black powder. CuO nanoparticles are used in areas of batteries, catalysts, solar energy, superconductors, magnetic storages etc. CuO nanoparticles are dispersed in water to make CuO nanofluids. CuO nanofluids have very high thermal conductivity and heat transfer properties which makes it suitable for using it in heat exchangers and other thermal applications. The main demerit of CuO nanofluid is that it has the tendency to agglomerate with time and thus it tends to reduce the surface area. But since they are continuously flowing through the heat exchanger this problem is neglected.

III. CONCLUSION

In this review paper, we proposed a theory of heat exchanger with curved tubes along with nanofluids as coolant. The idea was completed as proposed and the outcome is verified. When water in the conventional heat exchanger is substituted with nanofluids, the heat transfer rate increases as the thermal conductivity of nanofluids is higher than that of water due to its increased surface area. When the straight tubes are replaced by curved tubes we find that the heat transfer rate is increased both for water and nanofluid, this is because the use of curved tubes increases the turbulence and fluid velocity which helps in increasing the heat transfer rate.

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