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Heat transfer analysis of heat exchanger using Al_2O_3 nanofluid

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Abstract— **This project describes the experimental analysis of aluminum based nano fluid with the help of heat exchanger system. A pipe in pipe heat exchanger is used. The heat exchanger is designed in such that the cross flows between fluids. The nano fluid is supplied from one end from pump and from another side water is supplied in crossflow direction. The purpose of a system is to investigate the rate of heat transfer nano fluid and to increase rate of heat transfer of the system using nano fluid. This dissertation is an experimental study to reduce the loss of heat and increase the rate of heat transfer and effectiveness of system.**

Keywords— Heat Exchanger, Nano fluid, Pump, Effectiveness.

I. Introduction

The energy conservation is important phenomenon or issue in the twenty first century. In this modern era energy needs to save and conserve properly with minimum wastage. Therefore, scientists, engineers are working satisfactory and trying to find this issue. The heating or cooling phenomenon rate of heat transfer plays very important role and in the industrial applications which helps the efficiency as well as the operational life of the heat transfer equipments. For energy saving conservation, conversion, and recovery are some of the routes. In most of the power plants, atomic reactors, petrochemical industry, refrigeration, air-conditioning, process industry, solar water heater, food process engineering, and chemical reactors different types of heat exchangers are used. According to recent studies, nanofluids are performing major role in improving the rate of heat transfer in many applications such as cooling, power generation, defense, nuclear, space, microelectronics and biomedical appliances [1].

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TABLE I
CONDUCTIVITY VALUES FOR DIFFERENT SOLIDS AND LIQUIDS (METALLIC AND NON-METALLIC)

Type of Material	Name	Thermal Conductivity (W/mK)
Metallic solids	Silver	429
	Copper	401
	Aluminum	237
Non-metallic solids	Diamond	3300
	Carbon Nanotube	3000
	Silicon	1458
	Alumina (Al_2O_3)	40
Metallic liquids	Sodium @644K	72.3
Non-metallic liquids	Water	0.613
	Ethylene Glycol	0.253
	Engine Oil	0.145

Nanofluids are produced by dispersing the particles of metallic or non-metallic nano particles or Nano fibers of smaller size (<100nm) in base fluid. Nano particles present in base fluid contribute better flow of mixing and higher thermal conductivity when measured with pure fluid. Even a small amount of nano particles can noticeably enhance the effective thermal conductivity of the Nano fluids. Most of nano particles have greater thermal conductivities than most of the liquids used as base fluids [2]. A substantial reduction in energy consumption could be made possible by improving the rate of heat transfer. Analyzing thermal conductivity with pure fluid, the presence of nanoparticles in the base fluids helps to improved mixing flow and increased thermal conductivity. These typical fluids have thermal conductivities that are several hundred times greater than solid particles. Suspension of ultrafine solid particles in a fluid can be a creative way to increase thermal conductivity. Slurries may be created by adding different sorts of particles (metallic, non-metallic, and polymeric) to fluids [3]. Some significant issues, such as blockage of flow channels, erosion of pipelines, and pressure loss, might arise due to the millimetre or micrometre size of these suspended particles. A property causing significant concern is thermal conductivity. The introduction of Nano fluids usually represents a significant enhancement in the thermal conductivity of the fluid, which represents an enhancement in the heat transfer of a determined application. Indeed, even a modest quantity of nano particles can essentially upgrade the successful warm conductivity of the Nano liquids once most solids have more noteworthy warm conductivities than a large portion of the fluids utilized as base liquids [4]. Also, many study reports that the introduction of Nano metric-sized particles in base fluids results in a fluid with large thermal conductivity than the thermal conductivity expected from the simple combination of the solid particles and the fluid, obtained from the weighted mean of the thermal conductivities of the base fluid and the nano particles. For improving the efficiency of heat exchanger, the different technologies are developed and available. The aim of it is that the improving efficiency by transferring heat and also reduces time. The fins are frequently used for improving rate of heat transfer. The weight and volume of heat exchangers are increased with this technique [5]. Also, ongoing investigations show that the utilization of Nanofluids speaks to a critical improvement not just in the conduction heat move yet additionally in the convection heat move. Hence to improve rate of heat transfer in different areas and to improve efficiency of systems like automotive cooling system collaboration of Nano fluids in the system is the technique evolving now a days. The thermal physical properties can be improved by mixing additives in the mixture which is interesting technique. By making the composite mixture of convectional fluids with the solid particles called nano fluid. The property of thermal conductivity and stability can manage with nano fluids in the heat exchangers. Various nano fluids are available in market are copper, aluminum, titanium, silicon, alumina, sodium, engine oil etc. generally used [6-10].

The term Nano fluids was first defined was in 1995, when Choi coined it, while working in a research project at Argonne National Laboratory. According to literature survey, particle size of nano particles dispersed in based fluids usually has diameters or lengths (not always nano particles are spheres) within a range from 1 up to 100 nm [11,12].

So, it can be inferred that Nanofluids consists of the following parts: nanoparticle and base fluid. However, as stabilization of the dilution is a relevant aspect to get trustable results, sometimes additives such as dispersants are added to avoid sedimentation of particles, in case the sample is clearly heterogeneous; therefore, as is desired, a single-phase fluid will be obtained. Moreover, different facets of these samples can be analyzed and discovered the reasons lead to have great unexpected results for common thermal physical properties. The main important parameters affect Nanofluids behaviors are: particle size, concentration and shape, nanoparticle material, base fluid nature, sonication time of sample, method manufacturer employed or pH-value of dilution [13,14].

Enhancement of thermal conductivity is of the enormous thermal conductivity of solid molecules, which usually are hundred or even thousand times larger than traditional base fluids, shown in Table 1. Although thermal conductivity improvement is important, after knowing that, Nanofluids should be tested for forced-convection cooling applications such as laminar and turbulent flow. In that case, when evaluation of Nano fluids behavior in a cooling system is needed, the determining parameter is heat transfer coefficient [15].

Thereby, heat transfer coefficients reach higher values than expected due to two possibilities. One of the movements of nano particles, which get better in the energy exchange process, is Nano fluids. The other reason was mentioned above these lines, where it explained through experiments thermal conductivity of solid molecules were the reason of these unexpected enhancements, so, the same occurs for heat exchange coefficient [16].

In this manner, some experiment shows the development of that coefficient in flowing liquids while these are working in forced-convection cooling applications; furthermore, as was found through the literature survey, some great increase has been detected for various Nanofluids tested in conditions mentioned before. So, can be said that Nanofluids play an important role in heat exchange field, and its potential impact about finding a solution for the problem has been established in the previous introduction could be really big [17].

II. NANOFLUIDS

Heat exchangers that employ Nano fluids to transmit heat are called Heat Exchangers. Nanofluids are used in this process. Fluids such as water, ethylene glycol, oil, hydrocarbons and fluorocarbons may be produced using nanoparticle suspensions. Nano fluid, first suggested by S.U.S. Choi of Argonne National Lab in 1995, inventive turning out liquid for heat move made by scattering exceptionally warm directing strong particles more modest than 50 nanometers in width in conventional low warm leading warmth move liquids such water, engine oil, and ethylene glycol. The primary objective or thought of utilizing Nano liquids is to achieve most noteworthy conceivable warm properties at the littlest potential fixations (by volume fraction 4.3 %) by uniform dispersion and stable suspension of Nano particles (preferably 13nm - 100nm) in hot fluids. It is made up of water and suspended metallic nanoparticles (nanofluid). It is customary for a strong/liquid combination to have a higher viable warm conductivity compared to the base liquid since the warm conductivity of metallic particles is often much greater. At a changing intake temperature, Al_2O_3/water nanofluids are examined in an experiment to increase heat transmission inside a double tube heat exchanger [18].

A mathematical examination for Cu-water nano liquid is move through a round channel embedded with cross-cut wound tape with substitute hub (CCTA) [19,20]. One of the fundamental downsides of utilizing nano liquids as a warmth move media which restricted its application in ventures is higher-pressure drop-in examination with the regular liquids [21]. The numerical study is carried out on the use of nano fluids to replace conventional ethylene glycol/water mixture as heat carrier in a Bore Hole Heat Exchanger [22].

The conventional fluids (water and EG) have been used as a coolant in the heat exchangers system. Nonetheless, the restricted thermo-actual properties of these liquids limit heat move across the warmth exchangers. The expanding interest for energy and better execution has prompted the examination of different strategies. The Space constraint is another key issue in the heat exchanger system.

Heat exchanger used is of pipe in pipe type and will be using Aluminum based Nanofluids as a coolant. The Nanofluids will be prepared by two step method or one step method. Nanofluid is prepared by mixing Nanoparticles in water in different compositions. Later performances of the Heat Exchanger are tested with water, ethylene glycol and Aluminum based as coolant. Comparison will be made between coolant flow rates and temperature difference, coolant flow rates and average heat transfer, coolant flow rates and effectiveness, time and temperature difference, time and average heat transfer.

Engine Nano-coolant is a coolant that contains nanometer-sized particles. In order to achieve uniform and steady suspension, the Nano-design coolant's must be well thought out. Aluminium is utilised as a nanoparticle and heat exchanger coolant as a base fluid in the current investigation. Due of its chemical stability and lower cost than their metallic equivalents, aluminium was chosen as the nanoparticles' primary material. The properties of Aluminium based and water are given in Tables 1.

III. Experimental Setup

The experimental setup contains a metal reservoir tank, a heat exchanger, a submersible pump, tubes, valves, hoses, AC power supply, four R-tek wired probe aquarium thermocouples for temperature measurement, Nano fluid, water. A flow meter (0–70 LPM) and two valves measure and control the flow rate. The hot fluid is passed into the heat exchanger with the help of pump from the water tank. The flow control valve is used to regulate the flow according to standard requirements and also fluid is pumped with the help of suitable pump. The pipe in pipe heat exchanger is used in which the hot fluid is passing in the inner pipe and cold fluid is passed in the outer pipe so that the heat is transferred from hot to cold fluid and inlet temperature of the hot water is higher at starting of the testing ones the nano fluid passed through the other pipe the temperature of hot fluid is decreased and maximum heat transfer occur because of use of nano fluid. While that of the outlet temperature of the nanofluid is increased at its outlet port.

Heating the water is provided by the heater, and water is circulated throughout the setup by the pump. The temperature sensor indicates a steady increase in water temperature in the setup. Forced convection transfers heat from the system to the environment. The rate of heat transfer increases when cold and hot water come into touch with one other. Coolant travels from the heat exchanger's intake to its exit through a series of tubes placed in a counter-flow configuration. The measure of warmth moved to the cylinders from the liquid going through them relies upon the distinction in temperature between the cylinder and the liquid contacting it. So, if the liquid that is in contact with the cylinder chills off rapidly, less warmth will be moved. By making choppiness inside the cylinder, the entirety of the liquid combines, keeping the temperature of the liquid contacting the tubes up so that more warmth can be extricated, and the entirety of the liquid inside the cylinder is used effectively. The water inlet and outlet temperature, water inlet and outlet temperature are observed and calculations are carried. Figure 1 shows maximum rate of heat transfer.

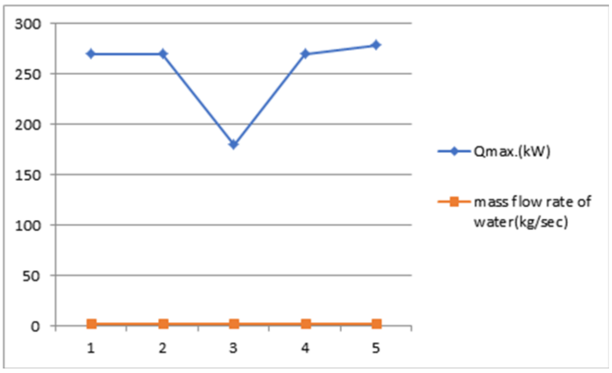

Figure 1: Graph of Maximum rate of heat transfer vs mass flow rate of water

Rate of heat transfer is calculated by

$$Q = m.\, Cp.\, \Delta T \quad (1)$$

m is the mass flow rate, which is determined as

$$m = \rho \times V * A \quad (2)$$

Where m = mass flow rate in kg/s, Cp - Specific Heat in kJ/kg K, ΔT is change in temperature, ρ is density in kg/m^3, V is velocity in m/s and A is cross sectional area of pipe. Comparison of maximum heat transfer using water and nanofluid is shown in figure 2.

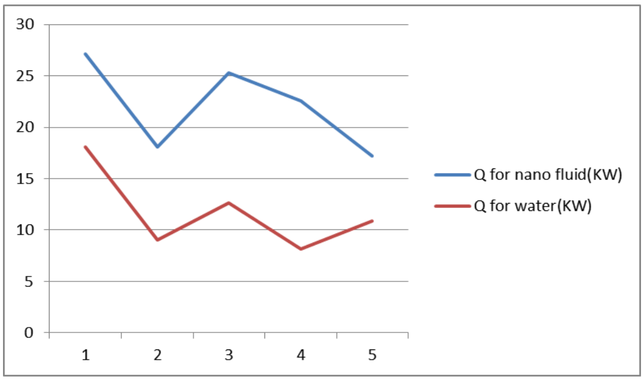

Figure 2: Comparison o f maximum heat transfer using water and nanofluid

IV. Conclusions

Nanofluids have a high heat transfer rate compared to conventional coolants, making them a viable choice for a wide range of heat transfer applications, and their use will continue to expand. The usage of nanofluids was also found to be promising, although the field confronts a number of obstacles in its development. Use of nanofluids is heavily influenced by its stability and cost.

Each of these concerns should be studied in great depth in the applications. It may be said that if the physics and engineering of nanofluids are completely understood and their full potential investigated, they can be duplicated on a huge scale and employed in numerous applications.

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