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RESEARCH ARTICLE

STUDY OF TUBE IN TUBE CONCENTRIC PARALLEL FLOW HEAT EXCHANGER USING NANOFLUID.

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Abstract

Heat exchanger finds wide applications in different areas like domestic, industrial, research, military and weapons etc. In some applications like power generation, aerospace it is necessary to attain a high heat transfer. But the conventional fluids such as water limits the heat transfer characteristics of heat exchanger. It was proved many years ago that the suspension of nanoparticles in conventional fluid can increase the thermal conductivity of nanofluid.So the advancement in nanotechnology had made it possible to make a fluid having nanoparticles of metal suspended in a conventional fluid. Thus this fluid is called nanofluid, which have more enhanced heat transfer characteristics than the conventional fluid. The text of this paper deals with the analysis of a parallel flow tube in tube heat exchanger using nanofluid. The nanofluid used is Aluminium Oxide with 5% volume fraction using water as a base fluid.

The experiment on set up of tube in tube heat exchanger is performed. The observations are recorded with water as working fluid and then the analysis is carried out for heat transfer coefficient of nanofluid at different volume fraction percentage with the help of ansys.

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Introduction:-

There are various fields in which heat exchangers are being used for the purpose effective purpose. The industrial survey in previous year comments that there is demand of heat exchanger with increased heat transfer rate than which is being provided by the conventional. Various attempts are made to use suspended micro particles in the conventional fluid. It has the effect but it used to clog the flow in micro channel. Later in early 20's when the nanotechnology was evolving, the idea was proposed to use nanofluids for increase heat transfer rate. This characteristic of nanofluid made nano fluid a dominant contestant in the area of heat transfer. So the technology available today is sufficient to prepare nanofluid. There are many different types of nanofluids that can be made by using different nano particles and base fluid combinations. Some of the most common nanoparticles used are Alumina Oxide

(Al2O3), Copper Oxide (CuO), Zinc Oxide (ZrO2), and Silica Oxide (SiO2), silver, copper. The most common base fluids used for nanofluids are de-ionized water, oil and ethylene glycol.

Nomenclature:-

Kf = Thermal conductivity of nanofluid (W/m2K)
Kl = Thermal Conductivity of Water(W/m2K)
Kp = Thermal Conductivity of nanoparticles(W/m2K)
Φ = Volume fraction (%)
Cnf = Specific Heat Of Nanofluid (J/Kg K)
Pnf = Density of nanofluid(kg/m3)

Pp = Density of nanoparticles (kg/m3)
Pl = Density of water

Abbreviations:-
Tin = inlet temperature (K)
Tout = outlet temperature(K)
Dia = Diameter (m)
CFD = Computational Fluid Dynamics

Literature review:-

Nanofluid technology coupled with new heat-transfer-related studies on micro channelflow has provided a new option of revisiting suspensions of nanoparticles. The first proposition in this area was from Argonne National Laboratory (ANL) through the seminal work of Choi,who designated the nanoparticle suspension a nanofluid. From a purist's point of view, this designation may not be acceptable—every fluid is "nano" because of its molecular chains—but the term has been accepted andbecome popular in the scientific community. It must be kept in mind that biologists have been using the term nanofluid for different types of particles, such as DNA, RNA, proteins, or fluidscontained in Nano pores. The attractivefeatureswhich made nanoparticles probable candidates for suspension in fluids are a large surface area, less particle momentum, and high mobility. With respect to conductivity enhancement, starting from copper, one can go up to multi-walled carbon nanotubes (MWCNTs), which at room temperature exhibit 20,000 times greater conductivity than engine oil.

Many researches are carried out to improve the heat transfer rate of base fluids using nanofluids. VisineeTrisakri [1]shows the use of additives is a technique applied to enhance the heat transfer performance of base fluids. Recently as an innovative material, nanometer-sized particles have been used in suspension in conventional heat transfer fluids. The suspended metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of base fluid. Eastman Et.Al[3] showed that 10mm copper particles in ethylene glycol could enhance the conductivity by 40% with small particle loading fraction. With cupric oxide the enhancement was 20% for a volume fraction of 4%. These results clearly show the effect of particle size on the conductivity enhancement.DasEt.Al[2] measured the conductivities of alumina and cupric oxide at different temperature ranging from 200C to 500C and found linear increase in the conductivity ratio with temperature. However the same load fraction the ratio of increase was higher for cupric oxide than alumina. In a recent study [2] the present authors have shown that the enhancement of thermal conductivity of nanofluids increases even more at elevated temperature which makes it more attractive for cooling at high heat flux applications. This enhancement of thermal conductivity received an impressive breakthrough when Eastman et al. (2001) reported an increase of thermal conductivity by an outstanding 40% with only 0.04% of nano-particles of purecopper having average size less than 10 nm.

Along with this the conductive and convective model [4] [5] for nanofluid is being used by many researchers to predict the behavior of nanofluid. Thermal conductivity of different nanofluids is studied by the by the A k Singh[6] at different nano particles size and concentration.

When the particles are properly dispersed, nanofluids are expected to give the following benefits.

1. Higher heat conduction: The large surface area of nanoparticles allows for more heat transfer. Particles finer than 20 nm carry 20% of their atoms on theirsurface, making them instantaneously available for thermal interaction. Another advantage is the mobility of the particles, attributable to the tiny size, which may bring about micro-convection of fluid and hence increased heat transfer.
2. Stability:Because the particles are small, they weigh less, and the chances of sedimentation are also less. This reduced sedimentation can overcome one of the major drawbacks of suspensions, the settling of particles, and make the nanofluids more stable.
3. Microchannel cooling without clogging. Nanofluids will not only be a better medium for heat transfer in general, but they will also be ideal for microchannel applications where high heat loads are encountered. The combination of microchannels and nanofluids will provide both highly conducting fluids and a large heat transfer area. This cannot be attained with meso- or micro-particles because they clog microchannels. Nanoparticles, which are only a few hundreds or thousands of atoms, are orders of magnitude smaller than the microchannels.

4. Reduced chances of erosion: Nanoparticles are very small, and the momentum they can impart to a solid wall is much smaller. This reduced momentum reduces the chances of erosion of components, such as heat exchangers, pipelines and pumps.
5. Reduction in pumping power: To increase the heat transfer of conventional fluid by a factor of two, pumping power must usually be increased by a factor of ten. It can be shown that if one can multiply the conductivity by a factor of three, the heat transfer in the same apparatus double. The required increase in the pumping power will be very moderate unless there is a sharp increase in fluid viscosity. Thus, a very large savings in pumping power can be achieved if a large thermal conductivity increase can be brought about with a small volume fraction of particles.

Factors governing:-

Properties of nanofluid:-

Following factors play very important role in determining the behavior of nanofluids.

1. Volume fraction: This is the percentage of amount of nanoparticles with respect the total volume of the nanofluid. More the volume fraction more heat transfer rate. But some scientists believe that after a certain large amount of volume fraction the heat transfer rate will actually start decreasing.
2. Nanoparticles used and size of nanoparticle: More fine thenanoparticles more the heat transfer rate of nanofluid.
3. Base fluid used: The heat transfer characteristics are also dependednt on the base fluid's thermal properties.
4. Temperature : The properties of nanofluid are unaffected at the higher temperature. Nanofluids are able to give their good performance at high temperature also.

Selectionofnanofluid:-

In starting we had lot of options for nanofluid. But there are several factors we need consider for the selection of nanofluid, which are as follow.

1. Availability: The major concern about this project was the availability of nanofluid. Because whatever the nanofluid we are going to use should be available readily. If it becomes too difficult to access the nanofluid then the project will be on hold for months.
2. Cost: As the nanofluid is rarely manufactured by few manufactures obviously it would be costlier. But the cost of nanofluid should be within our budget.
3. Heat transfer charcteristics of nanofluid: This is the main aspect which will be analysed by using Maxweell's model for nanofluid. The heat transfer characteristics of nanofluid can be predicted by the graphs obtained from the analysis

Maxwellmodel:-

The Maxwell framed the formula for effective value of thermal conductivity of nanofluid with respect to.

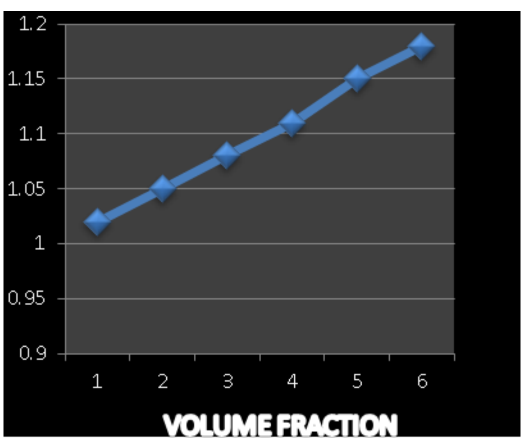

Fig 1: Graph for effective nanofluid thermal conductivity forAluminium Oxide

the thermal conductivity of base fluid. The Maxwell model is as below,

$$(K_f/K_l) = 1 + \frac{3(\frac{Kp}{Kl} - 1)\emptyset}{(\frac{Kp}{Kl} + 2) - (\frac{Kp}{Kl} - 1)\emptyset}$$

Using this equation the graph is plotted for various nanoparticle volume fractions:
From previous study and the cost of nanofluid it was decided that aluminium will be selected for nanoparticles in Nanofluid. Hence Maxwell model is utilized for aluminium oxide and aluminium nanofluid with water as a base fluid as water .

From the graphs shown it can be inferred that the effective thermal conductivity of aluminum and aluminium oxide is of nearly same range it is because the base fluid we are using is water which has very less thermal conductity. Also it can be seen that the there increase in effective thermal conductivity along with the increase in volume fraction. According to previous study on the topic we selected a nanofluid

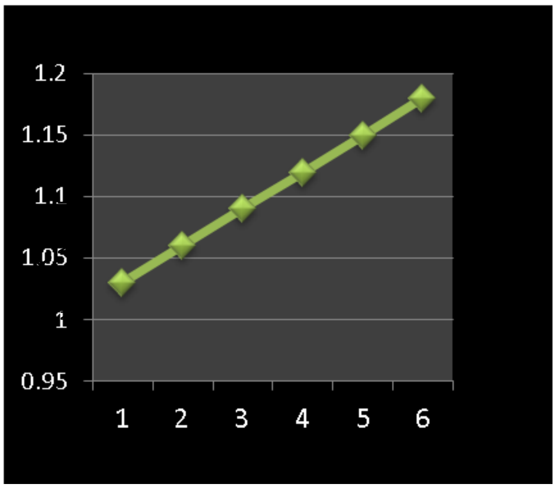

Fig.2 :Graph for effective nanofluid thermal conductivity for Aluminium.

with volume fraction of 5%. So the nanofluid with aluminium oxide as nanoparticles with water is base fluid with 5% volume fraction is selected.

Propertiesofnanofluid:-

- **Density of Nano Fluid:-**

The density of a nano fluid can be calculated by using the mass balance as:
Pnf= (1-□) Pf+ □ Pp)
For typical nanofluids with nanoparticles at a value of volume fraction less than 1%, a change of less than 5% in the fluid density is expected.

- **Specific Heat of Nano FluidsThe specific heat of nanofluids can be calculated by using mass balance as:-**

Cnf= (1-□)PfCf+ □ PpCp / Pnf
Using the above equation one can predict that small decreases in specific heat will typically result when solid particles are dispersed in liquids.

- **Thermal conductivity of nanofluid can be obtained by using the Maxwell model as explained earlier.**

Experimental setup and procedure:-

As we can see in the diagram the hot fluid is carried by the inner tube of heat exchanger and cold fluid will be carried by the outer tube of the heat exchanger. The hot fluid inlet is taken from the heater. During the flow hot fluid will exchange the heat from the cold fluid. Cold fluid is the limiting character in the process of heat exchange. So by increasing the thermal properties of cold fluid we can have a good approach on increasing the effectiveness of heat exchanger. The cold fluid when it comes out from the outer tube it is needed to be recirculated in order to maintain the overall amount of fluid being used by the whole system. Hence we need to construct a return line of cold fluid in such a waythat it give away its heatat certain rate before entering the sump of cold fluid.

In the second stage of experiment cold fluid (i.e. water) will be replaced by the nanofluid. The reading of the cold fluid and nanofluid will be compared for the heat transfer capabilities of the heat exchanger. The whole procedure and schematic diagram can infer from the setup diagram shown above.

Data processing:

The experimental data is used to calculate the overall heat transfer, convective heat transfer coefficient in following steps:

Q = m Cnf (Tin – Tout) , where Tin is theinlet temperature of fluid and Tout is the outlet temperature of fluid, m is the mass flow rate of the fluid, Cnf is the specific heat of the nanofluid.

Q = U A Δt

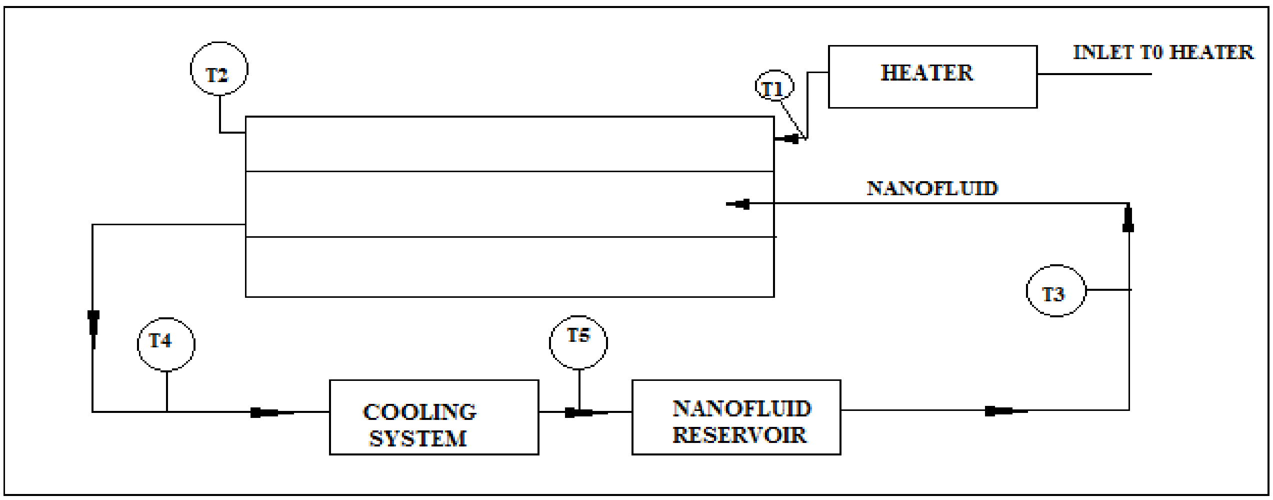

Fig.3 Actual Set up Of the experiment

Table No.1 Observations For Water As Working Fluid

T1	T3	T2	T4	m_h Kg/sec	m_c (kg/sec)
44	41	20	33	0.35	0.038
45	42	20	34	0.35	0.034
44	41	20	35	0.35	.035

Q = total heat transfer
A = heat transfer(HT) surface area
U= overall HT coefficient
Δt = temperature difference between fluids exchanging fluids

But for this equation we need the overall heat transfer coefficient and the surface area. Surface area can be calculated from the formula
A = πdl

$$U = \frac{1}{\left(\frac{Do}{Dihi}\right) + \left(\frac{Do}{2k}\right) * \ln\left(\frac{Do}{Di}\right) + \left(\frac{1}{Ho}\right)}$$

From the aboe formula we can get the overall heat transfer coefficient, Thus by using all the data explained above the analysis of fluid can be done.

In order to proceed for the calculations we need to go for following calculation.
$Nu = 0.023\ (Re)^{0.8}\ (Pr)^{0.4}$

Fig 4. Actual Setup.

Concentric tube in tube
Inner Tube**:**

- Inner dia-10.6 mm
- Outer dia-12.5 mm

Outer Tube**:**

- Inner dia-29mm
- Outer dia-33mm
- Length – 1600mm

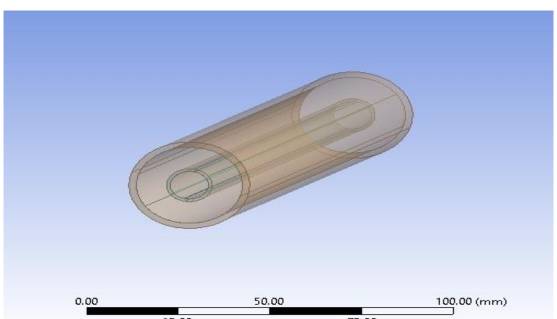

Fig.5 Modeling of heat exchanger in ansys.

CFD Analysis- The CFD analysis is carried out in Ansys Workbench 14.0. The modeling of heat exchanger is done in solid works and the same file is imported in the ansysy. The setup is made same as the one which is used in experimental procedure. Then the boundary conditions are entered as calculated. The analysis is carried out for the conduction and forced convection for single phase nanofluid. The calculation is similar what we discussed in data processing but instead of base fluid as water, properties of nanofluid are obtained and used. The type of mesh used is fine mesh. All the boundary conditions including material, thickness of wall, low rates etc were computed and edited in ansys.

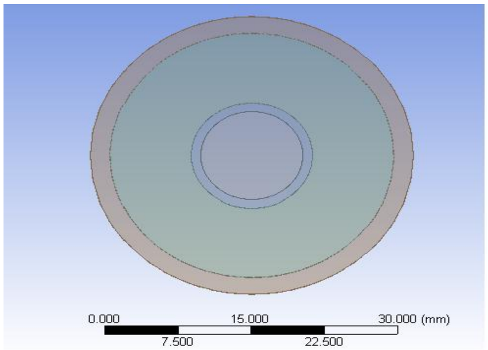

Fig6. Setup OF heat exchanger in Ansys

Table No2- Nomenclature of temperatures in **Table No.1**

T1I(K)	Hot Fluid Outlet Temperature
T2(K)	Cold Fluid Inlet Temperature
T3(K)	Hot Fluid Outlet Temperature
4(K)	Cold fluid Outlet Temperature
m_{h} ,m_{c}	Mass flow rate for cold and hot fluid

Result and conclusion:-

Calculation for overall heat transfer coefficent for using water as the working fluid we got overall heat transfer coefficient as 491 W/m2k. For the same conditions replacing Aluminum Oxide as the working fluid from the fig7, showing results of CFD,we can estimate approximately 18 to 20 % increase in overall heat transer coefficient for parallel flow tube in tube heat exchanger at 5% volume fraction. Also from the other particle volume concentration it can be inferred that there is a increase in overall heat transfer coefficient. Thus nanoluid having Aluminium Oxide with water as base becomes a potentially valid candidate for using in a tube in tube like parallel flow heat excanger.

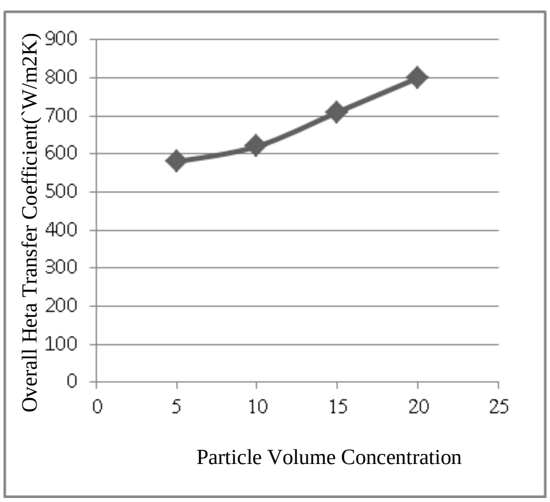

Fig. 7. A graph for overall heat transfer coefficient obtained from the CFD analysis for various volume fractions

Futurescope:-

The results obtained in computerised analysis can be varified for with actual experimentation, which will tend tend to vary from the above observations. The detailed study can be carried out to determine causes for the variation of the resukts in actual experimentation.

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