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Study of Heat Transfer Using Nanofluids in Automobile Radiator with Twisted Tubes

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ABSTRACT

Automobile industries nowadays are going for various advancements in their technology, automobile radiator is one of them. Researches prove that nanofluids have better thermal conductivity as compared to conventional coolants. By using those nanofluids in an automobile radiator, various results of heat transfer will be analyzed. Also, by replacing conventional radiator with twisted tube radiator there will be observable increase in the turbulence. This research paper shows various properties of nanofluid and shows their use in radiator for beneficial results in heat transfer.

Keywords : Nanofluids, automobile radiator, twisted tubes, thermal conductivity, cooling system.

I. INTRODUCTION

Nanoparticles are the particles having size that ranges from 1 to 100 nm. They are also called as Ultra-fine particles. Particles as small as 10 nm have been used in nanofluid research. When particles are not spherical but rod or tube-shaped, the diameter is still below 100nm, but the length of the particles may be on the order of micrometers. It should also be noted that due to the clustering phenomenon, particles may form clusters with sizes on the order of micrometers.

A nanofluid is the suspension of nanoparticles in a base fluid. Nanofluids are those fluids that show promising properties of heat transfer enhancement due to their anomalously high thermal conductivity.

II. PHYSICAL PROPERTIES OF NANOFLUID

1. **Thermal conductivity,** k The thermal conductivity of all nanofluids was measured using a KD2 Pro conductimeter (Decagon Devices Inc.). The KD2 Pro is the commercial device that measures the thermal conductivity with the help of the transient hot wire technique. The sample was introduced in a sealed glass tube (22 ml) where the sensor was inserted vertically. It is very important to ensure the vertical position of the needle to reduce convective heat transfer inside the sample and improve the accuracy of the measurements, especially for low viscosity nanofluids. The heat conductance is inversely related to the characteristic dimension of the probe inserted into the fluid which depends on the direction of fluid flow over the probe. When considering a heated

probe inserted into a cooler fluid, the fluid flow near the probe from free convection will be upward, as the warmer, less dense material near the probe is forced upwards by forces of gravity working on the surrounding, denser material. If the needle is inserted into a fluid vertically, the fluid flow will be parallel to the axis of the needle, and the characteristic dimension is the length of the needle, not the diameter, thus decreasing the free convection.

2. Specific heat, cP The specific heat for each nanofluid was measured in a Differential Scanning Calorimeter (DSC), model DSC1 (Mettler Toledo, USA). The calculation of the specific heat capacity is based in the DIN standard (DIN 51007), The sequence used in the determination was as follows: isotherm of 5 minutes at 25ºC, dynamic segment from 25ºC to 95ºC at heating rate of 10ºC/min and isotherm of 5 minutes at 95ºC. As a consequence of the nature of the sample (liquid) the crucible (Aluminium) was sealed in order to avoid loss of material by evaporation.

3. Viscosity, η The viscosity and rheological behaviour of nanofluids were obtained by conducting tests under steady state conditions using a Haake RheoStress 1 rotational rheometer (Thermo Scientific). A cylinders system composed of two concentric cylinders was used. In the gap between the inner cylinder (diameter = 34 mm) and the outer cylinder (diameter = 36.88 mm) the sample was introduced. Before each test, a pre-treatment, in which the samples were submitted to a constant shear stress, was applied to the nanofluids for 30 seconds to ensure similar starting conditions for all the measurements.

4. Stability The stability of the nanofluids was analysed through the evolution of the amount of light backscattered by the nanofluid from an incident laser beam. A Turbiscan Lab Expert (Formulaction SA, France) was used to carry out the tests. Measurements are based on the multiple light scattering theory. This equipment consists of a pulsed near-infrared light source and a detector that measures the light backscattered by the sample. For each nanofluid, the backscattering profiles were obtained along the height cell. To analyse the stability of nanofluids the measurements were carried out at different time intervals up to a total time of 48 hours.

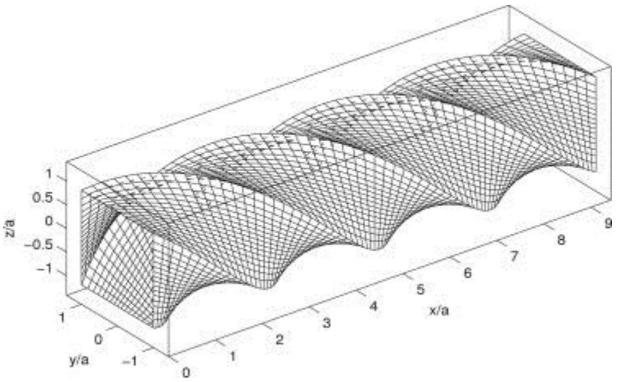
5. Clustering Clustering is the formation of larger particles through aggregation of nanoparticles. Clustering effect is always present in nanofluids and it is an effective parameter in thermal conductivity. Hong et al. [58] investigated this effect for Fe(10 nm)/ethylene glycol nanofluids. The thermal conductivity of nanofluids were determined as a function of the duration of the application of the ultrasonic vibration, which was varied between 0 min, that is, no vibration applied, and 70 min. It was seen that thermal conductivity ratio increased with increasing vibration time and the rate of this increase became smaller for longer vibration time. Furthermore, the variation of thermal conductivity of nanofluid with time after the application of vibration was investigated and it was found that thermal conductivity decreased as time progressed.
Below table shows various properties of nanofluid with different base fluids-
Considering the above properties , availability and cost taking **Cuo** as nanoparticle into account for the experiment conduction.

III. NANOFLUID PREPARATION

There are mainly two methods of nanofluid production, namely, two-step technique and one-step technique. In the two-step technique, the first step is the production of nanoparticles and the second step is the dispersion of the nanoparticles in a base fluid.

Table 1 Literatures of CuO, Al_2O_3 and Hybrid nanofluid.

Nanoparticle	Base fluid	Size (nm)	Enhancement of thermal property (%)	Preparation method
CuO	DI water	20	12.4	Single step
	Water	31	5.5	Two step
	EG	31	9	Two step
	EG/water	27	15.6-24.5	Two step
	DI water	50	13-25	Two step
Al_2O_3	EG/water	36.5	9.8-17.8	Two step
	EG	13	12.82	Two step
	EG/water (20:80)	36	32.36	Two step
	EG/water (40:60)	36	30.51	Two step
Al_2O_3/Cu	Water	15	13.6	Single step
TiO_2/Cu	Water	55	68 (Heat transfer coefficient)	Single step
Nano Diamond/ Nickel	Water	30	21	Two step
Nano Diamond/ Nickel	EG	30	13	Two step
MWCNT/γ Alumina	Water		20.6	Two step
Ag/MWCNT/Graphene	DI water/EG		20	Single step
Ag/MWCNT/Graphene	DI water	<10nm	8	Single step



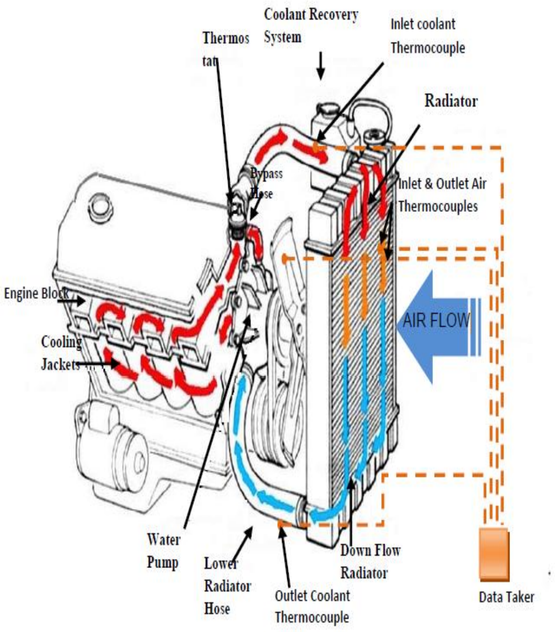
Two-step technique is advantageous when mass production of nanofluids is considered, because at present, nanoparticles can be produced in large quantities by utilizing the technique of inert gas condensation. The main disadvantage of the two-step technique is that the nanoparticles form clusters during the preparation of the nanofluid which prevents the proper dispersion of nanoparticles inside the base fluid .

One-step technique combines the production of nanoparticles and dispersion of nanoparticles in the base fluid into a single step. There are some variations of this technique. In one of the common methods, named direct evaporation one-step method, the nanofluid is produced by the solidification of the nanoparticles, which are initially gas phase, inside the base fluid. The dispersion characteristics of nanofluids produced with one-step techniques are better than those produced with two-step technique. The main drawback of one-step techniques is that they are not proper for mass production, which limits their commercialization .

IV. TWISTED TUBE RADIATOR

A radiator consists of longitudinal tubes through which coolant flows. The outlet of the engine block acts as the inlet of radiator and vice-versa. The flow through radiator takes place with the help of radiator tubes that are encased inside a radiator. Now, these tubes when replaced by twisted ones, makes it a twisted tube radiator. The following diagram displays a contrast between a conventional radiator tube and a twisted tube.

V. EXPERIMENTAL SETUP



An engine, two radiators- one conventional and another fabricated with twisted tubes, nanofluid (SiO2), venturimeter, thermometer.

VI. HEAT TRANSFER CALCULATIONS

Using effectiveness NTU method based on below mentioned formulae for heat transfer calculation -

1. Energy balance equation,

   (mCp)h (Thi-The) = (mCp)c (Tce-Tci)

   Where,

   m= mass flow rate of coolant

   Thi ; The= temperature of coolant at inlet and exit respectively.

   Tci ; Tce= temperature of air at inlet and exit respectively.

   Cph ; Cpc=specific heat of coolant and air respectively.

2. Heat transfer,

   q = mw×Cpw×ΔTw

3. LMTD,

   $\theta m = \frac{17.517-16}{\ln(\frac{17.517}{16})}5$

4. Flow area,

   $\mathbf{Af} = \frac{\boldsymbol{m}}{\boldsymbol{V\infty\rho}}$

   Where,

   Af = Total flow area

   V = Average velocity of water

   ρ = Density of water

5. $Af = n \times \frac{\pi}{4} \times d1^2$

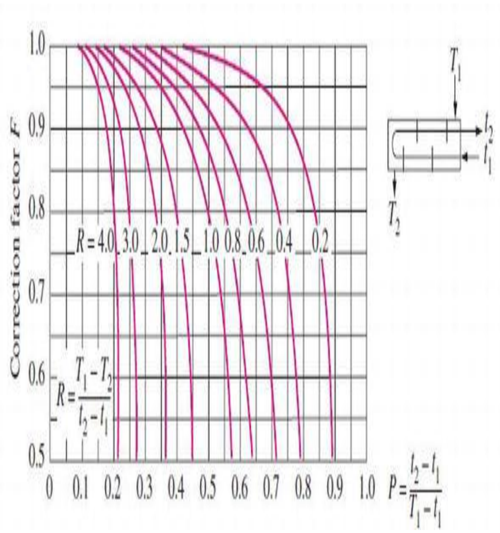
   Where, n = Number of tubes

   d1= Inlet diameter of tube

6. For correction factor required dimension parameters are,

   $$P = \frac{(Tce - Tci)}{(Thi - Tci)}$$

   Refer the graph given below for the correction factor-



7. Area of the heat transfer after considering correction factor is given as,

   $A = \frac{q}{U.F.\theta m(counter\ flow)}$

8. Final acceptable design parameters
   - Number of tubes per pass
   - Number of passes

- Length of tube per pass

9. Effectiveness of Heat Exchanger

   Ch = (m× Cp)water

   Cc = (m× Cp)air

   (a) Capacity ratio (C) :

   $$C = \frac{Cmin}{Cmax}$$

   (b) NTU :

   $$NTU = \frac{U.A}{Cmin}$$

10. Effectiveness

$$\varepsilon = 1 - \exp\left[\left(\frac{1}{C}\right)(NTU)^{0.22}\{\exp[-C(NTU)^{0.78}] - 1\right]$$

VII. CONCLUSION

Nanoparticle exhibits phenomenal behavior when it comes to heat transfer properties. It has countless number of applications one of which is heat transfer rate.

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