# Heat Transfer Enhancement of Diesel Engine Radiator Using Nano-Fluid

**Swapnil Mane[1], Aishwarya Pachhapur[2], Amruta Mohite[3]**
[1, 2, 3] Dept of Mechanical Engineering
[1, 2, 3] Pimpri Chinchwad College Of Engineering & Research.

***Abstract-*** *In a diesel engine lot of heat is developed because of the burning, just a segment of heat is used to create the power rest of heat is wasted as fume heat. The excess motor temperature result in breakdown of the greasing up oil, wear of the motor parts. So a cooling framework is required named Radiator, so as to expel the heat from the cooling coat of the motor. For this liquid-cooled framework, the waste heat is expelled through the circling coolant encompassing the gadgets or entering the cooling diverts in gadgets. Nano-fluids are a generally new characterization of liquids which comprise of a base liquid with Nano sized particles (1-100nm) suspended inside them. These particles made increment conduction and convection coefficients, taking into account more heat exchange out of the coolant.*

***Keywords***- Radiator, Nano-fluid, CuO Nano-fluid, Conduction, Convection.

## I. INTRODUCTION

These days, alumina is a standout amongst the most utilized oxides because of its utilization in numerous regions, for example, slight film coatings, heat-safe materials, and propelled fired rough grains. Improvement in heat move is dependably popular, as the operational speed of these gadgets relies upon the cooling rate. New innovation and propelled liquids with more prominent potential to improve the stream and warm attributes are two alternatives to upgrade the heat exchange rate and the present article manages the last choice.

Conventional fluids, for example, refrigerants, water, motor oil, ethylene glycol, and so forth have poor heat exchange execution and consequently high conservatives and viability of heat exchange system are important to accomplish the required heat exchange. Among the endeavors for upgrade of heat exchange the use of added substances to liquids is increasingly perceptible. Ongoing advances in nanotechnology have permitted improvement of another class of liquids named nanofluids.. Such liquids are liquid suspensions containing particles that are altogether smaller than 100 nm, and have a mass solids warm conductivity higher than the base liquids. Nanofluids are shaped by suspending metallic or non-metallic oxide nanoparticles in conventional heat exchange liquids. These alleged nanofluids show great warm properties contrasted and liquids routinely utilized for heat exchange and liquids containing particles on the micrometre scale. Nanofluids are the new window which was opened as of late and it was affirmed by a few creators that these working liquid can upgrade heat exchange execution. In this report information is introduced on a test examination of the convective fierce heat exchange qualities of nanofluids (CuO water) with 0.5, 1.0, 1.5 vol. %. The heat exchange expanded with an expansion in particle concentration.It is a solution consisting of nanoscale solid particles and conventional base fluid. These microscopic particles are comprises of high thermal conductivity and their large surface-to-volume ratio can even enhance the heat exchange interaction between solid and fluid particles.

## II. METHODOLOGY

There are mainly two methods for preparation of nanofluid. The two methods are one-step method and two-step method. In this paper, we have used two-step method as it gives better result as compared to one-step method.

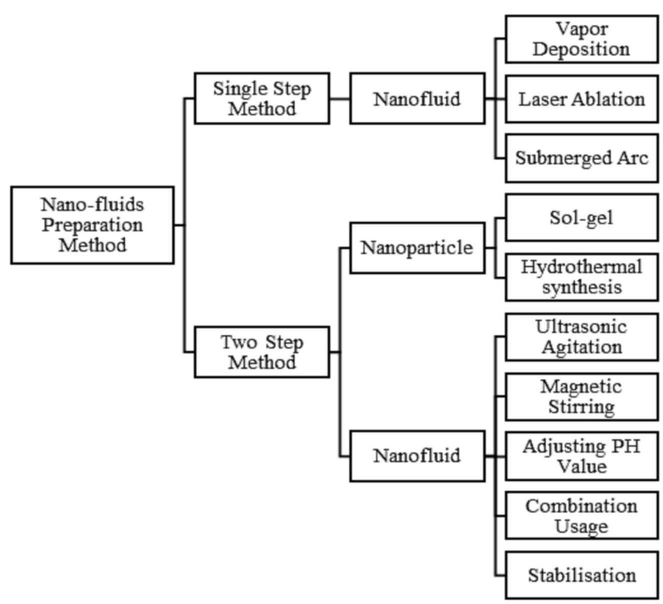



Fig.2.1 Preparation method of Nano-fluid.

CuO nanofluid is prepared in three different concentrations. This variation is used in order to have efficient and better enhancement in heat transfer. Two-step method includes preparation of nanoparticle which is mostly done by Sol-gel method. Copper oxide (CuO) nanoparticles (virtue 99.99%) having normal molecule size of 5-10 nm are prepared. The prepared nanoparticles are then dispersed in base fluid with amount of 100ml by magnetic stirring method, it gives uniform mixture of nanofluid which is quite stable than other.

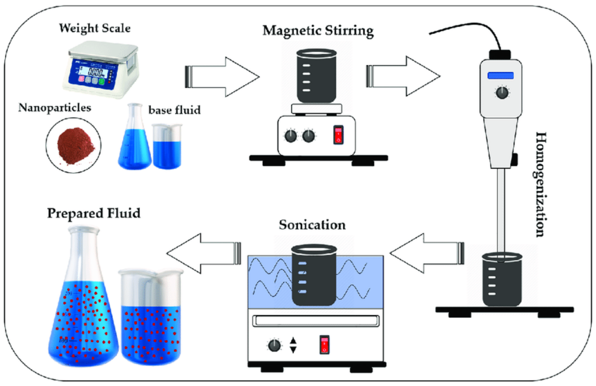



Fig.2.2 Magnetic stirring method.

## III. SPECIFICATIONS OF MAJOR EXPERIMENTAL COMPONENTS

### 3.1Specifications of Radiator:

For this experimental setup we have selected a standard radiator of Comet Twin Cylinder Diesel Engine (VCT10) from the market having following standard specifications.

No of tubes = 74
Height of tube = 0.382 m
Length of tube = 0.002 m
Width of tube = 0.015 m
Fan Motor type = DC motor,
Fan speed = 1200-1500 rpm

### 3.2Specifications of Pump:

For the pumping purpose we have selected a standard pump having following specifications.

Rating Power = 0.5 HP
Frequency = 50 Hz
Volts = 220 V
Maximum Discharge = 42 L/min
Maximum Height to delivery of fluid = 38 m
Power = 0.37 kW
Speed of the rotor = 2850 rpm

### 3.3Specification of Connecting Hoses:

Material = Polyester rubber.
At Inlet of Radiator (Small hose pipe)-
Inner diameter = 0.032 m, Outer diameter = 0.037 m
At Outlet of Radiator (Big hose pipe)-
Inner diameter = 0.038 m, Outer diameter = 0.043 m

### 3.4Specifications of Frame:

Cross section of frame =0.04 m
Thickness of frame = 0.002 m

### 3.5Specifications of Rotameter:

Flow rate = 1- 10 LPM

All the standard components are assembled together in a proper sequence to form the experimental setup. The ideal experimental setup is shown in the following CAD model which is made on Creo

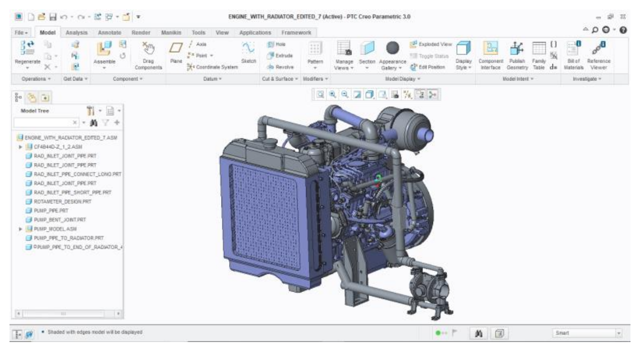


Fig. 3.1.1 CAD Assembly

The fig 3.1.1 shows the isometric view of the entire experimental setup. The assembly of all the components with all its sequential connections is illustrated in this model.

## IV. CONSTRUCTION AND WORKING OF TEST RIG

1. Radiator with cooling fan
2. Water pump
3. Connecting hose pipes
4. Iron frame
5. Nanofluid
6. Digital temperature sensor
7. Rotameter
8. PVP

**4.1Radiator with Cooling Fan:**

Fig.4.1.1 Radiator with cooling fan

Radiators are offered in various configurations. These changing configurations are offered to impact; coolant development, inflexibility for mounting, as well as pipes methods. The most well-known are down-stream and cross-stream. Each design conveys its own favourable position. The downstream radiator design the tanks are situated at the top and base of the centre. The liquid enters through the top tank and streams down through the tubes with the assistance of gravity facilitating the remaining task at hand of the water siphon. On the cross stream, the tanks are situated on the sides of the radiator's centre, enabling the siphon to push the coolant over the centre from appropriate to left. Cross-stream can permit the radiator top to be situated on the low-weight (suction) side of the system, which avoids the weight made by a high-stream water siphon from constraining coolant past the radiator top at high rpm. Cross-stream systems are additionally offered in a solitary, twofold, or even triple pass direction. These directions enable the radiator to cool the liquid on different occasions by isolating the liquid to be cooled. Single Pass radiators enable the progression of coolant to go through the radiator one time. Twofold Pass radiators do it twice. In Triple Pass, they course through the radiator multiple times. The activity of a radiator is to expel however much heat from the hot coolant as could be expected. To achieve this, the coolant goes from the tanks on the closures of the radiator to thin tubes in the radiator. Heat goes from these tubes to the dainty aluminium balances that encompass them, and after that dissipates into the surrounding air.

The activity of a radiator is to expel however much heat from the hot coolant as could be expected. The radiator utilized in this test is a sort of cross stream having one liquid unmixed and other liquid blended. The radiator is utilized for the gensets to trade the heat from motor to the outer condition. It is associated with the outlet hose of the motor water coat. The hot liquid from the motor water coat comes at the highest point of the radiator channel, where it is gone through the radiator tubes. The blades are around the outskirts of the radiator tubes for expanding the convective heat transfer coefficient with the surrounding air. The radiator tubes are put vertically though the air is disregarded the blades in the flat course. From now on it is called as the cross stream heat exchanger. The hot liquid coursing through the tubes of the radiator is being cooled by the streaming air and it is gathered at the base of the radiator and again go to the motor water coat through the siphon. Presently the liquid which is send to the motor water coat has brought down its temperature.

The radiator is a type of cross flow one fluid unmixed and other fluid mixed type. The radiator is used for the purpose of transferring the heat from the fluid which is in the tubes to the outside of the surrounding. There are several fins around the periphery of the tubes. The radiator is made up of aluminium material. The fins are also made up of the aluminium metal. The heat is transferred from the fluid to the tube by convection and from tube thickness to the fins by conduction and then from fins to air again by the convection. The forced convection takes place with help of the fan which is mounted behind the radiator.

**4.2Water Pump:**

The pump is an electronic device utilized to pump the water having considerable level difference. The maximum limit of the water pump utilized in this project is that it gives forty two litres for each moment stream rate. The maximum head that can be created utilizing this pump is thirty eight meters.The drive produced for this pump is one half torques. The revolutions every moment taken by this pump is two thousand eight hundred and fifty. In this project we are utilizing this pump to pump the liquids from the radiator outlet to the engine jacket for example the collecting tank.The situation of the pump in this test apparatus is in the middle of the radiator outlet and the engine jacket for example the collecting tank.


Fig.4.2.1 Water pump.

The frequency at which the pump will work is fifty hertz. The power required for the activity of the pump is 0.37 kilowatt. The current required is 2.6 A. The voltage required for the task of the pump is 220 V. The pump will give the progression of the liquid inside the system. It is consequently a significant part of the exploratory test rig.

**4.3 Connecting hoses:**

Fig.4.3.1 connecting hoses.

A hose is a flexible hollow tube designed to convey liquids starting with one area then onto the next. Hoses are likewise some of the time called pipes (the word pipe more often than not alludes to an unbending tube, though a hose is typically a flexible), at least one for the most part tubing. The state of a hose is normally cylindrical (having a circular cross segment). Hose design depends on a blend of utilization and execution. Normal components are estimate, pressure rating, weight, length, straight hose or curl hose, and chemical compatibility. Hoses are produced using one or a blend of a wide range of materials. Applications for the most part use nylon, polyurethane, polyethylene, PVC, or manufactured or normal rubbers, in view of the earth and pressure rating required. As of late, hoses can likewise be made from uncommon evaluations of polyethylene (LDPE and particularly LLDPE). Other hose materials incorporate PTFE (Teflon), tempered steel and different metals. Material of hose is high strain polyester rope with internal breadth of pipes 32 and 38mm. It is utilized to convey the coolant. The hoses are utilized to convey the high temperature liquid from the engine external jacket to the channel of the radiator and from the radiator engine to the engine water jacket. The material of the hoses is so chosen to such an extent that they withstand the high temperature liquid.

**4.4Iron Frame:**

Fig4.4.1 Frame.

Iron is the least expensive of all the metals used. It is wieldable, very hard and, although it easily rusts, very durable. Its structural strength prevents it from being used to create load-bearing girders and structural beams. Iron frame is made by using hollow rectangular bar. It is manufactured for supporting the radiator. It is manufactured by cutting and welding the rectangular bar.

**4.5 Nanofluid:**

Fig.4.5.1Nanofluids of different CuO concentrations

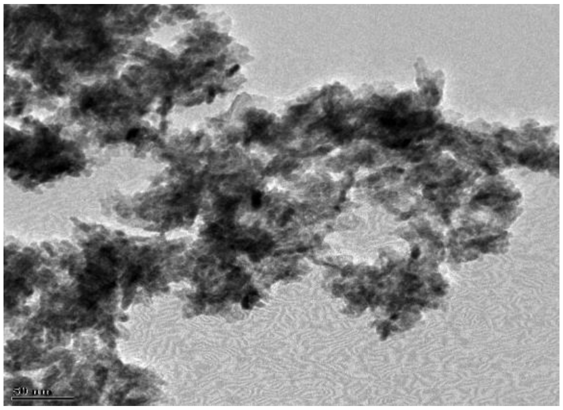


Fig.4.5.2CuO nanoparticles in the solution

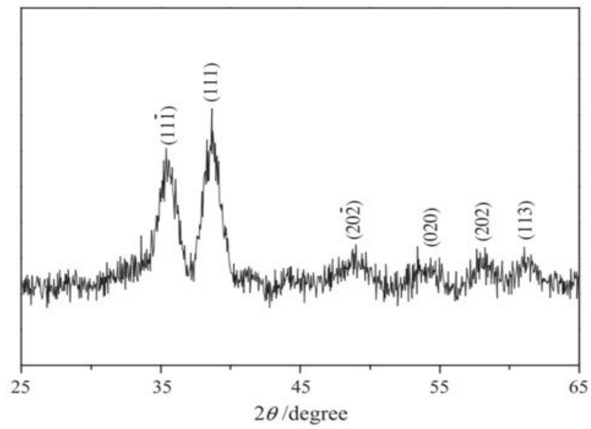



Fig.4.5.3: XRD of nanoparticles

Nanofluids are colloidal suspension of ultra-fine metallic or non-metallic particles in a given liquids. Regardless of every single other property, it is notable for its high thermal conductivity and better reaction as heat transfer medium. Nanofluids can be of two sorts, for example, metallic nanofluids and non-metallic nanofluids. Metallic nanofluids are set up by scattering nanoparticle produced using metals, for example, aluminium, copper and nickel and so on and non-metallic nanofluids are made by scattering nanoparticles of non-metals for example metal oxides, different allotropes of carbon (Graphene, CNT) and so forth. Synthesis and stability of nanofluids are the two extremely essential prerequisites to think about nanofluids. The best possible use of the capability of nanofluids relies upon the readiness and stability of nanofluids. In this investigation Copper oxide (CuO) nanoparticles (virtue 99.99%) having normal molecule size of 5-10 nm are utilized for blending in base liquid with amount of 100 ml.

**4.6Digital Temperature Sensors**

Fig.4.6.1 Digital thermocouple

The conventional sensors utilized for the temperature detecting is currently supplanted with the new advanced sensors. The sensors needs direct current cell for the operating. In this test rig an opening is made in the hoses and the information test is embedded for estimating the temperature of the liquid streaming inside the hoses. We have utilized two sensors to quantify the temperature of the radiator liquid which is streaming in the delta and the outlet hoses of the radiator. The size of the advanced sensor is little. It is light in weight. It is financially savvy and compact. The fundamental favorable position of the advanced temperature sensor is that because of the light in weight and its compact size it very well may be effectively taken care of. Its movability is the one of the conspicuous highlights which helps in the temperature estimation. LCD display addition board with two catch battery. This sensor is utilized to quantify the channel and leave temperature of coolant just as delta and leave temperature of air.

**4.7 Rotameter:**

Fig.4.7.1 Rotameter

The rotameter or the stream meter is the gadget which is utilized for estimation of the progression of the nanofluid in the radiator. The essential working of rotameter is that the buoy of the rotameter is in charge of the estimation of the stream. The buoy is comprised of hardened steel or some other erosion obstruction metal. At the point when the liquid enters at the delta of the rotameter (on the off chance that the rotameter is set vertically) the buoy will in general ascent in the rotameter tube because of its property of light self-weight. The ascent in the stature is demonstrated as far as the engraved scale on the glass tube of the rotameter. The ascent of the buoy demonstrates the measure of stream rate of the liquid through the hoses or pipes. The external body of the rotameter utilized in this exploratory test apparatus is made of the optical fibre. In this trial we need the readings for the few stream rates. Consequently for this reason the rotameter is utilized for the getting the distinctive stream rates. The guideline of the stream rate of the various liquids is kept up with the assistance of the rotameter. A handle is made accessible to control the stream rates. It is utilized to gauge stream of coolant in lpm. It ranges from 1 Lpm to 10 Lpm.

### 4.8 PVP Surfactant


Fig.4.8.1 PVP (Surfactant)

PVP represents polyvinylpyrrolidone, additionally ordinarily called polyvidone or povidone. It is water soluble polymer can be utilized as surfactant. It is soluble in different alcohols, for example, methanol and ethanol. When it is dry it is a light flaky hygroscopic powder. In arrangement, it has excellent wetting properties and promptly structures films. This makes it great as a covering or an added substance to coatings. Surfactants are aggravates that lower the surface tension between a strong and a liquid. PVP is utilized to maintain a strategic distance from isolation of CuO particles in the nanofluid. The stability of nanofluid is increment because of expansion of PVP.

## V. EXPERIMENTAL SETUP

Fig.5.1 Setup

The test system utilized in this examination it incorporates stream lines, a centrifugal pump, a stream meter, a forced draft fan and a heat exchanger (a car radiator). The pump gives a variable stream rate of 2-42 l/min. the stream rate to the test area is controlled by proper changing of a globe valve on the recycle line. The complete volume of the coursing liquid is consistent in every one of the investigations. The circuit incorporates protected tubes have been utilized as associating lines.

For heating the working liquid a twin chamber diesel engine (VCT10) is utilized. Two thermocouples were actualized on the stream line to record the radiator gulf and outlet temperature. Four thermocouples are introduced on the radiator to quantify the divider temperature of the radiator.
At the point when the test began, the location of the thermocouple exhibited the normal estimation of the readings was chosen as a point of normal divider temperature. Because of little thickness and enormous thermal conductivity of the tubes, it is sensible to liken within temperature of the tube with the outside one. The temperature was noted through the temperature marker. Blunder subtleties were estimated from alignment of every thermocouple by looking at the temperature which was estimated by thermometer.

## VI. EXPERIMENTAL CALCULATIONS AND RESULTS

### 6.1 Specific Heat of Coolants

Table 6.1.1: Specific heat of coolants

| **Sr No.** | **Coolant** | **Specific heat ( Cp) J/kg K** |
|---|---|---|
| 1. | Water | 4185 |
| 2. | CuO Nano fluid (0.5%) + Surfactant (3.0%) | 1018.073 |
| 3. | CuO Nano fluid (1.0%) + Surfactant (3.0%) | 520 |
| 4. | CuO Nano fluid (1.5%) + Surfactant (3.0%) | 323.293 |

### 6.2 Calculations for Water

Table 6.2.1: Water temperature readings

| Flow rate (Lpm) | $T_{hi}$ (°C) | $T_{ho}$ (°C) | $T_{ci}$ (°C) | $T_{co}$ (°C) |
|---|---|---|---|---|
| 7 | 47.5 | 45.5 | 37.7 | 42.5 |
| | 58.6 | 54.8 | 38.8 | 50.9 |
| | 64.3 | 59.7 | 39.1 | 54.3 |
| 6 | 52.9 | 50.6 | 37.2 | 43.3 |
| | 58.7 | 54.5 | 38.9 | 51.2 |
| | 63.1 | 58.3 | 39.1 | 54.6 |
| 5 | 52.9 | 49.4 | 37.9 | 46.6 |
| | 60.2 | 54.9 | 38.8 | 51.3 |
| | 63.6 | 57.7 | 38.9 | 54.6 |
| 4 | 56.6 | 50.9 | 38.6 | 48.8 |
| | 61.8 | 54.9 | 38.8 | 52.1 |
| | 66.6 | 59.3 | 38.8 | 54.2 |

Sample Calculations for 6 lpm:

Mean inlet and outlet temperatures-

1) $Thi = \frac{52.9+58.7+63.1}{3} = 58.33℃$
2) $Tho = \frac{50.6+54.5+58.3}{3} = 54.467℃$
3) $Tci = \frac{37.2+38.9+39.1}{3} = 38.4℃$
4) $Tco = \frac{43.3+51.2+54.6}{3} = 49.7℃$

Logarithmic Mean Temperature Difference-

$$\Delta Tm = \frac{(Thi - Tco) - (Tho - Tci)}{ln[(Thi - Tco)/(Tho - Tci)]}$$
$$= \frac{(58.23 - 49.7) - (54.467 - 38.4)}{ln[(58.23 - 49.7)/(54.5467 - 38.4)]}$$
$$\Delta Tm = 11.905$$

Table 6.2.2: Water mean temperature readings

| LPM | $T_{hi}$(°C) | $T_{ho}$(°C) | $T_{ci}$(°C) | $T_{co}$(°C) | $\Delta T_m$(°C) |
|---|---|---|---|---|---|
| 7 | 56.80 | 53.33 | 38.53 | 49.23 | 10.78195 |
| 6 | 58.23 | 54.47 | 38.40 | 49.70 | 11.9053 |
| 5 | 58.90 | 54.00 | 38.53 | 50.83 | 11.36806 |
| 4 | 61.67 | 55.03 | 38.73 | 51.70 | 12.87475 |

1) Heat Transfer (Q) through water:

Qh=mh*Cph*ΔTh=0.1*4187*(58.23-54.47)=1577.101 W

2) Heat Transfer through air:

Qc=mc*Cpc*ΔTc=0.2999*1200*(49.7-38.4)=4065.139 W

3) Average Heat Transfer:

Qavg=0.5*(Qh+Qc)=0.5*(1577.101+4065.139)=2821.12 W

4) Overall Heat Transfer:

Qavg=U*A*F*ΔTm

$$R = \frac{Tco - Tci}{Thi - Tho} = \frac{49.70 - 38.40}{58.23 - 54.47} = 3.000005$$
$$S = \frac{Tho - Thi}{Tco - Thi} = \frac{54.47 - 58.23}{38.40 - 49.70} = 0.189916$$

$$F = \frac{\ln[(1 - R * S)/(1 - S)]}{(1 - 1/R) * \ln[1 + R * \ln(1 - S)]}$$
$$= \frac{\ln[(1 - 3 * 0.1899)/(1 - 0.1899)]}{(1 - 1/3) * \ln[1 + 3 * \ln(1 - 0.1899)]}$$
$$F = 0.949844$$

$$U = \frac{Qavg}{A * F * \Delta Tm}$$
$$= \frac{2821.12}{0.979028 * 0.949844 * 11.90593}$$
$$U = 254.818\ W/m^2K$$

Table 6.2.3: Water Results (Q and U)

| LPM | Q (W) | U (W/m²K) |
|---|---|---|
| 7 | 2771.349 | 277.404 |
| 6 | 2821.112 | 254.818 |
| 5 | 3067.2867 | 299.008 |
| 4 | 3258.15 | 282.053 |

**6.3 Calculations for CuO Nano fluid (0.5%) + Surfactant (3.0%)**

Table 6.3.1 CuO Nano fluid (0.5%) + Surfactant (3.0%) temperature readings

| Flow rate (Lpm) | $T_{hi}$ (°C) | $T_{ho}$ (°C) | $T_{ci}$ (°C) | $T_{co}$ (°C) |
|---|---|---|---|---|
| 7 | 46.2 | 44.0 | 33.2 | 40.8 |
| | 58.6 | 54.6 | 38.2 | 50.8 |
| | 63.3 | 58.3 | 37.7 | 51.9 |
| 6 | 51.4 | 47.7 | 37.4 | 46.6 |
| | 58.3 | 53.9 | 38.1 | 51 |
| | 62.2 | 56.8 | 38.2 | 53.1 |
| 5 | 54.4 | 50.2 | 37.7 | 47.8 |
| | 59.3 | 53.3 | 38 | 51.6 |
| | 63.1 | 56.5 | 38.2 | 54.1 |
| 4 | 57.3 | 50.2 | 37.9 | 48.8 |
| | 61.9 | 54.6 | 37.9 | 51.3 |
| | 65.6 | 57.3 | 38.6 | 55.3 |

Sample Calculations for 6 lpm:

Mean inlet and outlet temperatures-

1) $Thi = \frac{51.4+58.3+62.2}{3} = 57.3°C$

2) $Tho = \frac{47.7+53.9+56.8}{3} = 52.8°C$

3) $Tci = \frac{37.4+38.1+38.2}{3} = 37.9°C$

4) $Tco = \frac{46.6+51+53.1}{3} = 50.23°C$

Logarithmic Mean Temperature Difference-

$$\Delta Tm = \frac{(Thi - Tco) - (Tho - Tci)}{\ln[(Thi - Tco)/(Tho - Tci)]} = \frac{(57.3 - 50.23) - (52.8 - 37.9)}{\ln[(57.3 - 50.23)/(52.8 - 37.9)]} = 10.50084$$

Table 6.3.2 CuO Nano fluid (0.5%) + Surfactant (3.0%) mean temperature readings

| LPM | $T_{hi}$(°C) | $T_{ho}$(°C) | $T_{ci}$(°C) | $T_{co}$(°C) | $\Delta T_m$(°C) |
|---|---|---|---|---|---|
| 7 | 56.03 | 52.30 | 36.37 | 47.83 | 11.64169 |
| 6 | 57.30 | 52.80 | 37.90 | 50.23 | 10.50084 |
| 5 | 58.93 | 53.33 | 37.97 | 51.17 | 11.13782 |
| 4 | 61.60 | 54.03 | 38.13 | 51.80 | 12.60495 |

1) Heat Transfer (Q) through nanofluid:

$\rho = \phi\rho p + (1 - \phi) * \rho b = 0.5 * 6000 + (1 - 0.5) * 1099.25 = 3549..625$ Kg/m[3]

$$Cph = \frac{\phi * \rho p * Cp + (1 - \phi) * \rho b * Cb}{\rho}$$

$$= \frac{0.5 * 6000 * 520 + (1 - 0.5) * 1099.25 * 3736.693}{3549.625}$$

=1018.074 J/kgK

$Qh = mh * Cph * \Delta Th = 0.354963 * 1018.074 * (57.3 - 52.8) =$

2) Heat Transfer through air:

$Qc = mc * Cpc * \Delta Tc = 0.29978 * 1200 * (50.233 - 37.9) = 443$

3) Average Heat Transfer:

$Qavg = 0.5 * (Qh + Qc) = 0.5 * (1626.201 + 4436.872) = 3031.$

4) Overall Heat Transfer:

Qavg=U*A*F*∆Tm

$$R = \frac{Tco - Tci}{Thi - Tho} = \frac{50.23 - 37.9}{57.3 - 52.8} = 2.741$$

$$S = \frac{Tho - Thi}{Tci - Thi} = \frac{52.8 - 57.3}{37.9 - 57.3} = 0.23196$$

$$F = \frac{\ln[(1 - R * S)/(1 - S)]}{(1 - 1/R) * \ln[1 + R * \ln(1 - S)]}$$

$$= \frac{\ln[(1 - 2.741 * 0.23196)/(1 - 0.23196)]}{(1 - 1/2.741) * \ln[1 + 2.741 * \ln(1 - 0.23196)]}$$

$F = 0.9141$

$$U = \frac{Qavg}{A * F * \Delta Tm}$$

$$= \frac{3031.537}{0.979028 * 0.914106 * 10.5008}$$

$U = 322.587 \ W/m^2K$

Table 6.3.3 CuO Nano fluid (0.5%) + Surfactant (3.0%) Result (Q and U)

| LPM | Q (W) | U (W/m²K) |
|---|---|---|
| 7 | 2849.546 | 264.003 |
| 6 | 3031.537 | 322.587 |
| 5 | 3217.542 | 328.254 |
| 4 | 3369.744 | 305.0881 |

**6.4 Calculations for CuO Nano fluid (1%) + Surfactant (3.0%)**

Table 6.4.1 CuO Nano fluid (1%) + Surfactant (3.0%) temperature readings

| Flow rate (Lpm) | $T_{hi}$ (°C) | $T_{ho}$ (°C) | $T_{ci}$ (°C) | $T_{co}$ (°C) |
|---|---|---|---|---|
| 7 | 45.4 | 42.7 | 34.6 | 41.3 |
| | 58.5 | 54.4 | 35.9 | 49.9 |
| | 62.8 | 57.0 | 36.6 | 55.3 |
| 6 | 51.6 | 47.6 | 34.8 | 43.5 |
| | 58.6 | 52.8 | 35.7 | 50.2 |
| | 62.9 | 56.2 | 36.2 | 54.3 |
| 5 | 53.9 | 48.4 | 35.6 | 45.5 |
| | 61.9 | 54.1 | 35.9 | 51.9 |
| | 65.5 | 56.7 | 36.3 | 55.0 |
| 4 4 | 58.7 | 51.0 | 35.8 | 47.8 |
| | 63.6 | 54.9 | 35.9 | 52.6 |
| | 66.7 | 56.4 | 36.5 | 55.2 |

Sample Calculations for 6 lpm:

Mean inlet and outlet temperatures-

1) $Thi = \frac{51.6+58.6+62.9}{3} = 57.7°C$

2) $Tho = \frac{47.6+52.8+56.2}{3} = 52.2°C$

3) $Tci = \frac{34.8+35.7+36.2}{3} = 35.567°C$

4) $Tco = \frac{43.5+50.2+54.3}{3} = 49.33°C$

Logarithmic Mean Temperature Difference-

$$\Delta Tm = \frac{(Thi-Tco)-(Tho-Tci)}{\ln[(Thi-Tco)/(Tho-Tci)]} = \frac{(57.7-49.33)-(52.2-35.567)}{\ln[(57.7-49.33)/(52.2-35.567)]} = 12.03031$$

Table 6.4.2 CuO Nano fluid (1%) + Surfactant (3.0%) mean temperature readings

| LPM | $T_{hi}$(°C) | $T_{ho}$(°C) | $T_{ci}$(°C) | $T_{co}$(°C) | $\Delta T_m$(°C) |
|---|---|---|---|---|---|
| 7 | 55.57 | 51.37 | 35.70 | 48.83 | 10.578 |
| 6 | 57.70 | 52.20 | 35.57 | 49.33 | 12.030 |
| 5 | 60.43 | 53.06 | 35.93 | 50.80 | 13.025 |
| 4 | 63.00 | 54.10 | 36.06 | 51.87 | 14.307 |

1) Heat Transfer (Q) through nanofluid:

$\rho = \phi\rho p + (1-\phi) * \rho b = 1 * 6000 + (1-1) * 1099.25 = 6000$ kg/m$^3$

$$Cph = \frac{\phi * \rho p * Cp + (1-\phi) * \rho b * Cb}{\rho} = \frac{1 * 6000 * 520 + (1-1) * 1200 * 3.362}{6000}$$

$Cph = 520\ J/kgK$

$Qh = mh * Cph * \Delta Th = 0.6 * 520 * (57.7 - 52.2) = 1716$ W

2) Heat Transfer through air:

$Qc = mc * Cpc * \Delta Tc = 0.2997 * 1200 * (49.33 - 35.567) = 4952.5$

3) Average Heat Transfer:

$Qavg = 0.5 * (Qh + Qc) = 0.5 * (1716 + 4952.507) = 3334.254$ W

4) Overall Heat Transfer:

$Qavg = U * A * F * \Delta T$

$$R = \frac{Tco - Tci}{Thi - Tho} = \frac{49.33 - 35.567}{57.7 - 52.2} = 2.5030$$

$$S = \frac{Tho - Thi}{Tci - Thi} = \frac{52.2 - 57.7}{35.567 - 57.7} = 0.24849$$

$$F = \frac{\ln[(1 - R * S)/(1 - S)]}{(1 - 1/R) * \ln[1 + R * \ln(1 - S)]} = \frac{\ln[(1 - 2.5030 * 0.24849)/(1 - 0.24849)]}{(1 - 1/2.5030) * \ln[1 + 2.5030 * \ln(1 - 0.24849)]}$$

$F = 0.91148$

$$U = \frac{Qavg}{A * F * \Delta Tm} = \frac{3334.254}{0.979028 * 0.91148 * 12.03031} = 310.583$$ W/m$^2$K

Table 6.4.3 CuO Nano fluid (1%) + Surfactant (3.0%) Result (Q and U)

| LPM | Q (W) | U (W/m$^2$K) |
|---|---|---|
| 7 | 3126.73 | 330.1 |
| 6 | 3334.25 | 310.58 |
| 5 | 3631.78 | 319.21 |
| 4 | 3767.6 | 303.31 |

**6.5 Calculations for CuO Nano fluid (1.5%) + Surfactant (3.0%)**

Table 6.5.1 CuO Nano fluid (1.5%) + Surfactant (3.0%) temperature readings

| Flow rate (Lpm) | $T_{hi}$ (°C) | $T_{ho}$ (°C) | $T_{ci}$ (°C) | $T_{co}$ (°C) |
|---|---|---|---|---|
| 7 | 45.2 | 42.5 | 32.7 | 41.6 |
| | 58.4 | 53.6 | 34.9 | 50.2 |
| | 62.2 | 56.3 | 33.8 | 53.3 |
| 6 | 50.3 | 45.6 | 33.3 | 44.6 |
| | 58.4 | 52.3 | 34.2 | 50.6 |
| | 63.3 | 56.4 | 34.1 | 52.5 |
| 5 | 53.5 | 47.5 | 33.5 | 44.2 |
| | 61.5 | 53 | 33.7 | 50.3 |
| | 65.5 | 56.2 | 34.1 | 52.2 |
| 4 | 56.1 | 47.8 | 33.4 | 46.1 |
| | 62.7 | 53.2 | 33.7 | 51.2 |
| | 66.3 | 53.2 | 34.3 | 52.5 |

Sample Calculations for 6 lpm:

Mean inlet and outlet temperatures-

1) $Thi = \frac{50.3+58.4+63.3}{3} = 57.33°C$

2) $Tho = \frac{45.6+52.3+56.4}{3} = 51.433°C$

3) $Tci = \frac{33.3+34.2+34.1}{3} = 33.867°C$

4) $Tco = \frac{44.6+50.6+52.5}{3} = 49.233°C$

Logarithmic Mean Temperature Difference-

$$\Delta Tm = \frac{(Thi - Tco) - (Tho - Tci)}{ln[(Thi - Tco)/(Tho - Tci)]} = \frac{(57.33 - 49.233) - (51.433 - 33.867)}{ln[(57.33 - 49.233)/(51.433 - 33.567)]} = 12.2286$$

Table 6.5.2 CuO Nano fluid (1.5%) + Surfactant (3.0%) mean temperature readings

| LPM | $T_{hi}$(°C) | $T_{ho}$(°C) | $T_{ci}$(°C) | $T_{co}$(°C) | $\Delta T_m$(°C) |
|---|---|---|---|---|---|
| 7 | 55.27 | 50.80 | 33.80 | 48.37 | 11.2012 |
| 6 | 57.33 | 51.43 | 33.87 | 49.23 | 12.2286 |
| 5 | 60.17 | 52.23 | 33.77 | 48.90 | 14.5714 |
| 4 | 61.70 | 51.40 | 33.80 | 49.93 | 14.4881 |

1) Heat Transfer (Q) through nanofluid:

$\rho = \phi\rho p + (1 - \phi) * \rho b = 1.5 * 6000 + (1 - 1.5) * 1300.75 = 8349.625$ kg/m$^3$

$$Cph = \frac{\phi * \rho p * Cp + (1 - \phi) * \rho b * Cb}{\rho}$$

$$= \frac{1.5 * 6000 * 0.52 + (1 - 1.5) * 1300.75 * 3045.352}{8349.625}$$

$Cph = 323.293\ J/kgK$

$Qh = mh * Cph * \Delta Th = 0.83496 * 323.293 * (57.33 - 51.433) = 1592.631W$

2) Heat Transfer through air:

$Qc = mc * Cpc * \Delta Tc = 0.29978 * 1200 * (49.233 - 33.867) = 5528.$

3) Average Heat Transfer:

$Qavg = 0.5 * (Qh + Qc) = 0.5 * (1592.631 + 5528.102) = 3560.37\ W$

4) Overall Heat Transfer:

Qavg = U*A*F*ΔTm

$$R = \frac{Tco - Tci}{Thi - Tho} = \frac{49.233 - 33.867}{57.33 - 51.433} = 2.60452$$

$$S = \frac{Tho - Thi}{Tci - Thi} = \frac{51.433 - 57.33}{33.867 - 49.233} = 0.25142$$

$$F = \frac{ln[(1 - R * S)/(1 - S)]}{(1 - 1/R) * ln[1 + R * ln(1 - S)]}$$

$$= \frac{ln[(1 - 2.60452 * 0.25142)/(1 - 0.25142)]}{(1 - 1/2.60452) * ln[1 + 2.60452 * ln(1 - 0.25142)]}$$

$F = 0.89548$

$$U = \frac{Qavg}{A * F * \Delta Tm}$$

$$= \frac{3560.37}{0.97903 * 0.89548 * 12.2286}$$

$U = 332.1$ W/m$^2$K

Table 6.5.3 CuO Nano fluid (1.5%) + Surfactant (3.0%) Result (Q and U)

| LPM | Q (W) | U (W/m$^2$K) |
|---|---|---|
| 7 | 3323.49 | 333.36 |
| 6 | 3560.37 | 332.1 |
| 5 | 3614.38 | 279.31. |
| 4 | 3828.74 | 310.01 |

**6.6 Results**

Table 6.6.1 Result Table of Heat Transfer (Q) for 0.5% CuO Nanofluid

| Lpm | Heat Transfer of Water(W) | Heat Transfer of CuO (0.5%) Nano fluid with Water + PVP (W) | Enhancement in Heat Transfer of CuO (0.5%) Nano fluid with Water + PVP (Surfactant 3%) (W) |
|---|---|---|---|
| 7 | 2771.349 | 2849.546 | 2.822% |
| 6 | 2821.118 | 3031.537 | 7.459% |
| 5 | 3067.287 | 3217.542 | 4.899% |
| 4 | 3258.15 | 3369.744 | 3.425% |

Table 6.6.2 Result Table of Overall Heat Transfer (U) for 0.5% CuO Nanofluid

| Lpm | Overall Heat Transfer coefficient of Water (W/m$^2$K) | Overall Heat Transfer coefficient of CuO (0.5%) Nano fluid with Water + PVP (Surfactant 3%) (W/m$^2$K) | Enhancement in Overall Heat Transfer Coefficient of CuO (0.5%) Nano fluid with Water + PVP (Surfactant 3%) (W/m$^2$K) |
|---|---|---|---|
| 7 | 277.404 | 264.003 | -4.831% |
| 6 | 254.818 | 322.587 | 26.595% |
| 5 | 299.008 | 328.254 | 9.781% |
| 4 | 282.537 | 305.811 | 8.237% |

Table 6.6.3 Result Table of Heat Transfer (Q) for 1% CuO Nanofluid

| Lpm | Heat Transfer of Water (W) | Heat Transfer of CuO (1%) Nano fluid with Water + PVP (W) | Enhancement in Heat Transfer of CuO (1%) Nano fluid with Water + PVP (Surfactant 3%) (W) |
|---|---|---|---|
| 7 | 2771.349 | 3126.735 | 12.824% |
| 6 | 2821.118 | 3334.254 | 18.189% |
| 5 | 3067.287 | 3631.782 | 18.404% |
| 4 | 3258.15 | 3767.597 | 15.636% |

Table 6.6.4 Result Table of Overall Heat Transfer (U) for 1% CuO Nanofluid

| Lpm | Overall Heat Transfer coefficient of Water (W/m²K) | Overall Heat Transfer coefficient of CuO (1%) Nano fluid with Water + PVP (Surfactant 3%)(W/m²K) | Enhancement in Overall Heat Transfer Coefficient of CuO (1%) Nano fluid with Water + PVP (Surfactant 3%)(W/m²K) |
|---|---|---|---|
| 7 | 277.404 | 330.099 | 18.996% |
| 6 | 254.818 | 310.583 | 21.884% |
| 5 | 299.008 | 319.215 | 6.758% |
| 4 | 282.537 | 303.306 | 7.351% |

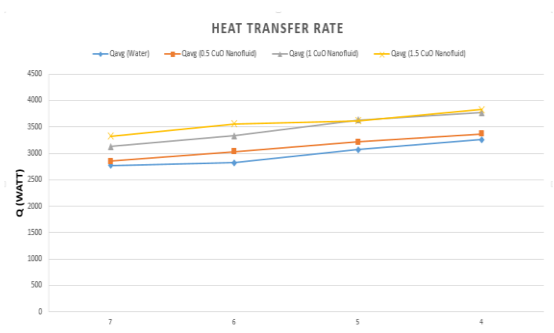
Table 6.6.5 Result Table of Heat Transfer (Q) for 1.5% CuO Nanofluid

| Lpm | Heat Transfer of Water (W) | Heat Transfer of CuO (1.5%) Nano fluid with Water + PVP (W) | Enhancement in Heat Transfer of CuO (1.5%) Nano fluid with Water + PVP (Surfactant 3%) (W) |
|---|---|---|---|
| 7 | 2771.349 | 3323.492 | 19.933% |
| 6 | 2821.118 | 3560.367 | 26.204% |
| 5 | 3067.287 | 3614.375 | 17.836% |
| 4 | 3258.15 | 3828.74 | 17.513% |

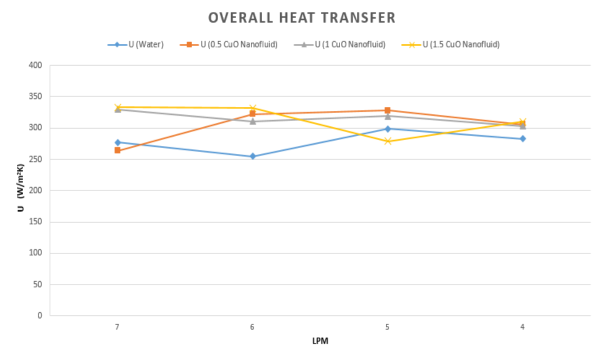
Table 6.6.6 Result Table of Overall Heat Transfer (U) for 1.5% CuO Nanofluid

| Lpm | Overall Heat Transfer coefficient of Water (W/m²K) | Overall Heat Transfer coefficient of CuO (1.5%) Nano fluid with Water + PVP (Surfactant 3%)(W/m²K) | Enhancement in Overall Heat Transfer Coefficient of CuO (1.5%) Nano fluid with Water + PVP (Surfactant 3%) (W/m²K) |
|---|---|---|---|
| 7 | 277.404 | 333.358 | 20.171% |
| 6 | 254.818 | 332.097 | 30.327% |
| 5 | 299.008 | 279.31 | -6.588% |
| 4 | 282.537 | 310.009 | 9.723% |

### 6.7 Graph:




Graph 6.7.1 Plot between Heat Transfer Rates vs. Discharge




Graph 6.7.2 Plot between Overall Heat Transfer Rates vs. Discharge

## VII. CONCLUSION

The experiment conducted on the Twin Cylinder Diesel Engine (VCT10) radiator by replacing the conventional coolant by the CuO Nano fluid with surfactant proved comparatively effective. The results obtained so far are the evidence of increase in the effectiveness of the radiator. The following inferences can be drawn by demonstrating the experiment successfully:

1. The heat transfer rate of CuO nanofluid is greater than that of conventional coolant as the conductivity of the Copper is higher than the simple coolant.
2. The size of the radiator can be reduced in the case if we want same heat transfer rate as that of the conventional coolant.
3. The most important the NOx emission can be considerably reduced as the engine temperature is reduced below 1100°C.
4. It is observed that maximum heat transfer enhancement of 26.2% occurred at 1.5% volume concentration at 6 Lpm flow rate compared to base fluid.

Thus we finally conclude that this experiment proved to be very beneficial in all- round aspects improving the overall engine performance covering all important aspects.

## VIII. FUTURE SCOPE

1. It may be used in thermal engineering, medical and many other applications. The future scope of this experiment is not yet completed there are much more areas for research and working.
2. There is a great challenge in finding out more effective coolant having better thermophysical properties for the

better heat transfer rates and at the same time it is very important that it should be environment friendly.

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