A

PROJECT REPORT

ON

"INVESTIGATION OF THERMAL BEHAVIOUR OF A RADIATOR USING NANOFLUID AS A COOLANT"

Submitted in Partial Fulfilment of the Requirements for the Degree of Bachelor of Technology in Mechanical Engineering

Under Guidance of

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CERTIFICATE

This is to certify that Project title "**INVESTIGATION OF THERMAL BEHAVIOUR OF A RADIATOR USING NANOFLUID AS A COOLANT"** is to be delivered by Mr. SHISHANT KUMAR VIMAL (B.Tech Final Year, Roll No- 2004340039) and Mr. YOGANK YADAV (B.Tech Final Year, Roll No- 2004340047) under my guidance in partial fulfilment of the Bachelor's Degree in Mechanical engineering from Bundelkhand Institute of Engineering and Technology, Jhansi, U.P, India, 284128 during the academic year 2023-2024.

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CANDIDATE DECLARATION

We hereby declare that the project work presented in this report, entitled "**INVESTIGATION OF THERMAL BEHAVIOUR OF A RADIATOR USING NANOFLUID AS A COOLANT"**submitted to Mechanical Engineering Department, Bundelkhand Institute of Engineering and Technology, Jhansi is an original work, conducted by ourselves during session 2023-24, under the guidance of **Dr. Nagendra Prasad Yadav, Professor & Head of Mechanical Engineering Department, BIET JHANSI.** Further the work has not been submitted elsewhere for the award of any other degree. The students would be solely responsible for any plagiarism issues.

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ABSTRACT

The Cooling system plays important roles to control the temperature of car's engine. One of the important elements in the car cooling system is cooling fluid. The usage of wrong cooling fluid can give negatives impact to the car's engine and shorten engine life. An efficient cooling system can prevent engine from overheating and assists the vehicle running at its optimal performance. With the development of new technology in the fields of "nano-materials" and "nano-fluids", it seems very promising to use this technology as a coolant in the internal combustion engines.

This project investigates the heat transfer behavior of a radiator enhanced with nanofluids. With the increasing demand for efficient cooling systems in various industries, exploring nanofluids' potential to enhance heat transfer in radiators is imperative. Nanofluids, engineered colloidal suspensions containing nanoparticles, offer promising thermal properties due to their unique characteristics. This study aims to experimentally examine the heat transfer performance of a radiator utilizing nanofluids as the coolant. The investigation involves characterizing the thermal conductivity, viscosity, and other relevant properties of the nanofluid. Experimental setups are conducted to measure the heat transfer rate of the radiator under various operating conditions like flow rate & different concetration. The findings of this research contribute to a deeper understanding of nanofluid-based cooling systems and offer insights into their potential applications in improving thermal management.

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CHAPTER 1
INTRODUCTION

1.1 NANOFLUID

Nanofluids are a new class of nanotechnology-based heat transfer fluids, obtained by dispersing and stably suspending nano particles with typical dimensions on the order of 10 nm. Nanofluids (Nanoparticle fluid suspensions) is the term coined by Choi (1995) to describe this new class of nanotechnology-based heat transfer fluids with augmented thermal properties, both superior to the properties of their own hosting fluids and the conventional particle fluid suspensions. Micro sized particles helps to improve thermal conductivity and convective heat transfer of liquids when mixed with base fluids. Mean while the fluid path is disturbed and high pressure drop occurred due to sedimentation, excessive wear, and clogging due to micro-sized particles. These problems are overcoming and improvements in thermal properties are achieved by using nano fluids. In nanofluids the nano particles of (1-100nm) and base fluid mixed thoroughly is identified by Choi in the year 1995at the Argonne National Laboratory.

The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably<1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably<10 nm) in host fluids. To achieve this goal it is vital to understand ho Nanofluids can be used as coolants in micro-electronic devices where the sizes have been diminishing resulting in high heat generation which need to be removed efficiently for the optimal functioning of these devices In the automobile industries nano fluid scan play a very important role in removal of excess energy that is generated due to the combustion of the fuel. When flowing through the tubes of the radiator nanofluid can lose its heat to the surrounding air through its walls. In all manufacturing processes which require heat transfers, the conventional fluids can be replaced by nanofluids. Understanding the underlying mechanisms which cause the enhancements, it is important to investigate the properties and flow characteristics of nanofluids.

1.2CLASSIFICATION OF NANOFLUIDS

The classification of nanofluids is based on the type of nanoparticles chosen for nanofluid production. In general, the nanofluids can be classified into four different groups, which are

i. Metal based Nanofluids
ii. Metal oxide based Nanofluids
iii. Carbon based Nanofluids
iv. Composite based Nanofluids
v. Polymer-Coated Nanoparticle-Based Nanofluids

1.2.1 Metal Based Nanofluids:

These nanofluids contain metallic nanoparticles suspended in a base fluid. Examples include nanofluids containing silver (Ag), gold (Au), copper (Cu), aluminum (Al), etc. Metallic nanoparticles are known for their high thermal conductivity and are used to enhance heat transfer in various applications.

- **Silver (Ag)**: Silver nanoparticles are known for their excellent thermal conductivity, which can significantly enhance the heat transfer properties of nanofluids. Additionally, silver nanoparticles exhibit antimicrobial properties, making them suitable for applications where bacterial growth needs to be controlled, such as in HVAC systems or medical devices.
- **Gold (Au)**: Gold nanoparticles possess unique optical properties and high stability. They are often utilized in biomedical applications for drug delivery, imaging, and therapy due to their biocompatibility and surface functionalization capabilities.
- **Copper (Cu)**: Copper nanoparticles offer high thermal conductivity and are commonly used to improve the heat transfer efficiency of nanofluids. They find applications in electronics cooling, heat exchangers, and thermal interface materials.

1.2.2 Oxide Based Nanofluids:

Oxide nanoparticle-based nanofluids consist of oxide nanoparticles dispersed in a base fluid. Common oxide nanoparticles include titanium dioxide (TiO_2), alumina (Al_2O_3), silica (SiO_2), zinc oxide (ZnO), etc. These nanoparticles offer stability, chemical inertness, and other desirable properties depending on the specific oxide used.

- **Titanium Dioxide (TiO_2)**: TiO_2 nanoparticles are widely used due to their stability, photocatalytic properties, and low toxicity. They find applications in sunscreen lotions, water treatment, and as UV blockers.

- **Alumina (Al_2O_3)**: Alumina nanoparticles are known for their high hardness, chemical inertness, and thermal stability. They are used in abrasives, ceramic materials, and as fillers in polymers to improve mechanical properties.

1.2.3 Carbon-Based Nanofluids:

Nanofluids containing carbon-based nanoparticles are becoming increasingly popular. This category includes carbon nanotubes (CNTs), graphene, carbon black, and fullerenes. Carbon-based nanoparticles offer excellent thermal conductivity, mechanical strength, and other unique properties, making them suitable for various applications such as heat transfer enhancement, reinforcement in composites, and energy storage.

- **Carbon Nanotubes (CNTs)**: CNTs exhibit exceptional mechanical strength, thermal conductivity, and electrical properties. They are employed in reinforced composites, energy storage devices, sensors, and biomedical applications.
- **Graphene**: Graphene, a single layer of carbon atoms arranged in a two-dimensional honeycomb lattice, possesses high thermal and electrical conductivity, mechanical strength, and barrier properties. It finds applications in electronics, energy storage, coatings, and biomedical devices.

1.2.4 Composite Based Nanofluids:

Composite nanoparticle-based nanofluids contain a combination of different types of nanoparticles dispersed in a base fluid. These composites are designed to exploit synergistic effects between different nanoparticles, aiming to achieve enhanced properties compared to individual nanoparticle types. For example, a composite nanofluid may combine metallic and oxide nanoparticles to achieve both high thermal conductivity and stability.

1.2.5 Polymer-Coated Nanoparticle-Based Nanofluids:

Some nanofluids utilize polymer-coated nanoparticles to improve stability and dispersion within the base fluid. Polymer coatings can help prevent nanoparticle agglomeration and improve compatibility with the base fluid. These nanofluids are commonly used in biomedical applications, drug delivery systems, and coatings.

1.3 ROLE OF NANOFLUIDS IN HEAT TRANSFER

Nanofluids leverage the unique properties of nanoparticles to enhance heat transfer and fluid dynamics. The interaction between nanoparticles and the base fluid leads to improved thermal performance mechanisms behind nanofluid Heat Transfer

- **Enhanced Thermal Conductivity**: Nanoparticles have high thermal conductivities compared to the base fluid. Heat is transferred more effectively from higher-conductivity nanoparticles to the fluid.

- **Increased Surface Area**: Nanoparticles have large surface areas relative to their volume. This increases the contact area between nanoparticles and fluid molecules, promoting heat exchange.

- **Boundary Layer Reduction**: Nanofluids disrupt the thermal boundary layer near heat transfer surfaces. This reduction enhances convective heat transfer by maintain the steep temperature gradient.

- **Altered Flow Behaviour:** Nanoparticles can influence fluid viscosity and flow characteristics. Modified flow behavior leads to improved mixing and convective heat transfer.

1.4 APPLIATIONS OF NANOFLUIDS IN HEAT TRANSFER

- **Cooling Systems:-** Nanofluids are utilized as coolants in radiators. Enhanced heat transfer leads to improved engine cooling efficiency. Reduced risk of engine overheating and enhanced vehicle performance.
- **Electronics and Computer Cooling:-** Nanofluids dissipate heat in high- power electronics. Improved cooling of computer chips and electronic components. Increased reliability and lifespan of electronic devices.
- **Solar Thermal Systems:-** Nanofluids enhance heat absorption in solar collectors. Improved energy conversion efficiency in solar power generation. Higher utilization of solar energy for heating and electricity production.
- **Heat Exchangers:-** Nanofluids enhance the efficiency of heat exchangers. Increased thermal conductivity promotes more efficient heat transfer. Potential for compact and more effective heat exchanger designs.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE REVIEW

Routbort et al. (2007) have provided a comprehensive review and assessment of nanofluid technology, emphasizing its potential applications in transportation and other fields. Nanofluids, which are suspensions of nanoparticles in conventional fluids, exhibit unique thermal and fluidic properties that could enhance heat transfer and overall performance in various systems. The paper discusses the synthesis methods of nanofluids, their thermal properties, and the challenges associated with their practical implementation. [1]

Leong et al. (2010) explores the impact of nanofluid-based coolants on the performance of an automotive car radiator. Through experimental analysis, the researchers investigate changes in thermal characteristics, heat transfer rates, and pressure drops when nanofluids are used instead of traditional coolants in the radiator. The study aims to assess the feasibility and effectiveness of employing nanofluid-based coolants for improving the overall efficiency of automotive cooling systems. [2]

Peralta-Videa et al. (2011) has explored that Nanofluids, the fluid suspensions of nanomaterials, have shown many interesting properties, and the distinctive features offer unprecedented potential for many applications. This paper summarizes the recent progress on the study of nanofluids, such as the preparation methods, the evaluation methods for the stability of nanofluids, and the ways to enhance the stability for nanofluids, the stability mechanisms of nanofluids, and presents the broad range of current and future applications in various fields including energy and mechanical and biomedical fields. At last, the paper identifies the opportunities for future research. [3]

Chavan et al. (2014) has provided Nanofluids are suspensions of metallic or nonmetallic nanopowders in base liquid and can be employed to increase heat transfer rate at various applications. In the present study, forced convective heat transfer in an Al2O3/water nanofluid has experimentally been compared to that of pure water in automobile radiator.

Five different concentrations of nanofluids in the range of 0–1.0 vol.% have been preparedby the addition of Al_2O_3 nanoparticles into the water . [4]

Sidik et al. (2015) employs computational fluid dynamics (CFD) simulations to analyze the behavior of nanofluids within radiator systems. The authors investigate flow patterns, temperature distribution, and pressure drop in comparison to traditional coolants. The simulation results reveal intricate details about how nanofluids influence the heat transfer process and provide insights into designing efficient radiator configurations. [5]

Shirvan et al. (2017) investigates heat transfer phenomena in a double pipe heat exchanger that is filled with a porous medium. Double pipe heat exchangers are commonly used in various industrial processes for efficient heat transfer between two fluids. By incorporating a porous medium into the heat exchanger, the authors likely explore how this affects heat transfer characteristics and efficiency. [6]

Pandya et al. (2020) provides a broad perspective on the use of nanofluids for heat transfer enhancement. The paper discusses various nanoparticles, base fluids, and their impacts on thermal conductivity and convective heat transfer. The authors address the challenges and future prospects of utilizing nanofluids in heat exchangers and radiators, setting the stage for further investigation in this field. [7]

Mert et al. (2021) designed and tested a radiator using nanofluid as the coolant. They evaluated the cooling efficiency, pressure drop, and thermal performance under different operating conditions. The findings show case the potential of nano fluids to enhance the overall heat dissipation capabilities of radiators, demonstrating their applicability in real-world scenarios. [8]

Ajeeb et al. (2023) investigates, Al_2O_3-water nano fluids were used as coolants in a plate heat exchanger. There researchers measured heat transfer rates and pressure drops for different nano fluid concentrations and flow rates. The results indicated a considerable enhancement in heat transfer compared to the base fluid. However, challenges related to nano particle sedimentation and stability were highlighted, suggesting the need for careful consideration in practical applications. [9]

2.2 SUMMARY OF LITERATURE REVIEW

- The literature review on the investigation of heat transfer behavior of radiators using nanofluids as coolants reveals a growing body of research focused on enhancing the thermal performance of cooling systems. Nanofluids, which are colloidal suspensions of nanoparticles in a base fluid, have gained considerable attention due to their potential to improve heat transfer characteristics compared to traditional coolants.
- The potential benefits of using nanofluids in radiators for automobiles are highlighted, shedding light on their ability to mitigate overheating issues.
- The paper provides an overview of the critical aspects of nanofluids, focusing on their significance in mechanical engineering applications..
- The finding show case the potential of nano fluids to enhance the overall heat dissipation capabilities of radiators, demonstrating their applicability in real- world scenarios.
- The simulation results reveal intricate details about how nano fluids influence the heat transfer process and provide insights into designing efficient radiator configurations.
- The study aims to assess the feasibility and effectiveness of employing nano fluid-based coolants for improving the overall efficiency of automotive cooling systems.

The cooling of the engine of a vehicle is one of the key challenges for better fuel consumption and performance of the engine. In view of that, nano-fluid-based coolant is the better option for getting efficient cooling for the engine.

2.3 AIM & OBJECTIVE

This investigation aims to systematically study the heat transfer behavior of a radiator when utilizing nanofluids as the coolant. The primary objectives of this study include:

1. Fabrication of experimental setup for experimental analysis
2. Conduction of experiment for the analysis of the change in temperature with respect to different concentration of nano fluid.
3. Conducting experimental studies to assess the heat transfer enhancement achieved by using nano fluids compared to traditional coolant.

CHAPTER 3

EXPERIMENTATION

3.1 EXPERIMENTAL SETUP

Heat transfer takes place between the coolant and surrounding through the radiator fin with the help of radiator fan.

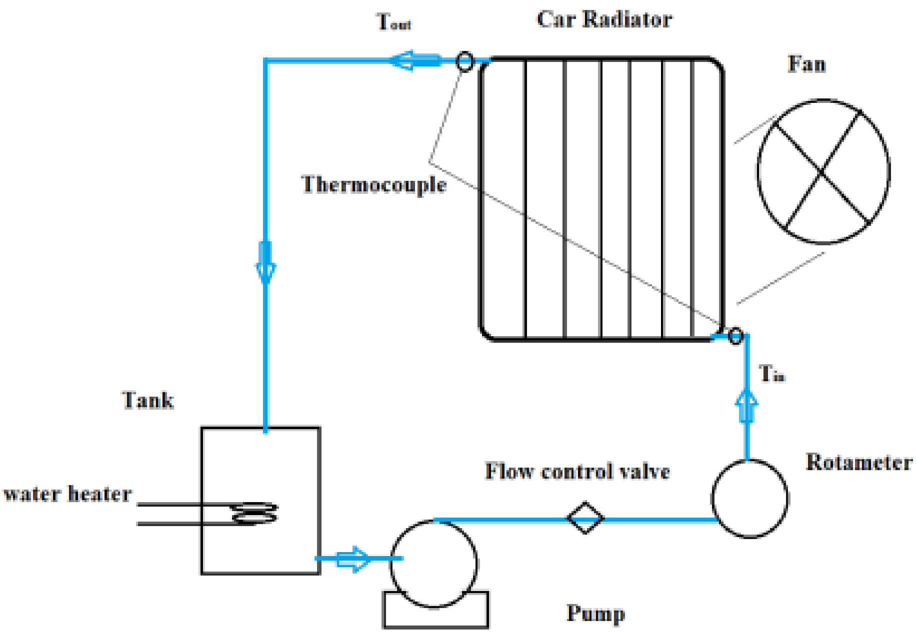


Fig3.1: Schematic diagram of experimental procedure

Experimental setup includes: -

3.1.1 Radiator:-Maruti car radiator is used in the test rig. It is a type of heat exchanger which is designed to transfer the heat from hot coolant that flows through it to the air blown through it by the fan. The radiator used is of aluminium. Radiators are made by brazing thin aluminium fins to flattened aluminium tubes. The coolant flows from the inlet to the outlet through many tubes mounted in a parallel arrangement. The fins conduct the heat from the tubes and transfer it to the air flowing through the radiator.

DIMENSIONS OF TUBE:

Internal Diameter: 6 mm

External Diameter: 6.82 mm

Thickness of tube: 0.41 mm

Length of Tube: 340 mm

Material of the tube: Aluminium

Total No tubes used: 49 (25 in one column & 24 in second column)

3.1.2 Fan:-Cooling fan maintains an engine temperature constant. Cars have electric fans; they turn on when the temperature of the coolant goes above a set point. They turn back off when the temperature drops below that point. The cooling fans are used to force the air through the radiator to accelerate heat exchange and cool the liquid.

3.1.3 Water Pump:-This is the heart of the engine cooling system. It pumps coolant through the whole cooling system, and into the engine block. When the coolant has reached a certain temperature, the water pump will push the coolant into the radiator where it will be cooled and returned to the engine.

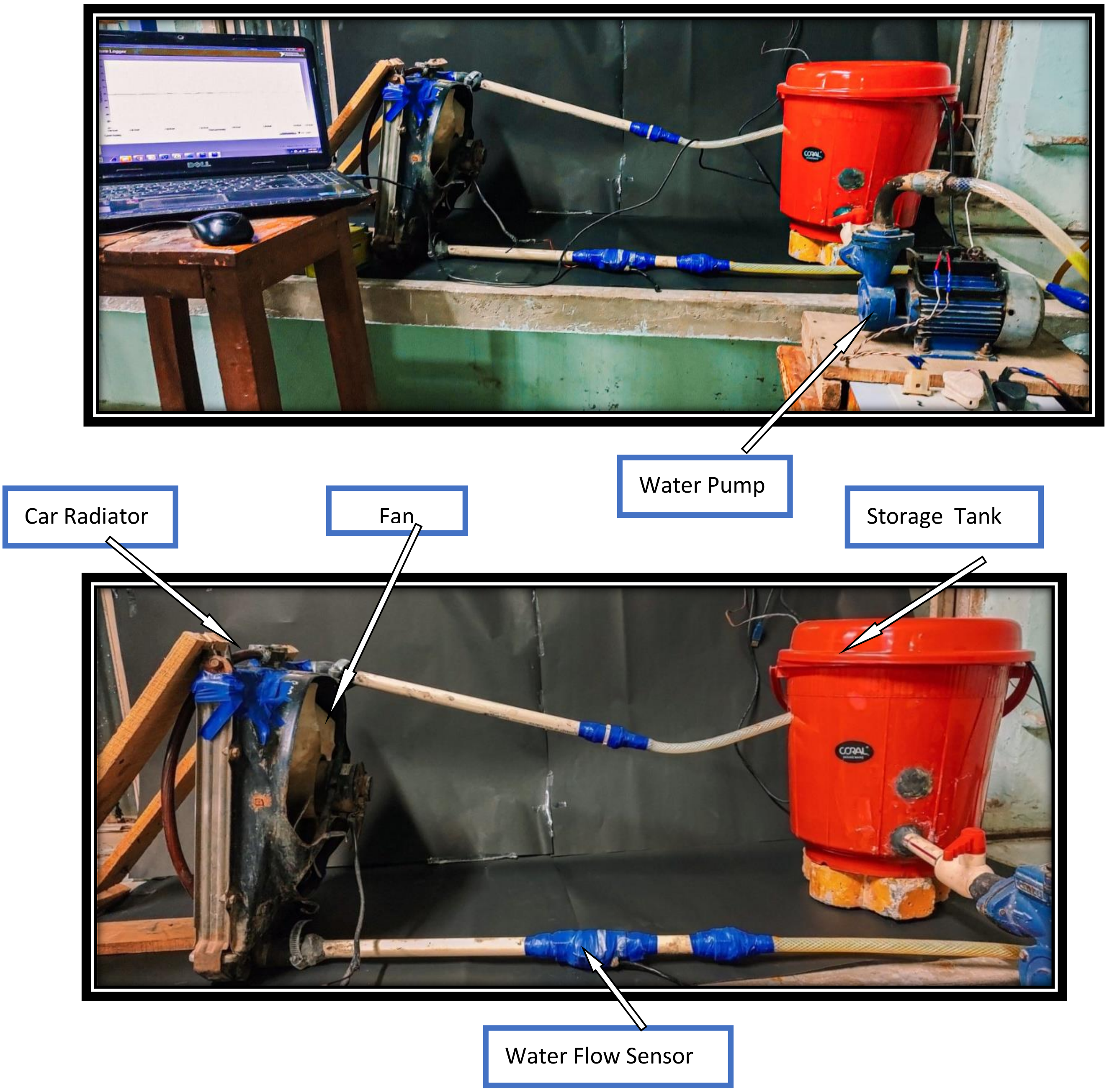
3.1.4 Water Heater:- 3000-watt heater is used to heat the coolant in the sump tank like as coolant heated in Automobile engine.

3.1.5 Storage Tank:- In this experimental setup, a plastic storage tank is used to store the coolant, which flows through the tubes in the radiator. In the storage tank, the inlet is at the bottom, which is connected to the water pump, followed by the radiator and outlet.

3.2 MEASURING INSTRUMENT

3.2.1 Water Flow Sensor:- Water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, rotor rolls. Its speed changes with different rate of flow. The hall-effect sensor outputs the corresponding pulse signal. It has a measuring capacity of flow rate in a range of 1 to 30 l/min. In experimental setup water flow sensor is connected with the Arduino Uno. It's based on the ATmega328P microcontroller. The Uno is connected to a computer via USB & gives the real time data.

3.2.2 Thermocouple Sensor:- A thermocouple is a temperature sensor (electrical device) used to measure temperature. It comprises two types of metal which are joined together at one end forming a junction. When the junction is cooled or heated it produces a so-called “temperature-dependent voltage” which is used to measure temperature. We have two temperature sensors for measuring the temperature, one for the engine temperature and the other for the outlet temperature.



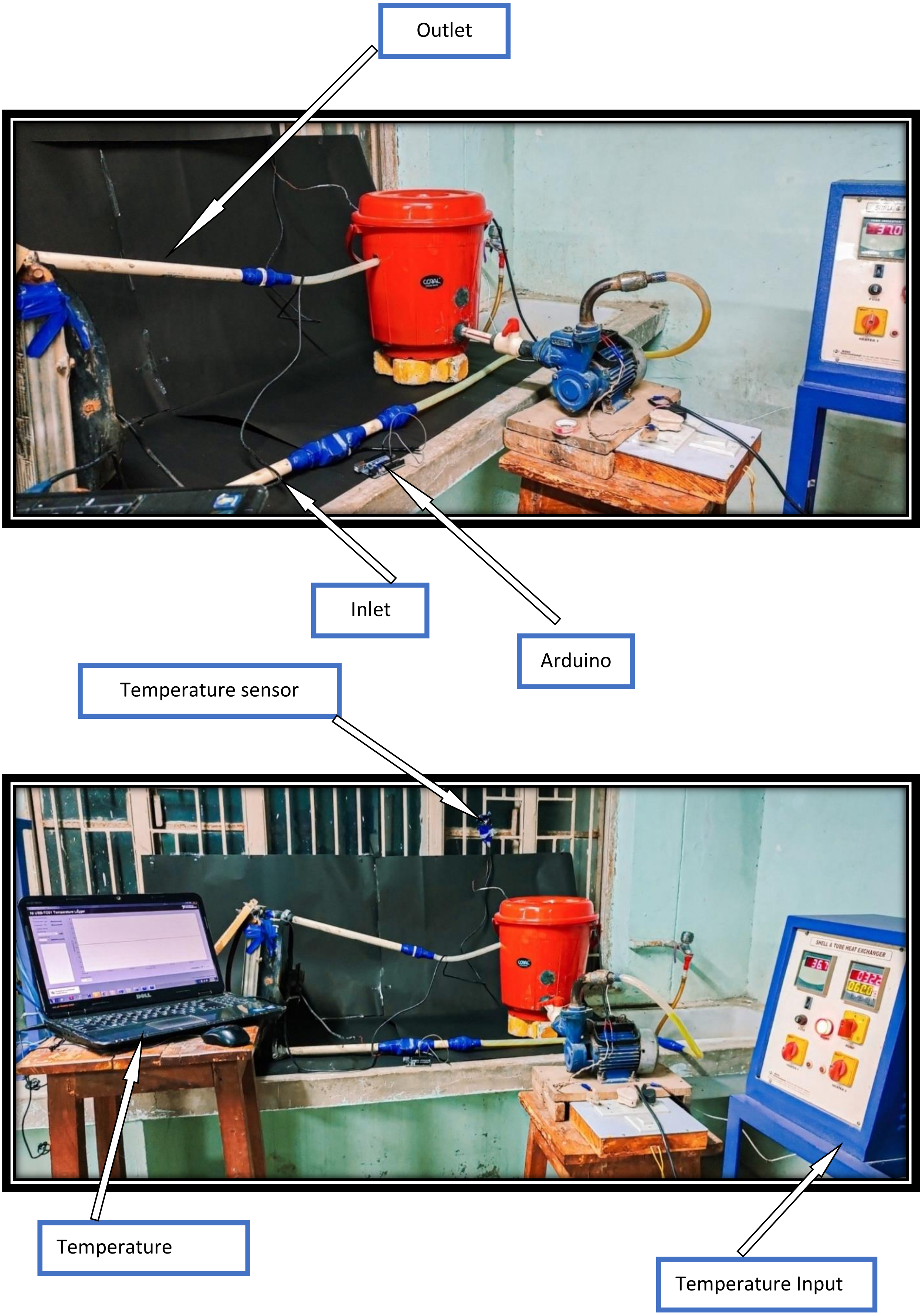


Fig 3.2 Experimental Setup

3.3 SPECIFIATION

Table 3.3 Specification of Components

Radiator	Maruti, single pass cross flow type radiator, Capacity 3.5 liter.
Water Flow Sensor	Maximum 30 lpm.
Heater	220 V AC, 3000 W
Pump	Continuous duty, 220 V, 50 H_Z, 0.5 HP, 0.373 W
Tubes	Heat Resistant PVC Pipes
Storage Tank	Plastic Bucket
Thermocouple	Dip type, Digital temperature sensor
Arduino	Microcontroller board based on the ATmega328P

3.4 THERMOPHYSICAL PROPERTIES OF THE FLUID

Table 3.4 THERMOPHYSICAL PROPERTIES OF THE FLUID

Thermo physical properties	Base fluid (Water)	Nanofluid (Ethylene glycol)	Nanofluid with 10%conc.	Nanofluid with 20%conc.	Nanofluid with 30%conc.
Density (kg/m^3)	**1000**	**1090**	**1009**	**1018**	**1027**
Specific heat (j/kg-k)	**4186**	**4145**	**4105.031**	**3984.78**	**3871.408**
Conductivity (w/m-k)	**0.5548**	**0.687**	**0.618**	**0.635**	**0.649**

3.5 MATHEMATICAL FORMULA

3.5.1 HEAT TRANSFER THROUGH THE WATER [16]

$$\dot{Q}_w = \dot{m}_w \, C_{pw} \, (T_i - T_o)$$

3.5.2 HEAT TRANSFER THROUGH THE NANOFLUID [16]

$$\dot{Q}_{nf} = \dot{m}_{nf} \, C_{pnf} \, (T_i - T_o)$$

3.5.3 DENSITY [9]

$$\rho_{nf} = \emptyset \rho_{nf} + (1 - \emptyset)$$

3.5.4SPEIFIC HEAT [9]

$$(\rho C_p)_{nf} = \emptyset (\rho C_p)_p + (1 - \emptyset)\,(\rho C_p)_w$$

3.5.5 THERMAL CONDUCTIVITY [9]

$$k_{nf} = \frac{k_p + k_w(\emptyset - 1) - \emptyset(\emptyset - 1)(k_w - k_p)}{k_p + (\emptyset - 1)k_w + \emptyset(k_w - k_p)} k_w$$

where ρ_{nf}, Cp_{nf} and k_{nf} are known as density, specific heat and thermal conductivity of nanofluid; ϕ stands for volumetric concentration of coolant; ρ_p, Cp_p and k_p are the density, specific heat and thermal conductivity of coolant and ρ_w, Cp_w and k_w are the density, specific heat and thermal conductivity of water.

3.6 CODE FOR WATER FLOW SENSOR

3.6.1 ARDUINO

The Arduino Uno is a popular microcontroller board used for building digital devices and interactive objects. It's based on the ATmega328P microcontroller and comes with various input and output pins that allow you to connect it to sensors, actuators, and other electronic components. The Uno is easy to use, versatile, and well-supported by a large community of makers and developers. The Uno has a total of 14 digital input/output pins, of which 6 can be used as PWM (Pulse Width Modulation) outputs, and 6 analog input pins. These pins allow you to interface with a wide range of sensors, actuators, LEDs, displays, and other electronic devices.

The Uno can be connected to a computer via USB, allowing for easy programming and communication. It can be programmed using the Arduino Integrated Development Environment (IDE), which provides a user-friendly interface for writing, compiling, and uploading code to the board.

3.6.2 FLOW SENSOR WIRING DIAGRAM WITH ARDUINO

This sensor only has 3 pin outs. Red and Black for the power, which are VCC and GROUND. And the Yellow one is the signal or pulse.

We can just hook up the VCC to 5V, GROUND to GROUND, and the signal to any pins of Arduino. But since we do not want to pass even a single pulse without counting it. We need to connect the signal or pulse to only interrupt pins. If you are using Arduino Uno the interrupt pins will only be available on pins 2 or 3.

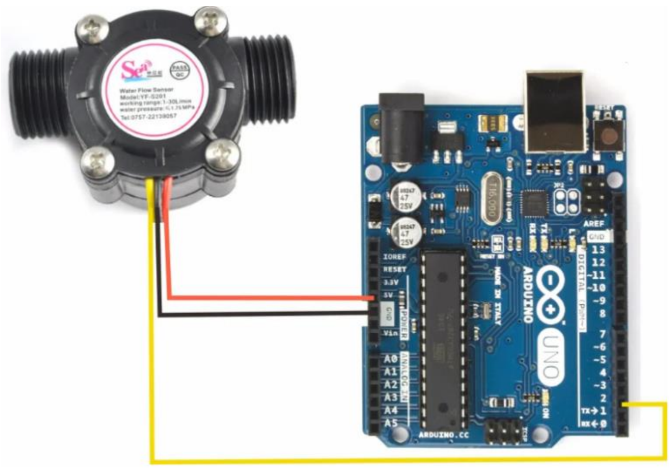


Fig3.3 : Flow sensor wiring diagram with arduino

3.6.3 CODE FOR FLOW RATE IN LPM [15]

```
int sensorPin = 2;
volatile long pulse;
unsigned long lastTime;
float volume;
void setup() {
pinMode(sensorPin, INPUT);
Serial.begin(9600);
attachInterrupt(digitalPinToInterrupt(sensorPin), increase, RISING);
}
void loop() {
volume = 2.663 * pulse / 1000 * 30;
if (millis() - lastTime > 2000) {
pulse = 0;
lastTime = millis();
}
Serial.print(volume);
Serial.println(" L/m");
}
void increase() {
pulse++;
}
```

3.7 EXPERIMENTAL PROCEDURE

- This experimental setup contains a radiator, reservoir tank, an electric heater, a pump, a water flow sensor, heat transfer fluid (HTF) tubes, control valves, a fan and a DC power supply.
- Control valves were used for measuring and regulating the mass flow rate. All HTF tubes were insulated for avoiding heat loss from the surface of the tubes to the surrounding.
- At the beginning of the experiment, we determined a certain volume of fluid to be used with water, coolant and Nano-fluid in all concentrations.

- Put the fluid in the tank with the heater and turn heater on, then put the tank thermocouple adjusted to (40-55) degrees Celsius.
- The nanofluid in the tank is heated up to the required temperature and the pump is turned ON permitting the nanofluid to flow over the car radiator.
- Simultaneously the coolant fan is turned ON to absorb the heat from the nanofluid and accordingly dissipate to the atmosphere.
- Measuring the temperature at radiator inlet.
- Fluid passes through radiator for cooling.
- Measuring the temperature at exit of radiator.
- The fluid moves to the reservoir again.
- Repeat the previous steps with different concentration, flow rate and tempreature.

CHAPTER 4

RESULT AND DISCUSSION

4.1 OBSEVATION TABLES

TABLE 4.1.1 WATER (FOR TEMPERTURE, FLOW RATE & HEAT TRANSFER RATE)

Flow Rate (LPM)	T in (°C)	T out (°C)	Q (w)
2.07	40	38.5	213.486
4.12	40	38.9	313.1128
5.90	40	39.2	328.1824
8.08	40	39.3	392.6468
2.07	45	40.8	597.7608
4.12	45	41.6	967.8032
5.90	45	42.25	1128.127
8.08	45	42.5	1402.31
2.07	50	43.55	917.9898
4.12	50	44.35	1608.261
5.90	50	45	2051.14
8.08	50	45.5	2524.158
2.07	55	45.5	1352.078
4.12	55	46.6	2391.043
5.90	55	47.15	3220.29
8.08	55	47.85	4010.607

TABLE4.1.2 NANOFLUID WITH 10% CONCENTRATION (FOR TEMPERTURE, FLOW RATE & HEAT TRANSFER RATE)

Flow Rate (LPM)	T in (°C)	T out (°C)	Q (w)
2.07	40	37.95	277.7053
4.12	40	38.15	501.2243
5.90	40	38.6	540.2221
8.08	40	38.8	640.3848
2.07	45	39.85	697.65
4.12	45	41.3	1002.449
5.90	45	41.5	1350.555
8.08	45	42	1600.962
2.07	50	42.1	1070.182
4.12	50	43.05	1882.978

5.90	50	43.8	2392.412
8.08	50	44.3	3041.828
2.07	55	43.1	1612.046
4.12	55	44.2	2926.066
5.90	55	45.45	3685.086
8.08	55	46.75	4402.646

TABLE 4.1.3 NANOFLUID WITH 20% CONCENTRATION (FOR TEMPERTURE, FLOW RATE & HEAT TRANSFER RATE)

Flow Rate (LPM)	**T in** (°C)	**T out** (°C)	**Q (w)**
2.07	40	36.6	447.0923
4.12	40	37.3	710.0878
5.90	40	37.9	786.5956
8.08	40	38.4	828.8342
2.07	45	38.5	854.7353
4.12	45	39.2	1525.374
5.90	45	39.7	1985.217
8.08	45	40.1	2538.305
2.07	50	41	1183.48
4.12	50	41.9	2130.263
5.90	50	42.8	2696.899
8.08	50	43.2	3522.546
2.07	55	42.3	1670.021
4.12	55	43	3155.946
5.90	55	43.6	4270.09
8.08	55	44.1	5646.433

TABLE 4.1.4 NANOFLUID WITH 30% CONCENTRATION (FOR TEMPERTURE, FLOW RATE & HEAT TRANSFER RATE)

Flow Rate (LPM)	**T in** (°C)	**T out** (°C)	**Q (w)**
2.07	40	34.3	728.2118
4.12	40	35.3	1200.911
5.90	40	36	1455.649
8.08	40	36.5	1761.491
2.07	45	37	1022.052

4.12	45	37.9	1814.142
5.90	45	38.7	2292.648
8.08	45	39	3019.698
2.07	50	39.9	1290.34
4.12	50	40.8	2350.719
5.90	50	41.3	3166.037
8.08	50	41.8	4126.921
2.07	55	41.4	1737.488
4.12	55	42.4	3219.463
5.90	55	42.9	4403.339
8.08	55	43.3	5888.412

4.2 Effect of flow rate on heat transfer at inlet temperature (40°C, 45°C, 50°C, 55°C) for all different concentration of nanofluid

4.2.1 Heat transfer rate at different temperature for pure water

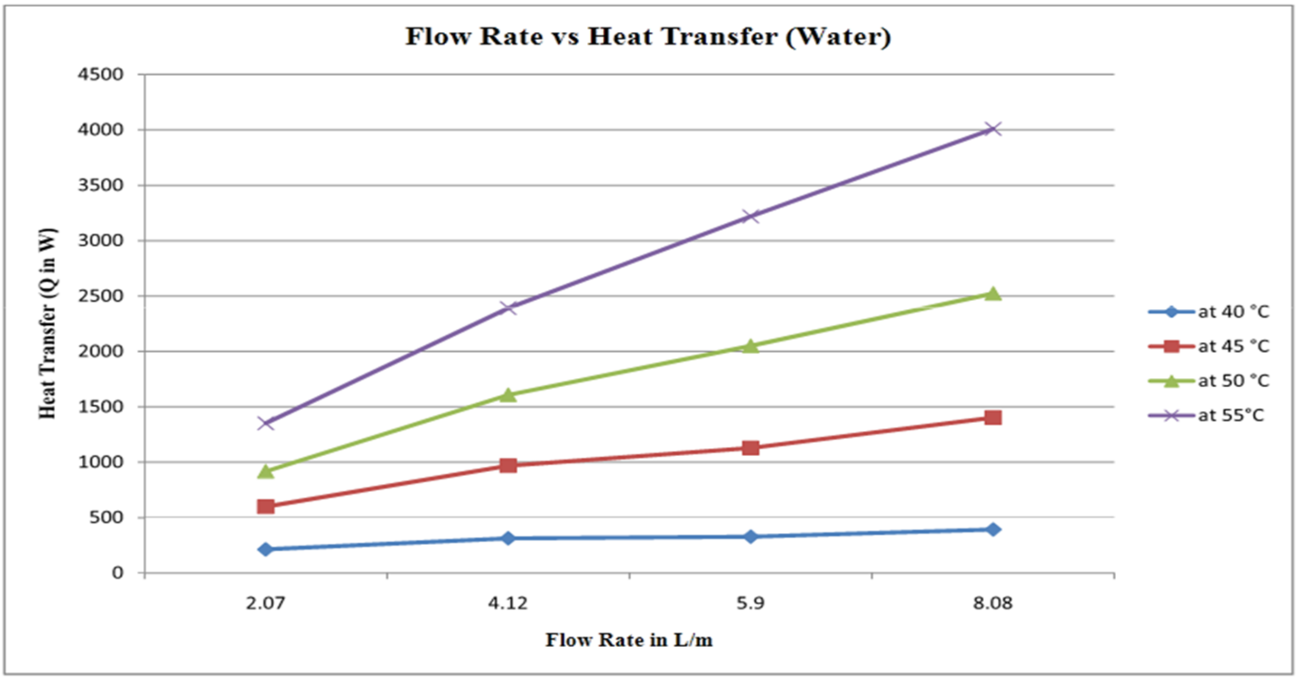


Fig 4.1 Flow Rate vs Heat Transfer rate (water)

The variation of heat transfer rate from the radiator with coolant flow rate at different engine temperature is given in Fig. 4.1.

With the increase in flow rate, the heat transfer rate increases for pure water at different temperatures because the mass flow rate of water increases with increasing the flow rate. So the heat transfer rate directly depends on the flow rate.

4.2.2 Heat transfer rate at different temperature (for nanofluid with 10% concentration)

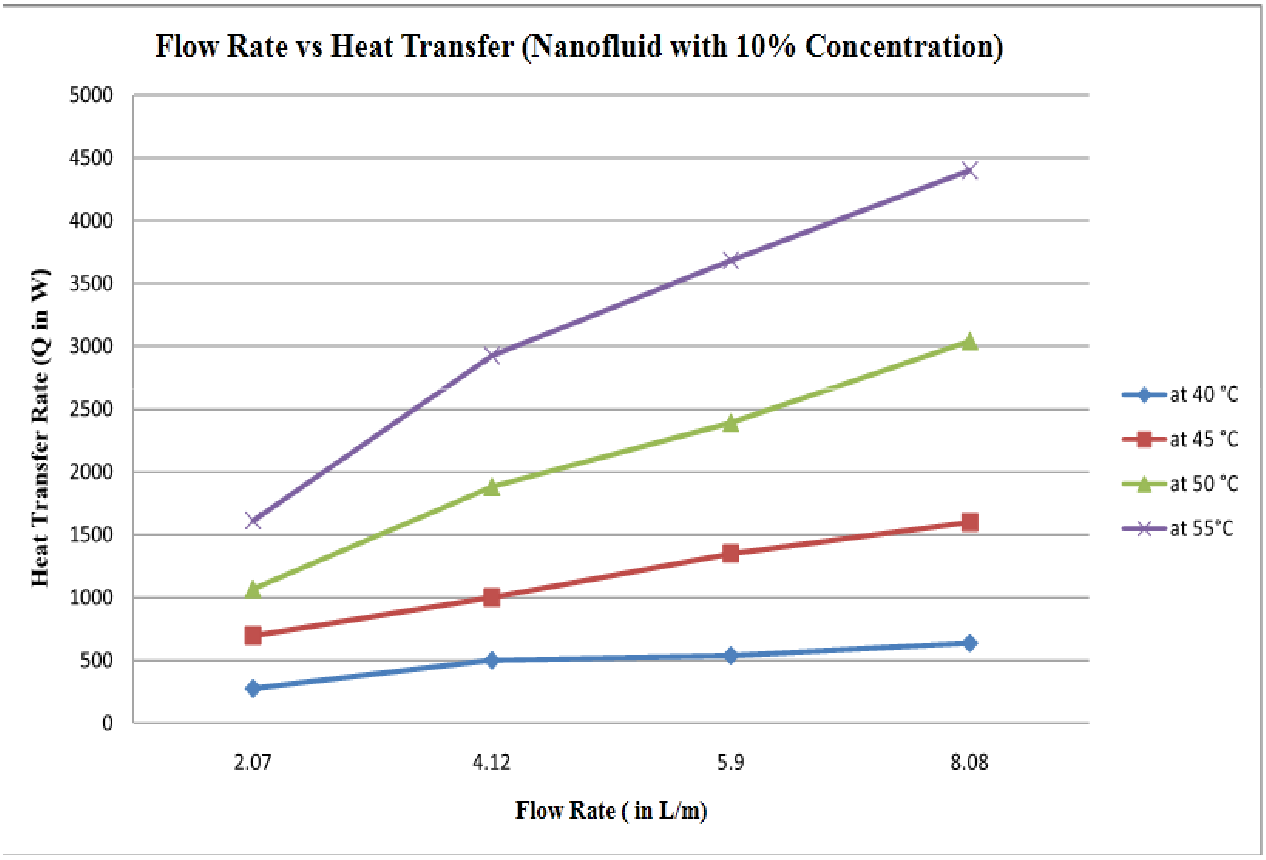


Fig 4.2 Flow Rate vs Heat Transfer (Nanofluid with 10% conc.)

Fig 4.2 shows the variation in heat transfer rate at different flow rate with different engine temperature in 10% concentration nanofluid. With the increase in flow rate, the heat transfer rate increases for nanofluid with a 10% concentration because the mass flow rate of coolant increases with increasing the flow rate. So the heat transfer rate directly depends on the flow rate. The maximum heat transfer rate was found at 55°C.

4.2.3 Heat transfer rate at different temperature (for nanofluid with 20% concentration)

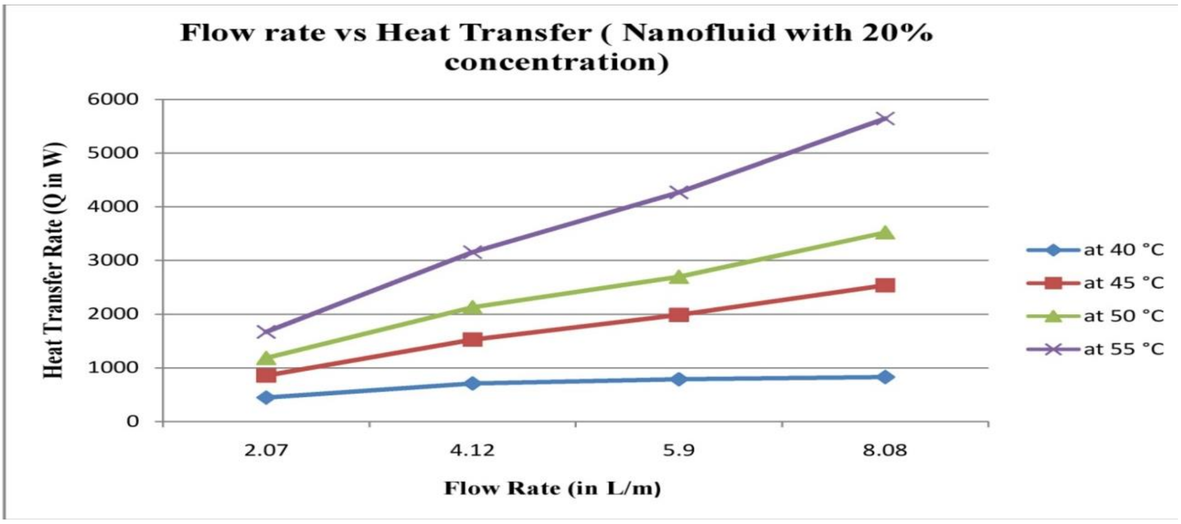


Fig 4.3 Flow Rate vs Heat Transfer (Nanofluid with 20% conc.)

Fig 4.3 shows the variation in heat transfer rate at different flow rate with different engine temperature in 20% concentration nanofluid. With the increase in flow rate, the heat transfer rate increases for nanofluid with a 20% concentration because the mass flow rate of coolant increases with increasing the flow rate. So the heat transfer rate directly depends on the flow rate. The maximum heat transfer rate was found at 55°C.

4.2. Heat transfer rate at different temperature (for nanofluid with 30% concentration)

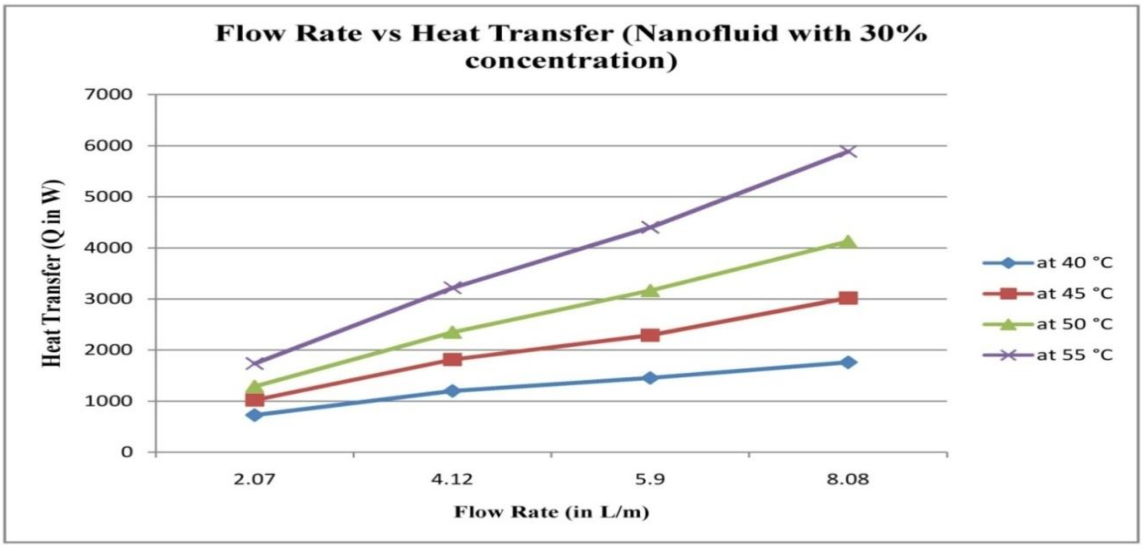


Fig 4.4 Flow Rate vs Heat Transfer (Nanofluid with 30% conc.)

The variation of heat transfer rate from the radiator with coolant flow rate at different engine temperature is given in Fig. 4.4. With the increase in flow rate, the heat transfer rate increases for nanofluid with a 30% concentration. So the heat transfer rate directly depends on the flow rate. The maximum heat transfer rate was found at 55°C

4.3 Effect of flow rate on heat transfer for all different concentration of nanofluid by fixed the inlet temperature

4.3.1 AT FIXED ENGINE TEMPERATURE 40°C

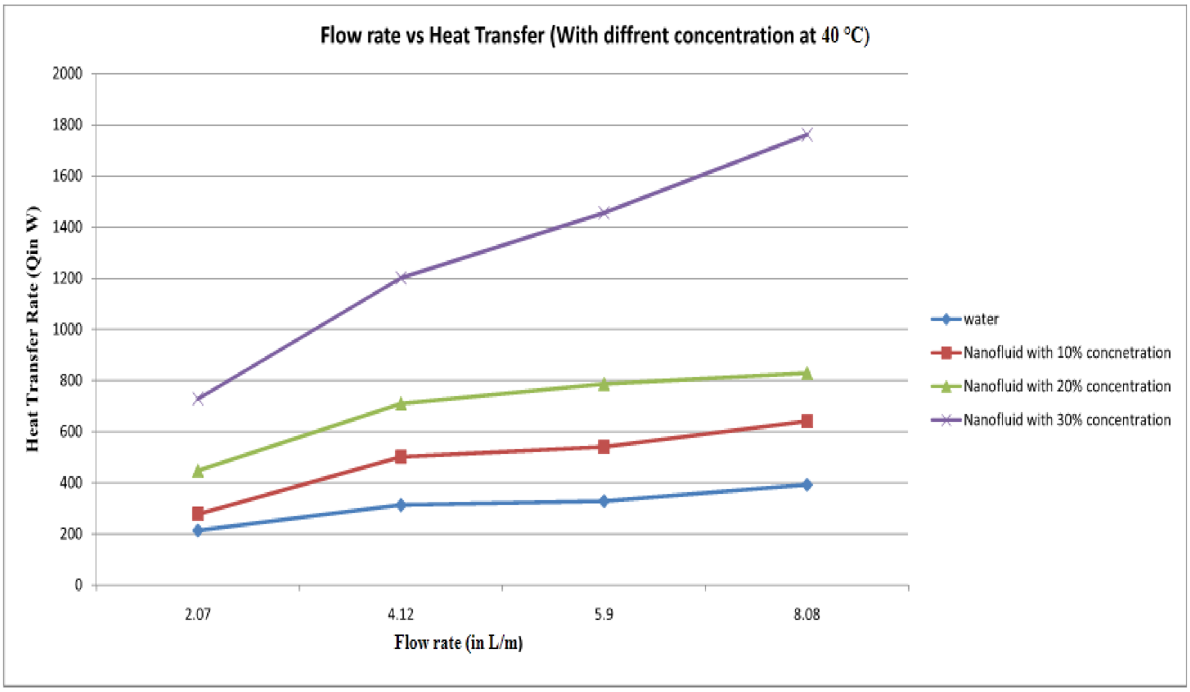


Fig 4.5 Flow Rate vs Heat Transfer (with different conc. At 40°C)

Fig 4.5 relates between flow rate and heat transfer rate and shows variation of heat transfer rate with different flow rate at different concentrations of nanofluid. With Increase in different concentration and flow rate, heat transfer rate also increases at fixed temp 40°C. In the graph nanofluid is having better heat transfer rate.

4.3.2 AT FIXED ENGINE TEMPERATURE 45°C

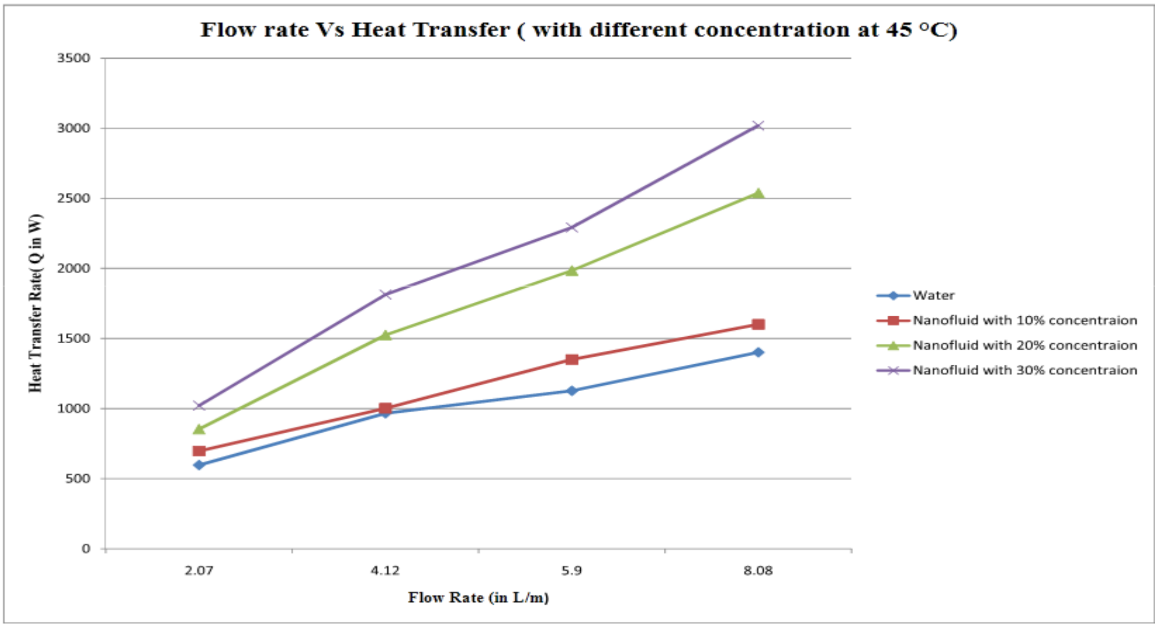


Fig 4.6 Flow Rate vs Heat Transfer (with different conc. At 45°C)

Relationship between flow rate and heat transfer rate and shows variation of heat transfer rate with different flow rate at different concentrations of nanofluid is given in Fig 4.6. With Increase in different concentration and flow rate, heat transfer rate also increases at fixed temp 45°C. In the graph nanofluid is having better heat transfer rate.

4.3.3 AT FIXED ENGINE TEMPERATURE 50°C

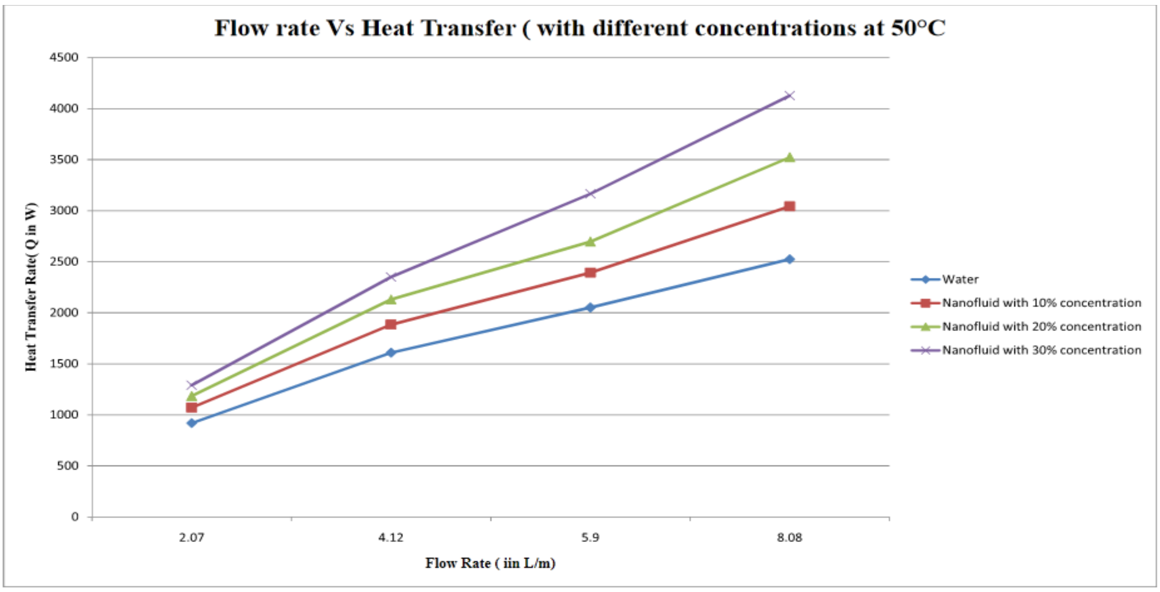


Fig 4.7 Flow Rate vs Heat Transfer (with different conc. At 50°C)

Fig 4.7 relates between flow rate and heat transfer rate and shows variation of heat transfer rate with different flow rate at different concentrations of nanofluid. With Increase in different concentration and flow rate, heat transfer rate also increases at fixed temp 50°C. In the graph nanofluid is having better heat transfer rate.

4.3.4 AT FIXED ENGINE TEMPERATURE 55°C

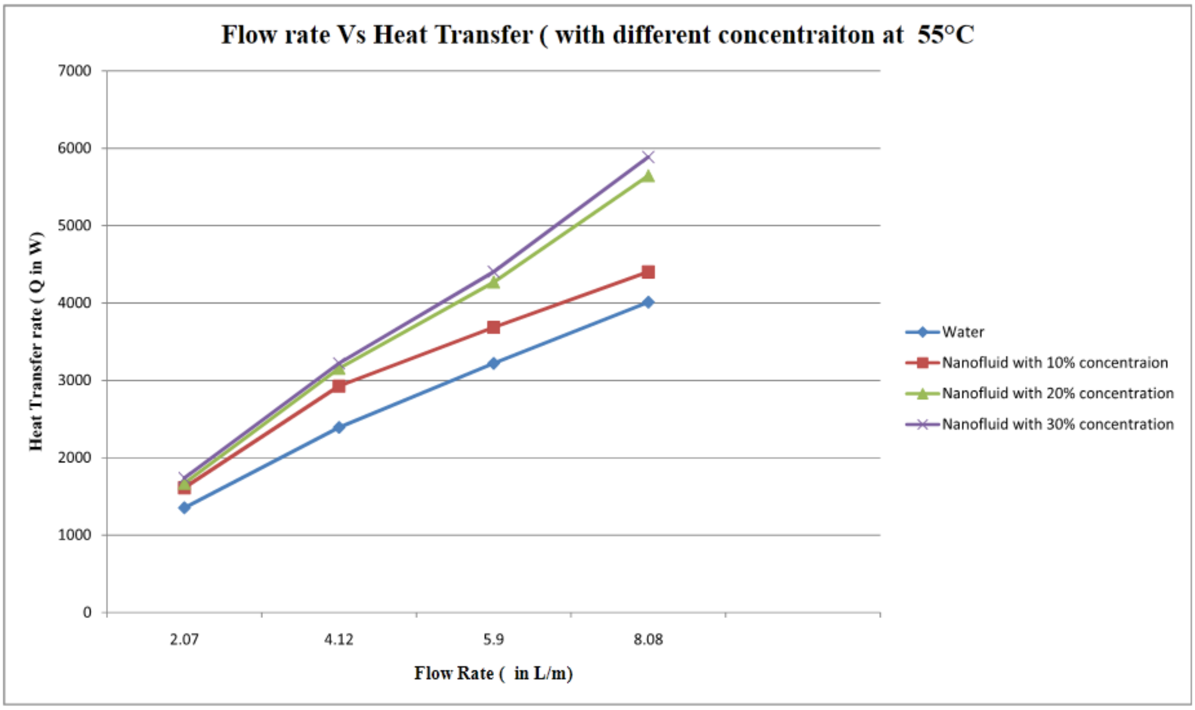


Fig 4.8 Flow Rate vs Heat Transfer (with different conc. At 55°C)

Fig 4.8 relates between flow rate and heat transfer rate and shows variation of heat transfer rate with different flow rate at different concentrations of nanofluid. With the Increase in different concentration and flow rate, heat transfer rate also increases at fixed temp 55°C. In the graph nanofluid is having better heat transfer rate.

4.4 Effect of flow rate on outlet temperature of nanofluid at (40°C, 45°C, 50°C, 55°C) inlet temperature for all concentrations

4.4.1 AT FIXED ENGINE TEMPERATURE 40°C

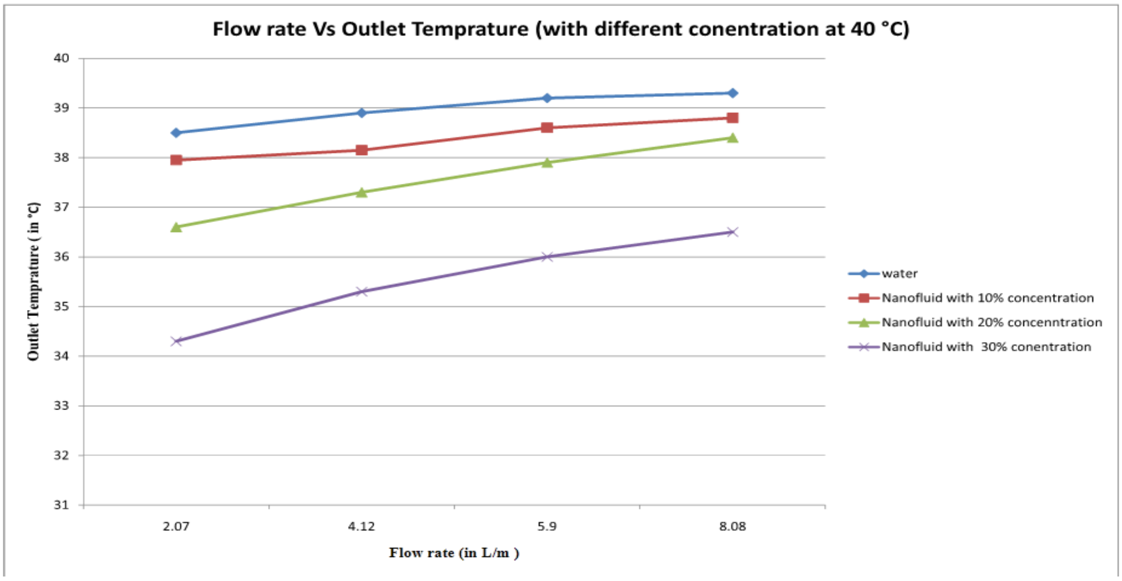


Fig 4.9 Flow Rate vs Outlet Temperature (with different conc. At 40°C)

Fig 4.9 shows relationship between flow rate and outlet temperature with different flow rate at different concentration of nanofluid. At a constant inlet temperature of 40 °C, the temperature difference between the inlet and outlet decreases with an increase in flow rate for all conc. Also, the decrease in outlet temperature is maximum for 30% and minimum for water at all inlet temperatures.

4.4.2 AT FIXED ENGINE TEMPERATURE 45°C

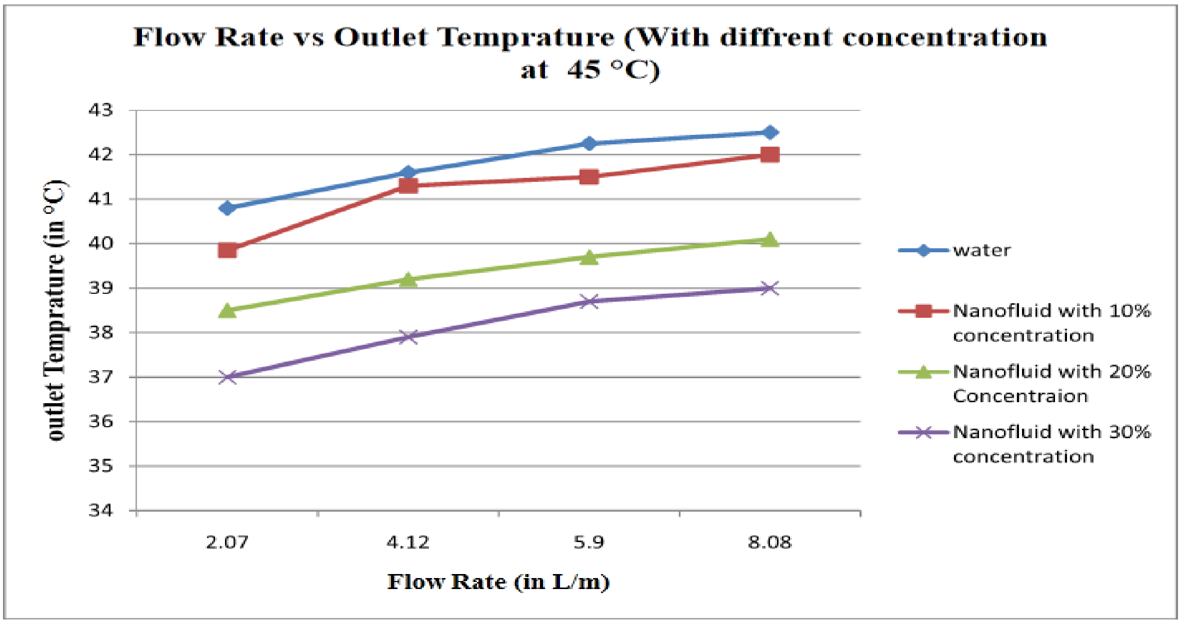


Fig 4.10 Flow Rate vs Outlet Temperature (with different conc. At 45°C)

Fig 4.10 shows relationship between flow rate and outlet temperature with different flow rate at different concentration of nanofluid. At a constant inlet temperature of 45 °C, the temperature difference between the inlet and outlet decreases with an increase in flow rate for all conc. Also, the decrease in outlet temperature is maximum for 30% and minimum for water at all inlet temperatures.

4.4.3 AT FIXED ENGINE TEMPERATURE 55°C

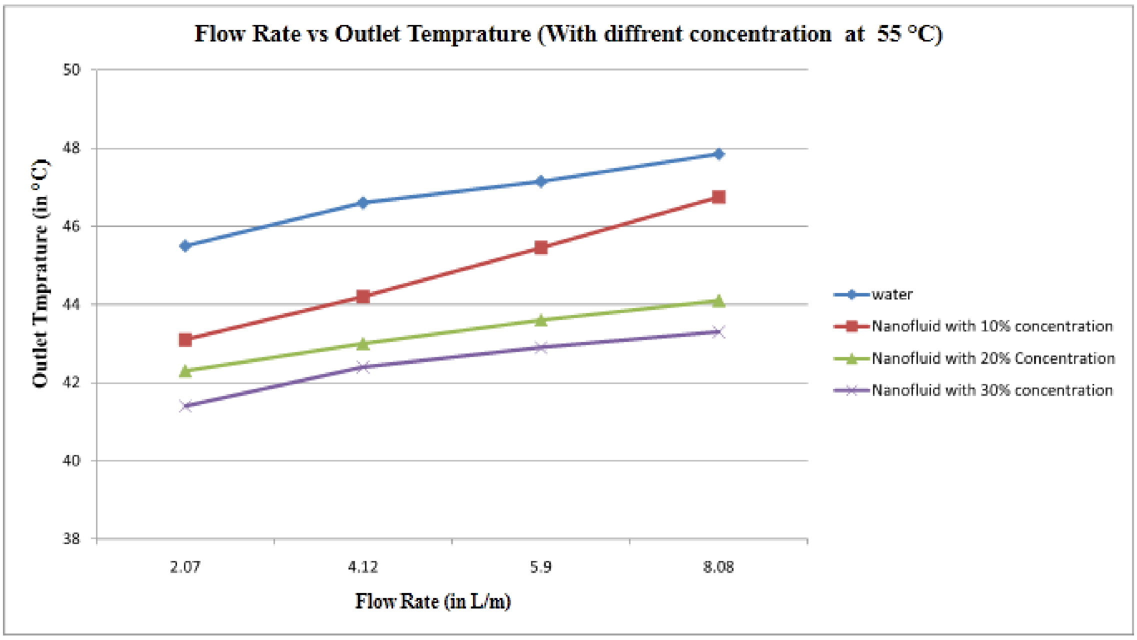


Fig 4.11 Flow Rate vs Outlet Temperature (with different conc. At 55°C)

Fig 4.11 shows relationship between flow rate and outlet temperature with different flow rate at different concentration of nanofluid. At a constant inlet temperature of 55 °C, the temperature difference between the inlet and outlet decreases with an increase in flow rate for all conc. Also, the decrease in outlet temperature is maximum for 30% and minimum for water at all inlet temperatures.

4.5 Effect of engine temperature on outlet temperature at a fixed flow rate for all concentrations

4.5.1 AT FIXED FLOW RATE 2.07 LPM

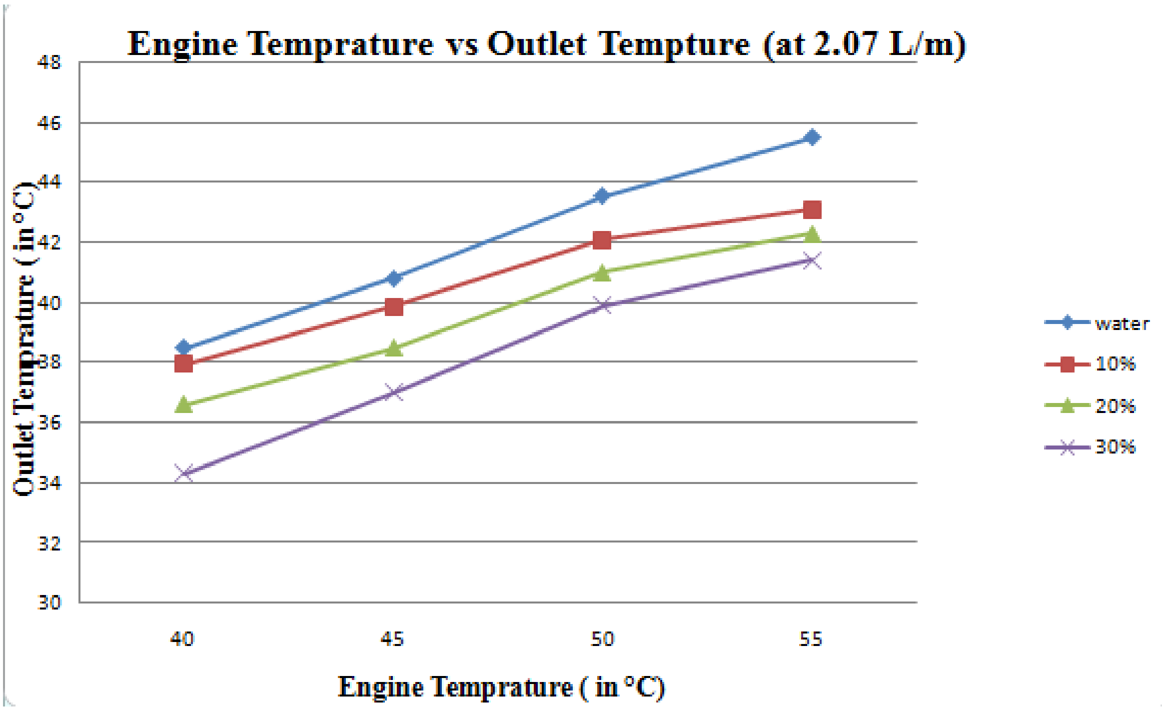


Fig 4.12 Engine Temperature vs Outlet Temprature (at 2.07 l/m)

Fig 4.12 shows relation between engine temperature and outlet temperature at different concentration of nanofluid at a fixed flow rate. At a constant flow rate of 2.07 l/m, outlet temperature decreases with an increase in inlet temperature for all concentrations. Also, the decrease in outlet temperature is maximum for 30% and minimum for water at all inlet temperatures.

4.5.2 AT FIXED FLOW RATE 8.08 LPM

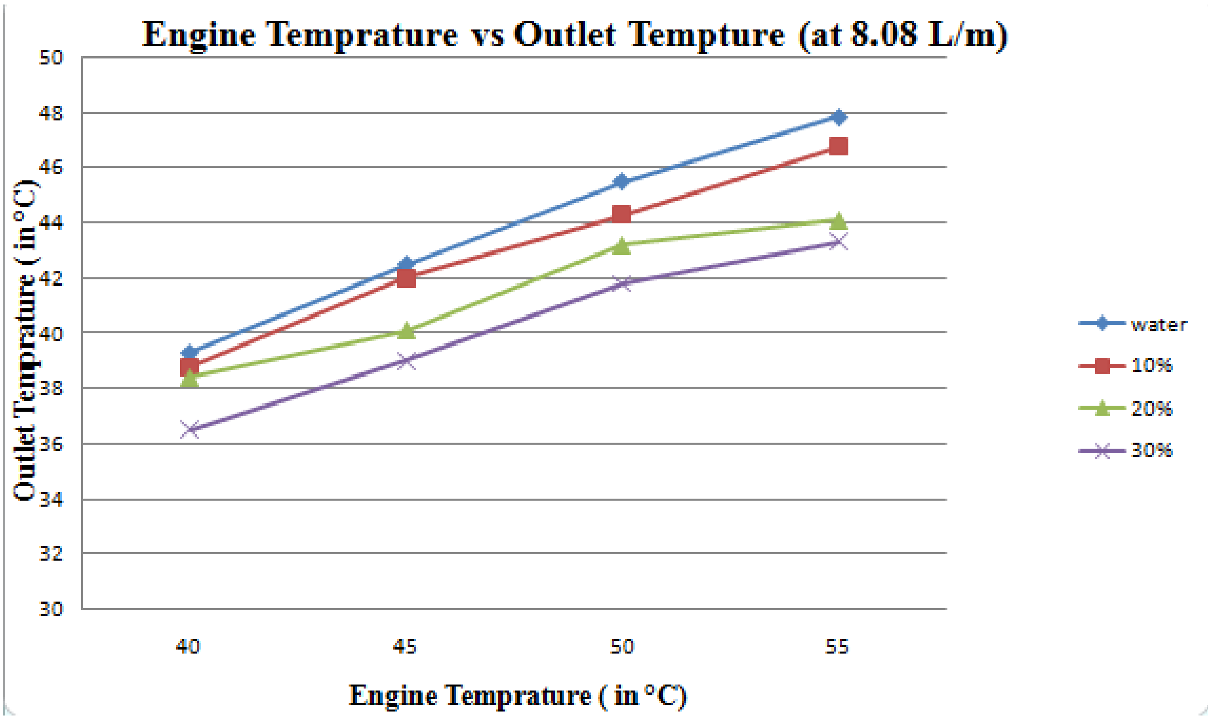


Fig 4.13 Engine Temperature vs Outlet Temperature (at 8.08 l/m)

Fig 4.13 shows relation between engine temperature and outlet temperature at different concentration of nanofluid at a fixed flow rate. At a constant flow rate of 8.08 l/m, outlet temperature decreases with an increase in inlet temperature for all concentrations. Also, the decrease in outlet temperature is maximum for 30% and minimum for water at all inlet temperatures.

CHAPTER 5
CONCLUSIONS

5.1 CONCLUSIONS

The Experimental study was done on the radiator vehicle at different concentrations of nanofluid (form 10% to 30%) and different engine temperature (40 to 55°C) to evaluate the outlet temperature of fluid and heat transfer by the fluid at different flow rate of the coolant with constant air flow rate .

Key conclusions are as follows:-

- The outlet temperature of the coolant decreases with increase concentration of nanofluid. Higher temperature as observed in water and ;lowest temperature found it 30%of the coolant at different flow rate and engine temperature.
- The heat transfer rate of the radiator increases by the coolant and maximum heat transfer rate is found at 30% concentration of nanofluid for all flow rate and engine temperature.
- The heat transfer rate increases by increasing concentration of coolant because of increasing the thermal conductivity of the fluid.
- The enhancement in the heat transfer rate is observed in the range of 1.4 to 8.45 times at different combinations of volume flow rate (2.07, 4.12, 5.90 & 8.08 lpm) and engine temperature (40 to 55°C) and concentrations of nanofluid (form 10% to 30%)

5.2 SCOPE FOR FUTURE WORK

Here are some potential scopes for future work in investigating the thermal behavior of radiators using nanofluid as a coolant:

- Explore different nanofluid compositions to find the optimal combination that enhances heat transfer while maintaining stability and cost-effectiveness.
- Evaluate the radiator's performance with nanofluid coolant under extreme temperature conditions, such as in cryogenic environments or high-temperature applications.
- Conduct long-term tests to assess the stability and reliability of nanofluid coolant in radiator systems, considering factors like nanoparticle settling, corrosion, and degradation over time.
- Develop computational models and simulations to accurately predict the thermal behavior of radiators with nanofluid coolant, allowing for virtual testing and optimization before practical implementation.
- Scale up the experimental setup to mimic real-world industrial radiator systems and validate the feasibility and scalability of using nanofluid coolant on a larger scale.

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