Experimental Investigation of Enhancement of Heat Transfer Rate in an IC engine Radiator Using Al_2O_3 based Nano-Fluid.

A project report submitted to the Department of Mechanical Engineering, Sonargaon University, in partial fulfillment of the requirement for the degree of Bachelor of Science in Mechanical Engineering.

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Authors

Abstract

Heat exchangers play an important part in the field of energy conservation, conversion and recovery. Numerous studies have focused on direct transfer type heat exchanger, where heat transfer between fluids occurs through a separating wall or into and out of a wall in a transient manner. There are two important phenomena happening in a heat exchanger: fluid flow in channels and heat transfer between fluids and channel walls. Thus, improvements to heat exchangers can be achieved by improving the processes occurring during those phenomena. Nano fluids, on the other hand, display much superior heat transfer characteristics compared to traditional heat transfer fluids. Nano fluids refer to engineered fluids that contain suspended nanoparticles with average size below 100 mm in traditional heat transfer fluids such as water, oil and ethylene glycol. An experimental system will be designed and constructed to investigate heat transfer behavior of Aluminum oxide (Al_2O_3) of Nano fluid a car-radiator heat exchanger. Heat transfer characteristics will be measured under the turbulent flow condition. The experiments is planned to be conducted for wide ranges of Pellet numbers, and volume concentrations of suspended nanoparticles. The outcome expectation is to measure the significance of Pellet number on the heat transfer characteristics. The optimum volume concentrations in which the heat transfer characteristics become the maximum enhancement is also addressed. Finally, the structure of aluminum oxide (Al_2O_3) Nano fluid is compared. The

Water tank holds 35 liters of water. By heating the water to 44 degrees and entering the engine and whose output was through radiator cooling, by this system able to reduce the maximum temperature by 4.89%. Then put the same amount of water in the water tank and this time by mixing coolant with water and heating it to 44 degrees and entering the engine and the output of which was through radiator cooling, At last able to reduce the maximum temperature by 7.10%. Finally, again the same amount of water in the water tank and this time mixed aluminum oxide (Al_2O_3) with water and heated it to 45 degrees to enter the engine and whose output was through radiator cooling, in the way able to reduce the maximum temperature by 10.95%.

Keywords: Cooling system, Heat transfer, Nano Fluid.

TABLE OF CONTENTS

List of figures

List of Tables

Table No. Page no.

Chapter I: Introduction

1.1 Introduction:

Now a days the demand of IC engine is on prime. so, it is more challenging for IC engine industries to provide an efficient and economical engine. Only 25% of heat is converted to useful power & the remaining heat transfer is dissipated. If the heat dissipation is not done properly it will cause a serious damage to the engine. The performance of the engine is based on fuel system, lubrication system and cooling system etc. Cooling system is the most important factor to increase the efficiency of the engine. Heat transfer through the radiator can be improved by maximizing the heat transfer area and increasing the heat transfer coefficient of aluminum oxide (Al_2O_3) in water as the Nano fluid is used to increase the heat transfer coefficient [2].

Continuous technological development in automotive industries has increased the demand for high- efficiency engines. A high-efficiency engine is based not only on its better performance but also its better fuel economy and lower Emissions. Today, there is a need for dimensions and weight reduction of heat transfer systems in transport industries. Using different fin types and micro channels, various tube inserts or rough surfaces show some efforts made for increasing the cooling rate of radiators. Another way is changing the working fluid of radiators. Conventional heat transfer fluid such as water, ethylene glycol (EG), and engine oil have relatively poor heat transfer performance. So, the high compactness of heat transfer systems is necessary to achieve the required heat transfer.

One method for improving the heat transfer of car radiator fluids is adding small solid particles, in the range of Nano, to the base fluid. This new category of fluids is called Nano-fluids.

However, these nanoparticles in base fluids are metallic or metallic oxide and always have cylindrical or spherical shapes. Nano particles the additives of Nano fluids, play an important role in changing the thermal transport properties of Nano fluids also they change the fluid characteristics because thermal conductivity of the particles is higher than ordinary fluids

Materials with higher thermal proper’s are required to increase the performance of radiator. The use of Nano fluids is one of the methods to increase heat transfer in radiators. In this research, cooling of car radiator has been investigated by using Nano fluids. Results of the research indicated that the used Nano fluid can increase heat transfer up to 50%. Reduce on in size and weights of the radiators are among the achievements of this research [1].

In addition to reducing the produce on cost, better design on of cars are possible when the radiator becomes smaller in size. On the other hand, better cooling has positive effects on fuel consumption on and the amount of fuel Consumption. Nano fluids are potential heat transfer fluids which enhances the thermos physical properties and heat transfer performance. It can be applied in many areas for better performances for energy, heat transfer and other performances. Work depicts that at high speeds, about 65% of the total energy output from a truck is expended in overcoming the aerodynamic drag [2].

This fact is partly due to the large radiator in front of the engine positioned to maximize the cooling effect of oncoming air. With the advancement of nanotechnology, the new generation of heat transfer fluids called, “Nano coolants” have been developed and researchers found that these fluids are making higher thermal conductivity compared to that of conventional coolants. Nano fluids which consist of carrier liquids such as water, ethylene glycol is dispersed with tiny Nano-scale particles known as nanoparticles. Nano fluids seem to be a potential replacement for the conventional coolants in engine cooling system for automobiles. Recently there has been considerable research findings are reported, that the superior heat transfer performances of Nano coolants [4].

Nano particles are very small in size, usually < 100 nm. Nano-fluids used many applications like microelectronics, fuel cells, pharmaceutical process, hybrid power engines, engine cooling, vehicle, thermal management, domestic refrigerator, heat exchangers, in grinding, mashing, boiler flue gas temperature reduction, geothermal extractions [5]

That hotter the radiator, the better is the heat transfer with surrounding air. With water as the coolant, The highest temperature a radiator could operate is 373K,i.e.,the boiling point of water. Addition of ethylene water in sealed radiator can substantially raise coolant pressure alongwith boiling point. [6].

This work is focused on the addition of Al_2O_3 Nano particles to coolant in an automotive cooling system. Relevant data, Nano fluid properties and empirical correlations were

obtained from literatures to investigate the heat transfer enhancement of an automotive or radiator operated with Nano fluid-based coolants. Experimentation is done for the comparison of overall heat transfer coefficient and the heat transfer rate of the engine cooling system with and without application of Al_2O_3 Nano fluid in base fluid [9].

1.2 Objectives:

The objectives of this project work are:

1.2.1 To develop high heat transfer system using Nano fluid to replace cooling water.

1.2.2 To increase the heat transfer rate of engine cooling fluid.

1.2.3 To investigate the effect of temperature and volume fraction on thermal conductivity.

Chapter II: Literature Review

2.1 Historical Background:

Mohammad Hossein Aghabozorg et al, experimentally studied the overall heat transfer coefficient of an automobile radiator using graphene Nano platelets based coolant with the volume fractions of 0.1-0.5% and the Nano fluid flow rates of 12.5g/s- 62.5g/s. They also varied the ambient air velocity and the Nano fluid inlet temperatures from 1-5 m/s and 35 to 45 respectively. Their results stated that the overall heat transfer coefficient enhanced up to 104% at 0.5% volume fraction, 62.5g/s flow rate and 5 m/s ambient air velocity compared to the base fluid and 39% enhancement in pressure drop was recorded at the highest mass flow rate of 62.5g.[7]

Kallalu Harika.,Tummala.Likhitha et al, experimentally studied heat transfer characteristics of Al2O3/water based Nano fluids in an automobile radiator with the volume fractions of 0.1%,0.5%,1.5%. The experiments done at different heat load (16,12 8 kw) and coolant and air flow rate conditions. The Maximum percentage increase of the coolant heat transfer rate, coolant heat transfer coefficient, and coolant Nussle number is 14.79, 14.72, and 9.51, respectively, which occurs at maximum load and at 0.1 Vol%. The maximum values of air side heat transfer coefficient and Nussle number also occur at the same load and concentration and have 14.45% and 13.94% increase over that of the base fluid, respectively. [8].

H. Masuda et al. studied the thermal conductivity enhancement of Al_2O_3 nanoparticles with water as base fluid affected by surfactant and nanoparticle cluster formation in base fluid. Cluster formation was studied by using transmission electron microscope (TEM). It was observed that as the concentration of nanoparticles was increased the agglomerate or cluster formation between nanoparticles also increased. This cluster formation reduced the thermal conductivity enhancement. Agglomerate formation depended on particle size, shape, concentration, viscosity of base fluid. Large size of cluster formation at high concentration leads to free region in base fluid and provide high thermal resistance which reduce the enhancement in conductivity. Remedy suggested for Nano fluid clustering was sonication and surfactant addition. [9]

2.2 Application:

This project is a continuance of all the other theoretical studies that have been done on the subject. We are experimentally proving that Nano particles in fluids would enhance efficiency without compromising pressure. This would mean that the technology would be a step closer to being used in industrial settings.

The major application of this project is in industrial heat transfer settings such as power plants, desalination plants, and maybe even in the Radiators of trucks.

The project is meant to increase the efficiency of current systems without significant investment, and reduce the cost of future systems by increasing the efficiency of smaller parts to do the job [3].

2.3 Long life Learning:

There were many things that were implemented by us during the time we did this project. The nature of the project required the use of many new devices and components, but we did have to improvise with other things. The short time we had to do the project also constrained our ability due to tight deadlines. This project involved highly detailed measurements due to the nature of the material we are working with, and the environment we are working in. We had to use many time management methods, specialized components, and also complex CAD designs.

The first major hurdle that we needed to face was the time we had. Within the short times we had to design, manufacture, assemble, and test our theories. A project plan was implemented and designed to help us reach the project's objective in the planned time span, therefore a step-by-step execution plan was required. Hence a Gantt chart was created, and deadlines were set. There were deadlines from the instructor, and others we set for ourselves. The Gantt chart aided us in formulating and visualizing our tasks for the months that were to come. We had to learn how to detail it in a way that fits with our needs and time constraints.

The second hurdle was finance. Being students, we only have limited financial capabilities, and we have to work within our means to achieve our project objectives. We had to learn to manage our finances properly, and therefore we had to do some of the work ourselves, or come up with novel solutions for the issues. In instance like heating the water we made the decision to use a water container we had and only the heating mechanism of a water heater. That saved us a lot of money.

The third hurdle was specialized components and spare parts collect from local market, it's price and quality analysis is very difficult. We had to come up the of sensors or measuring instrument that would produce valid and accurate results. Aluminum oxide nanoparticles are not very easy to get in our country except from certain chemical shops. We had to learn to handle them in a way as to not harm ourselves or our surroundings. As for the testing we had to come up with a method that would result in accurate readings without requiring extra sensors. For example, we would test the surrounding air temperature once before each specific test, and use the same sensor for testing the temperature after the air passes the radiator.

The fourth hurdle is designing a system that would work. We had to design our system from scratch without having any previous work to build off. We started by modeling our idea of the prototype using Solid works. We learned design through our university CAD and SolidWorks design courses. We also used the computer labs provided by the university for this purpose. We used tutorials from YouTube to be able to design the prototype faster and easier.

For example, we used the base frame and pipe fittings we made to get the cured shape. We were also able to use a pump and valves that were predesigned and part of the software. This greatly aided our visualization, and designing time.

The final hurdle, after fully setting it up as per design, is finding some leakage, some instruments not working properly, and re-leak proofing them, and re-collecting the instruments from the market that were not working properly. Through this we are able to verify the correct quality instruments.

We actually had to overcome all these hurdles to complete our project, which made us competent to take the right decisions by applying them in the field of work and real life.

2.4 Impact of Engineering Solutions:

In the most basic sense of our work the idea is efficiency. That is our key, and that is what we need to achieve. If we can show that current equipment could be configured to do much more than designed that would save a lot of money. The impact of the project touches many areas of our lives from the power coming to our homes to the water we drink even the industrial machines used to transport everything we see. We want to increase the efficiency of everything that heat transfer plays a role in, and we choose to start with radiators, because it is what we could afford with the time we had. Heat transfer plays a role in the transportation, power generation, and even water production.

Increasing the efficiency of transport would decrease fuel consumption. If the efficiency of a ship that transports goods is increased that means it requires less fuel to run, and that makes it cheaper, and that results in more affordable goods for all. If we make the trucks that move ore from mines more efficient that would mean they can work more, and lower the cost on companies making them able to spend more on other things like increasing wages. If we make the cars, we currently have run more efficiently that means we lower the fuel consumption, and by that we reduce the carbon foot print on the planet.

Increasing the efficiency of power production would mean lowering their impact on the environment. Most power plants rely on heat transfer, and use water to do that, which we have shown is a very poor conductor of heat. Suspending Nano particles in the water would only require the introduction of ultrasound devices to suspend the particles, and prevent precipitation.

That would greatly cut the cost of power, because they can provide the same amount with less fuel, and by burning less fuel we would reduce the carbon foot print on the plane.

2.5 Contemporary Issues Addressed:

Our world doesn't have a finite number of resources therefore we need to do the most with the resources we are running out of, and we also have to take care of the planet that we are slowly killing. With small changes to even the existing machines and infrastructure we can achieve this. With the rising fuel costs, we can have our IC engine consume less fuel by making them consume it more efficiently. By doing this, the fuel reserves in the Middle East region and other areas of our world will be more sustainable. All of these have a compounded benefit because the save the environment.

Chapter III : Theoretical aspects

3.1 Logarithmic mean temperature difference (LMTD):

In thermal engineering, the logarithmic mean temperature difference (LMTD) is used to determine the temperature driving force for heat transfer in flow systems, most notably in heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold feeds at each end of the double pipe exchanger. For a given heat exchanger with constant area and heat transfer coefficient, the larger the LMTD, the more heat is transferred. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties.

<u>Equation:</u> Assume that a generic heat exchanger has two ends (which we call "A" and "B") at which the hot and cold streams enter or exit on either side; then, the LMTD is defined by the logarithmic mean as follows[10]:

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

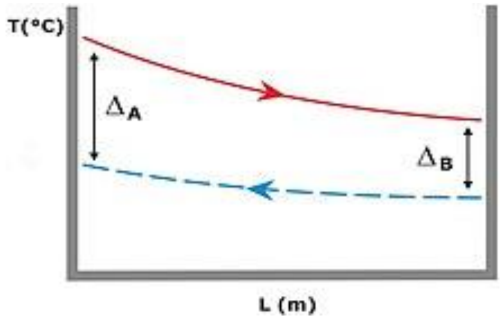
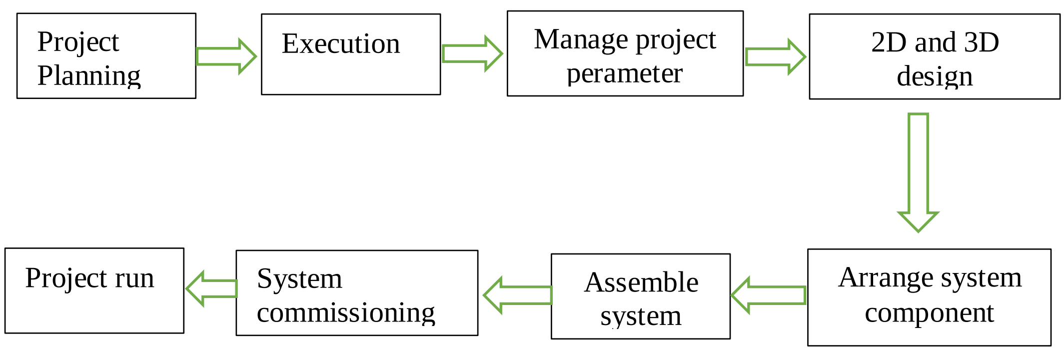


Figure: (3.1): LMTD

3.2 Project Execution Monitoring:

Block diagram:



Meetings with Advisors

To be in the right track, our plan was to connect the Supervisor Saikat Biswas every time to follow up on our progress in the project and show him the results and some issues in order to discuss and find solutions and directions. So, the best decision was to connect and follow up with him every time if we needed the required help or faced some difficulties to save time. Therefore, we connect to online or physical meet him whenever we need.

3.3 Challenges and decision making:

Literally, we couldn't have any issues with the group gathering except the time conflicts among our team member and we had resolved it out either by meeting on weekends or in whenever we had some free time. Other than that, all team members were collaborative and supportive wherever we had any issues related to the project.

We had faced some difficulties finding some of the required parts and when these parts found, they were not be within the good quality. Also, our biggest problem was the continual changes of these parts to execute and finish our project in a good picture. These were some of the issues we had met with.

3.4 Description of project task :

Week	Task	Description
1	Design of the project phase 1	Stating the require parts and material specifications.
1	Market survey	Looking for equipment and parts in respect to price, functionality and quality.
2	Design of the project phase 2	Using the result form our market survey to design the system.
2	Design testing system phase 1	First system design draft using solid works.
3-4	Purchasing the system parts	This step includes gathering the financial plan and buying the required parts.
5	Assemble the system	Building the testing system using expert technicians for electrical wiring.
6	Checking the system functionality	Checking the system for any water leakage our any insulation problems.
7-8	Data gathering phase 1	Collecting data without using aluminum oxide (Al_2O_3)
9-10	Data gathering phase 2	Collecting data using aluminum oxide (Al_2O_3).

Table (3.1): Dates, tasks and description of all the tasks.

3.5 Implementation:

Since the beginning of the project, we took into consideration that it is really important to understand our main task of the project to be able to work in consistence way, for instance the project design, cost, parts, assembly and ordering the nanoparticles must be available at its function time. As shown in table 3.1 the project main task and its description are explained.

Main tasks	Description
Project design	SolidWorks and AutoCAD used to draw our design.
Cost	We searched on the internet and visited some Local stores to know the prices before buying.
Purchasing parts	After knowing the prices and costs, we bought High quality parts with good prices.
Virtual design	After collecting all parts, we redesign us Completed system using SolidWorks.
Assembly	In the summer break we assembled our system and using expert technicians for electrical wiring.
Nano-particles Aluminum Oxide (Al_2O_3)	We will order of Nano-particles Aluminum Oxide (Al_2O_3) from the trusted Shop.

Table (3.2): the project main tasks and its description.

Chapter IV: Design and Construction

4.1 System components:

Designing a cooling system requires several components. For example: motor, radiator, fan, heater, coolant, thermometer, pressure valve. Some other things like thread tape, silicone is used to prevent leakage. The main system components are described below:

Radiator:

The shell & tube heat exchanger was the component that we found hard time providing. After long search we found the smallest Vehicle use shell & tube heat exchanger of stainless-steel type 316 L, 248 mm long consisting of 34 tubes. The tube diameter is 2.2 mm with a tube wall thickness of 0.19 mm, and area of 0.05 m^2 as shown in figure (4.2). The radiator we are using here is to reduce the Amount of Temperature in this project.

Figure (4.1): Shell & Tube Heat Exchanger

Water pump:

The pump we will purchase the pump locally, and its specifications and figure outperform The other available pumps. The pumps we used before either broke down or couldn’t give us the required pumping power. Water pump are using the pump as an alternative power to the Engine. We are using it as a feed water pump.

Figure (4.2): water pump.

Fan:

A 220V fan has been used air flow power is approximately 116.7 m/min to enhance more power to cool down water inside the radiator.

Figure (4.3): Cooling Fan We are using increase efficiency for radiator in this project.

Heater:

1200-watt Elegant shockproof handle made form pure copper to ensure maximum transmission of heat.

Figure (4.4): Heater We are using increase water temperature.

Instrumentation system:

Our instrument included several gauges mainly: temperature controller “thermometer” shown in below figure and pressure gauges below figure. The availability and the reading ranges of the instruments were all selected based on the specific specifications. Pressure Gauge help us Determine how much Pressure is entering the radiator and how much pressure is exiting.

Fig. (4.5): Pressure Gauge & Thermometer

Fluid:

Aluminum Oxide (Al_2O_3) Nano powder / Nanoparticles Dispersion (Al_2O_3) Nanoparticles Aqueous Dispersion, Alpha, 20wt%, 30nm) ”120ml/120g” Aluminum oxide Nano fluid acting as coolant. It is very effective in removing heat [12].

Figure (4.6): Aluminum Oxide (Al_2O_3).

Electronic scale:

As illustrated in the below figure, we have used an electronic scale to measure the Nano particles. It has been used to know the weight of Nano particles before being in the water. Using a weight scale to accurately measure nanoparticles in this project [11].

Fig (4.7): Electric Scale.

4.2 CAD design of project:

Figure (4.8) The project design by Auto Cad. It shows the function of the system with the devices and the way the whole system operates. The approach of the system design started with finding a heat exchanger and we chose a car radiator with a fan. However, the water pump used in cars are mechanical (it connects to the engine) which cannot be properly worked in the experiment. This caused us to try an electrical pump with features that AutoCAD in section. In addition, we planned to use Metal frames for the fan and heat exchanger to fix them on the table. We need to find the best quality places with the minimum prices (to control our budget) to do the frames and the table. After choosing the proper parts and devices, we used Solid Works software in order to simulate the assembly of the system. Last but not the least, we must assemble the components of the experiment in the way we instructed by the advisor with the consideration of previous works. Finally, we will do several experiments with and without using Nano particles and publish our results and recommendations we observed.

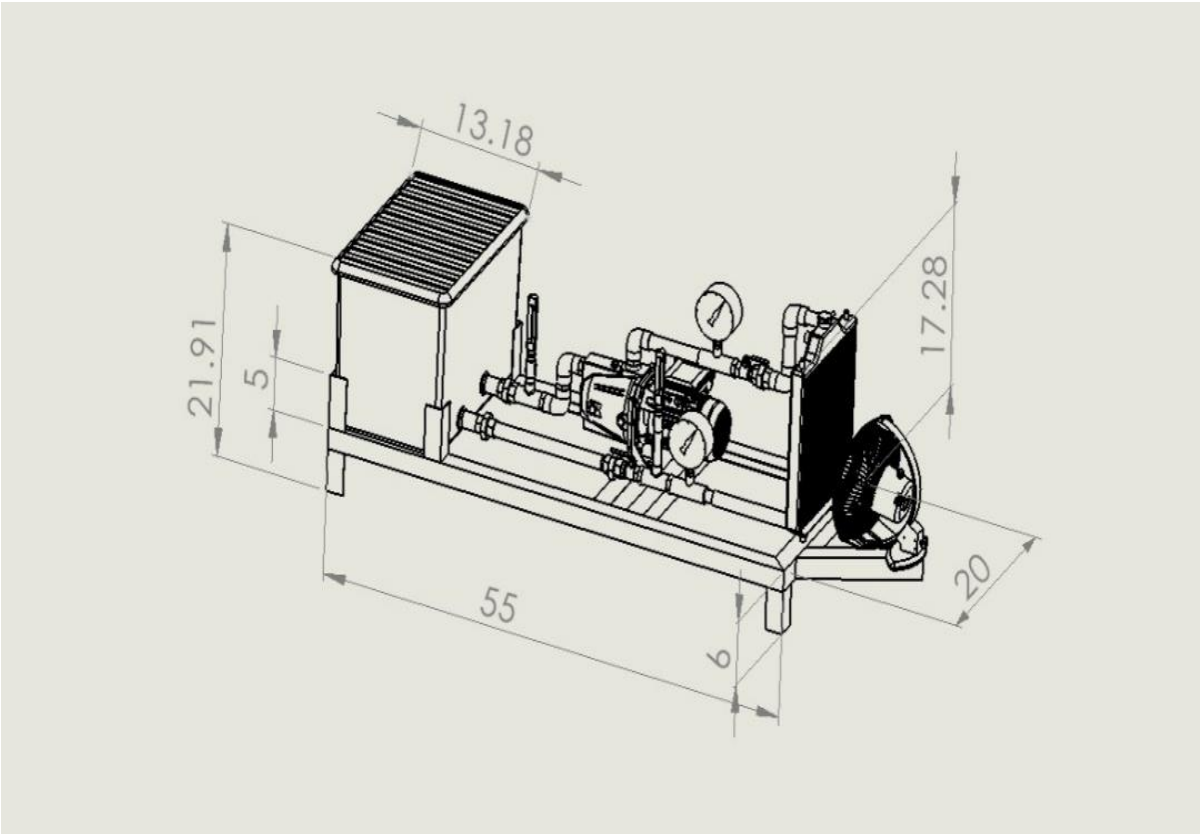


Figure (4.8) CAD design of projects.

4.3 SolidWorks Design:

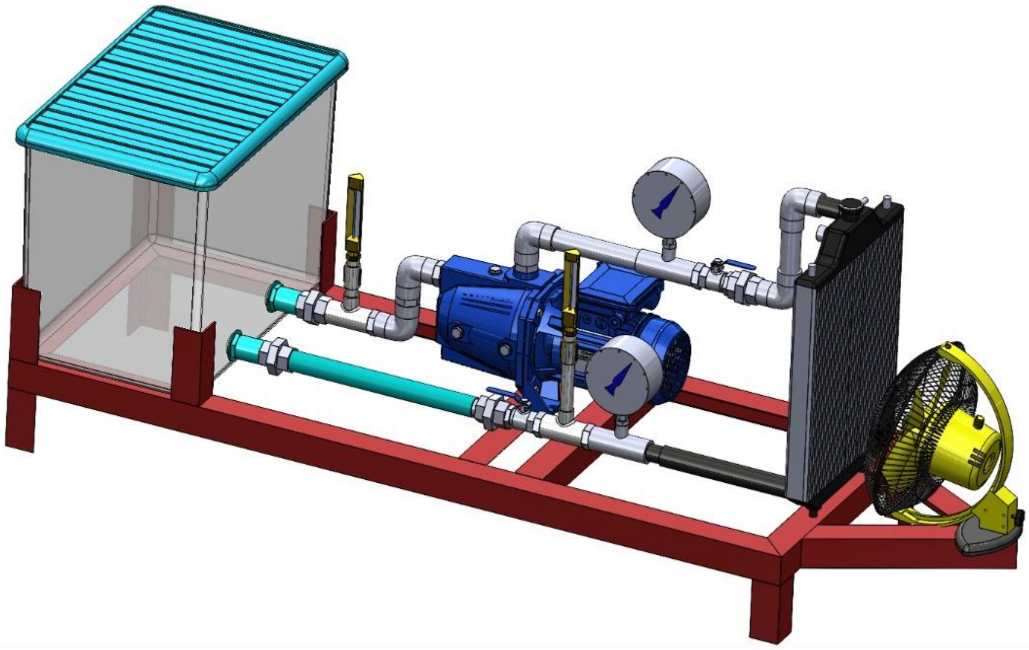


Figure (4.9), Isometric view of the design of the experimental set up.

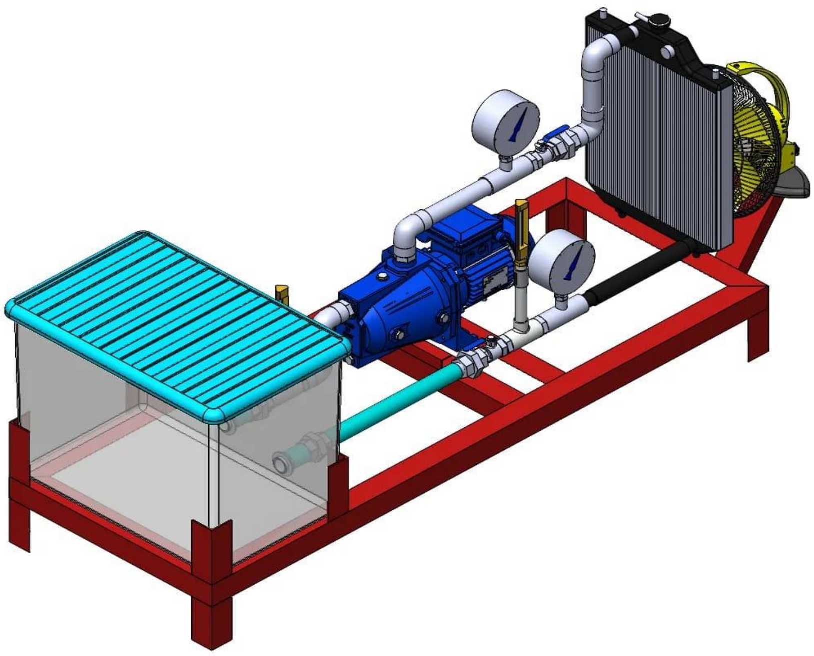


Figure (4.10), Another Isometric side view of the design of the experimental set up.

4.4 Construction of the Apparatus:

Our design for short is a project that can be used to transfer heat from hot water in a heat exchanger to Nano-fluid and make temperature calibrations for the same by using two thermometer in the cycle. The complete system includes flow meters will be fitted in the pipes and carrying Nano-fluid to check its flowing rate as it shown in figure (4.1). After the required specifications and sizing are enlisted, we searched in the market

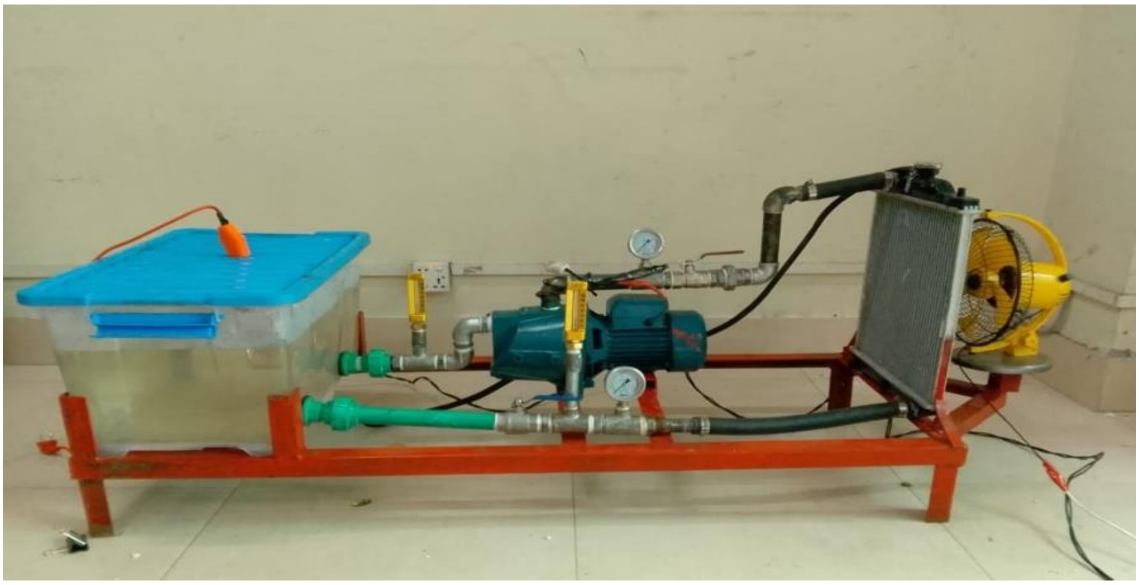
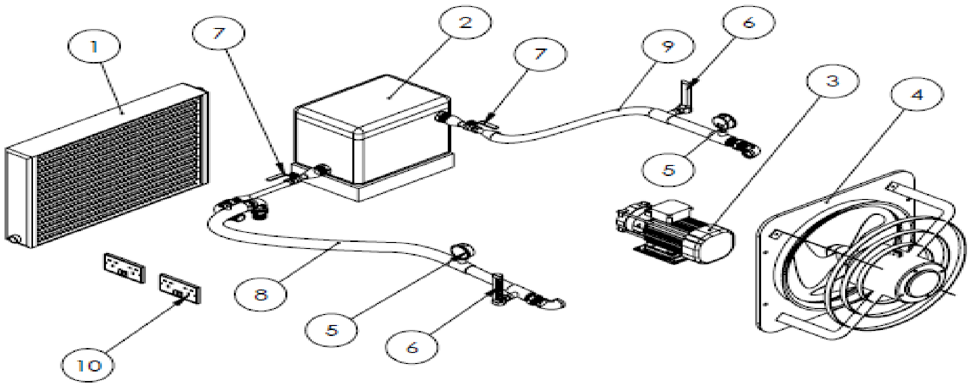


Figure (4.11): Final constructed project.



Item No	Name
01	**Radiator**
02	**Water Container**
03	**Pump**
04	**Fan**
05	**Pressure Gauge**
06	**Thermometer**
07	**Ball Valve**
08	**Hose**
09	**Heater**
10	**Electric Socket**

Figure (4.12), Exploded view of the design of the experimental set.

4.5 List of components with price:

Item	Quantity	Price (BDT)
Aluminum oxide (Al_2O_3)	1	2000
Frame	1	1000
Fan	1	1000
Radiator (Heat exchanger)	1	2000
Water container	1	700
Water pump	1	3200
Pipe	1	500
Pressure gage	2	1200
Thermometer	2	1100
Electricity wiring		500
Technician work		1000
Fittings	12	1700
Heater	2	600
Total	**25**	**16600**

Table (4.1): Represent price and quantity.

Chapter V: Experimental data collection

5.1 Experimental data (observation 01):

Time	V. water L	T.in, W (Celsius)	T .out, W (Celsius)	Temperature Reduction%
5 min	35	38	36	5.26%
8 min	35	40	38	5.00%
10 min	35	42	40	4.76%
12 min	35	44	42	4.55%

Table (5.1): Observed 01 for a pure water, without Nano particle.

Average Temperature Reduction% = 5.26+5.00+4.76+4.55÷4

= 4.89%

V. water, L	V. coolant water% of V. water	T.in, w (Celsius)	T. out, w (Celsius)	Temperature Reduction %
35	35%	38	36	5.26%
35	45%	40	37.5	6.25%
35	48%	42	39	7.14%
35	50%	44	41	6.18%

Table (5.2): observed 01 data for water mixed with coolant.

Average Temperature Reduction% = 5.26+6.25+7.14+6.18÷4

= 6.21%

V. water, L	V. Nano coolant water% of V. water	T.in, w (Celsius)	T .out, w (Celsius)	Temperature Reduction %
35	0.1%	38	35	7.89%
35	0.5%	40	35.5	11.25%
35	1%	42	37	11.90%
35	1.5%	44	38.5	12.5%

Table (5.3): observed 01 data for Aluminum Oxide (Al_2O_3) Nano Fluid.

Average Temperature Reduction% =7.89+11.25+11.90+12.5÷4

= 10.89%

5.2 Experimental data (observation 02):

Time	V. water L	T. in, W (Celsius)	T. out, W (Celsius)	Temperature Reduction%
5 min	35	39	37	5.13%
8 min	35	41	39	4.88%
10 min	35	42	40	4.76%
12 min	35	44	42	4.55%

Table (5.4): Observed 02 for a pure water, without Nano particle.

Average Temperature Reduction% =5.13+4.88+4.76+4.55÷4

= 4.83%

V. water, L	V. coolant water% of V. water	T. in, w (Celsius)	T. out, w (Celsius)	Temperature Reduction %
35	35%	39	37	5.12%
35	45%	41	38.5	6.09%
35	48%	42	39	7.14%
35	50%	44	41	6.82%

Table (5.5): observed 02 data for water mixed with coolant.

Average Temperature Reduction%=5.12+6.09+7.14+6.82÷4

= 6.29%

V. water, L	V. Nano coolant water% of V. water	T. in, w (Celsius)	T. out, w (Celsius)	Temperature Reduction %
35	0.1%	39	36	7.69%
35	0.5%	41	36.5	10.98%
35	1%	42	37.5	10.71%
35	1.5%	44	38.5	12.5%

Table (5.6): observed 02 data for Aluminum Oxide (Al_2O_3) Nano Fluid.

Average Temperature Reduction% = 7.89+10.98+10.71+12.5÷4

= 10.47%

5.3 Experimental data (observation 03):

Time	V. water L	T.in, W (Celsius)	T .out, W (Celsius)	Temperature Reduction%
5 min	35	38.5	36.5	5.19%
8 min	35	40	38	5.00%
10 min	35	42.5	40	4.70%
12 min	35	45	43.5	3.33%

Table (5.7): Observed 03 for a pure water, without Nano particle.

Average Temperature Reduction% = 5.19+5.00+4.70+3.33÷4

= 4.55%

V. water, L	V. coolant water% of V. water	T.in, w (Celsius)	T .out, w (Celsius)	Temperature Reduction %
35	35%	38.5	36.5	5.19%
35	45%	40	37	6.25%
35	48%	42.5	39.5	7.05%
35	50%	45	41.5	7.88%

Table (5.8): observed 03 data for water mixed with coolant.

Average Temperature Reduction% = 5.19+6.25+7.05+7.78÷4

= 6.57%

V. water, L	V. Nano coolant water% of V. water	T.in, w (Celsius)	T .out, w (Celsius)	Temperature Reduction %
35	0.1%	38.5	35.5	7.79%
35	0.5%	40	35	12.05%
35	1%	42.5	37.5	11.76%
35	1.5%	45	39.5	12.22%

Table (5.9): observed 03 data for Aluminum Oxide (Al_2O_3) Nano Fluid.

Average Temperature Reduction% = 7.79+12.05+11.76+12.22÷4

= 10.95%

5.4 Experimental data (observation 04):

Time	V. water L	T.in, W (Celsius)	T .out, W (Celsius)	Temperature Reduction%
5 min	35	38	36	5.26%
8 min	35	41	39	4.87%
10 min	35	42	40	4.76%
12 min	35	45	43	4.44%

Table (5.10): Observed 04 for a pure water, no Nano particle**.**

Average Temperature Reduction% =5.26+4.87+4.76+4.44÷4

= 4.83%

V. water, L	V. coolant water% of V. water	T.in, w (Celsius)	T .out, w (Celsius)	Temperature Reduction %
35	35%	38	36	5.26%
35	45%	41	37.5	8.54%
35	48%	42	38.5	8.33%
35	50%	45	42	6.66%

Table (5.11): observed 04 data for water mixed with coolant.

Average Temperature Reduction% = 5.26+8.54+8.33+6.66÷4

= 7.20%

V. water, L	V. Nano coolant water% of V. water	T.in, w (Celsius)	T .out, w (Celsius)	Temperature Reduction %
35	0.1%	38	35	7.89%
35	0.5%	41	36.5	10.97%
35	1%	42	36.5	13.10%
35	1.5%	45	40	11.11%

Table (5.12): observed data for Aluminum Oxide (Al_2O_3) Nano Fluid.

Average Temperature Reduction% = 7.89+10.97+13.10+11.11÷4

= 10.76%

5.5 Experimental data (observation 05):

Time	V. water L	T.in, W (Celsius)	T .out, W (Celsius)	Temperature Reduction%
5 min	35	39.5	37.5	5.06%
8 min	35	42	40	4.76%
10 min	35	43	41	4.65%
12 min	35	45	43	4.44%

Table (5.13): Observed 05 for a pure water, without Nano particle.

Average Temperature Reduction% = 5.06+4.76+4.65+4.44÷4

= 4.73%

V. water, L	V. coolant water % of V. water	T.in, w (Celsius)	T .out, w (Celsius)	Temperature Reduction %
35	35%	39.5	37.5	5.06%
35	45%	42	39.5	5.95%
35	48%	43	40	6.97%
35	50%	45	41.5	7.78%

Table (5.14): observed 05 data for water mixed with coolant.

Average Temperature Reduction% = 5.06+5.95+6.97+7.78÷4

= 6.44%

V. water, L	V. Nano coolant water% of V. water	T.in, w (Celsius)	T. out, w (Celsius)	Temperature Reduction %
35	0.1%	39.5	36.5	7.59%
35	0.5%	42	37.5	10.71%
35	1%	43	38	11.62%
35	1.5%	45	39	13.33%

Table (5.15): observed data for Aluminum Oxide (Al_2O_3) Nano Fluid.

Average Temperature Reduction% = 7.59+10.71+11.62+13.33÷4

= 10.81%

Chapter VI: Result

6.1 Sample calculation of LMTD:

<u>Pure water LMTD(Observation 01):</u>

Air Temp in = 27°C

Air Temp out = 36°C

Average Hot water temperature in = 38+40+42+44÷4

= 41°C

Average Hot water temperature in = 36+38+40+42÷4

= 39°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14-3}{\ln(14)-\ln(3)}$$

$$= 7.14°C$$

<u>Pure water mixed with Coolant LMTD(observation 01):</u>

Air Temp in = 27°C

Air Temp out = 34°C

Average Hot water temperature in = 38+40+42+44÷4

= 41°C

Average Hot water temperature in = 36+37.5+39+41÷4

= 38.37°C

$$\textbf{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14-4.37}{\ln(14)-\ln(4.37)}$$

$$= 8.27\ °C$$

<u>Pure water mixed with Aluminum Oxide (Al_2O_3) Nano Fluid LMTD(observation 01):</u>

Air Temp in = 27°C

Air Temp out = 31°C

Average Hot water temperature in = 38+40+42+44÷4

= 41°C

Average Hot water temperature in = 35+35.5+37+38.5÷4

= 36.5°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14-5.5}{\ln(14)-\ln(5.5)}$$

$$= 9.10\ °C$$

Pure water LMTD(observation 02):

Air Temp in = 28°C

Air Temp out = 35.5°C

Average Hot water temperature in = 39+41+42+44÷4

= 41.5°C

Average Hot water temperature in = 37+39+40+42÷4

= 39.5°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{15.5-7}{\ln(15.5)-\ln(7)}$$

$$= 7.81°C$$

Pure water mixed with Coolant LMTD (observation 02):

Air Temp in = 28°C

Air Temp out = 34°C

Average Hot water temperature in = 39+41+42+44÷4

= 41.5°C

Average Hot water temperature in = 37+38.5+39+41÷4

= 38.37°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{13.5-4.87}{\ln(13.5)-\ln(4.87)}$$

$$= 8.46°C$$

Pure water mixed with Aluminum Oxide (Al_2O_3) Nano Fluid LMTD (observation 02):

Air Temp in = 28°C

Air Temp out = 31°C

Average Hot water temperature in = 39+41+42+44÷4

= 41.5°C

Average Hot water temperature in = 36+36.5+37.5+38.5÷4

= 37.12°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{13.5-6.12}{\ln(13.5)-\ln(6.12)}$$

$$= 9.33\ °C$$

Pure water LMTD (0bservation 03):

Air Temp in = 26°C
Air Temp out = 36.5°C
Average Hot water temperature in = 38.5+40+42.5+45÷4
= 41. 5°C

Average Hot water temperature in = 36.5+38+40+43.5÷4
= 39.6°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{15.5 - 3.1}{\ln(15.5) - \ln(3.1)}$$

$$= \quad 7.70°C$$

Pure water mixed with Coolant LMTD (observation 03):

Air Temp in = 26°C
Air Temp out = 34. 5°C
Average Hot water temperature in = 38.8+40+42.5+45÷4
= 41.5°C

Average Hot water temperature in = 36.5+37+39.5+41.5÷4
= 38.63°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{15.5 - 4.13}{\ln(15.5) - \ln(4.13)}$$

$$= \quad 8.60\ °C$$

Pure water mixed with Aluminum Oxide (Al_2O_3) Nano Fluid LMTD (observation 03):

Air Temp in = 26°C

Air Temp out = 31°C

Average Hot water temperature in = 38.5+40+42.5+45÷4

= 41. 5°C

Average Hot water temperature in = 35.5+35+37.5+39.5÷4

= 36.87°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{15.5 - 5.87}{\ln(15.5) - \ln(5.87)}$$

$$= \quad 9.92°C$$

Pure water LMTD (observation 04):

Air Temp in = 27°C

Air Temp out = 36. 5°C

Average Hot water temperature in = 38+41+42+45÷4

= 41. 5°C

Average Hot water temperature in = 36+39+40+43÷4

= 39. 5°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14.5-3}{\ln(14.5)-\ln(3)}$$

= 7.30 °C

Pure water mixed with coolant (observation 04):

Air Temp in = 27°C

Air Temp out = 34. 5°C

Average Hot water temperature in = 38+41+42+45÷4

= 41. 5°C

Average Hot water temperature in = 36+37.5+38.5+42÷4

= 38.5°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14.5-4}{\ln(14.5)-\ln(4)}$$

= 8.15°C

Pure water mixed with Aluminum Oxide (AI203) Nano Fluid LMTD (observation 04):

Air Temp in = 27°C

Air Temp out = 31°C

Average Hot water temperature in = 38+41+42+45÷4

= 41. 5°C

Average Hot water temperature in = 35+36.5+36.5+40÷4

= 37°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14.5-6}{\ln(14.5)-\ln(6)}$$

= 9.63 °C

Pure water LMTD(observation 05):

Air Temp in = 28°C

Air Temp out = 37°C

Average Hot water temperature in = 39.5+42+43+45÷4

= 42.37°C

Average Hot water temperature in = 37.5+40+41+43÷4

= 40.38°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14.37 - 3.38}{\ln(14.37) - \ln(3.38)}$$

= 7.59°C

Pure water mixed with Coolant LMTD (observation 05):

Air Temp in = 28°C

Air Temp out = 34. 5°C

Average Hot water temperature in = 39.5+41+43+45÷4

= 42.38°C

Average Hot water temperature in = 37.5+39.5+30+41.5÷4

= 39.62°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14.37 - 5.12}{\ln(14.37) - \ln(5.12)}$$

= 8.96°C

Pure water mixed with Aluminum Oxide (Al_2O_3) Nano Fluid LMTD(observation 05):

Air Temp in = 28°C

Air Temp out = 32°C

Average Hot water temperature in = 39.5+42+43+45÷4

= 42.38°C

Average Hot water temperature in = 36.5+37.5+38+39÷4

= 37.75°C

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{ln\Delta Tin - ln\Delta Tout}$$

$$= \frac{14.38 - 5.75}{\ln(14.38) - \ln(5.75)}$$

= 9.41°C

6.2 Temperature In and Out Comparison:

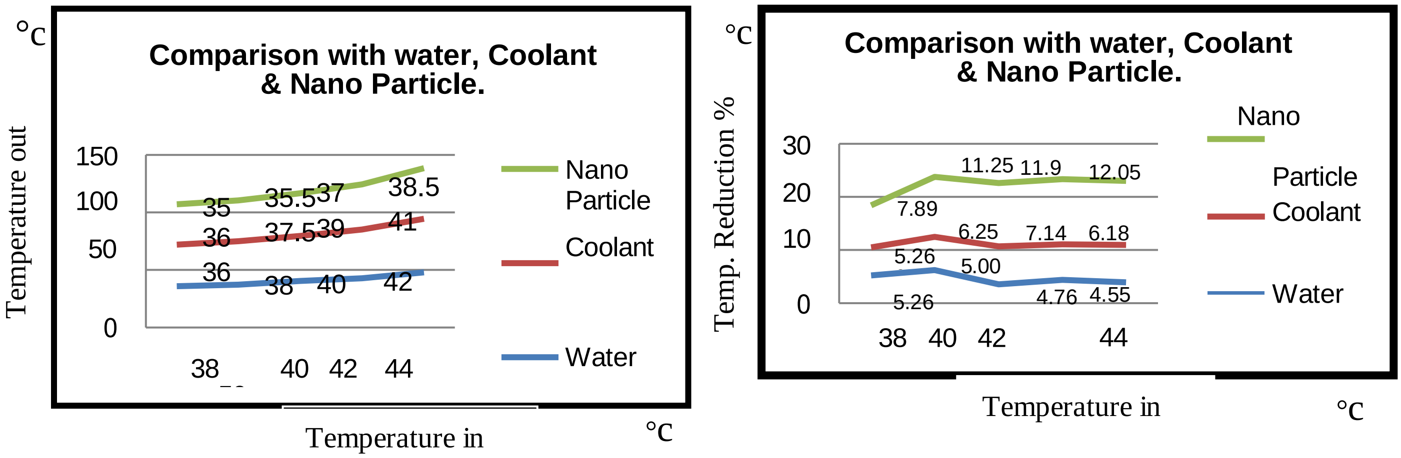


Figure (6.1) Temperature In and Out Comparison.

We are using water to see that our average temperature has dropped by 5.26% Later when we are using coolant our average temperature dropped to 7.14% But when we used aluminum oxide (Al_2O_3) with water our average temperature dropped by 12.5% . By doing this Experiment we can conclude that if we use aluminum oxide, we can reduce the temperature even more.

So, we can suggest that it is best to use aluminum oxide (Al_2O_3).

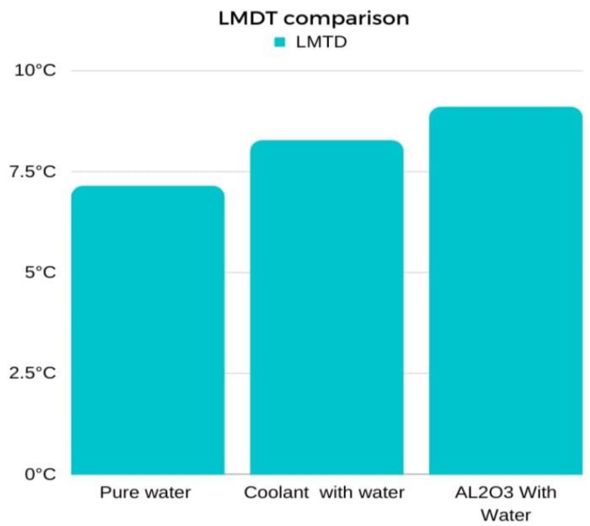


Figure (6.2): Temperature Reduction Comparison

6.3 All Temperature Reduction Comparison:

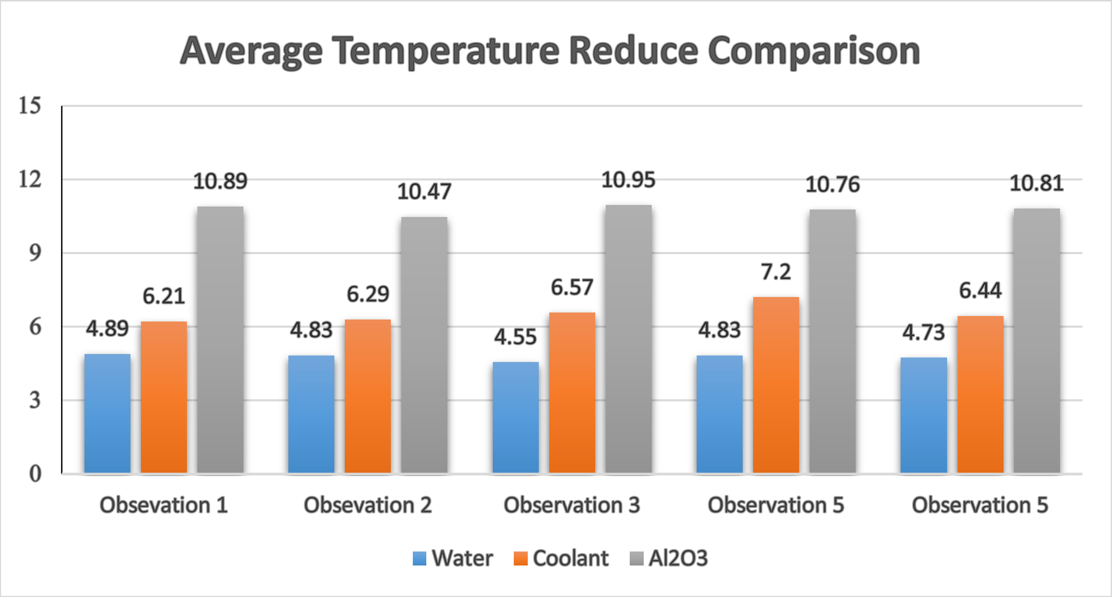


Figure (6.3): Temperature Reduction Comparison.

6.4 All Observation LMTD comparison:

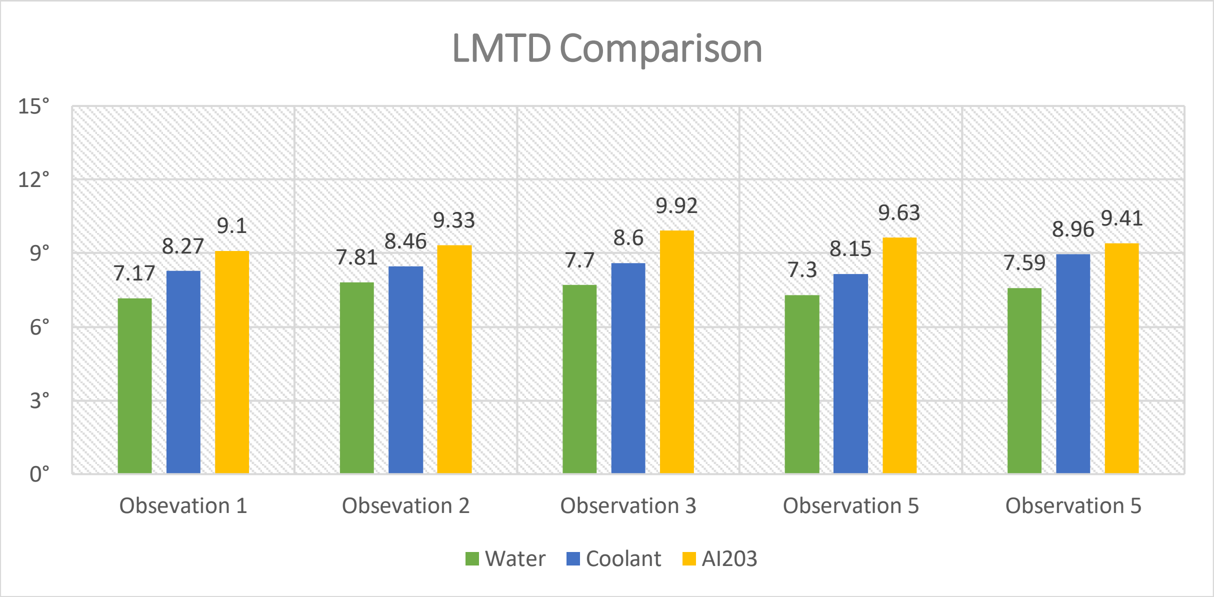


Figure (6.4): Temperature Reduction Comparison.

6.5 All Observation Temperature In and Out reduce result:

Observation	Time(Min)	Water	Coolant	Al_2O_3
Observation 01	8.25	4.89%	6.21%	10.89%
Observation 02	8.25	4.83%	6.29%	10.47%
Observation 03	8.25	4.55%	6.57%	10.95%
Observation 04	8.25	4.83%	7.20%	10.76%
Observation 05	8.25	4.73%	6.44%	10.81%

Table (6.1): Temperature In and Out reduction result.

6.6 All observation LMTD result:

	Water (°C)	**Coolant (°C)**	**Al_2O_3 (°C)**
Observation 01	7.14°	8.27°	9.10°
Observation 02	7.81°	8.46°	9.33°
Observation 03	7.70°	8.60°	9.92°
Observation 04	7.30°	8.15°	9.63°
Observation 05	7.59°	8.96°	9.41°

Table (6.2): Logarithmic mean temperature different.

Chapter VII: Conclusion and Discussion

7.1 Conclusion:

To put our work in a few words, the project was intended to design an experiment to study the enhancement of heat transfer rate in IC engine radiator systems using aluminum oxide. The main aim of this project is to prove experimentally what already has been proved theoretically that Nano fluids increase the heat transfer rate with no pressure drop. Despite facing some inconsistencies of results due to environment conditions, the goal of the project has been achieved. Another important outcome of this project is that adding nanoparticles to fluids does not affect friction between the layers of fluids. By doing this experiment we can conclude that if we use aluminum oxide we can reduce the temperature even more. We have 35 liters of water in the water tank. By heating the water to 44 degrees and entering the engine and whose output was through radiator cooling, we were able to reduce the maximum temperature by 4.89%. Then we put the same amount of water in the water tank and this time by mixing coolant with water and heating it to 44 degrees and entering the engine and the output of which was through radiator cooling, we were able to reduce the maximum temperature by 7.10%. Finally, we kept the same amount of water in the water tank and this time mixed aluminum oxide (Al_2O_3)with water and heated it to 45 degrees to enter the engine and whose output was through radiator cooling, we were able to reduce the maximum temperature by 10.95%. In this way we collect total 5 data as well as extract the LMTD value of each which we have shown in the above result with table and also showing the comparison figure. By looking at all kinds of experimental data, I realized that it is possible to reduce the temperature more than water and coolant using Nano fluid.

7.2 Discussion:

The first objective of this work was to design and build machinery. Leakage was not completely preventable but the overall performance was quite satisfactory. Rapid cooling using aluminum oxide radiators was one of the main objectives of this thesis. After finishing the work, it is clear that the engine can be cooled using aluminum oxide. We obtained one value using pure water and another value using coolant with water and another value using coolant with water which is satisfactory from the previous two results. And the LMTD value of each experiment was also calculated. Finally we noticed that the use of aluminum oxide was more satisfactory than water and coolant.

7.3 Future recommendation:

- In order to further study the behavior of heat transfer in Aluminum oxide Nano fluid, other types of nanoparticles are advice to be used.
- To get the best and most accurate results, environment's conditions have to be monitored in a way that they do not affect the experiment negatively, giving misleading data.
- Using a metallic water tank would decrease the use of ultrasound waves.
- We recommend experimenting Nano fluids in IC engine applications. So, we can suggest that aluminum oxide is best for IC engines than pure water and coolant.

References:

[1] Pawan, S., Amrutkar, Patil, S. R.,"Automotive Radiator Performance – Review", International Journal of Engineering and Advanced Technology,Vol. 2, Issue 3, 2013, pp. 1543-1560

[2] Beck, M.,"Thermal conductivity of metal oxide nanofluids-PhD thesis", Georgia Institute of Technology, 2008.

[3] Wiggle, R. R., Hospadaruk, V., Tibaudo, F. M.,"Corrosion of Cast Aluminum Alloys under Heat Transfer Conditions",Technical Report No SR-81-11, Research Staff Report, Ford Motor Company, Dearborn, MI, 1981.

[4] Peyghambarzadeh, S. M., Hashemabadi, S. H., Hoseini S.M., SeifiJamnani, M.,"Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiators", International Communication in Heat and Mass Transfer, 2011, pp. 1283–1290.

[5] Rebsdat, S., Mayer, D.,"Ethylene Glycol", In Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH,Weinheim, 2002.

[6] Beynon, E., Cooper, N. R., Hannigan,"H. D. Soap and Chemicals Specialties", Vol. 47, No. 2, 1971, pp. 44-52

[7]. Mohammad Hossein Aghabozorg. Alimora Rashidi.,Saber BMohammadi., "Experimental Investigation Of Heat Transfer Enhancement Of Fe2O3-CNT/Water Magnetic Nano Fluids Under Laminar, Transient and Turbulent Flow Inside A Horizontal Shell And Tube Heat Exchanger", Experimental Thermal and Fluid Science 72 (2016); 182– 189.

[8] Kallalu Harika., Tummala.Likhitha., Pulla Varsha Rani.,R.Ramakanth., "Experimental Determination And Comparison Of Heat Transfer Coefficient And Pressure Drop For Water And Copper Oxide Nano Fluid In Shell And Tube Heat Exchangers Using Helical Baffles" International Journal of Current Engineering and Technology, (2017); Vol.7, No.3, 851-856

[9] H. Masuda et al. [Jan-1993 Article from Research gate].

[10] https://en.learnmecha /info/Logarithmic_mean_temperature_difference.

[11] https://www.crownscales.co.in/blog/what-is-digital-electronic-weighing-scale-and-how-it-works.

[12] https://pubchem.ncbi.nlm.nih.gov/compound/Aluminum-Oxide.