"EXPERIMENTAL ANALYSIS OF HEAT TRANSFER RATE IN RADIATOR USING NANO PARTICLES"

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Abstract:* Continuous technological development in automobile industries has increased the demand for high efficiency engines. A high efficiency engine is not only based on its performance but also for better fuel economy and less emission. Reducing a vehicle weight by optimizing design and size of a radiator is a necessity for making the world green. There are several different approaches and any one of these can take to optimize the heat transfer performance of radiator design. Heat transfer fluids have inherently low thermal conductivity that greatly limits the heat exchange efficiency. While the effectiveness of extending surfaces and redesigning heat exchange equipment to increase the heat transfer rate has reached a limit, many researchers made an attempt to improve the thermal transport properties of the fluids by adding more thermally conductive solids into liquids. Liquid dispersions of nanoparticles, which have been termed "nanofluids", exhibit substantially higher thermal conductivities than those of the corresponding base fluids. In dissertation work using four stroke four cylinder engines as a experimental set up. In this project, different proportions of Al_2O_3 nanoparticles by weight have been added to conventional fluid (water), and based on that the enhancement in heat transfer rate has been found out by taking readings & calculating heat transfer rate.

Index Terms **–nano fluid, fin design, tube type, Flow arrangement, fin and tube material,** ***Al_2O_3 nanoparticles***

I. INTRODUCTION

An automobile's cooling system is the collection of parts and substances(coolants) that work together to maintain the engine's temperature at optimal levels. Comprising of many different components such as water pump, coolant, a thermostat, etc, the system enables smooth and efficient functioning of the engine at the same time protecting it from damage. While it is running, an automobile engine generates enormous amounts of heat. Each combustion cycle entails thousands of controlled explosions taking place every minute inside the engine. If the automobile races on and the heat generated within isn't dissipated, it would cause the engine to self-destruct. Hence, it is imperative to concurrently remove the waste heat. While the waste heat is also dissipated through the intake of cool air and exit of hot exhaust gases, the engine's cooling system is explicitly meant to keep the temperature within limits. The cooling system essentially comprises passages inside the engine block and heads, pump to circulate the coolant, a thermostat to control the flow of the coolant, a radiator to cool the coolant and a radiator cap controls the pressure within the system. In order to achieve the cooling action, the system circulates the liquid coolant through passages in the engine block and heads. As it runs through, the coolant absorbs heat before returning to the radiator, to be cooled itself. Next, the cooled down coolant is recalculated and the cycle continues to maintain the engine's temperature at the right levels.

Water Cooling Systems

A water cooling system accomplishes the cooling action with the help of water. There are various components that make up the cooling system and they are the Air Blower, Cooling Fans, Radiator Pressure Caps, Water Pipes, Coolant Hoses, Radiator Parts, Radiators and Water Pumps. Each of these components plays an essential role. For instance, the radiator cools the coolant so that it can be reused, the water pump pumps the coolant through the system via water pipes, the Air Blower draws air through the radiator to achieve the cooling action, etc.

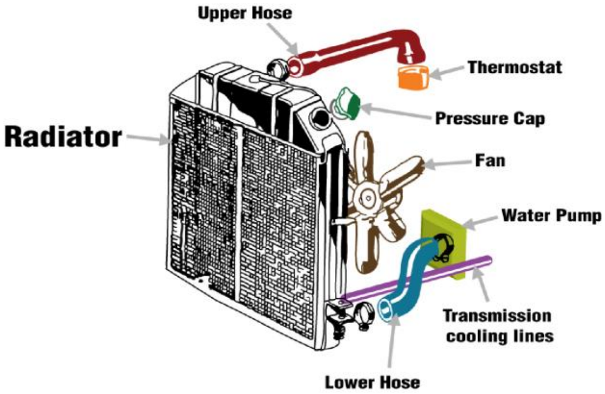


Figure 1 Concept of Radiator

Engine cooling fluids

An engine coolant is a fluid which flows through the engine and prevents it from overheating by transferring the heat generated by the engine to other components .A feature of an ideal coolant entail a low viscosity, high thermal capacity, has chemical inertness and is low-cost .An emerging and new class of coolants is nanofluids which consist of a carrier liquid, such as water, dispersed with tiny nano-scale particles known as nanoparticles. This nanoparticles dispersed into the carrier liquid enhances the heat transfer capabilities compared to the carrier liquid alone.

Nanofluids

Nanofluids are a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides. Common base fluids include water and ethylene glycol. Nanofluids having higher thermal conductivity and the convective heat transfer coefficient compared to the base fluid.

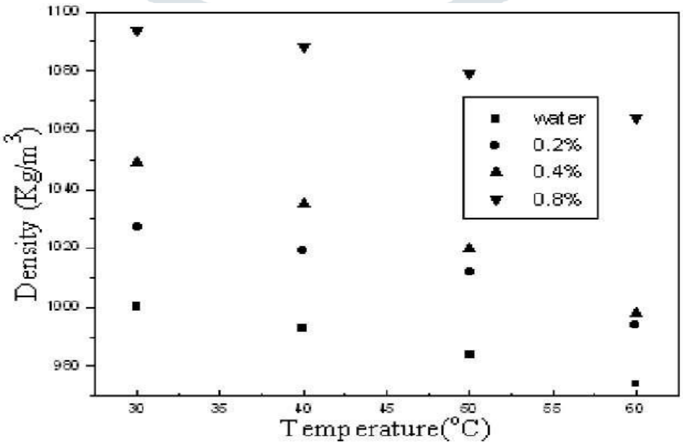
Potential Benefits Of Nanofluid

- Nanoparticles provide extremely high surface area for heat transfer and therefore have great potential for use in higher heat transfer.
- By using nanofluid, we get better heat transfer so we can design compact and lighter heat exchange system with same heat transfer capacity.
- Use of nanofluid result in significant energy and cost saving because the heat exchange system can be made smaller and Lighter.

II. LITERATURE REVIEW

L.Syam Sundar, et al. worked on flow properties of the base liquid (water, ethylene glycol) are well known and it is necessary to know the flow properties of nanofluid at different concentrations for theoretical analysis. Flow characters like density, specific heat, kinematic viscosity are estimated experimentally and theoretically. Temperature based flow properties are also estimated.

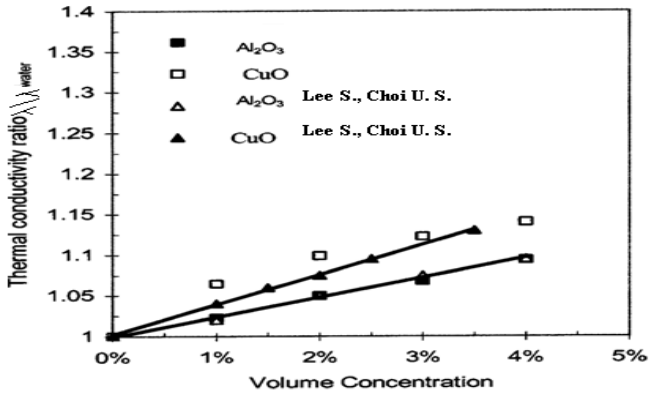
Density of nanofluid at different temperatures with different concentrations.



Density of nanofluid at different temperatures of 0.2%, 0.4% and 0.8% concentrations. Density of nanofluid is decrease with the increase temperature because of reduced of mass with temperature at same volume.

S.K. Das, et al worked on experiments detail show the effect of increase of with temperature on thermal conductivity for nanofluids with water as base fluid and particles of Al_2O_3 or CuO as suspension material. A temperature oscillation technique is utilized for the measurement of thermal diffusivity and thermal conductivity.

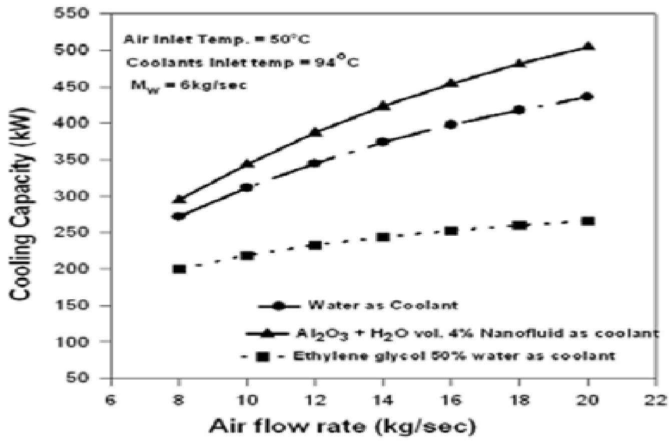
Enhancement of thermal conductivity at room temperature



Thermal conductivity at room temperature for Al_2O_3 and CuO nanofluids of water at various particles volume concentrations.

V. Vasu, K. Rama Krishna, A.C.S. Kumar, worked on application of nanofluids in thermal design of compact heat exchanger. In this paper a theoretical analysis was carried with ε – NTU rating method by using Al_2O_3 + H_2O Nanofluid as coolant on automobile flat tube plain fin compact heat exchanger and different characteristics.

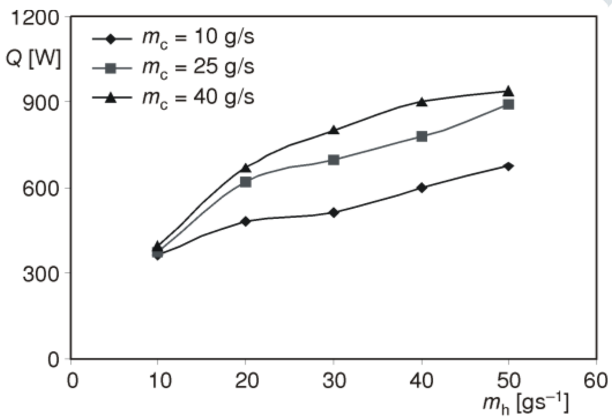
Comparison of nanofluid as coolant with conventional coolant (water)



Nanofluids possess higher heat transfer characteristics than conventional coolants water and 50% ethylene glycol.

Somaye NASR at al (2011) conducted experiments on concentric tube and plate heat exchanger and found out comparison of heat transfer rate at different nanoparticle concentration and mesh size of particle and different type of nanoparticle. The experimental results show that the heat transfer rate and heat transfer coefficients of the nanofluid in both of the heat exchangers is higher than that of the base liquid.

Effect of hot and cold flow rate on heat transfer rate of nanofluids in concentric tube heat exchanger & plate heat exchanger



Concentric tube heat exchanger

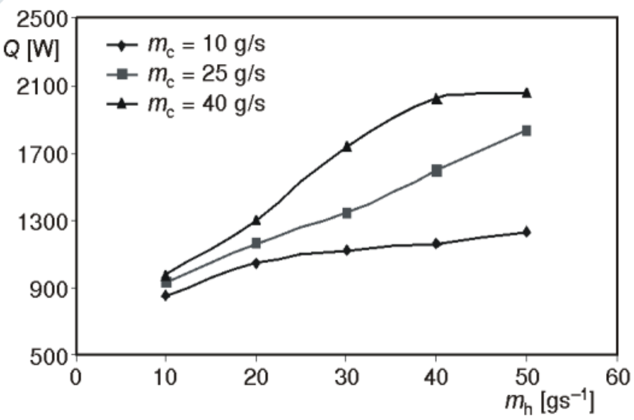
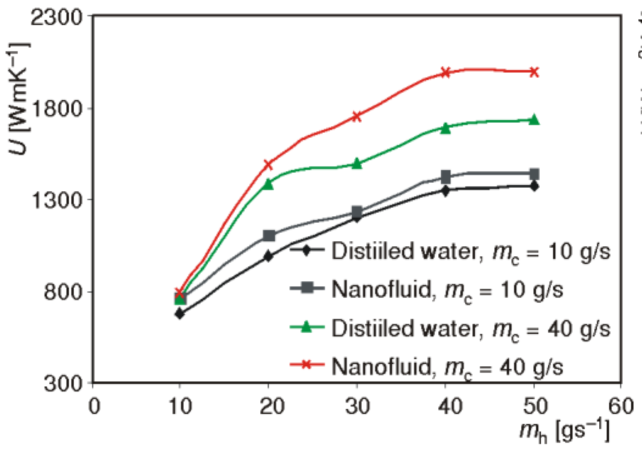


Plate heat exchanger

Comparison between heat transfer coefficient of distilled water and nanofluid in the concentric tube heat exchanger & plate heat exchanger



Concentric tube heat exchanger

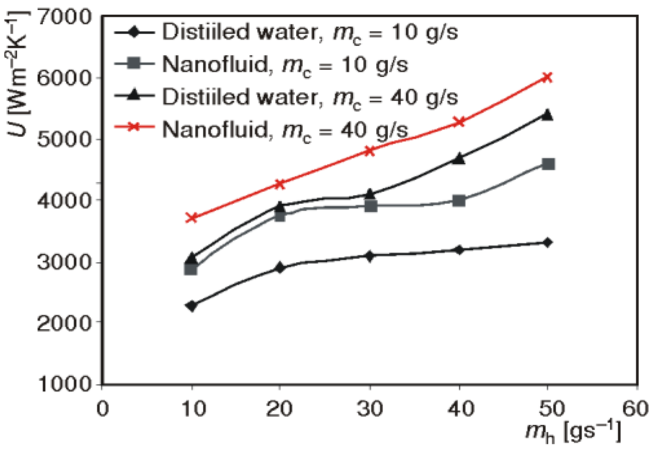


Plate heat exchanger

III. EXPERIMENTAL SET UP AND PROCEDURE

Minimum equipment required for experimental set up:

As per the schematic diagram shown below, following are the equipments (minimum) required for the set-up like Automobile radiator (Working apparatus), Water Pump, measuring instruments and Necessary piping and auxiliaries. Multi cylinder, four stroke, water cooled, direct injection CI engine is used for experimental purpose. Figure 3.1 shows the position of radiator in experimental setup.

Figure 2 Experimental Set-up

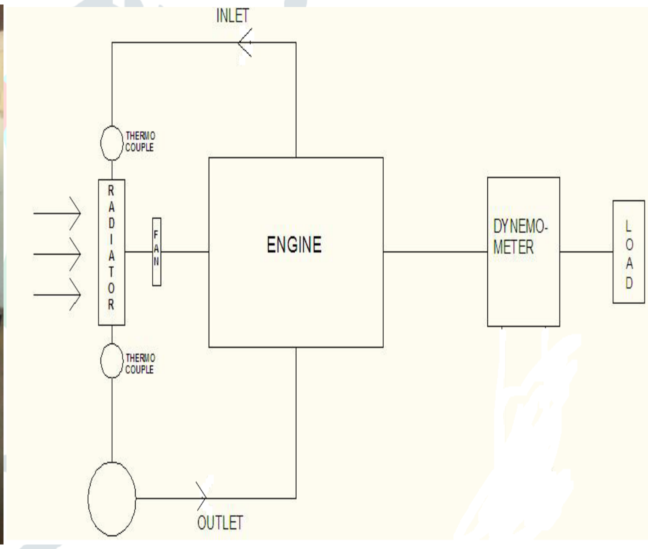


Figure 3 Schematic Diagram of the Experimental Set up

Table 1 Engine Specification

Make & Model	**Mahindra Engine MDI-3200**
General Details	Four stroke**,** Four cylinder, Vertical, Compression Ignition, Water cooled, Direct injection.
Water flow (lpm)	10
Velocity of air(m/s)	3.5
Tube size	Height 9.15 mm Diameter 3.30 mm Thick 0.3 mm
Fin size	Length 134.1 mm Width 43.15 mm Thick 0.33 mm
No of Tubes	117
No of Fins	108
Water inlet temp	90˚c

Air inlet temp	35°c
Bore	90.9mm
Stroke	92.4mm
Firing Order	1-3-4-2
Lubricating Oil	SAE 20 / SAE 40
Max. Power	40 B.H.P.@ 3000 rpm.

MEASURING PARAMETERS

- Temperature of water and air circuit.
- Power of engine output
- Engine speed
- Variable load

IV. OBSERVATIONS & SAMPLE CALCULATION

Reading taken: coolant pure water

Reading Taken at constant speed, constant flow rate & variable load

Table 2 Coolant – Pure water

Load Kg	Speed RPM	Mass flow rate of Coolant (lpm)	Velocity of Air (m/s)	Inlet temp. of Air °C	Outlet temp. of Air °C	Diff. in temp. of Air °C	Avg. temp. of Air °C	Inlet temp. of Coolant °C	Outlet temp. of Coolant °C	Diff. in temp. of Coolant °C	Avg. temp. of Coolant °C
W	N	m_c	V_a	ta_1	ta_2	ta_2-ta_1	Avg.	tc_1	tc_2	tc_1-tc_2	Avg.
				35	46	11		81	73	8	
8				36	47	11	11.33	82	73	9	8.33
				35	47	12		82	74	8	
				36	47	11		84	75	9	
16				35	47	12	11.66	84	75	9	8.66
				35	47	12		84	76	8	
				35	47	12		85	76	9	
24	1200	10	3.5	35	47	12	12	85	76	9	9
				35	48	12		85	76	9	
				35	48	13		86	77	9	
32				35	49	14	13.66	86	77	9	9.33
				35	49	14		86	76	10	
				35	49	14		86	76	10	
40				35	49	14	14	86	77	9	9.66
				35	49	14		86	76	10	

Table 3 Coolant – Pure water + (2%) Nanoparticles of Al_2O_3

Load Kg	Speed RPM	Mass flow rate of Coolant (lpm)	Velocity of Air (m/s)	Inlet temp. of Air °C	Outlet temp. of Air °C	Diff. in temp. of Air °C	Avg. temp. of Air °C	Inlet temp. of Coolant °C	Outlet temp. of Coolant °C	Diff. in temp. of Coolant °C	Avg. temp. of Coolant °C
W	N	m_c	V_a	ta_1	ta_2	ta_2-ta_1	Avg.	tc_1	tc_2	tc_1-tc_2	Avg.
				35	47	12		86	76	10	
8				35	47	12	13.66	86	77	9	9.33
				35	48	13		86	77	9	
				35	47	12		86	76	10	
16				35	48	12	13.66	86	76	10	9.66
				35	48	13		87	78	9	
				35	49	14		87	78	9	
24	1200	10	3.5	35	49	14	14	89	77	12	10.33
				35	49	14		87	77	10	
				35	50	15		89	77	12	
32				35	50	15	15	89	77	12	11.66
				35	50	15		89	78	11	
				35	50	15		89	78	11	
40				35	50	15	15	89	78	11	11.66
				35	50	15		90	77	13	

Table 4 Coolant – Pure water + (4%) Nanoparticle of Al_2O_3

Load Kg	Speed RPM	Mass flow rate of Coolant (lpm)	Velocity of Air (m/s)	Inlet temp. of Air °C	Outlet temp. of Air °C	Diff. in temp. of Air °C	Avg. temp. of Air °C	Inlet temp. of Coolant °C	Outlet temp. of Coolant °C	Diff. in temp. of Coolant °C	Avg. temp. of Coolant °C
W	N	m_c	V_a	ta_1	ta_2	ta_2-ta_1	Avg.	tc_1	tc_2	tc_1-tc_2	Avg.
				35	48	13		90	78	12	
8				35	47	12	12.66	88	77	11	11.33
				35	48	13		89	78	11	
				35	48	13		90	78	12	
16				35	48	13	13	89	77	13	12.33
				35	48	13		90	78	12	
				35	49	14		89	76	13	
24	1200	10	3.5	35	49	14	13.66	89	76	13	13
				35	48	13		89	76	13	
				35	49	14		89	76	13	
32				35	49	13	14	89	76	13	13.33
				35	49	14		89	76	14	
				35	49	14		89	76	14	
40				35	49	14	14	89	76	13	13.33
				35	49	14		89	75	13	

Table 5 Coolant – Pure water + (6%) Nanoparticle of Al_2O_3

Load Kg	Speed RPM	Mass flow rate of Coolant (lpm)	Velocity of Air (m/s)	Inlet temp. of Air °C	Outlet temp. of Air °C	Diff in temp. of Air °C	Avg. temp. of Air °C	Inlet temp. of Coolant °C	Outlet temp. of Coolant °C	Diff. in temp. of Coolant °C	Avg. temp. of Coolant °C
W	N	m_c	V_a	ta_1	ta_2	ta_2-ta_1	Avg.	tc_1	tc_2	tc_1-tc_2	Avg.
				35	48	13		91	77	14	
8				35	49	14	13.33	90	76	14	14
				35	48	13		91	77	14	
				35	49	14		90	76	14	
16				35	49	14	14	92	76	16	14.66
				35	49	14		91	77	14	
				35	49	14		92	77	15	
24	1200	10	3.5	35	49	14	14	92	77	15	15.33
				35	49	14		93	77	16	
				35	50	15		93	78	15	
32				35	50	15	15	93	78	15	15.33
				35	50	15		94	78	16	
				35	50	15		93	77	16	
40				35	50	15	15.33	93	78	15	15.66
				35	51	16		94	78	16	

SAMPLE CALCULATION FOR THE WATER AS COOLANT

The average heat transfer rate is

Qavg = 0.5 (Qa + Qc)
Where Qa and Qc are the heat transfer rates at the air and the coolant stream, respectively.
The air-side and heat transfer rates can be calculated as

Qa = ma Cpa (ta2-ta1)
Qc = mc Cpc (tc2-tc1)

For Coolant (Water) side
Qc = ma Cpc (tc2-tc1)
Qc = 0.25 × 4.187 × (90-82.6)
Qc **= 7.85 KW**

For Air side
Qa = ma Cpa (ta2-ta1)
Qa = 1.3 × 1.007 × (44-35)
Qa = 11.65 KW

V. RESULTS

Result Analysis

Figure 4 shows the graphical representation of total average heat transfer rate(air + water) Q vs. constant load & pure water as coolant. Figure 5, 6,7shows graphical representation of total average heat transfer rate(air + water) Q vs. constant load & different percentage of volume fraction of Al_2O_3 added in water (by weight).we can compare the experimental result coolant used as water & different percentage of Al_2O_3. It is observed that the heat transfer rate increases with the increase in the volume fraction of Al2O3 in water at constant flow rate (10 lpm). As the volume fraction of Al2O3 was increased beyond 6%, the nanoparticles were getting settled at the bottom of tank. Due to this limitation we used nanoparticles up to 6% only which was in good agreement with the experimental data.

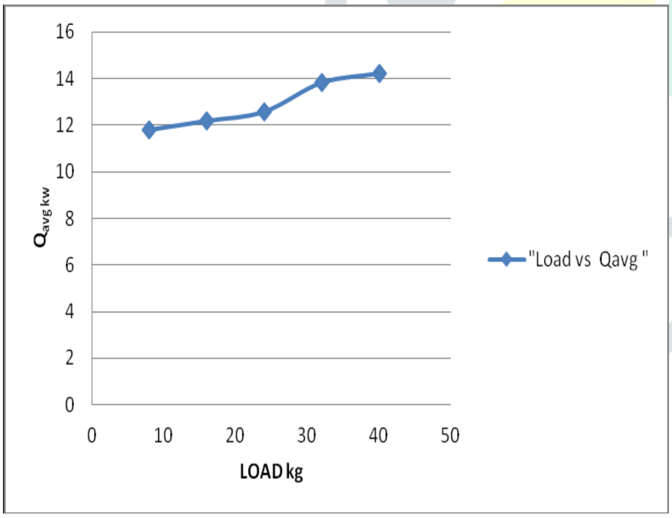


Figure 4 Q vs. Load Coolant used pure water

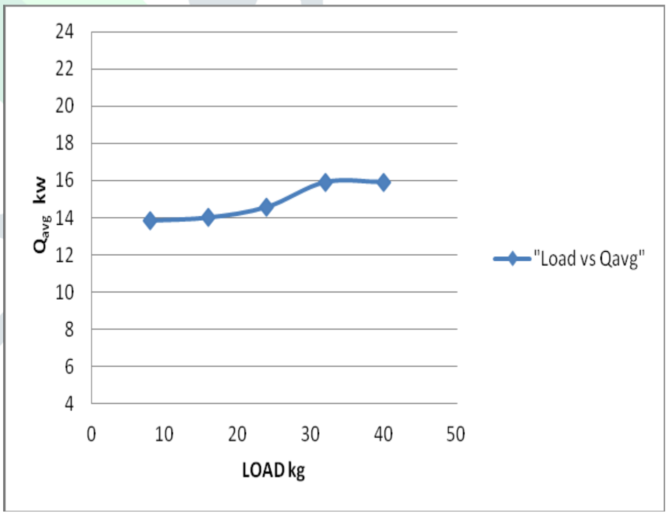
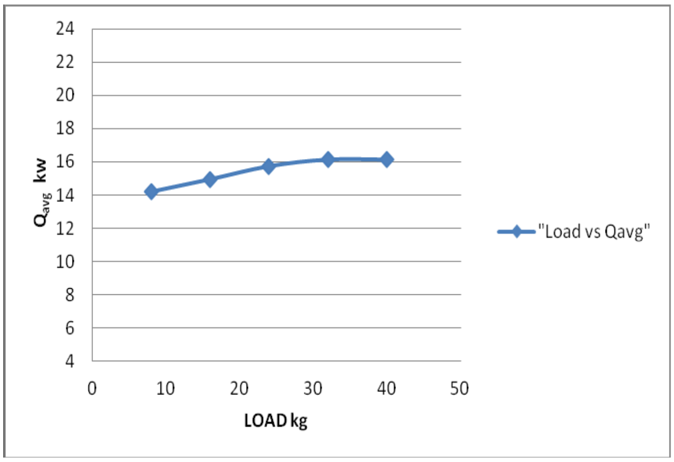


Figure 5 Q vs. Load Coolant used water + 2% (Al_2O_3)



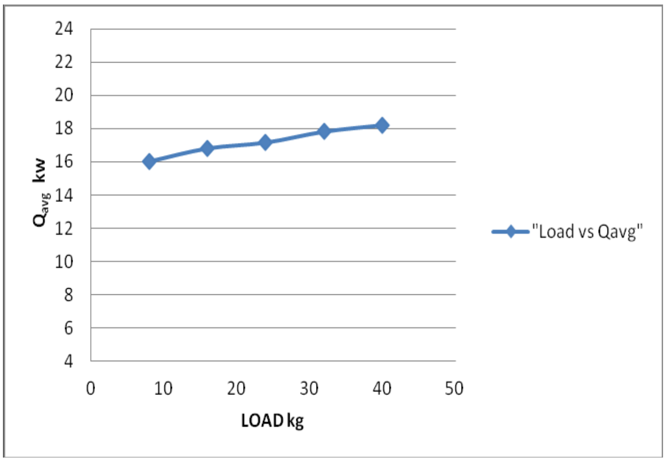


Figure 6 Q vs. Load Coolant used water + 4% (Al_2O_3) Figure 7 Q vs. Load Coolant used water + 6% (Al_2O_3)

Figure 5, 6,7shows the graphical comparison of heat transfer rate of coolant at constant mass flow rate when different volume fraction of Al2O3 nanoparticle was added to the water. It was observed that as volume of fraction of Al2O3 in water added the heat transfer rate increased for a given volume fraction of Al2O3 in water. At 10 lpm mass flow rate of coolant, at load 8 kg the value of heat transfer rate is 11.77 KW and 16.04 KW for 2 %, volume fraction of Al2O3 at same flow rate heat transfer rate is 13.82 KW, for 4% volume fraction heat transfer is 14.21 KW, for 4% volume fraction heat transfer is 16.04 KW.

Different volume fraction of Al2O3 added in water give increase in heat transfer rate shown in figure 8 its give clear idea how much heat transfer is increase. figure 9 shown how much percentage of heat transfer rate increase compare to water & different volume of Al2O3 added in water.

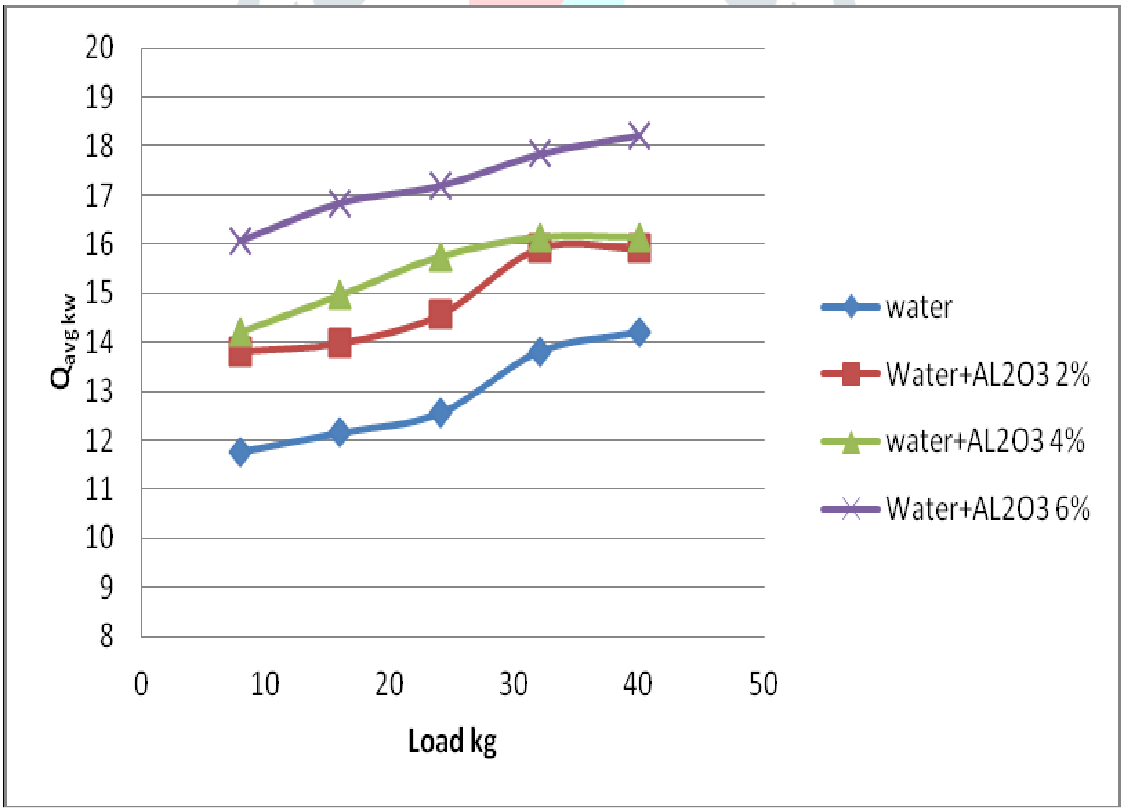


Figure 8 Heat transfer rate vs. Load Coolant used Different Volume Fraction of Al_2O_3

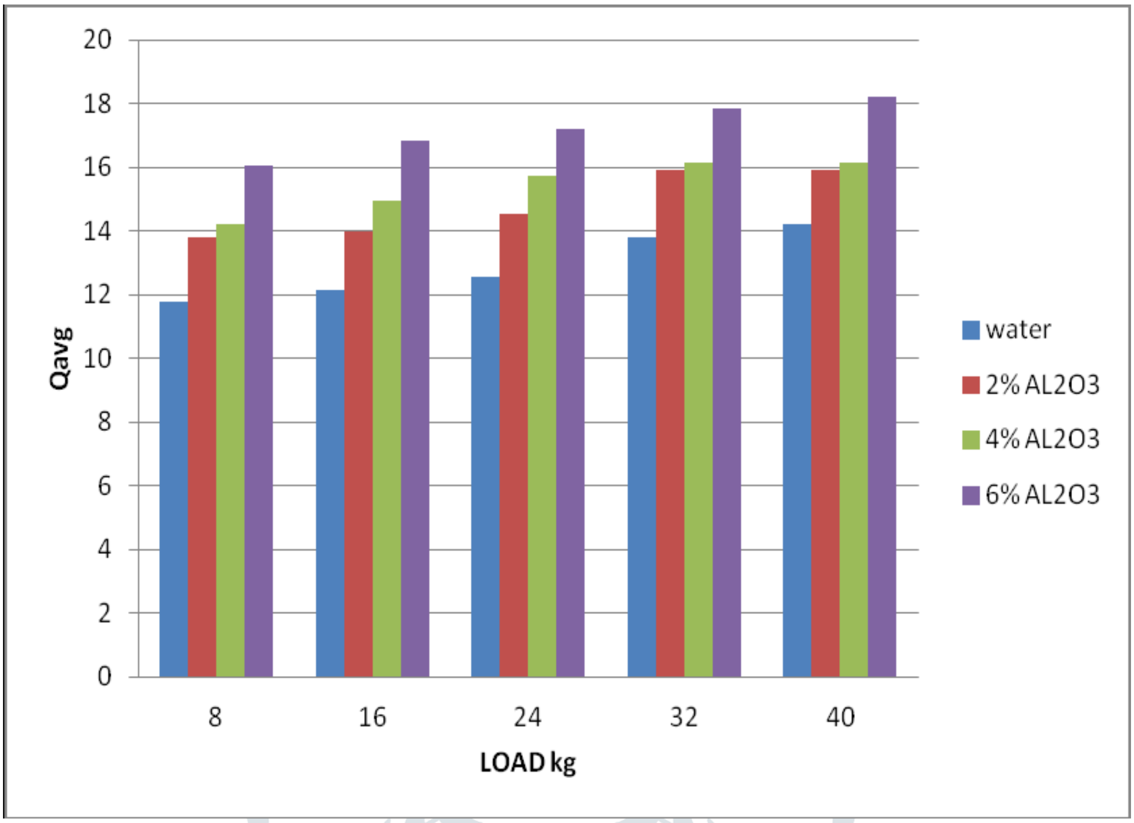


Figure 9 Percentage of Heat Transfer rate vs. Load Coolant used Different Volume Fraction of Al_2O_3

Table 6 Result Table

Sr. No.	Coolant flow rate (lpm)	Load(kg)	Heat transfer rates (KW)			
			Water	Water+2% of Al_2O_3	Water+4% of Al_2O_3	Water+6% of Al_2O_3
1	10	8	11.77	13.82	14.21	16.04
2	10	16	12.16	13.99	14.95	16.83
3	10	24	12.56	14.56	15.74	17.18
4	10	32	13.82	15.91	16.13	17.83
5	10	40	14.21	15.91	16.13	18.22

Table 6 shows the result of heat transfer rate for different volume fraction of nanoparticles in water.

VI. CONCLUSION

EFFECT ON HEAT TRANSFER RATE

The heat transfer rate in automobile radiator increases by adding nanoparticles of Al_2O_3 in water. The heat transfer rate in radiator, using water as coolant is 8 kg load at coolant flow rate of 10 lpm.Whereas heat transfer rate is 11.77 KW now adding 2% volume fraction Al_2O_3 in water heat transfer rate increase 14%.simultaneously adding 4% volume fraction of Al_2O_3 in water heat transfer rate increase 17% and adding 8 % volume fraction of Al_2O_3 in water There is an increase of about 26% in heat transfer rate in automobile radiator.

EFFECT ON COST

By adding nanoparticles to the water, the heat transfer rate in automobile radiator is increased. So for the same heat transfer radiator capacity, we can reduce the material of tubes and fins which will ultimately lead to the reduction in overall cost of the system.

EFFECT ON WEIGHT AND SPACE

By using nanofluid, we get better heat transfer, So we can design compact and lighter heat exchange system with same heat transfer capacity.

VII. SCOPE OF FUTURE WORK

- Different nanoparticles such as TiO_2, CuO, and ZrO_2 can be mixed to the water or ethylene glycol with different proportion and heat transfer rate can be found. Also composition of coolant can be optimized for different nanofluid.
- Nanoparticles with different sizes can also be used and heat transfer rate can be found.
- Other modified types of radiator can also be used for finding heat transfer rate of nanofluid.

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