STUDY ON THE BEHAVIOUR OF CUO NANO PARTICLES IN RADIATOR HEAT EXCHANGER FOR AUTO MOBILES

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ABSTRACT

In this present study, the forced convective heat transfer performance of automobile radiator has been studied experimentally by using Nano fluid (CuO-Water) as a coolant for an automobile radiator.. Experimental works were conducted to investigate the effect of Copper-Oxide (CuO) nanoparticles volume concentration and the operating temperatures on the rate of Nano fluids heat transfer in a radiator heat Exchanger. CuO nanoparticles were mixed with the base fluid water and also Sodium Lauryl Sulphate (SLS) powder was added to enhance the mixing process and stabilize the dispersion of the Nano fluids. Experimental runs were conducted at varying operating temperatures which include that, CuO-water at different temperature such as 40℃, 50℃, 60℃, 70℃, 75℃, 78℃, 80℃, 83℃. Among the operating temperatures selected for study 80℃, gives the best performance in heat transfer and the convection heat transfer coefficient. The results of the current work generally indicate that Nano fluids have the potential to enhance the heat transfer of a compact heat exchanger. Results indicate that, best overall heat transfer coefficient for the radiator is obtained at a hot fluid inlet temperature of 80℃, and at a flow rate of 0.075kg/sec.

KEYWORDS- *Nano fluids, CuO, Heat Exchangers, Radiator.*

I. INTRODUCTION

Automobile Radiators are typical heat exchangers used to cool the engine jacket water. To cool down the engine, a coolant is passed through the engine block, where it absorbs heat from the engine. The hot coolant is then fed into the inlet tank of the radiator (located either on the top of the radiator, or along one side), from which it is distributed across the radiator core through tubes to another tank on the opposite end of the radiator. As the coolant passes through the radiator tubes on its way to the opposite tank, it transfers much of its heat to the tubes which, in turn transfer the heat to the fins that are lodged between each row of tubes. Fins are used to greatly increase the contact surface of the tubes to the air, thus increasing the exchange efficiency. The cooled coolant is fed back to the engine, and the cycle repeats. Normally, the radiator does not reduce the temperature of the coolant back to ambient air temperature, but it is still sufficiently cooled to keep the engine from overheating.

Nano fluids are dilute liquid suspended Nano particles which have only one critical dimension smaller than ~100nm. Much research work has been made in the past decade to this new type of material because of its high rated properties and behavior associated with heat transfer. The thermal behavior of Nano fluids could provide a basis for a huge innovation for heat transfer. Nano fluids are prepared by dispersing and stably suspending Nano meter sized solid particles in conventional heat transfer fluids. Nano fluids consist of nanoparticles and base fluids. Nanoparticles are Al_2O_3, Fe, CuO, etc. Base fluids can be DI-water, Sodium Lauryl Sulphate, ethylene glycol, pump oil, transformer oil.

II. LITERATURE REVIEW

All internal combustion engines produce heat as a byproduct of combustion and friction. Pistons, valves and cylinder heads must be cooled to reduce the risk of detonation. Cooling systems must be properly designed, operated and maintained for proper engine operation and service life. Khot et al, [1] determined various methods for radiator performance evaluation and testing of the radiator are considered.

JP Yadav and Bharat Raj Singh stated that33% of the energy generated by the engine through combustion is lost in heat. To minimize the stress on the engine as a result of heat generation, automotive radiators must be redesigned to be more compact while still maintaining high levels of heat transfer performance. In an automobile, If this excess heat is not removed, the engine temperature becomes too high which results in overheating and viscosity breakdown of the lubricating oil, metal weakening of the overheated engine parts, and stress between engine parts resulting in quicker wear.

Changhua Lin developed a theoretical model for the calculation of Specific Dissipation (SD) to predict the effect of ambient and coolant radiator inlet temperatures. Results indicated that the effect of ambient and coolant inlet temperature variation on SD is small (less than 2%) and a 1 % variation in coolant flow rate will cause about ±0.6% SD variation. Therefore the coolant flow rate should be carefully controlled. Mintsa [10] predicted overall effect of an increase in the effective thermal conductivity with an increase in particle volume fraction by using Alumina and Copper Oxide.

K.Y. Leong et al found that the heat transfer rate is increased with increase in volume concentration of nano particles (ranging from 0% to 2%). About 3.8% heat transfer enhancement was achieved with addition of 2% copper particles at 6000 and 5000 Reynolds number for air and coolant respectively.

From the above literature, it can be concluded that the excess heat will harm the engine parts. This heat has to be removed through the radiator in automobiles. This heat removal rate depends mostly on the coolant flow rate. So, by adding the nanoparticles to the coolant the heat transfer rate will be increased. Thus, for the present work, we considered the available nanoparticles CuO and a stabilizer as Sodium Lauryl Sulfate to study the effect on the heat transfer rate in automobile engines, which has not done before.

III. EXPERIMENTAL SETUP

The performance of an automobile radiator is tested by designing and fabricating a test setup. Different components used in test setup are shown in below figure 1. One of the types of cross flow heat exchanger, Maruti Suzuki Alto 800 radiator is used in this experiment. It contains 36 Aluminium pipes of length and diameters are 31cm and 0.8cm respectively. A Radiator fan of 12V DC supply and requires 4 to 6 Amps of current is used in this project. It consists of 3 blades and frame for create blow. It is placed in front of the radiator with the help of nut and bolt fittings. This fan draws fresh air through the radiator i.e., pumping air at ambient temperature to decrease the temperature of coolant. A water pump of capacity ¼ Hp is used for pumping and circulating the water throughout the system. It is most desirable one, because it is less in weight and moderate in size. It consists of both suction and discharge ports.An immersion heater is attached to the thermally insulated water tank and it heats the water, which is initially filled in the tank. The capacity of this immersion heater is 198°C. A tank of 20 litres capacity is thermally insulated by insulating material (thermocol), and having 3 ports of suction, delivery and bypass ports respectively. It also consists of a fitting arrangement for heater. A Rota-meter is used for measuring the mass flow rate of the hot fluid that is circulating in the radiator of a range 10-100lit/s.

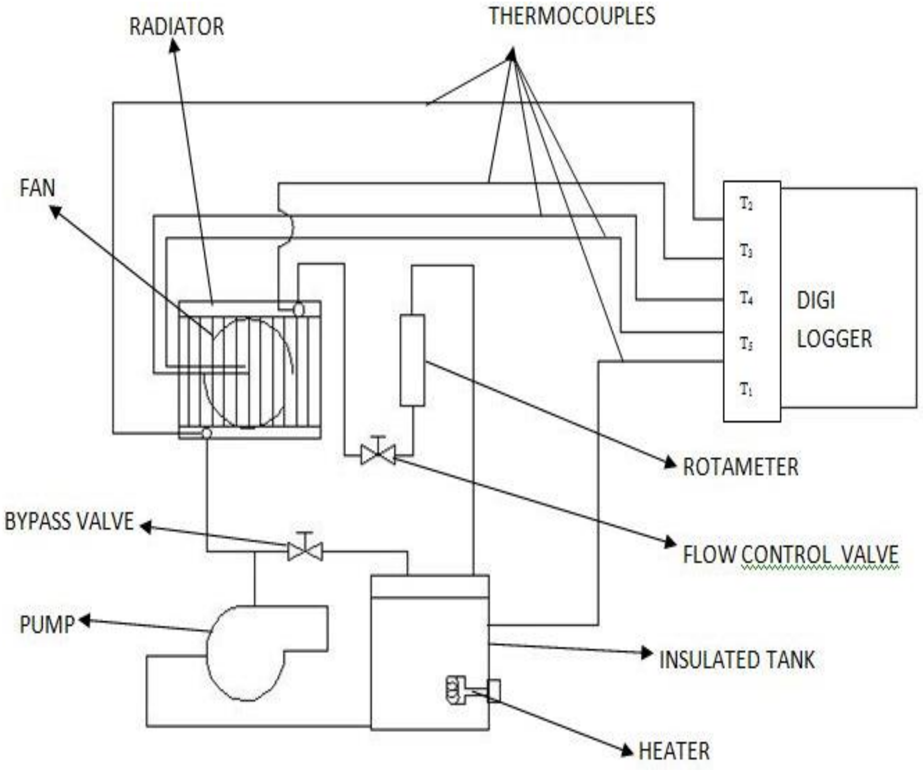


Fig 1 Schematic experimental setup

IV. METHODOLOGY

During the experimentation, initially a sufficient amount of water taken into the insulated tank, fitted with the heater. Then the mixture of CuO and SLS added in proper ratio of volume and stir manually until it dissolve in water. Then the heater is turned on until the water gains the required hot fluid inlet temperature (T1). Now switch on the pump to obtain constant coolant mass flow rate as well as the fan attached to the radiator. Wait for few minutes until the apparatus get stabilized. Then, required temperature readings are noted by varying the 5 way selector present on the digital logger. This process is repeated for various temperature of T1. From this experiment, the optimum hot fluid temperature is obtained. Overall heat transfer coefficient and heat transfer rates are calculated from the recorded values of coolant inlet (T2), coolant outlet (T3), air inlet (T4), air outlet (T5) temperatures using the governing equations. Then keeping this optimum operating temperature T1 as constant, the mass flow rate of coolant is varied from 0.025kg/s to 0.1kg/s in 4 steps. From the above experiments, the optimum conditions (optimum hot fluid inlet temperature and mass flow rates) of the radiator are calculated.

Fig 2 Experimental setup for testing the performance of radiator

V. RESULTS & DISCUSSION

The performance of an automobile radiator varies with different parameters, in our experiment we are concentrating on hot fluid inlet temperature and mass flow rate depending on these two parameters we are evaluating the performance of an automobile radiator. To know the optimum conditions i.e., the temperature and the mass flow rate where the efficiency of the automobile radiator increases, firstly we have to maintain either temperature or mass flow rate as a constant. Let us maintain the temperature as a constant and get know at what temperature the overall heat transfer coefficient will be more to the optimum temperature value the coolant is circulated through the radiator at different temperature such as 40℃ , 50℃, 60℃, 70 ℃, 75℃, 78℃, 80°C, 83°C.

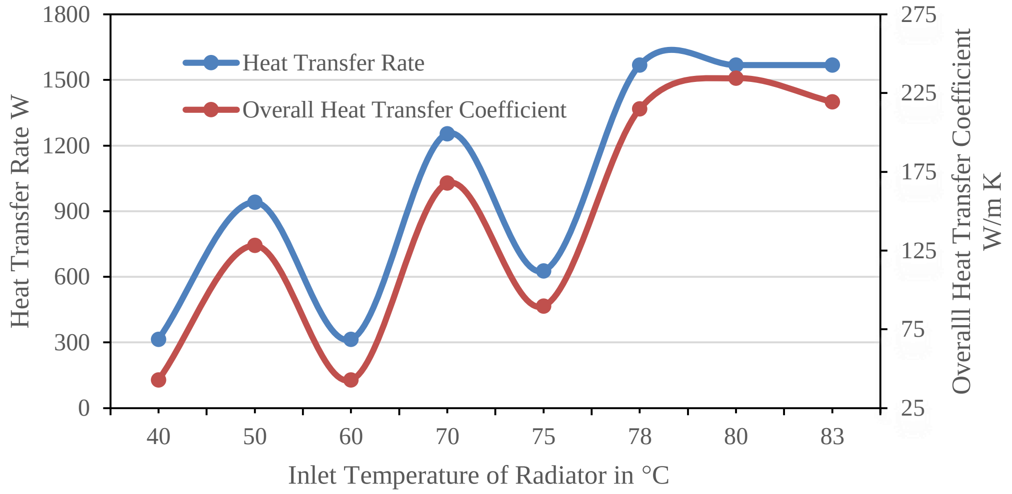
5.1 RESULTS

Temperature Reading Tables At Different Hot Fluid Inlet Temperatures

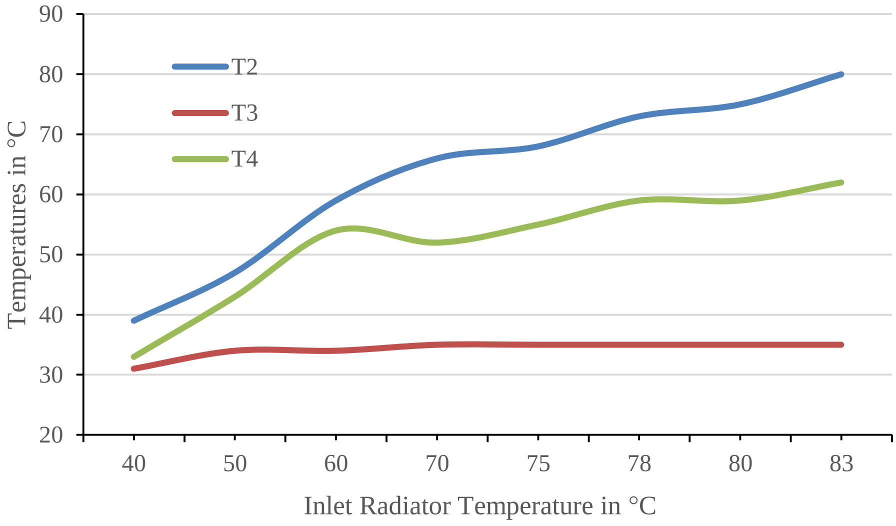
At first coolant pumped at temperature of (T_2) 40□ and the value of coolant outlet temperature (T_3), air inlet temperature (T_4), air outlet temperature (T_5) are noted with the help of digital indicator. By using all these parameters rate of heat transfer and then overall heat transfer coefficient values are calculated. The values that are obtained are tabulated in the following tables.

Table 1: Experimental results at various hot fluid Inlet Temperatures

SNo	T1	T2	T3	T4	Heat Transfer Rate	Overall Heat Transfer Coefficient
1	40	39	31	33	313.5	42.8
2	50	47	34	43	940.5	128.26
3	60	59	34	54	313.5	42.84
4	70	66	35	52	1254	167.72
5	75	68	35	55	627	89.76
6	78	73	35	59	1567.5	214.87
7	80	75	35	59	1567.5	234.47
8	83	80	35	62	1567.5	219.41



Graph 1. Effect of hot fluid inlet temperature on Heat transfer and Overall heat transfer coefficient



Graph 2. Variation of T2, T3 and T4 with Inlet radiator temperature

Optimum Hot Fluid Inlet Temperature

At 80^0C the optimum overall heat transfer coefficient value is obtained, that is 234.47 W/m^{2o}C, at a rate of heat transfer 1567.5 W.

From the table, we can see that the hot fluid inlet temperature is 80^0C the overall heat transfer coefficient value is 234.47 W/m^{2o}C and the further increase in the coolant inlet temperature the overall heat transfer coefficient value is being decreased. As the overall heat transfer coefficient value is more at 80°C we can say that optimum temperature value is 80^0C. Now maintaining the coolant inlet temperature constant at 80^0C we have to vary the mass flow rates to find out that what temperature and mass flow rate the overall heat transfer coefficient will be more.

The coolant mass flow rate are varied such as 0.035kg/s, 0.05kg/s, 0.075kg/s, 0.1kg/s. the experiment is carried out by maintaining coolant inlet temperature at 80 and varying the mass flow rate. The values of coolant outlet temperature (T_3), air inlet temperature (T_4), air outlet temperature (T_5) are noted with the help of digital indicator. By using all these parameters rate of heat transfer and then overall heat transfer coefficient values are calculated. The values that are obtained are tabulated in the following tables.

Temperature Reading Tables of Different Mass Flow Rates at Constant Hot Fluid Inlet Temperature

Optimum Hot Fluid Mass Flow Rate

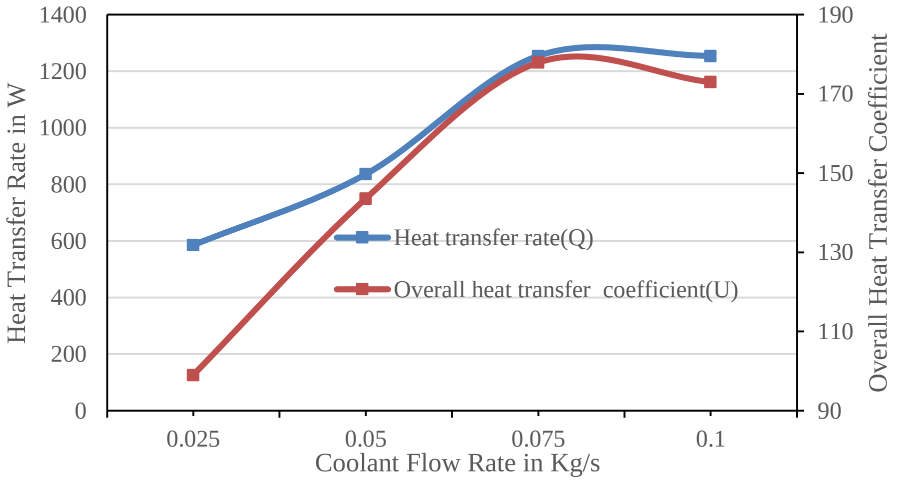
The optimum over all heat transfer coefficient value is obtained at 0.075 kg/s of mass flow rate and keep the hot fluid inlet temperature value as constant.

Table 2: Optimum mass flow rate

Flow rate (kg/s)	Heat transfer rate(Q) (W)	Overall heat transfer coefficient(U) ($w/m^2\,{}^oC$)
0.025	585.2	98.98
0.050	836	143.56
0.075	**1254**	**177.93**
0.1	1254	172.98

From the above table, we can see that the overall heat transfer coefficient value is more when the coolant mass flow rate is 0.075kg/s and the further increase in mass flow rate the overall heat transfer coefficient value is being decreased. So we can say that 0.075kg/s is the optimum mass flow rate where maximum overall heat transfer coefficient values will be more.

The overall heat transfer coefficient values at different coolant inlet temperature are summarized in the table



Graph 3. Coolant Flow rate vs Heat transfer Rate

Coolant Flow rate vs Heat transfer Rate and Overall heat transfer coefficient

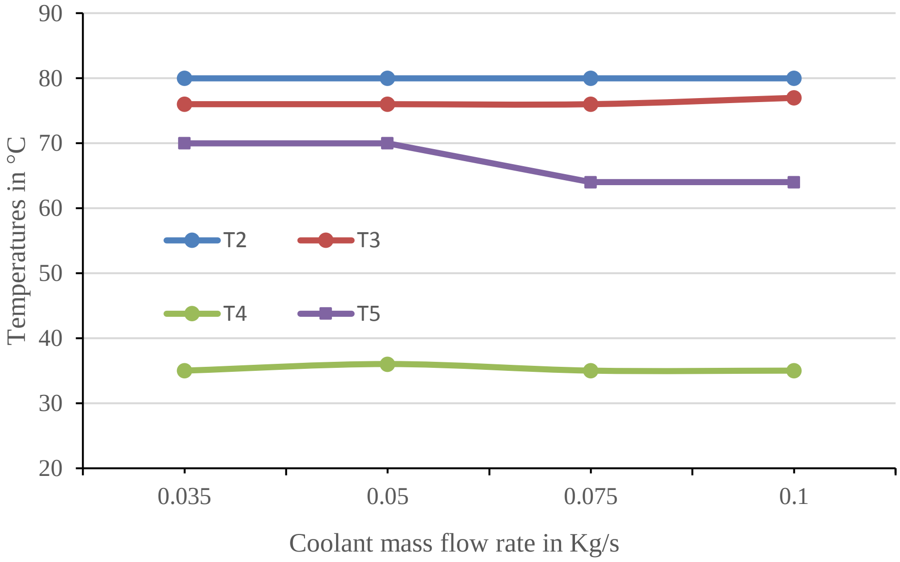
According to the values obtained a graph is plotted between coolant inlet temperature and overall heat transfer coefficient. Graph is plotted between overall heat transfer coefficient and hot fluid inlet temperature.

The values of coolant inlet temperature are taken on x-axis and the values of overall heat transfer coefficient are taken on y-axis. From the graph 5.1 it is clear that the overall heat transfer coefficient value is maximum at coolant inlet temperature 80℃ and the value is 234.47 $W/m^{2o}C$.Similarly, the overall heat transfer coefficient values at different mass flow rate are summarized in the table.

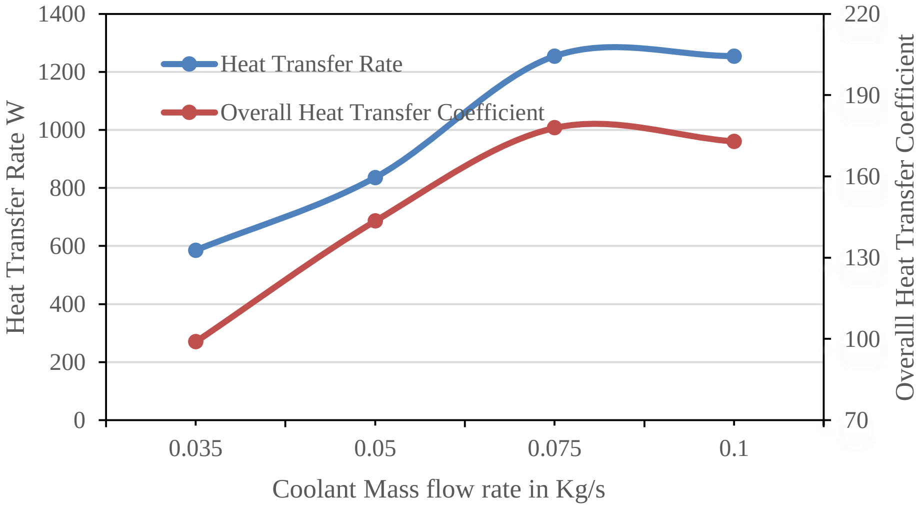
In the above table represents the optimum flow rate of 0.075m/sec add obtained maximum Overall heat transfer coefficient value is 177.78 $W/m^{2o}C$.it is best result for this experiment. According to the values obtained a graph is plotted between mas flow rate and overall heat transfer coefficient.

Table 3. Overall heat transfer coefficient values at different mass flow rates

SNo	Mass Flow rate Kg/s	T2 °C	T3 °C	T4°C	T5 °C	Heat Transfer Rate Watts	Overall Heat Transfer Coefficient W/m K
1	0.035	80	76	35	70	585.2	98.98
2	0.05	80	76	36	70	836	143.56
3	0.075	80	76	35	64	1254	177.93
4	0.1	80	77	35	64	1254	172.93



Graph 4. Variation of Temperatures with different coolant mass flow rates



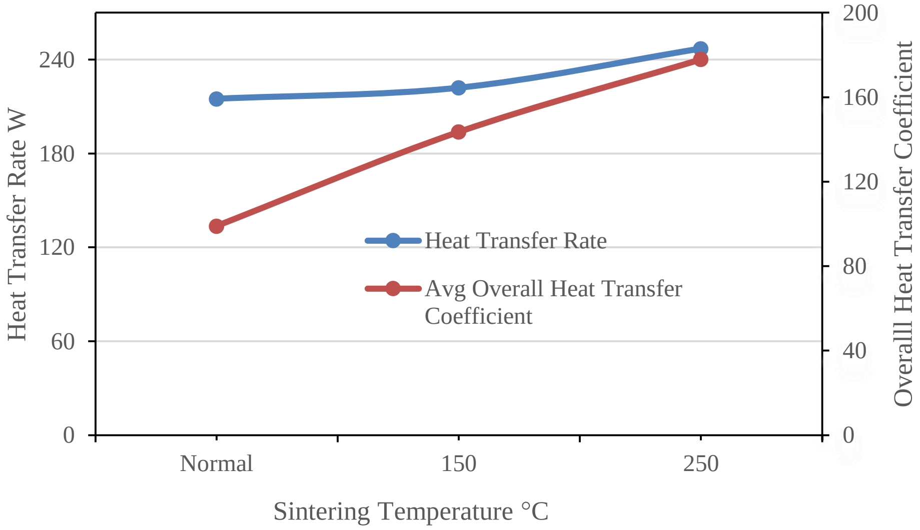
Graph 5. Graph for overall heat transfer coefficient at different mas flow rates.

The values of mass flow rate are taken on x-axis and overall heat transfer coefficient values on y-axis. From the graph it is clear that the overall heat transfer coefficient value is maximum when the mass flow rate is 0.075kg/s and the value is 177.93 W/m^{2}°C
Similarly, the overall heat transfer coefficient of CuO at optimum temperature and mass flow rate is summarized in the following table

Table 4. Overall heat transfer coefficient at various sintering temperatures

S no	Sintering Temperature °C	Hot Fluid inlet Temperature °C	Mass Flow rate Kg/s	Heat Transfer Rate W	Avg Overall Heat Transfer Coefficient W/m K
1	Normal	80	0.075	214.97	98.98
2	150	80	0.075	222.02	143.56
3	250	80	0.075	247.06	177.93

According to the values obtained a graph is plotted between sintering condition and overall heat transfer coefficient.



Graph 6. Graph plotted between overall heat transfer coefficient and sintering condition.

The values of sintering condition are taken on x-axis and values of overall heat transfer coefficient are taken on y-axis. From the graph it is clear that the overall heat transfer coefficient value is maximum at sintering condition at 250℃ and the value is 247.06 w/m^2 ℃

5. 2 Discussion

- Experiments are conducted to find out optimum hot fluid temperature and mass flow rate.
- As per the results obtained from the graph plotted between overall heat transfer coefficient and mass flow rate, the overall heat transfer value is 247.06W/m^2℃.
- The maximum value of overall heat transfer coefficient and heat transfer rate are found to be 80℃ fluid inlet temperature and 0.075kg/sec mass flow rate.
- Addition of small amount of CuO nanoparticles into demineralized water as the base fluid would increase the rate of heat transfer and convection heat transfer coefficient by at least 17.3% and 40% respectively.
- Nano fluids as the coolant for automotive radiator and various ranges of operating temperatures and volume concentrations may need to be explored in order to better optimal conditions.

VI. CONCLUSION

In this experimental study, the heat transfer performance of automobile radiator has been estimated by using CuO Nano fluids at various coolant temperature ranges and mass flow rates.

- The optimum hot fluid temperature and mass flow rates are determined using its inlet temperature based on the overall heat transfer coefficient and heat transfer rates.
- The Nano coolants found to enhance the thermal performance of the automobile radiator.
- With the increase in the coolant flow rate, the heat transfer performance increase for the various coolants namely CuO-water.
- After several iterations the optimum overall heat transfer coefficient is find out to be 247.06 W/m² °C at the mass flow rate 0.075kg/sec and inlet temperature 80℃.

VII. FUTURE SCOPE

In the application of Nanofluids instead of water enhance thermal performance of the automobile radiator system, some associated problems such as stability and sedimentation should also be studied in detail.

The research work also drawn the attention of the many researchers to concentration on farm equipment development for improved performance in their field. The thermal management of heavy vehicles such as cars, tractor and earth moving equipment through Nano mechanism are essential areas for future researchers. Nano fluids shows promising potential as the coolant for automotive radiator and more ranges of operating temperature and volume concentrations may need to be explored in order to better understand its full potential.

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