# CFD Analysis of Heat Transfer Enhancement of A Car Radiator using Nanofluid as A Coolant

Vinod M. Angadi[1],
P G. Student: Thermal Power Engineering,
Gulbarga /Karnataka/India

R. Nagaraj [2]
Associate Professor: Mechanical Department,
PDA College of Engineering.
Gulbarga/Karnataka/India

Dr. O. D. Hebbal [3]
Professor: Mechanical Department,
PDA College of engineering.
Gulbarga/Karnataka/India

***Abstract* - In automobiles radiators like car is device performed to cool by circulating fluid in it, which consist of water as a coolant or a mixture of water and some external additives like anti freezing materials like ethylene glycol these fluids added to water, this mixture we called as a base fluid. For our analysis in this paper,the heat transfer performance of pure water has been compared with their binary mixtures of $Al_2O_3$. Different amounts of nanoparticle have been added into these base fluids and its effects on the heat transfer performance of the car radiator have been analysis done using STAR CCM+ tool. In this paper $Al_2O_3$ particles are taken as an external additives used for enhancement of the thermal conductivity and heat transfer of the car radiator. So in car radiator liquid flow rate has been changed in the range of 2-6 litter per minute and fluid inlet temperature has been changed for all the experiments. The result shows that nanofluids clearly enhance heat transfer compared to their own base fluid. In the best conditions, the heat transfer enhancement of nano fluids more which can be compared to usual coolant used in radiator. The implementation of nanofluid increases the overall heat transfer coefficients determind in this paper.**

***Keywords: ethylene glycol ,nanofluids, Base fluids, star ccm+, aluminium oxide, enhancement***

## 1. INTRODUCTION

Water is the most widely used coolant for the heat exchangers in the thermal industry and in automobiles like car radiators, this device where more amount of heat is to be carried by the coolant to get effective performance from the radiator, we need to have good coolant and some additives, that will help in the base fluid, as the agents for enhancing the heat transfer, In this experiment we use water as the base fluid with small amount of the nano-fluids. Usually heat transfer fluids with suspended ultra fine particles of nanometre size are named as nanofluids, which have opened a new dimension in heat transfer processes. The recent investigations confirm the potential of nanofluids in enhancing heat transfer required for present age technology. The present investigation goes detailed into investigating the increase of thermal conductivity with temperature for nano fluids with water as base fluid and particles of $Al_2O_3$ as suspension material [1]. Nano particles materials are placed in form of suspension solid particles, inside the cooling fluids can effectively enhance the thermal quality of base fluid. It is well known that metals and metal oxides have higher thermal properties compared to conventional fluids. Nano-fluids are the ultra fine particles they may in the form of solid of metallic, made to suspend or dissolve in the base fluid. They are measured in size of nanometre (nm). From recent nano-technological research proved that they increase the properties of the basic coolants like, heat transfer capacity and thermal conductivity of the coolants, by adding small amount of the nano-particles to the base fluids. Present analysis is carried on The Increase in heat transfer capacity with variation of the size and amount of use in base fluid (water). This analysis is results of heat transfer and thermal conductivity enhancement will be seen at the end of the analysis. Results from the simulation values made to compared with the standard journels. Standard radiator model shown below taken for analysis [2]

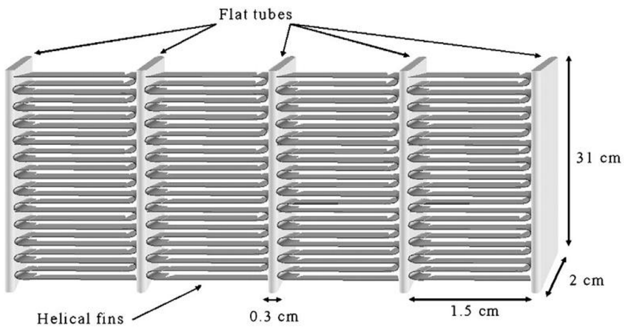


Figure 1.1: Schematic diagram of the Radiator [2].

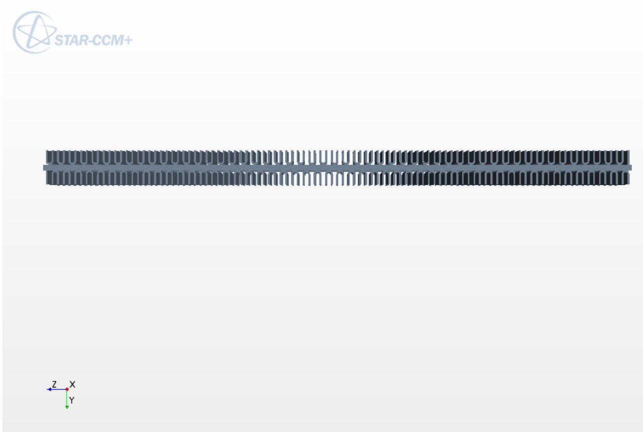
## 2. METHODOLOGY

Using computational fluid dynamic softwares availble to use like in STAR CCM+ tool. Simulation of the automobile radiator is carried out. Using nano fluids in the car radiator, enhanced thermal conductivity of the fluid is determined experimentally to do the analysis on the complex projects it cost more and time also consumes lot. More space and man power needed to carry out externally and some other negatives seen. But software analysis using computer is very useful because, its portable and very less cost needed compared to the practical work. Boundary conditions, iteration values, input values, easily variables in computer compared to practicle. where in experimental it's very costly to do experiments again and again by varying in input values like boundary conditions for models. So the CFD is tool to use in the analysis problems so here we vary the values easily without any problem.To obtain the higher heat transfer rate, and gradual increase in the thermal conductivity of the fluid, the aluminium oxide nano particle is the one it will give enhanced output from the radiator, mixing is done by the certain volumetric concentrations of the nano fluids to the basic fluid like water and vary the nano particle concentration to from 1% to up to the 6% to the water and made pass through the inlet of the radiator for analysis purpose [2]. In this analysis considered only the one part of the car radiator as heat exchanger to carry out the analysis, the radiators made to with long rectangular sections and at both side 51 fines are to makd to carry the heat from the plate. Fins are so arranged to the plate that only small part of the fins is come in contact with the long plate. The design of the heat exchanger fin, is made using CAD design in STAR-CCM+ software. radiators normally face different environmental conditions to operate, so these have to come out extreme cold and extreme hot conditions to work effectively without any problem, with better efficiency and long life. This kind of the model made to design using the effective tools. It has been proved that conventional fluids, such as water and Ethylene Glycol have poor convective heat transfer performance and therefore high compactness and effectiveness of heat transfer systems are necessary to achieve the required heat transfer [3]. Among the efforts for enhancement of heat transfer the application of nanoparticle additives to liquids is more noticeable and currently a large number of investigations are devoted to this subject.

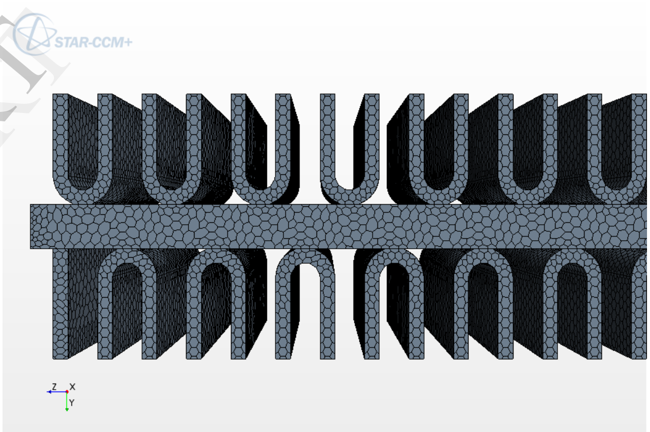
Table 2.1: Discreption of the CAD model

| | |
|---|---|
| Tube length | 31cm |
| Number of fins | 34 |
| Space between tubes | 1.5cm |
| Thickness of the tube | 0.3cm |
| Length of the tube | 2cm |
| Material used | Aluminum |
| Coolant used | Water |
| Nanofluids as additives | Aluminum oxide |

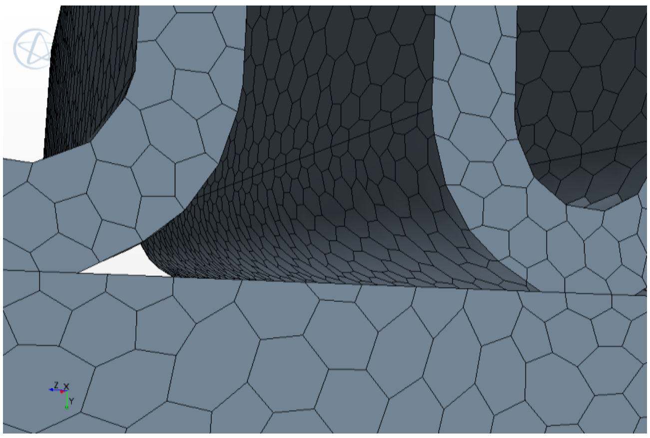
CAD model with dimensions are given in Table 2.1. radiator parts is designed by taking only one part of the actual radiator, hown in Figure 1.1,which is used for analysis. One of the main important part in analysis of model is meshing of the model. In this project different kind of meshing done to different surface made different parts like, long plate for inlet of water into the radiator,and the interface with plate and curve part of the fin more fine mesh is to be done, one to get heat transfer values exactly.and next one is the face of the fin which has more surface area compared to other part of the fine where normal meshing can be taken, and for at side of the fines it made cut from othe fines so it actualy single fin but our understandin and analysis we made equall half of fin so one cut part fine side is taken periodic coditions to the next part fin to start continues from that part,so at this part very fine meshing is done. Detailed methodology of the project are explained above. By applying the datasin the boundary conditions.we can get the analysis results from the radiators varing the inlet nanofluid concentraioms to the water.




(a) Radiator cut section of fins and flat tube in centre




(b) Meshed view of the radiator fins and flat tubes.



(c) Meshed view of the radiaor with fins and flat tube intrface

**Figure 2.1: CAD model of Radiator**

Figure 2.1 shown CAD model of Radiator designed taken from Table 2.1 and in Figure 2.1 (a) only one part of the radiator made used for analysis perpose. With long flat tube with both side fins are arranged for heat transfer. 51 fins are present each side of the flat tube. Second figure 2.1(b) meshed parts of fins and flat tubes arrangement at different mesh sizes are observed.and figure 2.1(c) Closed view of the fins and flat tubes are shown where different surface of the fins interfaced with flat tube [3].

## 3. DATA AND RESULTS

**Fin**: Radiator analysis is done for different concentration of the nanofluids with water. For fin we taken material as aluminium that having the properties like density of 2702.0 kg/m$^3$, and the specific heat of 903.0J/kg-K.,thermal conductivity of 237.0 W/m-K, respectively. and minimum to maximum allowable temperature is given from range of 1000K to 5000K respectively in the analysis. 40$^0$C is static temperature taken in initial conditions. Steady flow and three dimensional and material taken solid since it's is aluminium plate. In conditions the properties of the fines remain constants, so in complete analysis of the radiators these values remain kept same and constants. Since air is come into contact with the fine at outside, the convective boundary condition is taken in analysis [3].

**Water**: In the assigning the boundary conditions of the radiators for incoming water to the plate section lot many basic operations are to be done simultaneously like we have assign on boundaries for inlet of the water, temperature, velocity, mass flow rate, mass flow directions all these are assigned and made changed depending on the concentrations of the fluids we use. Since water is having different concentration of nanofliud of aluminium oxide.In every new analysis so for every time we have to change the boundary conditions for each iterations of the nanofluids, values of the inflow fluids to radiator is given by the tables and simulation values and results are shown below. And the performance values of the radiator from the simulation results are shown Figure 4.1 and Figure 4.2

### A. Governing Equations

1. Continuity Equation: $(\nabla.V) = 0$ (3.1)

2. Momentum Equations: $\rho nf(\nabla.V)$ V=∇P+$\mu nf\nabla$2V (3.2)

3. Energy Equations: $\rho nf C pnf(\nabla.V)$T=$knf\nabla 2T$ (3.3)

### B. Formula used

1. Flow rate of the coolant: q = (1000*60) m/s. (3.4)

2. Flow rate for each tube: = (flow rate)/(number of tube) (3.5)

3. Density (ρ): = mass/volume m^3 (3.6)

4. Mass flow / tube: = (mass flow rate for each tube * ρ)
= m˙/ (tube) = Q/ (tube) (3.7)

5. Velocity = (flow rate per tube)/ (tube area):
= (Q/ (tube))/At m^3/s (3.8)

6. Overall heat transfer:

$$\frac{1}{UA} = \frac{1}{\eta_0 \, h_0 \, A_0} \cdot (W/m^2 k) \quad (3.9)$$

### C. Boundary Conditions and Physics Selected

One of the most important operations of the fluid flow analysis of the radiator heat transfer is the applying the boundary conditions to the geometric parts of the radiators. According to the output requirement. we specify the respective inlet boundaries for the parts in the region. Let's see the different boundaries for radiators. The conservation equations of mass, momentum, and energy mentioned above equation (3.1) to (3.3) are nonlinear and coupled systems, which are solved subjected to the following boundary conditions. At the inlet of the flat tube, uniform axial velocity and temperature are prescribed. The inlet velocity determines the Reynolds number of the flow, and the inlet temperature has been taken as 50, which is typical for automotive radiators. The uniform axial velocity at the inlet assumed in the present study is an idealization of the actual flow pattern because considerable flow non uniformities arising from the fluid entering the top of the radiator will be inevitable in the actual case. At the outlet section of the tube. In STAR CCM+ the outflow boundary condition corresponds to fully developed velocity and temperature profiles, so that the axial derivatives of the velocity and the temperature at the exit plane are zero. For a higher reynolds number, the flow is not fully developed. Under such a condition, a pressure outlet boundary condition is adopted. All along the tube wall, a no-slip boundary condition is imposed for velocity. For an automobile radiator, a realistic thermal boundary condition on the outside of the wall is a prescribed free stream temperature. In our simulations, following Park and Pak (2002) [5] and an ambient air temperature of 30$^0$C were selected. This represents a mean vehicle speed between the idle and the full speed of 72 km/h [5].

**FINS:** Boundaries for the fins are different compared to inlet of the water to the radiators, initial conditions to the fines like inlet temperatures taken as the ambient 50$^0$C and the convective heat transfer coefficient is given 50W/m$^2$K.and by the different fin parts are to assigned respectively. At the edge of the fin assigned as the periodic type of the boundary conditions, periodic boundary condition is the one which will treat fin as complete. For the meshing of fines in complicated regions increase the mesh density in those regions meshing with finer mesh quality will give better result in that region. adjust the mesh size wherever need for correct results, selected mesh conditions like surface remesher, polyhedral mesher,and the prism layer these are the types of mesh used. After that part have to select physics to respective regions so that physical conditions are taken to the applied regions in the analysis of the radiators.

**Water:** In regions, the water made to pass through the plain rectangular flat tube of the width 0.03cm, length of 2cm, and height of 31cm [3-5] from Figure 1.1 at inlet of the boundary condition for the water is given the temperature and flow directions and the velocity, flow rate and flow is laminar has to be match with physics of the water given in the step continua, inlet boundary conditions given thet temperature of the water or in coming coolant with different concentrations of the nanofluid. As per our analysis for coolants the temperatures of the coolants must be more compared to when coming out from the radiators. that will results in the increase in the heat transfer from the coolants can be seen as per physical condition inlet and out let of the fluid.in selection of the physics for model for water considered as flow is laminar. Liquid, Three dimensional flow, constant densiti .stady flow, coupled energy,coupled energy. And in the fins thephysica are considered, constant density couplee solid energy gradiants, solid, stady, three dimensional. these are respectve physics taken for the analysis of the radiator. Using this physical values boundary are applied in regions.

## 4. SIMULATION RESULTS AND ANALYSIS

**S**imulation analysis of the car radiatoris donefor different vloumetric flow rates varing from 2 to 5 l/min of base water to that small quantity of the nanoparticles are addedto it to get analysis the enhancement of the the thermal conductivity of the fluid in the radiator. after adding the nanofluids to the base fluid enhanced heat transfer and mass flow results are shown. In following heat transfer graphs analysis results are given for 1% 3% 4% 6% of nano fluids at volumetric flow rate of 5 litter per minute. For each % of flow rate [3-5]

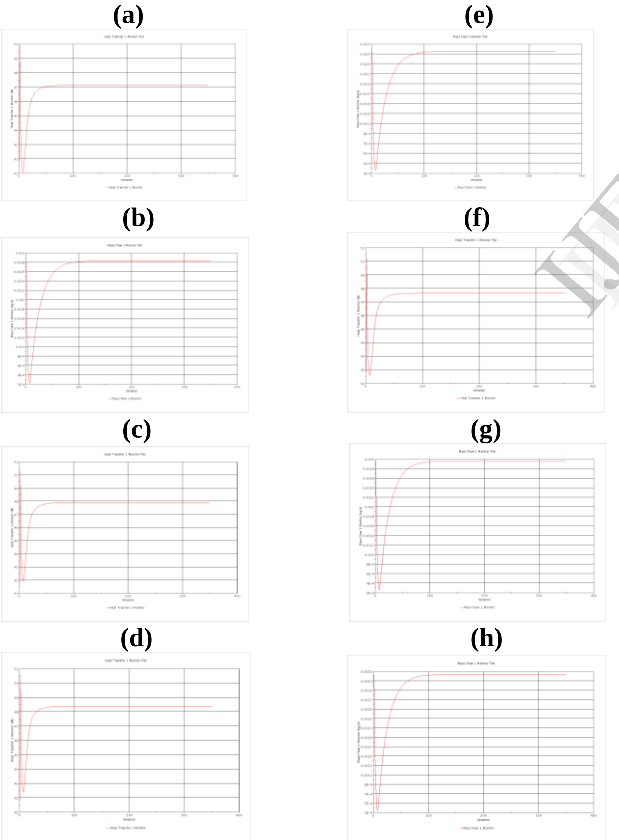



Figure 4.1: Heat Transfer (a,b,c,d,) and Mass flow rates (e,f,g,h,) at 5 l/min flow rates for 2%. 3%. 4%. 6% of Nano fluids respective

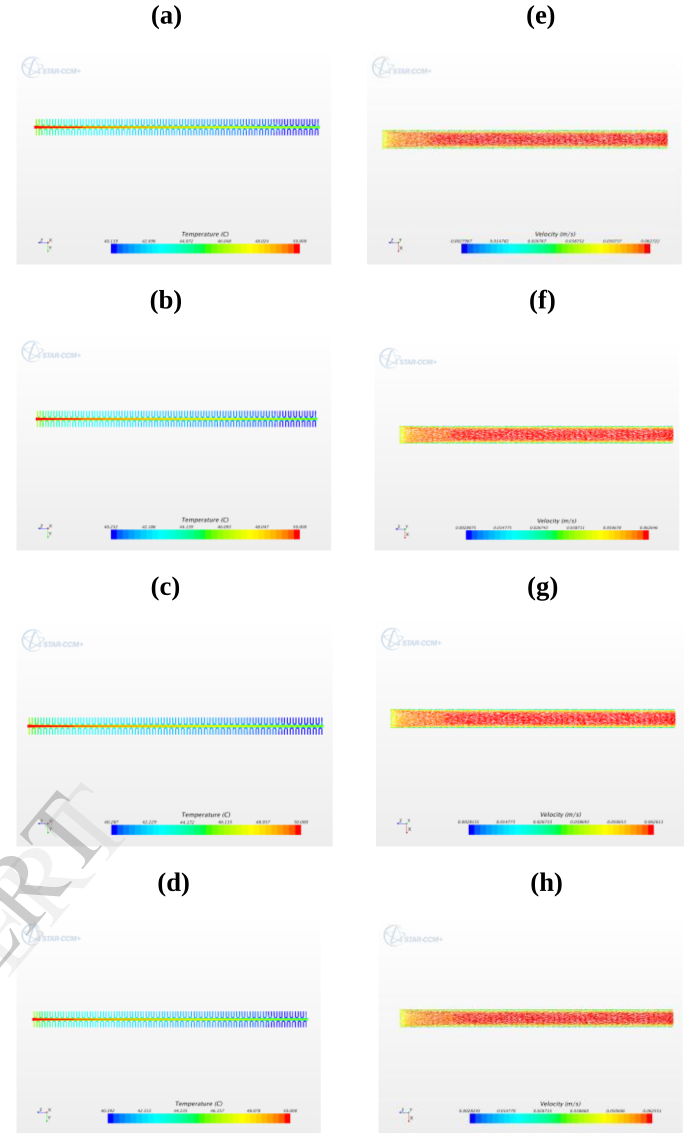



Figure 4.2: Scalar plot (a, b, c, d) and Vector (e, f, g, h) at 5 l/min flow rates for 2%. 3%. 4%. 6% of Nano fluids respective.

Figure 4.1: Shows the heat transfer and mass flow rate for 5 litter minute flow rate of plain water to that, nano fluids for 2%. 3%. 4%. 6% in the base fluids added and out put values are ploted in form four variablea with takin number of iterations onthe X axis.

Figure 4.2: Simulation results of the of the tempreature and the velocity are shown for the 2, 3, 4, 5. % of the nano fluids for volume flowrate of the 5 litter per minute. These simulation results made to compare with the simulation values of the plain water and with that enhanced heat transfer values will get. Simulation results are obtained with four paranetes like Heatransfer Mass flow rate and Temperature and the velocity componants from thses parameters its easy to analysis the nanofluids effectively.

Table 4.1: Overal Heat Transfer Co-efficient for different % Nano fluids

| flow rate | U-plain W/m$^2$ K | 1% | 3% | 4% | 6% |
|---|---|---|---|---|---|
| **2** | 139.57 | 140.33 | 141.77 | 142.50 | 144.30 |
| **3** | 152.44 | 153.32 | 155.00 | 156.00 | 157.22 |
| **4** | 160.24 | 161.39 | 163.11 | 164.00 | 165.55 |
| **5** | 166.21 | 167.16 | 169.00 | 170.00 | 171.20 |

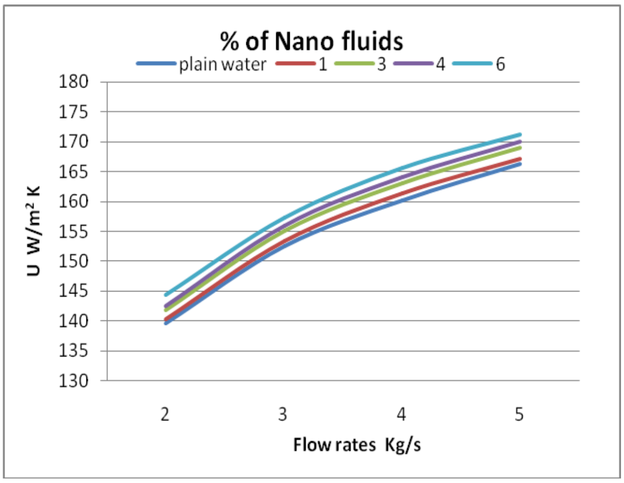



**Figure 4.3: Increase in Overall Heat Transfer coefficient with % of Nano fluids.**

Table 4.2: Thermal conductivity

| % of the nano fluid | Thermal conductivity (w/m k ) |
|---|---|
| 0 | 0.660225 |
| 1 | 0.678279 |
| 3 | 0.696671 |
| 4 | 0.753975 |
| 6 | 0.757485 |

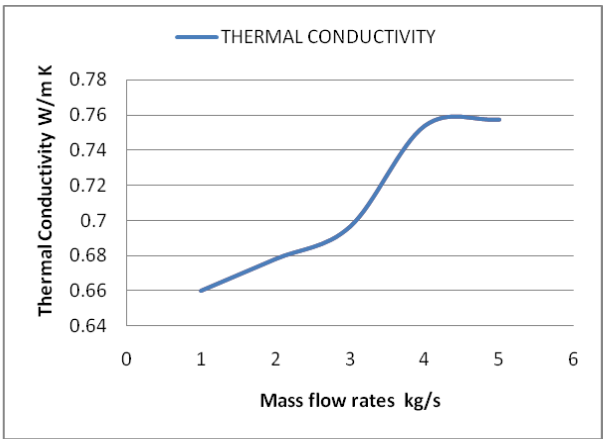



Figure 4.4: Variation In Thermal Conductivity With Mass Flowrates

Table 4.3: Overall Heat Transfer Co-efficient with Temperature

| Temperature | Overall Heat transfer *W/m$^2$ K* |
|---|---|
| 50 | 164.00 |
| 60 | 164.15 |
| 70 | 164.16 |
| 80 | 166.00 |

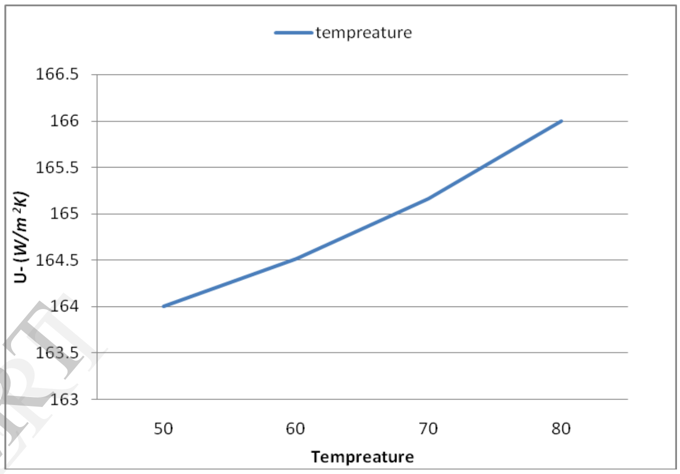



Figure 4.5: Increase of Overall Heat Transfer Coefficient with Temperature

As seen figure 4.2 Increase in the overall heat transfer co-efficient the characteristic curve show that increase with % of nano fluids. And in the figure 4.4 when % of the nano fluid increases in X-axis to that the thermal conductivity of the fluid also increases simultaneously. And figure 4.5 Increase in the heat transfer co efficient with temperature Hence from this we can conclude that from our project by using the nano fluids to the base fluid for any coolant that will enhance the thermal conductivity of the fluid and also heat carrying capacity of fluid.

## 5. CONCLUTION

From this analysis radiator, we conclude that Efficiency of radiator increases. Thermal conductivity of the system increases. The addition of nano-particles to the coolant has the potential to improve automotive and heavy-duty engine cooling rates. Also help in a reduced-size cooling system by removing heat from engine. Smaller and lighter radiators, which in turn benefit almost every aspect of vehicle performance and lead to increased fuel economy. Nano fluids will have a greater application in heat transfer problems. These analyses provide strong references to the design of cooling methods, shortened the design period, and reduced the design cost. From the practical point of view it is not costly to add surfactant and adjust the pH for the nanofluid to gain a very small increase in heat transfer performance of the radiator. To have the same increase in the overall heat transfer coefficient, it would be less costly and more practical to increase the airflow rate.

Although application of nanofluids, in water enhances, thermal performance of the automobile cooling system, some associated problems like stability and sedimentation should also be studied with details

- Efficiency of the heat transfer of nanofluids will more compared plain water. Thermal conductivity of the system increases.
- The overall heat transfer coefficient increases with enhancing with volumetric flow rate of the nanofluid significantly.
- The addition of nano-particles to the coolant has the potential to improve auto motive and heavy-duty engine cooling rates.
- Help in a reduced-size cooling system by removing heat from engine.
- Smaller and lighter radiators, which in turn plus point almost every aspect of vehicle performance and lead to increased, fuel economy.
- The overall heat transfer coefficient slightly with increasing inlet temperature of the nanofluid.

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