EFFECT OF NANOFLUIDS AND MASS FLOW RATE OF AIR ON HEAT TRANSFER RATE IN AUTOMOBILE RADIATOR BY CFD ANALYSIS

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Abstract

Air has the largest influence on the overall heat transfer rate of automobile radiator. It is generally known that the velocity of the airflow through the radiator is a function of the vehicle speed and the "heat transferred by a radiator is a function of the airflow rate across the radiator" This paper presents a Computational Fluid Dynamics (CFD) modeling simulation of mass flow rate of air passing across the tubes and coolants in to the tubes of an automotive radiator. An introduction to Nanofluids is termed as the next generation heat transfer elements. The mass concentration of nano particles is proportional to the rate of heat transfer within critical limit. Air flow and coolants simulation is conducted using commercial software STAR CCM+. The CFD process starts with defining the water type geometric clean up and meshing using the Hyper mesh V11.0 software and then it is followed by the meshing which create the surface mesh as well as volume mesh accordingly. After meshing, the boundary conditions are defining before solving that represents flow fields of the simulation. The flow characteristics are then analyzed, compared and verified according to known physical situation and existing experimental data.

***Keywords**: Radiator, Modeling, simulation, Heat transfer, Nanofluids, CFD*

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1. INTRODUCTION

CFD is a science that can be helpful for studying fluid flow, heat transfer, chemical reactions etc by solving mathematical equations with the help of numerical analysis. CFD employs a very simple principle of resolving the entire system in small cells or grids and applying governing equations on these discrete elements to find numerical solutions regarding pressure distribution temperature gradients, flow parameters and the like in a shorter time at a lower cost because of reduced required experimental work. Automobile Radiator are becoming highly power-packed with increasing power to weight or volume ratio. Increased demand on power packed radiators, which can dissipate maximum amount of heat for any given space. Nanofluids give higher heat transfer rate than base fluids. This study involves CFD simulation of the mass flow rate of air and heat transfer of fin and tube heat exchanger (radiator) at various coolants (Nanofluids). In this paper, CFD used to simulate flow and heat transfer in tube and fin heat exchanger. Coolants flow through the tubes of the radiator, heat is transferred through the fins and tube walls to the air by conduction and convection. The radiator of maruti van car is analyzed to get heat transfer rate at different mass flow rate of air and coolants in this study. CFD analysis gives accurate and exact result.

2. EXPERIMENTAL HEAT TRANSFER CALCULATION

Radiator is considered as a tube and fin type heat exchanger and Experimental maruti van radiator with dimension are as under.

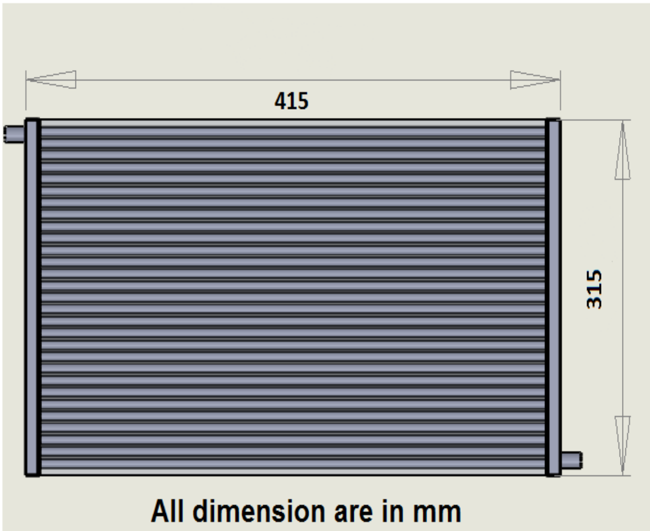

Fig 2.1: Experimental Radiator

Shell (fin) side Data:-
Media:-Air
Temperature:-30°C
Inlet Velocity: - 30 Kmph (Vehicle Speed)
Outlet Pressure: - 1.01325 bar

Tube Side Data:
Diameter of Tube: - 8 mm
No. of Tubes: - 57
Media: - water + Ethanol (50%), Cuo/water and Tio_2/water
Temperature (Engine):- 107 °C
Mass flow rate of coolants:-2.5 Kg/s

Outlet Pressure: - 1.01325 bar

Mass flow rate, Overall Heat transfer co-efficient and Heat transfer Rate are calculated as per its respective equations are:

Table 1: Experimental Results of Company

Sr. no.	Velocity of Car Km ph	velocity of Car m/s	Coolants	Engine temperature inlet Tube Side (^{0}C)	Tube Side Outlet Temperate (^{0}C)(Experimental)	Fin Side inlet temperature (^{0}C)	Fin Side Outlet temperature (^{0}C)(Experimental)
1	30	8.33333	water+ Ethanol	107	101.90	30	120.33
2	50	13.88889		107	93.95	30	111.53
3	80	22.22222		107	77.85	30	87.55
4	100	27 .77778		107	76.33	30	89.23
5	30	8.33333	CuO/water	107	85.12	30	88.45
6	50	13.88889		107	79.88	30	86.53
7	80	22.22222		107	76.53	30	87.65
8	100	27 .77778		107	74.93	30	91.50
9	30	8.33333	Tio_2/water	107	86.25	30	88.33
10	50	13.88889		107	81.53	30	85.89
11	80	22.22222		107	77.10	30	87.55
12	100	27 .77778		107	75.33	30	90.73

Mass flow rate m =A $*$ V $*$ ∮, Overall Heat transfer Co-efficient $1/U = 1/h_i + 1/h_o$, Heat transfer area A = n$*$∏$*$ d $*$ L + (n1$*$l1$*$b1 – n $*$∏$*$ d), *LMTD* $\Theta m = \Theta 1 - \Theta 2 / \ln (\Theta 1/\Theta 2)$ and Heat transfer rate $Q = U A \Theta m$

Total heat transfer rate of Cuo/water at 1.2 Kg/s mass flow rate of Air $Q = U A \Theta m$
$= 2535 * 0.989942 * 33.87$
$Q = 8.499 * 10^4 KW$

Table 2: Summary of Experimental Results

Sr. no.	Engine temperature inlet Tube Side (^{0}C)	velocity of Car m/s	Coolants	Tube Side Outlet Temperate (^{0}C)(Experimental)	Fin Side Outlet temperature (^{0}C)(Experimental)	Mass flow rate of air Kg/s	Heat transfer rate (KW)
1	107	8.33333	water+ Ethanol	101.90	120.33	1.2	90.12
2	107	13.88889		93.25	111.53	2	92.20
3	107	22.22222		77.85	87.55	3	$1.91 * 10^5$
4	107	27.77778		76.33	89.23	4	$2.18 * 10^5$
5	107	8.33333	CuO/ water	85.12	88.45	1.2	$8.49 * 10^4$
6	107	13.88889		79.88	86.53	2	$1.33*10^5$
7	107	22.22222		76.53	87.65	3	$1.985*10^5$
8	107	27.77778		74.33	91.50	4	$2.386*10^5$
9	107	8.33333	Tio_2/water	86.25	88.33	1.2	$8.398*10^4$
10	107	13.88889		81.53	85.89	2	$1.277*10^5$
11	107	22.22222		77.10	87.55	3	$1.93 * 10^5$
12	107	27.77778		75.33	90.73	4	$2.26 * 10^5$

3. CFD ANALYSIS

3.1 Modeling of Radiator

We perform first solid modeling of automobile radiator in Cre O software and then this solid model is transferred to Hypermesh_64 for water type geometric clean up and this geometric model is transferred to STAR CCM+ for meshing and CFD Analysis.

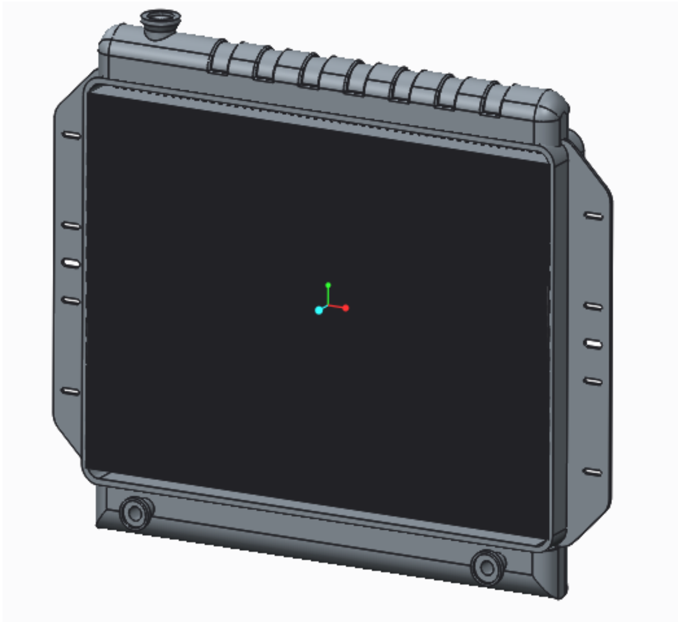

Fig.3.1.1: 3 D Model of Maruti Van Radiator

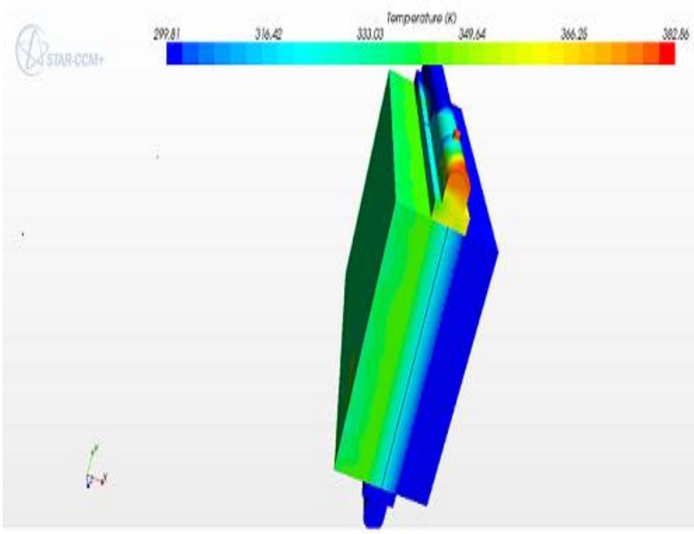

Fig.3.1.2: Water type geometric clean up model of radiator

3.2 CFD Analysis of Radiator in Star CCM+

In STAR CCM+, First of all selecting fluid physical model then creates and assign physical continuum. Specify porosity coefficients and then create actual heat exchanger interface. Then specify heat exchanger data specification via UAG table. Create reports, monitors and plots and running the simulation and visualising the results. Using different mass flow rate of air and different coolants as a base fluid and nanofluids, CFD analysis performed.

3.2.1. Result Analysis

Case-1: Mass flow rate of air 1.2 Kg/s and three coolants (base fluid and nanofluids)

Shell (fin) Side Data:-
Media:-Air
Temperature:-30°C
Inlet Velocity: - 30 Kmph (Vehicle Speed)
Flow: Turbulent

Tube Side Data:
Diameter of Tube: - 8 mm
No. of Tubes: - 57
Media: - water + Ethanol (50%), Cuo/water (10%/90%) and Tio_2/water (10%/90%)
Temperature (Engine):- 107 °C
Mass flow rate of coolants:-2.5 Kg/s
Flow: Turbulent

Tube Side Results:

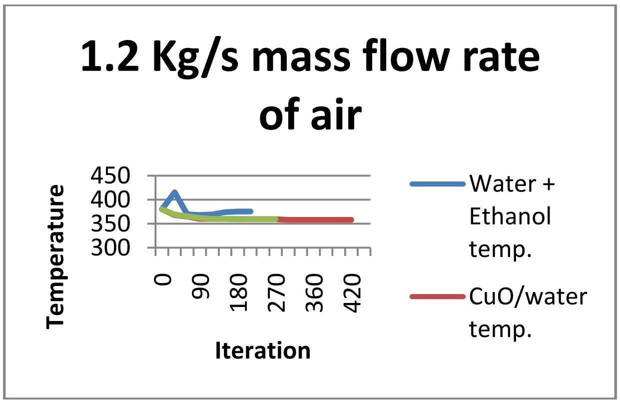

Fig: 3.2.1.1. Coolants Temperature Comparision Graph Shell side results

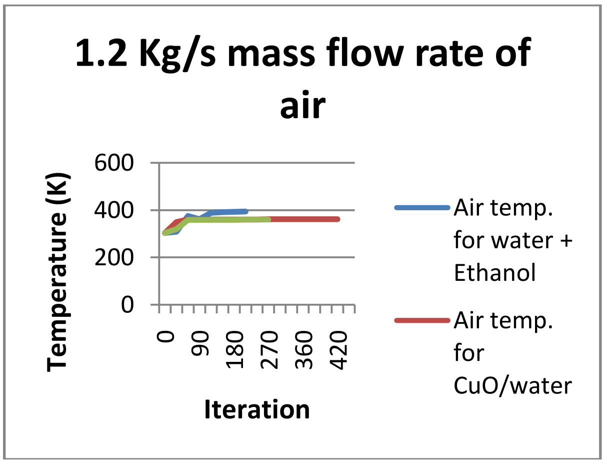

Fig: 3.2.1.2. Air Temperature comparision Graph

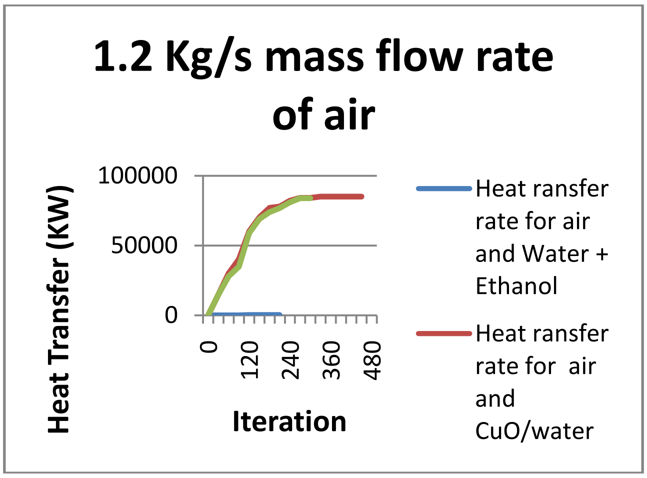

Fig: 3.2.1.2. Heat Transfer Comparision Graph

Case-2: Mass flow rate of air 4 Kg/s and three coolants (base fluid and nanofluids)

Shell (fin) side Data:-
Media:-Air
Temperature:-30°C
Inlet Velocity: - 100 Kmph (Vehicle Speed)
Flow: Turbulent

Tube Side Data:
Diameter of Tube: - 8 mm
No. of Tubes: - 57
Media: - water + Ethanol (50%), CuO/water (10%/90%) and Tio_2/water (10%/90%)

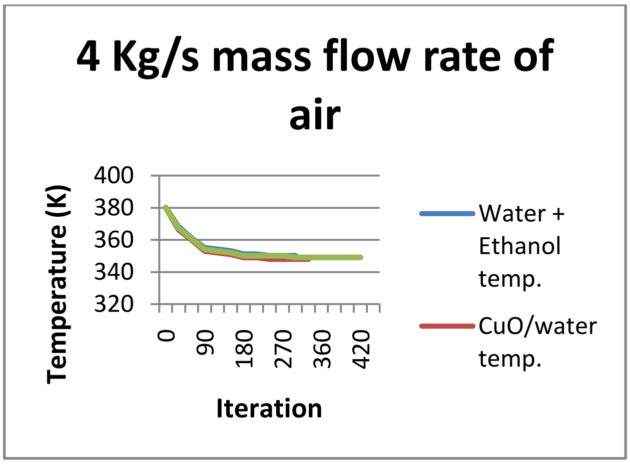

Fig: 3.2.1.4. Coolants Temperature Comparision Graph

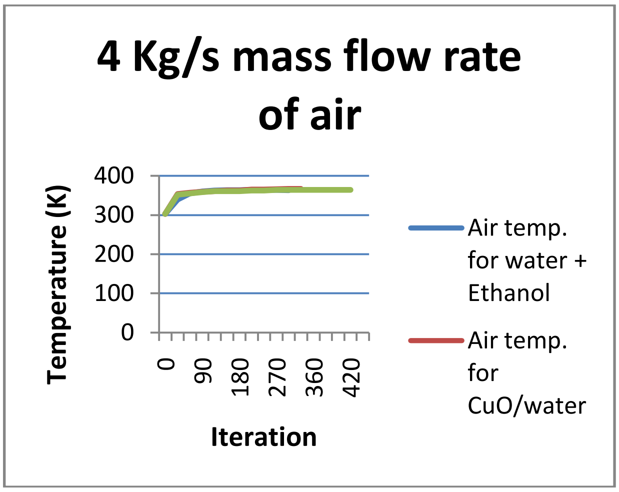

Fig: 3.2.1.5. Air Temperature comparision Graph

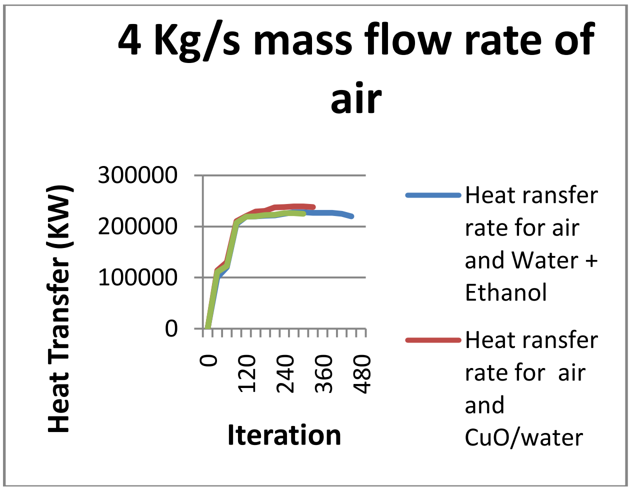

Fig: 3.2.1.6. Heat Transfer Comparision Graph

From above STAR CCM+ analysis there is a 380 K inlet temperatures of water+ ethanol, CuO/water and Tio_2/water decreased up to 375 K, 357 K and 359 K respectively and heat transfer rate higher in nanofluids than base fluids at 1.2 mass flow rate of air. So finally lower coolants outlet temperature and higher heat transfer occurs for CuO/water nanofluid at 4 Kg/s mass flow rate of air.

Table 3: CFD result summary

Sr. no.	Velocity of Car Km ph	Mass flow rate of air Kg/s	Coolants	Engine temperature inlet Tube Side (^0C)	Tube Side Outlet Temperate (^0C)	Fin Side Outlet temperature (^0C)	Heat transfer rate (KW)	
1	30	1.2	water+ Ethanol	107	102	121	90	120.33
2	50	2		107	94	113	92	111.53
3	80	3		107	77	88	$1.90 *10^5$	87.55
4	100	4		107	76.5	91	$2.2 *10^5$	89.23
5	30	1.2	CuO/water	107	84	90	$8.5 *10^4$	88.45
6	50	2		107	79	86	$1.32*10^5$	86.53
7	80	3		107	76	87	$1.98*10^5$	87.65
8	100	4		107	74	92	$2.38*10^5$	91.50
9	30	1.2	Tio_2/water	107	87	89	$8.4*10^4$	86.25
10	50	2		107	81	85	$1.28*10^5$	81.10
11	80	3		107	76	87	$1.92 * 10^5$	76.95
12	100	4		107	75	91	$2.25 * 10^5$	76.25

3.4 CFD Validation

To validate the CFD results, there is a comparison between CFD result and experimental data which is given below by table:

Table 4: Comparison between Experimental data and CFD results

Sr. no.	Coolants	Velocity of Car Km ph	Engine outlet temperature Tube Side (^0C) (Experimental	Engine outlet temperature Tube Side (^0C) by CFD	Fin Side Outlet temperature (^0C) (Experimental)	Fin Side Outlet temperature (^0C) by CFD	Percentage of variation in tube side temp.	Percentage of variation in fin side temp.
1	water+ Ethanol	30	101.90	102	120.33	121	0.10	0.33
2		50	93.25	94	111.53	113	0.75	1.47
3		80	77.85	77	87.55	88	0.85	0.45
4		100	76.33	76.5	89.23	91	0.15	0.77
5	CuO/water	30	85.12	84	88.45	90	1.12	0.55
6		50	79.88	79	86.53	86	0.12	0.53
7		80	76.53	76	87.65	87	0.53	0.65
8		100	74.33	74	91.50	92	0.33	0.50
9	Tio_2/water	30	86.25	87	88.33	89	0.75	0.67
10		50	81.53	81	85.89	85	0.53	0.89
11		80	77.10	76	87.55	87	1.10	0.55
12		100	75.33	75	90.73	91	0.33	0.27

4. CONCLUSIONS

The fluid flow and heat transfer analysis of an automobile radiator is successfully carried out by CFD analysis using STAR CCM+ software. So using CuO /water nanofluid as a coolant and 4 Kg/s mass flow rate of air optimum performance of radiator can be performed. CFD Analysis results fairly matches with the experimental results which show that CFD analysis is a good tool for avoiding costly and time consuming experimental work.

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