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Study of the Effect of Mass flow Rate of Air on Heat Transfer Rate in automobile radiator by CFD simulation using CFX.

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Abstract

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 ComputationalFluidDynamics (CFD) modeling simulation of mass flow rate of air passing across the tubes of an automotive radiator. An introduction to mass flow rate and its significance was elaborated in order to understand the complications involved in the research and thereafter arrive at the objectives. Knowing the geometry of tube in radiator is the crucial application of CFD to numerically model and thereby analyze the simulation. The Air flow simulation is conducted using commercial software ANSYS 12.1 The CFD process starts with defining the geometry using the CAD software 'Solid works' 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 analysed, compared and verified according to known physical situation and existing experimental data. The results obtained serve as good database for the future investigations.

Key words: Modeling, Simulation, CFD, Heating, Convection, Radiation, Heat transfer.

1. Introduction

There are two main types of cooling system for keeping the temperature of the automobile engine within the reasonable limits. These are the direct cooling or Air Cooling and the indirect Air or Water cooling systems. The indirect air cooling is called water cooling system. In indirect cooling, as the coolant flows 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 Tata indigo diesel car is analyzed to get heat transfer rate at different air velocity in this study.

2. Experimental heat transfer calculation

Radiator is considered as a Shell and Tube Type Heat Exchanger and Overall Dimensional Experimental Radiator are as under.

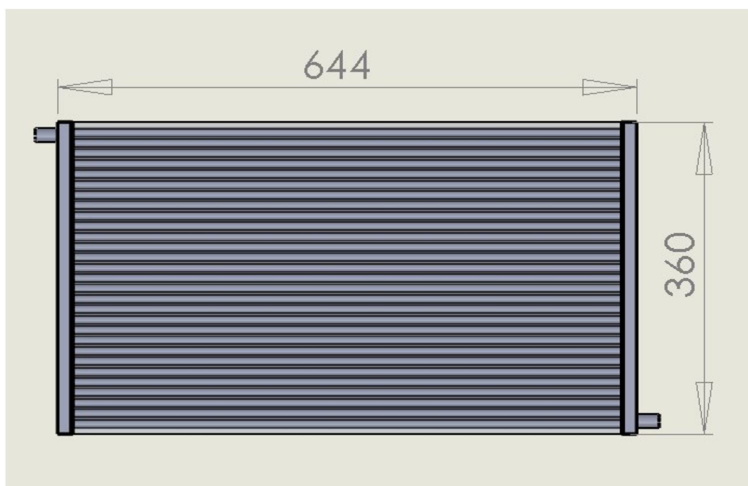

Figure (1): Experimental heat exchanger

Shell Side Data:-

Media: - Air
Temperature: - 35°C
Inlet Velocity: - 30 Kmph (Vehicle Speed)
Outlet Pressure: - 1.01325 bar

Tube Side Data:-

Diameter of Tube: - 7 mm

Table A: Experimental Results Given by Company

Sr No.	Velocity of Car Kmph	Velocity of Car m/s	Engine Temperature Tube Side Inlet	Tube Side Outlet Temperature (Experimental)	Shell Side inlet temperature	Shell Side Outlet temperature (Experimental)
1	30	8.333333333	95	87.12	35	60.52
2	40	11.11111111	95	86.92	35	62.15
3	50	13.88888889	95	86.52	35	63.52
4	60	16.66666667	95	86.14	35	63.89
5	70	19.44444444	95	85.95	35	64.52
6	80	22.22222222	95	85.14	35	65.27
7	90	25	95	84.96	35	66.29
8	100	27.77777778	95	84.52	35	68.26

No. of Tubes: - 29
Media: - Water + Ethanol (50%)
Temperature (Engine):- 95 °C
Inlet Velocity: - 2m/s
Outlet Pressure: - 1.01325 bar

Mass Flow Rate, Heat Transfer Rate and Overall Heat transfer Co-efficient are calculated as per its respective equations e.g. $m = A * V * \rho$, $Q = m * C_p * \Delta T$ and

$$U = \frac{Q}{A * (T_{outlet} - T_{mean})}$$

Table B: Experimental Result summary

Sr No.	Velocity of Car Kmph	Engine Temperature Tube Side Inlet	Tube Side Outlet Temperature	Shell Side inlet temperature	Shell Side Outlet temperature	Mass of Air(m)	Heat Transfer Rate
1	30	95	87.12	35	60.52	2.013	53.3696625
2	40	95	86.92	35	62.15	2.684	76.4727964
3	50	95	86.52	35	63.52	3.355	98.200179
4	60	95	86.14	35	63.89	4.026	121.7438244
5	70	95	85.95	35	64.52	4.697	143.267894
6	80	95	85.14	35	65.27	5.368	169.5901504
7	90	95	84.96	35	66.29	6.039	195.9124068
8	100	95	84.52	35	68.26	6.71	231.980133

3. CFD analysis

3.1 Modeling of radiator

After performing simple calculation, the modeling has been performed on the Solid works 2009 version and then after the analysis work has been performed on the ANSYS12.0 version**.**

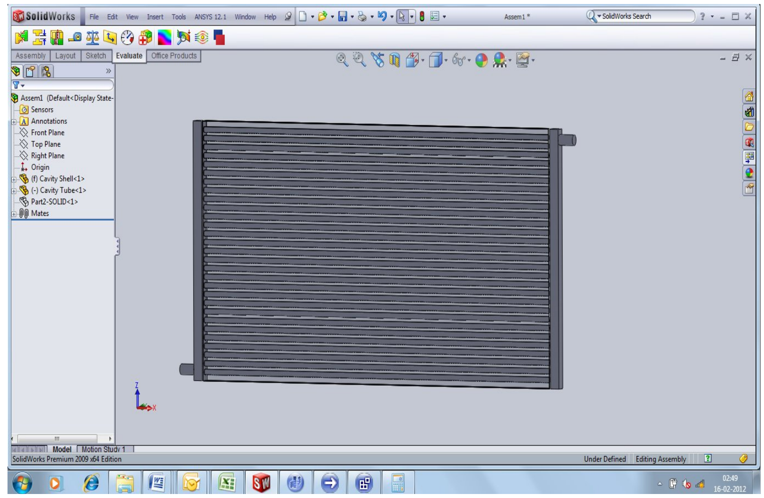

Figure (2): CAD model of radiator

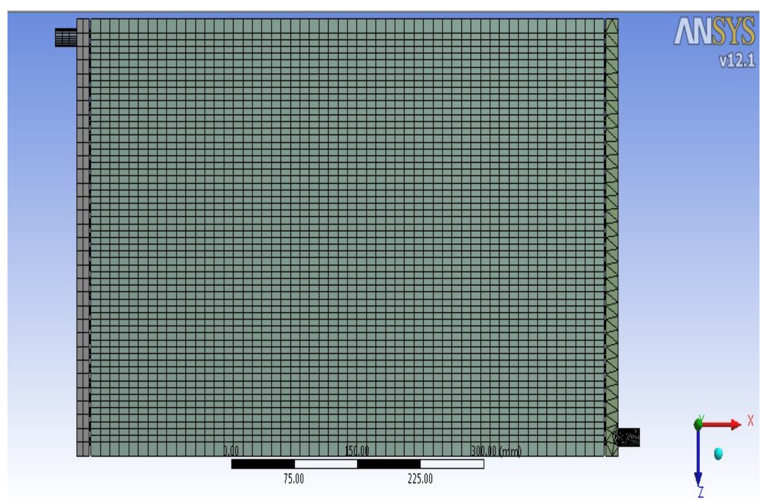

Figure (3): Meshed model of radiator

3.2 CFD analysis

The Cavity Pattern method is used for CFD Analysis of radiator in this study. In cavity model, there are basically two Domains. D-1:-Water with addition of glycols & D- 2:- Air Domain The input data and boundary conditions are chosen from the study of Changhua Lin and Jeffrey Saunders [5]. The properties of air and

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coolant were defined for standard conditions and kept constant throughout the analysis.

3.3 Results of Analysis

3.3.1 Tube Side Results: -

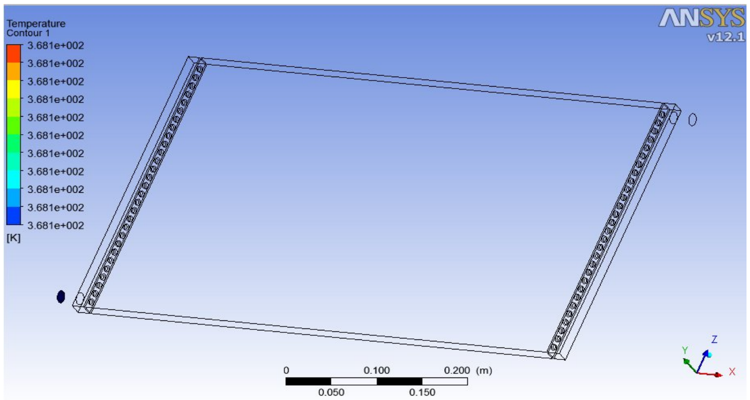

Figure (4): Inlet Temperature:-368*F (95* C)

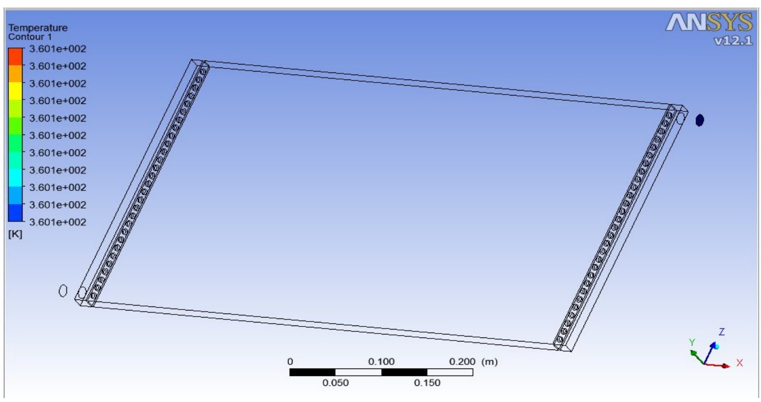

Figure (5): Outside Temperature:-359.94*F (86.94* C)

3.3.2 Shell Side Results:-

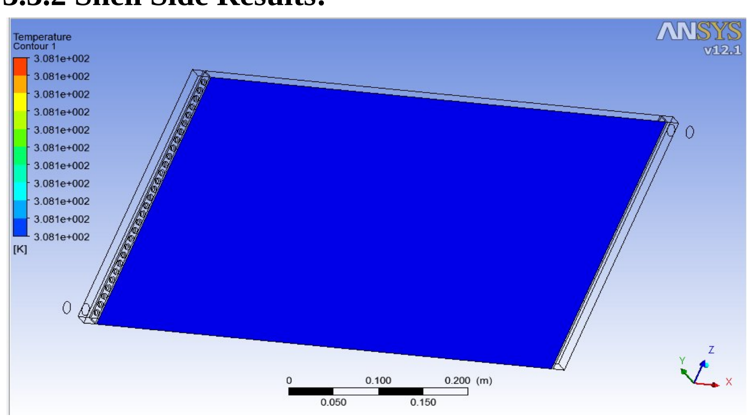

Figure (6): Inlet Temperature:-308*F (35* C)

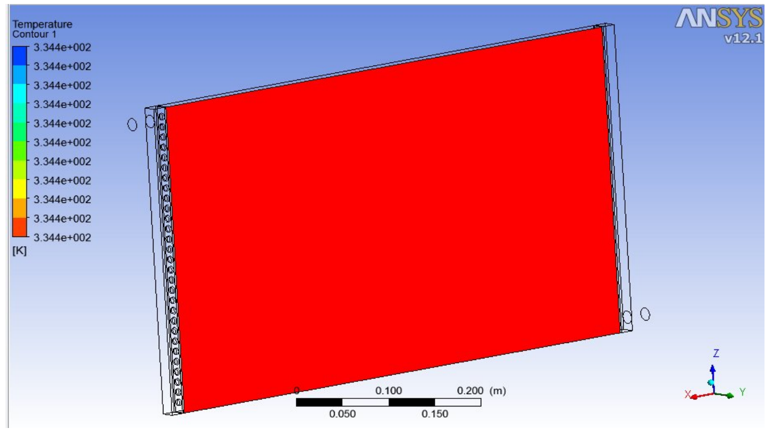

Figure (7): Outside Temperature:-334.25*F (61.25* C)

As Per above Procedure, We have done 8 iteration for different Velocity and inlet temperature configuration which results are as below.

Table C: CFD Result summary

Sr No.	Velocity of Car Kmph	Engine Temperature Tube Side Inlet	Tube Side Outlet Temperature	Shell Side inlet temperature	Shell Side Outlet temperature	Mass of Air(m)	Heat Transfer Coefficient	Thermal Efficiency
1	30	95	86.94	35	61.25	2.013	53.3696625	42.857143
2	40	95	86.652	35	63.21	2.684	76.4727964	44.629014
3	50	95	86.24	35	63.98	3.355	98.200179	45.295405
4	60	95	85.96	35	64.94	4.026	121.7438244	46.104096
5	70	95	85.79	35	65.2	4.697	143.267894	46.319018
6	80	95	84.15	35	66.28	5.368	169.5901504	47.193724
7	90	95	83.86	35	67.12	6.039	195.9124068	47.854589
8	100	95	83.15	35	69.23	6.71	231.980133	49.443883

3.4 CFD Validation

To validate the CFD results, comparisons were drawn between obtained results and received experimental data which is given below.

Table D: Comparison of Experimental results and CFD Results

Sr No.	Velocity of Car Kmph	Engine Temperature Tube Side Inlet	Tube Side Outlet Temperature (Experimental)	Tube Side Outlet Temperature	Shell Side inlet temperature	Shell Side Outlet temperature (Experimental)	Shell Side Outlet temperature	Percentage of variation Tube Side Temperature	Percentage of variation Shell Side Temperature
1	30	95	87.12	86.94	35	60.52	61.25	0.2066	1.2062
2	40	95	86.92	86.652	35	62.15	63.21	0.3083	1.6954
3	50	95	86.52	86.24	35	63.52	63.98	0.3236	0.7241
4	60	95	86.14	85.96	35	63.89	64.94	0.2089	1.6434
5	70	95	85.95	85.79	35	64.52	65.2	0.1861	1.0539
6	80	95	85.14	84.15	35	65.27	66.28	1.1745	1.5474
7	90	95	84.96	83.86	35	66.29	67.12	1.2947	1.2520
8	100	95	84.52	83.15	35	68.26	69.23	1.6209	1.4210

4. Conclusion and future scope

The heat transfer analysis of an automotive radiator is successfully carried out using numerical simulation built in commercial software ANSYS 12.1. Above Results Shows that the heat transfer rate as well as efficiency is increased, as the air mass flow rate increases. With the computational time and resources available, the results obtained were found to be satisfactory. However, to account for the variation of the inlet conditions with time as in practical cases, transient analysis can be done.

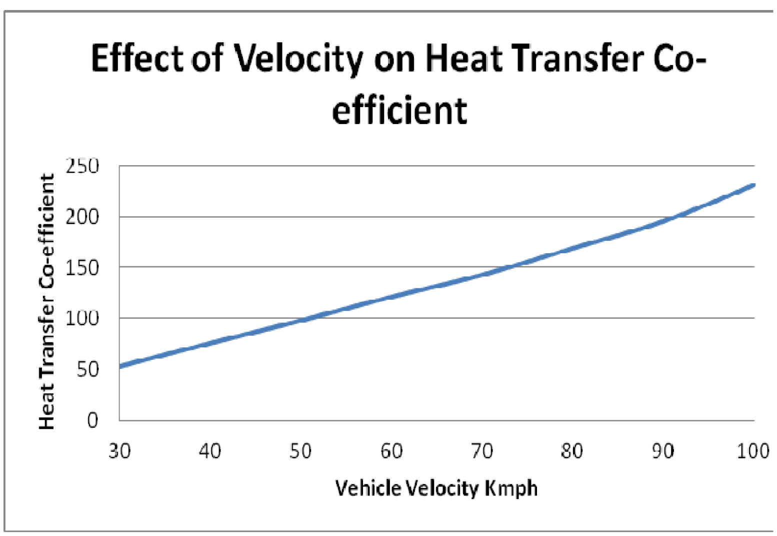

Figure (8): Velocity v/s heat transfer rate

5. References

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