Experimental Investigation of Optimum Tubes Profile Structure for Radiator Compactness

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Abstract-
Automotive engine cooling system takes care of excess heat produced during engine operation. Radiators are used for cooling internal combustion engines, piston engine aircrafts, railway locomotives, stationary gearing plants or any similar use in industrial and domestic applications. The flow behavior of coolant fluids in radiator tubes is of great importance to the designer. The proposed work throws light on geometrical aspects which are used in the core of radiators and their reflections on performance parameters of radiator. Also it focuses on geometric parameters optimization, coolant flow analysis through tubes which influences radiator performance and development of radiator prototype which generates the scope for reduced size and flexibility for coolant flow throughout the radiator.

Keywords- Radiator, Core, Tubes, Coolant flow, Nano Fluids.

I. INTRODUCTION

Modern automotive internal combustion engines generate a huge amount of heat. In order to prevent the overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat. The coolant is pumped through the engine, then after absorbing the heat of combustion is circulated to the radiator where the heat is transferred to the atmosphere. The cooled liquid is then transferred back into the engine to repeat the process.

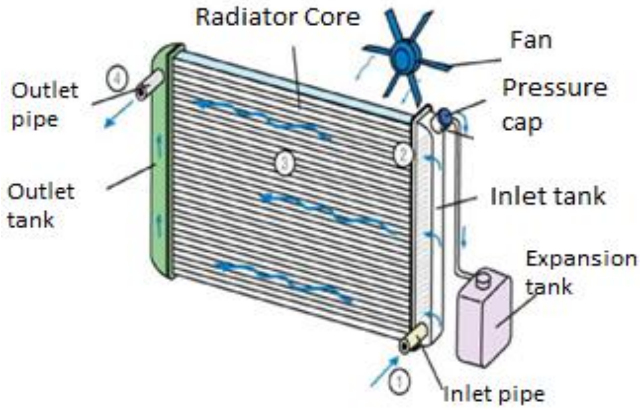


Fig. 1: Typical Radiator and its components

Though there are large usages of radiator, some difficulties and inconveniences arise while applying and installing them in particular applications. Several fields which are using radiators now facing certain issues related to it. These are may be due to its geometric or performance parameters. So this leads to study of the radiator, its functional parts, their designs and structures, arrangement of these into radiator assembly.

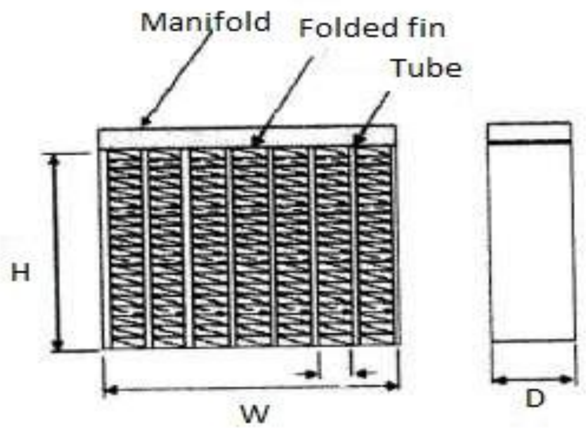


Fig. 2: Radiator geometry & nomenclature

Radiator is key component of engine cooling system. Recently compact sized radiators are highly demand in modern car industries. The problem of heat dissipation, overheating, chocking of water and energy losses are commonly occur in existing radiator and greatly reduce the engine efficiency. The changing of design parameter on Radiator fins, material, tube core and coolant flow arrangement may improve the heat transfer co-efficient and thermal conductivity of it. So, Radiator sizing is important factor while designing cooling system. Radiator size depends on heat load as well packaging space availability.

II. LITERATURE REVIEW

Mikk Maivel et.al.[1] presented work related to Laboratory measurements for the same size and type of radiator with parallel and serial connected panels for same conditions to calculate energy savings. Krunal Kayastha et.al. [2] proposed radiator having helical tubes structure and analyzed for two different pitches like 15mm and 20 mm. Two CAD models were compared at various mass flow rates like 2.3, 2.0, 1.0, 0.5 kg/sec in helical type tubes. C. Franklin [3] presented compact sized dual pass core radiator which involves arrangement of horizontal opposite flow with two directional pass having three tanks with flat tubes in the system. This resulted in increased area for heat transfer, splitting of pass direction and reduction in cooling time. Vahid Delavari et.al. [4] described the work related to use of flat tubes in radiator to carry out CFD simulation for heat transfer in nano fluids. The results gave idea about tube friction factor which increases as the concentration of nano particles in the nano fluid increased. A. Oliva et.al. [5] examined the effect of some geometrical parameters such as fin pitch, louver angle also the significance of coolant flow lay-out on the overall performance of radiator.

III. OBJECTIVES

The proposed work focuses on how to overcome the disadvantages of current radiator system which are related to size, weight, compactness, coolant flow arrangements and to achieve improvement. It consist study of geometric parameters of existing automobile radiator with its structure of tubes and core. Then development of prototypes of radiator based on existing tube structure keeping basic dimensions of radiator constant. Finally, experimental evaluation of performance of these radiators on standard test rig.

IV. DETAILS OF RADIATOR PROTOTYPES

Fig. 3: Existing Radiator Prototype

The parametric studies presented in this paper have been performed on a existing car radiator of 800cc.

The corresponding base line geometry is mentioned in table 1.

Core height	310 mm
Core width	320 mm
Core breadth	45 mm
Tube Rows	2
Total tubes	36
Tube cross section	circular
Tube height	310 mm
Tube diameter	6 mm

Table 1. Baseline geometry description of Existing Radiator under study.

Keeping basic dimension of existing radiator constant, prototype of radiator is developed having reduced number of rows and tubes in simplified way. During development intention is clear that tubes volume become constant in radiator core part.

Newly developed prototype gets reduced in number of rows and tubes. It is now having single row with 8 tubes. Volume of 36 tubes is equally converted into volume of 8 tubes. The calculation of geometrical parameters of developed prototype is as follows:

Volume of 36 tubes, $V_1 = 36\pi r_1^2 h$ **(1)**

After substituting values,

it gives $V_1 = 315541.57 \ mm^3$

After concerning with few Radiator Manufacturers, available tube diameters are listed out for simplified radiator prototype. For converting it in 8 no. of tubes, volume of newly manufactured single tube is evaluated as

$$V_2 = 39442.69 \ mm^3$$

Based on this volume, diameter of each tube is evaluated keeping initial and final height of tubes constant as follows;

$$r_2^2 = V_2 / (\pi h)$$

$$= 39442.69 / (\pi * 310)$$

$$= 40.5$$

Thus $r_2 = 6.36$ mm

and $d_2 = 12.73$ mm

In this way, new prototype of radiator 1 is prepared having single row with 8 tubes of 12.73 mm diameter of each tube.

Considering the performance regarding temperature drop material selected for tubes in manufactured radiator is copper.

Fig. 4: Fabricated prototype of Radiator 1

Core height	310 mm
Core width	320 mm
Core breadth	45 mm
Tube Rows	1
Total tubes	8
Tube cross section	circular
Tube height	310 mm
Tube diameter	12.73 mm

Table 2. Baseline geometry description of radiator prototype.

V. TESTING & RESULTS

For evaluating the performance of these two radiators standard test rig is developed which will give idea regarding effect of change in geometrical parameters on the performance of radiator. In testing set up, electrical heater is used as heat source which is kept in insulated steel tank.Also pump, rotameter, thermocouples, cooling fan, flow control valves and electric power consumption meter are incorporated into testing set up to carry out standard practice for evaluating radiator performance.

Fig. 5: Experimentation on Existing Radiator

The coolants used during testing of radiators are water, blend of water and ethylene glycol (50% + 50%) and nano fluid consisting of aluminium oxide as nano particles with different concentrations.

Those are as follows:

1. 2 % Al_2O_3 particles at glycol base.
2. 2.5 % Al_2O_3 particles at glycol base.
3. 3 % Al_2O_3 particles at glycol base.
4. 3.5 % Al_2O_3 particles at glycol base.

Case 1: Results for Existing Radiator

During conducting trial on existing car radiator i.e. first case of radiator having 36 tubes, nano fluids with Al_2O_3 particles of various concentrations are used. The difference between inlet and outlet temperature of radiator is plotted against the time steps through which temperature is reduced.

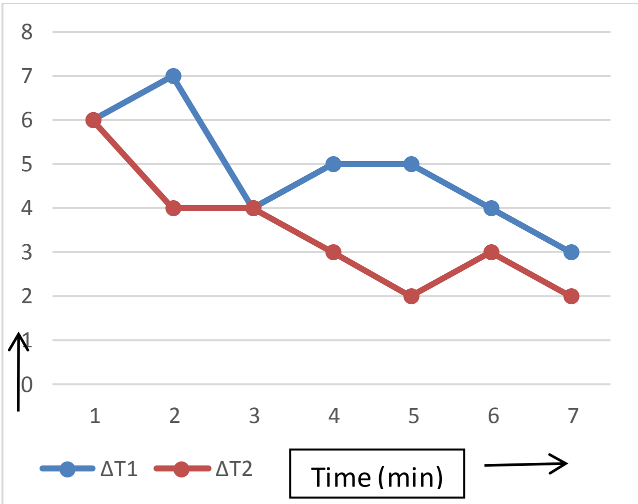
The coolant flow Q is maintained at 550 lph and air velocity at 2.4 m/s during all trials. Here,

ΔT1= difference between inlet and outlet temperature of radiator.

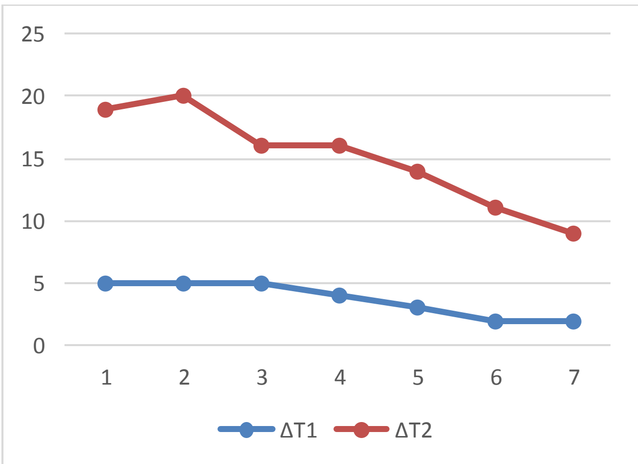
ΔT2= difference between inlet and outlet temperature of single reference tube of radiator.

The nature of Δt achieved through radiator for different coolants are as follows:

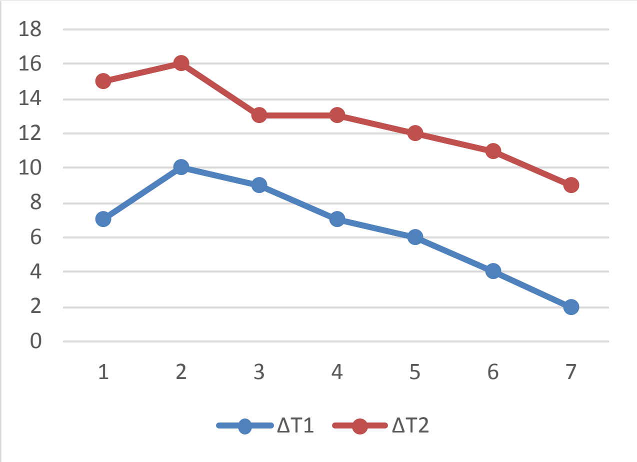
1. 2% Al_2O_3 Nanofluid



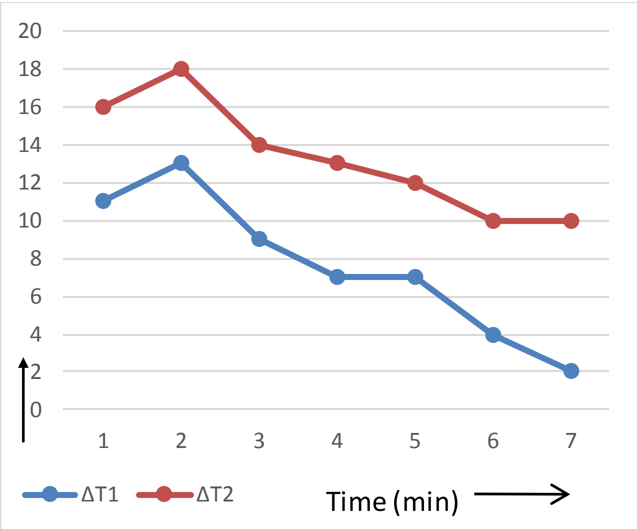
2. 2.5% Al_2O_3 Nanofluid



3. 3% Al_2O_3 Nanofluid



4. 3.5% Al_2O_3 Nanofluid



Case 2: Results for Radiator 1

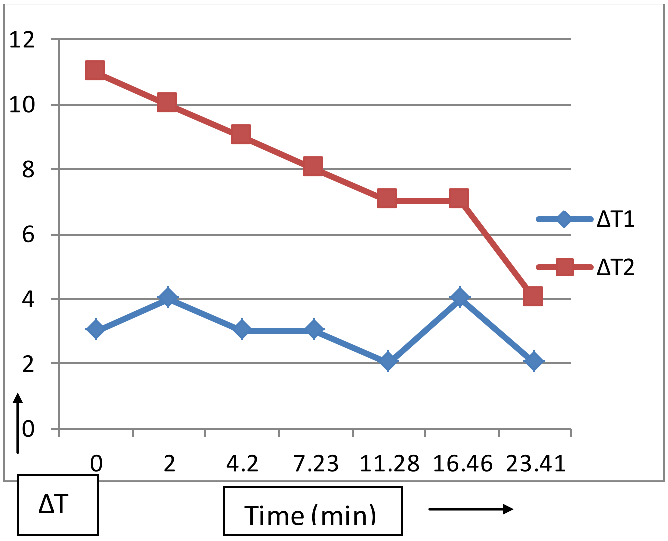
After conducting trials on existing car prototype of radiator with various coolants, for fabricated Radiator 1, temperatures at radiator inlet and outlet are noted down for each coolant and that temperature difference is plotted against time elapsed during temperature decrement.
The coolant flow Q is maintained at 550 lph and air velocity at 2.4 m/s during all trials.
Here,

$\Delta T1$= difference between inlet and outlet temperature of radiator.
$\Delta T2$= difference between inlet and outlet temperature of single reference tube of radiator.

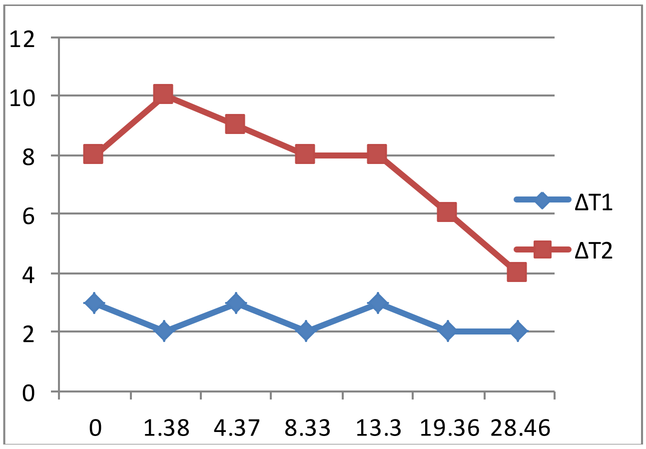
Fig. 6: Experimentation on Radiator 1

The nature of Δt achieved through radiator for different coolants are as follows:

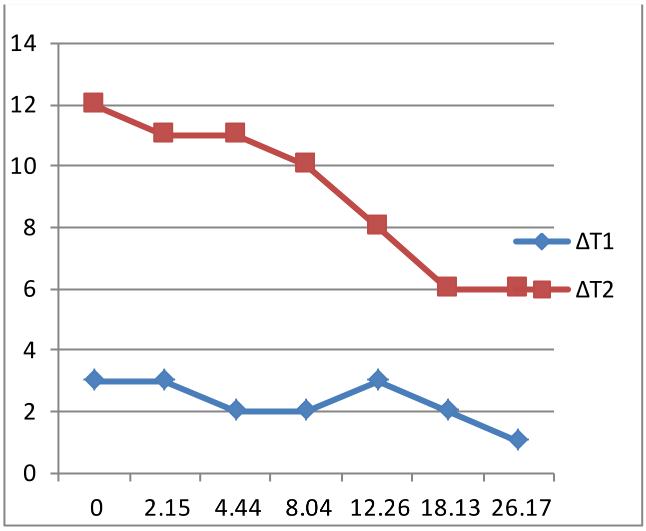
1. Water + Ethylene Glycol



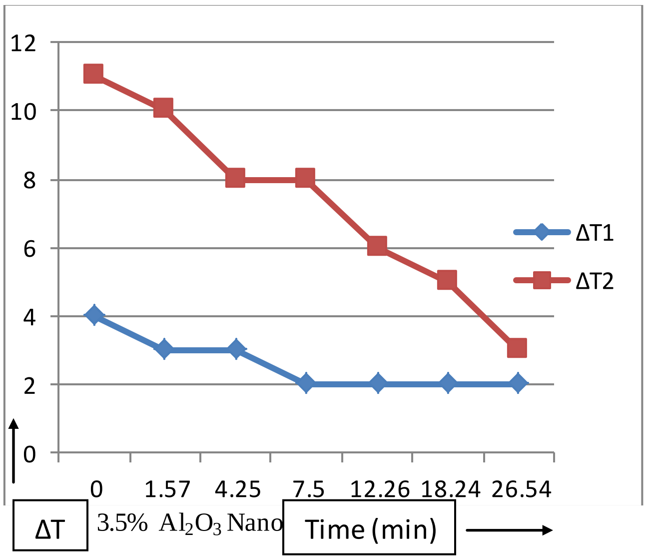
2. 2% Al_2O_3 Nanofluid



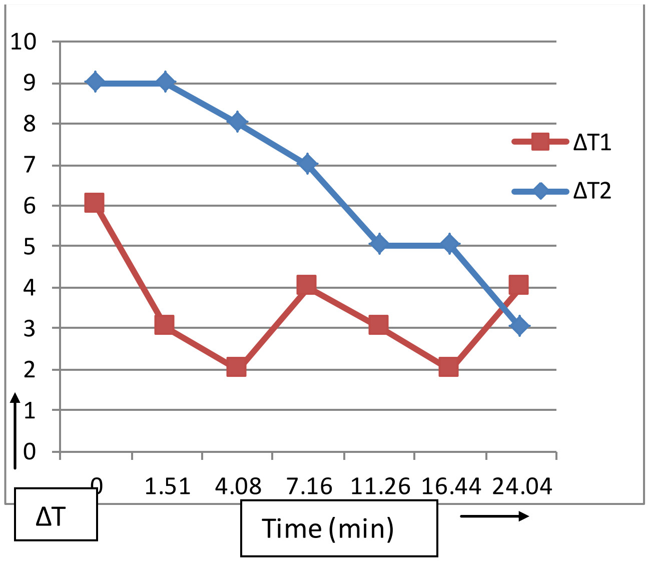
3. 2.5% Al_2O_3 Nanofluid



4. 3% Al_2O_3 Nanofluid



3.5% Al_2O_3 Nano



VI. DISCUSSIONS

These are ΔT curves generated for the first and second radiator prototype and can be used to understand the small changes in temperature drop based on changes in tube geometry for different types of coolant. It can be seen from the trials conducted up till now that for the two different tubes geometry of radiator, the temperature reduction is achieved with time. After heater is stopped, temperature of fluids started to decrease as time passes. For particular steps of heater temperatures, radiator inlet and outlet temperatures are recorded for each case. These are ΔT values plotted against that particular time of decreased heater temperature. Further, this temperature difference is getting sharper with the changes in coolant fluids. For increased percentage of nano particles concentration, there is increase in Δt.

VII. FUTURE SCOPE OF PROJECT

Additionally, the development of radiator prototype (Radiator 2) for the third case, its modeling, parametric studies, manufacturing and experimental performance evaluation will be carried out at standard test rig.

This will have two inlet and outlet tanks, one is for regular coolant and another for nano fluid. Inner tanks as shown in above fig. 7 will give passage to nano fluid with tubes having higher diameter than original tubes. These two series of tubes are going to surround each other and forms the concentric tubes structure. Inner series of tubes will provide passage to regular coolant and outer to nano fluid.

Proposed CAD model for Radiator 2 is as follow:

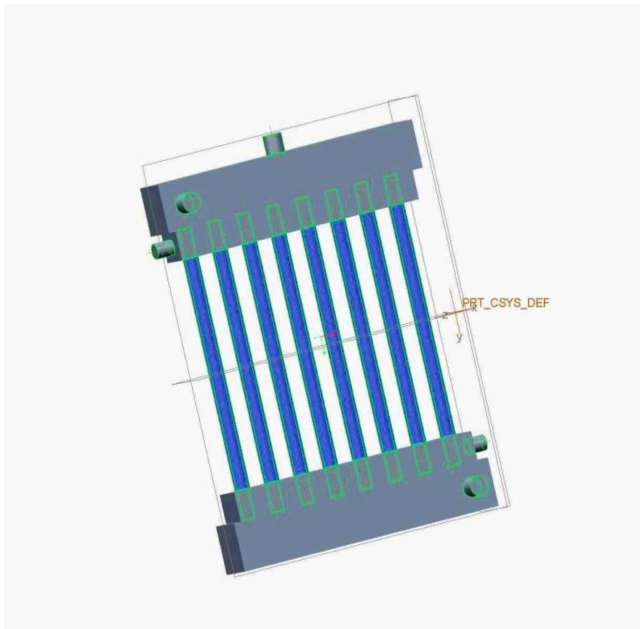


Fig. 7: CAD model for Radiator 2

Such prototype of radiator will get manufactured and again tested for its performance on the standard test rig. Similar coolants and nano fluids will be used for this purpose as that of previous two cases. Outcomes of all these trials on test set up will give idea about how radiators having different tube arrangement in the core are behaving to operating conditions. Comparison of all these trials (Radiator 1 and Radiator 2) and their results will form the basis to draw the conclusion of the work.

Also natural frequencies of these prototypes can be studied by using analysis tools. As there are possibilities of generation of vibrations during experimentation within set up, these radiators can be examined for effects of these sorts of vibrations. So this develops scope to study the vibrations related to radiators in the automotive engine cooling system.

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