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Design and Development Cases of Tubes Structure for Automobile Radiator Performance and Compactness

Vishal V. Kulkarni
Department of Mechanical Engineering.
JSPM's Jayawantrao Sawant College of Engg.
Savitribai Phule Pune University, Pune, India.

Abhijeet S. Dhakane
Department of Mechanical Engineering.
JSPM's Jayawantrao Sawant College of Engg.
Savitribai Phule Pune University, Pune, India.

***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. Also it focuses on developments in geometric parameters of tubes, flow of coolant through tubes which influences radiator performance. Finally case studies of radiator prototypes are proposed 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.

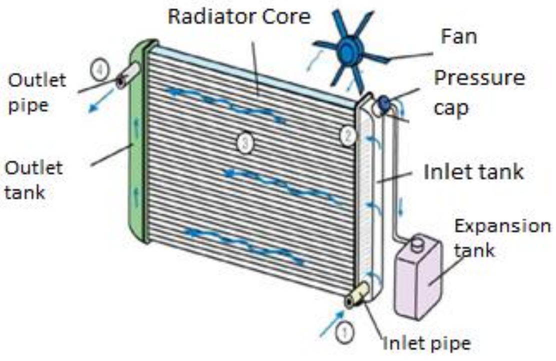

Fig. 1: Typical Radiator and its components

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.

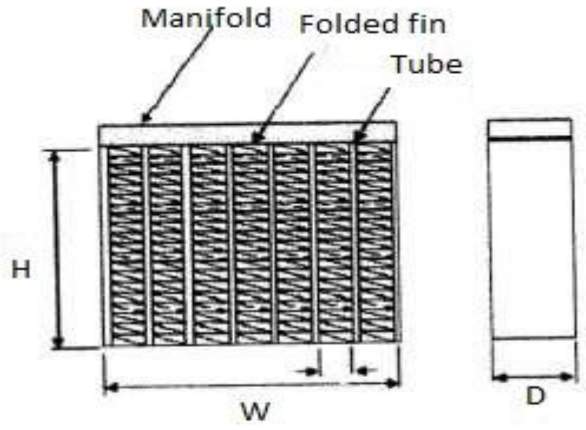

Fig. 2: Radiator geometry & nomenclature

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.

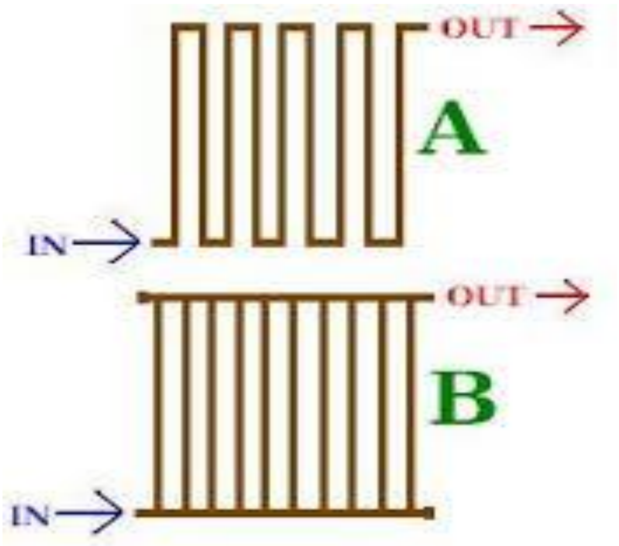

Fig. 3: Serial and parallel connected panels in Radiators.

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.

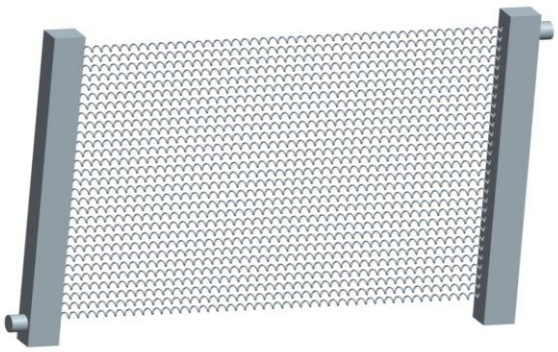
Fig. 4: Helical tubes structure in Radiator.

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.


Fig. 5: Dual Pass Core Radiator

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. It includes the case studies of such prototypes which can form the basis to invent possible solutions on problems related to automotive engine cooling system.

IV. DETAILS OF RADIATOR PROTOTYPES

The parametric studies presented in this paper have been performed on a existing car radiator of 800 cc which is shown in below fig. 6.


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Fig. 6: Existing Radiator Prototype.

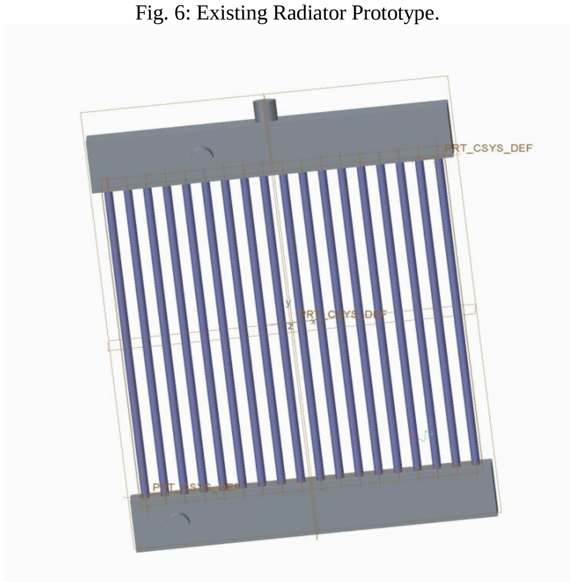
Fig. 7: CAD model of existing radiator.

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Table 1. Geometry description of Existing Radiator under study.

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
Tube thickness	1 mm

The CAD model for existing radiator having above geometrical specifications is as shown in fig. 7.

Details of Radiator 1

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 $V_1 = 315541.57 \text{ mm}^3$

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

$$V_2 = 39442.69 \text{ mm}^3$$

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

Table 2. Geometry description of radiator 1 prototype.

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
Tube thickness	1 mm

Using above geometrical specifications the CAD model for radiator 1 is developed.

Details of Radiator 2

This is another case of Radiator having typical structure of tubes in the core. It features concentric tube arrangement for allowing passage to flow of more than one fluid. Again this is developed based on geometry of the Radiator 1 as discussed in previous case. As there is tube in tube arrangement, this will get first tried in simple previous radiator 1 model.

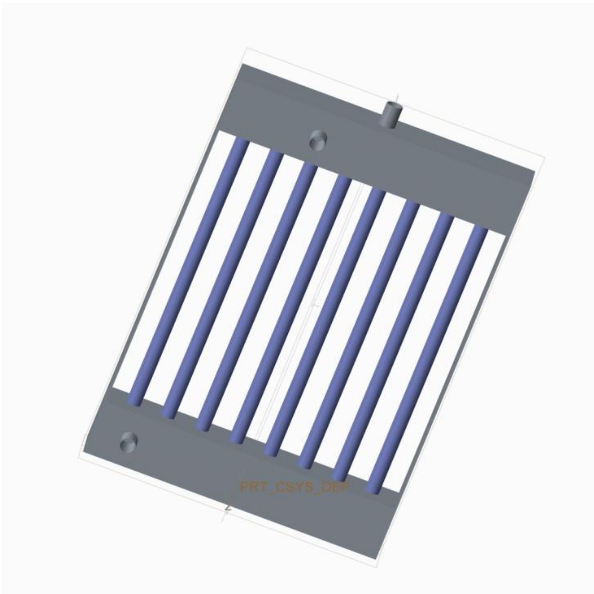

Fig. 8: CAD model of radiato1 prototype.

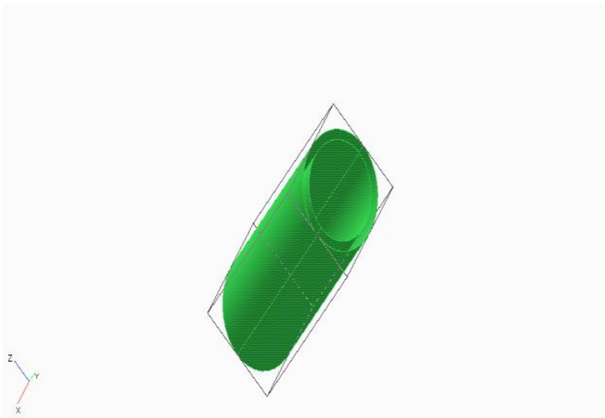

Fig. 9: Proposed form of concentric tubes.

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Changes are incorporated considering the arrangements of flow of fluids and ease of manufacturing the upper and lower tanks in radiator. Here the outer tube is reduced in height. So if the height of inner tube is say 300 mm, then height of surrounding tube is say for example 240 mm. This structure can provide two separate tanks for two different fluids.

The idea of nature of inner and outer tubes is illustrated in following CAD models:

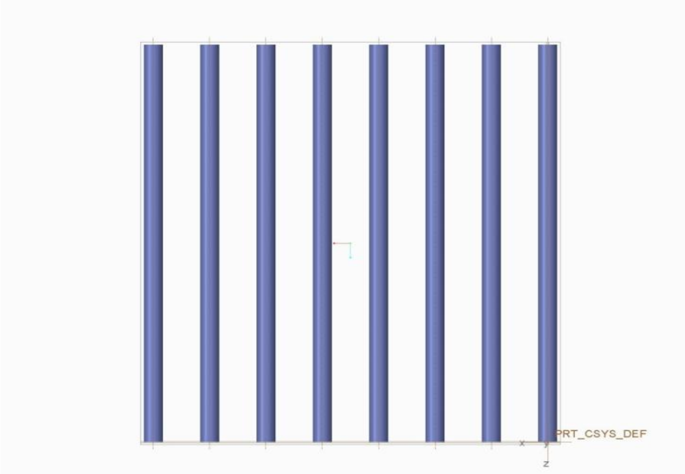

Fig. 10: CAD model for inner tubes.

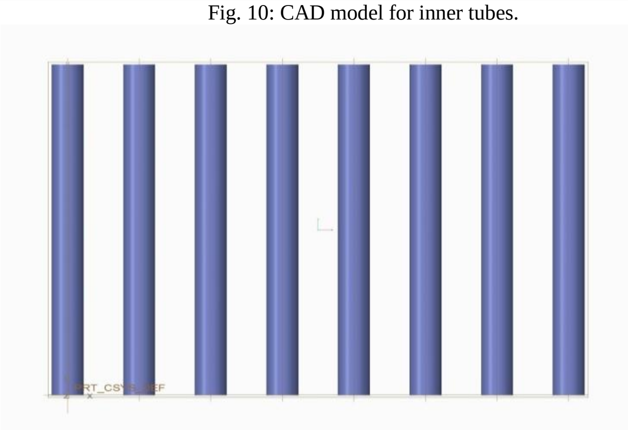

Fig. 11: CAD model for outer tubes.

Based on this tubes profile, radiator 2 prototype is decided. This will have two inlet and outlet tanks for two separate fluids/coolants for example say regular coolant and another for nanofluid. Inner tanks as shown will give passage to nanofluid with tubes having higher diameter than original tubes or vice versa. 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 nanofluid or it may reverse. The outer tubes can carry the circulation of fluid through the pipes joining to their upper and lower tanks. The CAD model of such a typical tubes structure is as shown below:

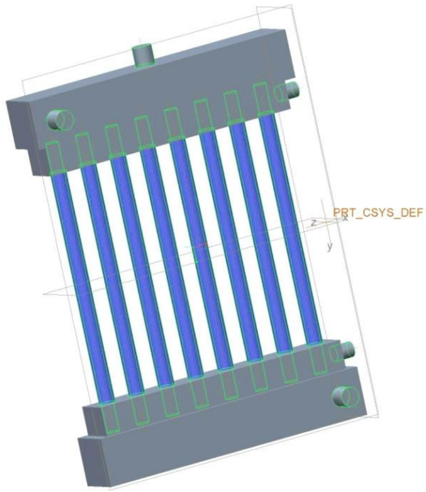

Fig. 12: CAD model for Radiator 2.

For finalizing the geometrical specifications of this radiator 2 prototype again the previously studied Existing radiator and Radiator 1 prototype is referred.

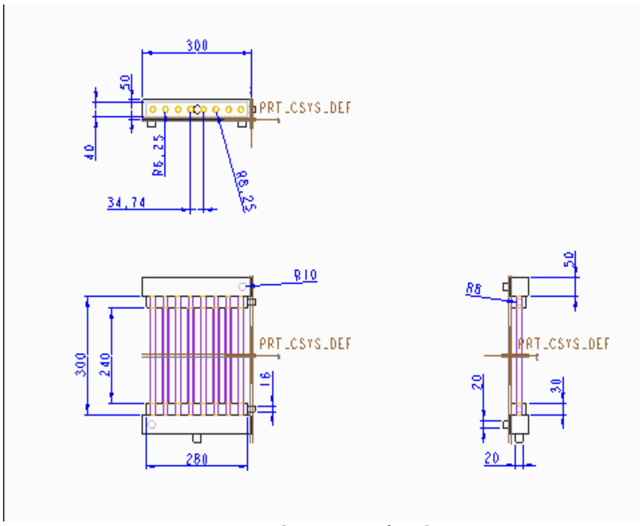

Fig. 10: Detail Drawing of Radiator 2 prototype.

V. CONCLUSIONS

Literatures indicate the different structures of tubes and core which are used in automobile radiators; also how these are going to contribute for radiator performance and improvements in shape and size of it. Based on this one of the model of existing radiator which is normally used in cars is studied. As focus is on developments in tubes and core, fins arrangements are not much considered in this study. Then two case studies are discussed which are related to modifications in tubes structure. Geometrical specifications of such simplified prototypes are compared with reference radiator. This simple form of tubes structure used to develop next radiator which is having concentric tubes structure. This second case of radiator provides flexibility to arrange multi fluids/coolants in the radiator with two manifolds/ tanks. This gives added advantage of using nanofluids as coolants in the radiator with regular coolants.

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