Modelling of Automobile Radiator by Varying Structure and Materials

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Abstract: Radiators used in the automotive application are a class of heat exchangers whose main purpose is to cool the coolant coming from the internal combustion engines. These coolants flow through tubes covered with fins that facilitate a faster way of heat transfer to the surrounding more efficiently. With the increase in efficiency of the engine cooling system it directly helps in the longevity of the engine in other words, the life of the internal combustion engine increases multifold times. Upon investigating we found different shapes that can be used to optimize the radiators efficiency. There are several other ways to improve the efficiency of a radiator. And these can be achieved by improving the surface area of the radiator, improving airflow through it, improving coolant property which flows through these tubes covered with fin all around and at last using alternate materials that prove to be more efficient than the present ones that are being used. The demand of the current times of climate change and energy crisis have paved way for improved heat transfer rates and designing radiators in smaller dimensions and sizes at the same time being more efficient than the previous generation of radiators. With the above conditions in mind, it has been found out that with a simple modification of changing the existing rectangular-shaped radiators into spiral-shaped ones thereby improving efficiency to improved levels, which finds its use in the current generation of vehicles which are benefitting from the improved rate of heat transfer taking place. The spiral radiator of copper tube used here is wound in two coils connected centrally. Spiral tubes of the radiator have circumferential fins. In this type of configuration, heat transfer rate will increase because of having a circumferential fin across the length of the spiral tube through which water flows. These design considerations have been done keeping in mind the major aims to achieve for this type of design and they are improving heat transfer rate and achieving compactness of shape of radiator. We also did Computational Fluid Dynamics or CFD Analysis to test the material properties for the application of heat transfer and how it fares against old materials.

Keywords: Spiral, radiator, circumferential fins, Heat transfer rate.

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I.INTRODUCTION

Energy conservation is energy-saving which is the core concept used here. Radiators are a type of heat exchangers which exchange thermal energies between two mediums for cooling and heating. Automobile radiator is a key component in the engine cooling system which helps in cooling the engine. Radiators cool the coolant being used in the automobiles which in turn cools down the temperature of the engine. Numerical investigation on the spiral radiator has been conducted to study flow characteristics and thermal performance by element analysis utilizing ε-NTU method. Experiment was performed and the results after comparison with the theoretical values were found an it claimed to be a better choice of configuration [1]. The experimental analysis done on spiral radiator with circumferential fins by comparing with Maruti Suzuki Alto radiator. The results obtained by the experiments are promising with the assumptions [2]. The flow characteristics and thermal performance of this spiral radiator is analyzed and investigated [3]. After studying different heat exchangers these radiators are made after performing thorough calculations, proceeded to CAD drawings of radiator and geometrical model are hence developed. Along with the above studies the power consumed by fan is also studied [4]. This paper conducted experimental prediction of Nusselt number and with ε-NTU method heat transfer coefficient for coolants in radiator tubes are also measured. The Colburn factor and pressure drop are the other factors which are estimated for this heat exchanger [5]. This paper dwells In the performance evaluation of a radiator that will be installed into a test-setup and certain parameters like mass flow rate of coolant, inlet coolant temperature; etc. are varied [6]. The various techniques that are being used to enhance the performance of automotive engine cooling system. It may be either conventional or modern approach [7]. Heat transfer characteristics and performance of Copper spiral heat exchanger are investigated and compared with pure water [8]. Instead of the conventional rectangular one, a circular shaped radiator is proposed. The objective has been to optimizing the circular shaped radiator for maximum heat transfer by modifying certain parameters like tube geometry, tank shape etc. using CFD analysis [9].The objective of work is to have a circular radiator which is compact made, minimum material, less costly and more efficient, that will work with minimum power consumption of fan and maximum utilization of air flow [10]. This paper's describes overall behavior report of radiators in operating conditions and also puts light on the differences between the old ε-NTU method and the modern CFD method.[11].

Different heat exchangers/radiators are studied; This Paper discusses concept of automobile radiator. An overview of this radiator is discussed in this paper and by the assuming general dimensions and properties like thermal conductivity, porosity, air resistance, mass flow rate, density etc. [12]. Analysis on the radiator with varying geometrical fin structure has been carried out by using both Nano fluids and conventional coolant, along with variations in temperature, pressure is also analyzed.[13]. This paper helps us by evaluating the effect of porosity on the mechanical characteristics of a mixture consisting of magnesium and these have been evaluated using universal testing machine (UTM).[14]. This paper helps us by solidifying that Silicon Carbide has good strength and high hardness which helps in overall strength of the material.[15]. When we talk about the spiral radiators, the first thing which strikes is the design of the spiral radiator is so compact than the previous other designs and at the same time spiral

radiators also showcase high heat transfer efficiency. These radiators will have a header from where the coolants enter through and flow spirally through in one or more spirally wound coils which are in a circular pattern. When compared with the new design of spiral radiators, the rectangular radiators will have a lower heat transfer rate. Spiral radiators as their designs are unique will have lesser space requirements and are more compact when compared with the other types of radiators. In addition to this, taking advantage of their design this spiral profile produces pressure drop at a lower level and it requires less pumping energy when compared with the other radiators for the same capacity. With all the heat exchangers we have a common issue of thermal expansion but since the spiral path has a self-cleansing ability, which helps with that issue. As we know the heat is better transferred if provided with more surface area which we get in the spiral radiators and that too in a very compact design which doesn`t take much space. But these radiators are designed keeping in mind about the vehicle design requirements. All the radiators of different size and shape will not be able to be installed onto the car. Different automobiles require a different volume of radiators. So, it is needed to design the radiator tubes to satisfy both high heat transfer as well as the optimum size of the radiator according to the design requirements. The selection of radiator geometry is more important for particular heating or cooling applications as the needs are specific in different automobiles. Various geometries are available for radiator design. In the traditional configuration of a radiator, the coolant is passed through the engine where it absorbs heat from the engine then hot coolant is transferred to the inlet tank of the radiator which is located at the upper side then coolant is distributed in the radiator tubes and flows towards a lower tank of the radiator. Coolant while flowing through radiator tubes transfer heat to the tubes and then to fins which are located on radiator tubes. Fins exchange heat to air passing through it. The contact surface of tubes is increased with the help of these fins to improve the total heat transfer area. The low-temperature coolant transferred back to the engine and the same cycle repeats. Coolant temperature is not reduced to ambient temperature by a radiator but the resulted cooling effect is sufficient to keep the engine from overheating. Because if we cool the coolant below its ambient temperature, then it might affect the combustion efficiency of the IC Engine used in the car, as it might lower the overall temperature of the engine and that will hamper their performance. To increase the heat transfer area circumferential fins are provided to the spiral tubes. The path of airflow flowing over spiral tube is exactly opposite to the path of coolant flowing through the radiator which results in a high heat transfer rate.

II.MATERIALS PROPERTIES

Old radiators are made of copper tubes and aluminum fins which were rectangular and are being used in the automobiles all around the world. Whereas the newly proposed radiator is in spiral shape with tube being made of copper but the fin material has been replaced with 4 different materials and they are Lead Zirconate Titanate, Barium Titanate, Lithium Niobate, Boron Carbide. The following table showcases the physical properties of both the new and old radiator materials:

Table 1: Thermal Properties of the Materials

Sl. No	Properties / Materials	Thermal Conductivity [w/m3]	Density [g/cm^3]	Specific Heat [j/kg.k]
1	Copper	398	8.96	376.812
2	Aluminum	227	2.73	921.096
3	Lead Zirconate Titanate	2.25	7.500	465
4	Barium Titanate	6	6.06	527
5	Lithium Niobate	19	4.618	630
6	Boron Carbide	17	2.52	840

III.METHODOLOGY

The existing radiators are rectangular whose dimensions are given in the below table, along with the spiral radiators dimensions. At first, the rectangular radiator design was completed and we did CFD (Computational Fluid Dynamics) Testing too to measure the rate of heat exchange possible with the existing design. After that we constructed this new spiral-shaped radiator with the dimensions provided in the table below. And we performed Computational Fluid Dynamics (CFD) testing on this design too to observe and compare the heat transfer rates of the two designs.

Table 2: Design Parameters

Parameters	Existing Radiator	New Radiator
Length (mm)	350	300
Width (mm)	30	30
Height (mm)	310	310
Volume (mm^3)	3255000	2790000

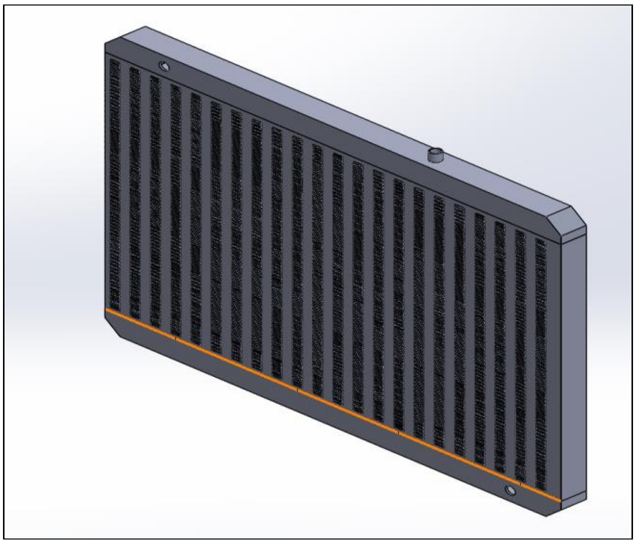


Fig.1: 3D CAD Model of Rectangular Shaped Radiator: (Existing Design)

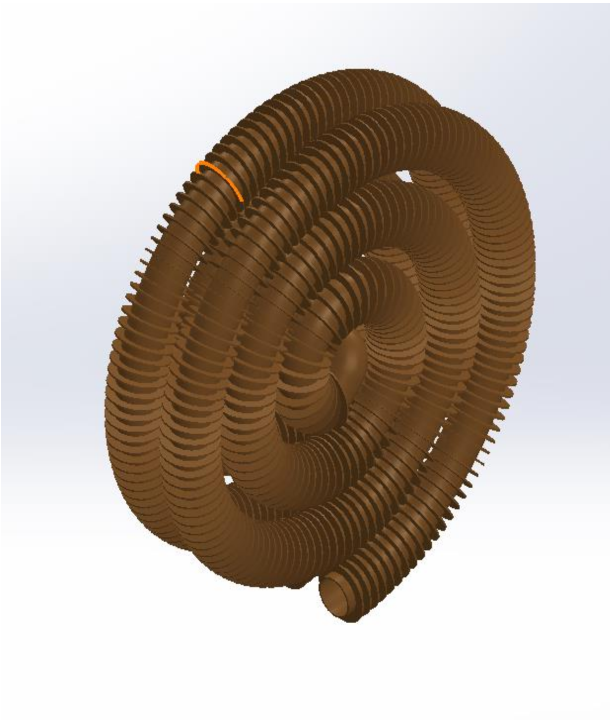


Fig.2: 3D CAD Model of Spiral Shaped Radiator: (New Design)

IV.RESULT AND DISCUSSIONS

Fig. 3 shows a design having fin made up of aluminium and a tube made up of copper. In the given diagram in corners we can find that temperature is low because the coolant is flowing through the tube. Compared to the corners where the temperature is high in the central part of the fin portion.

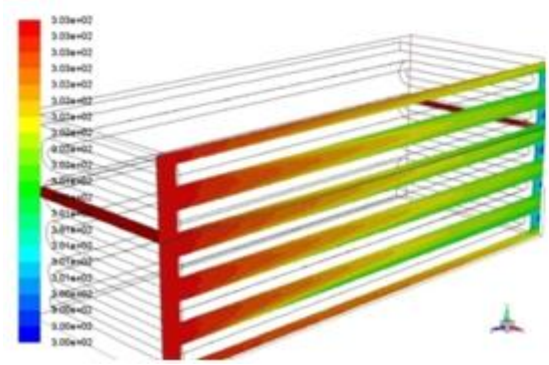


Fig.3: Heat Analysis Process of Existing Design

Fig.4 shows a new design in which a new material named lithium niobate is used and to the left in the analysis picture is shown the temperature bar which shows the amount of heat transfer taking place in each corner of the material. The analysis shows a temperature decrease.

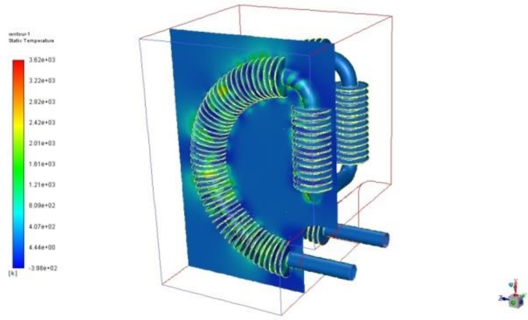


Fig. 4: Heat Analysis Process of New Design (Lithium Niobate)

Fig.5 explains about the thermal heat analysis conducted through CFD for the material boron carbide. Boron carbide is used in many heat applications but when tested for thermal analysis it didn't fetch effective results compared to lithium niobate but close to that of aluminium copper.

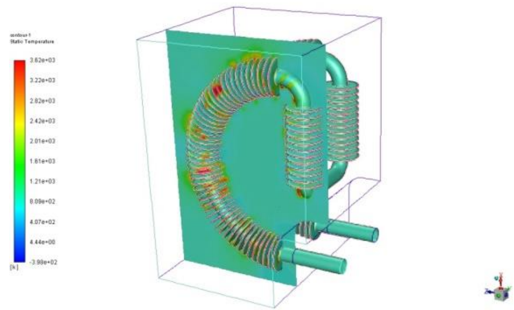


Fig.5: Heat Analysis Process of New Design (Boron Carbide)

In Fig 6 is the material barium titanate has been analysed for heat transfer using CFD analysis and it has shown an average heat transfer rate compared to the previous materials.

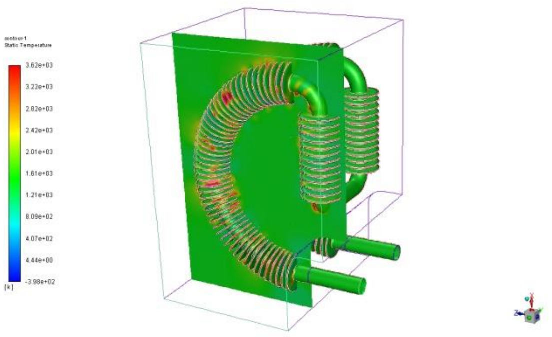


Fig.6: Heat Analysis Process of New Design (Barium Titanate)

In the Fig 7 the heat analysis of the material lead zirconate titanate has been shown. And heat spots were found on the material and these spots indicated low heat transfer rates and increases with the heat. These spots can be found more with this material and this is due to the less thermal conductivity of the material. Hence lead zirconate titanate is the last of all materials that are to be considered as a material for the radiator.

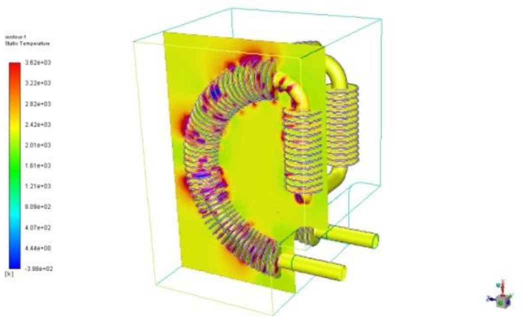
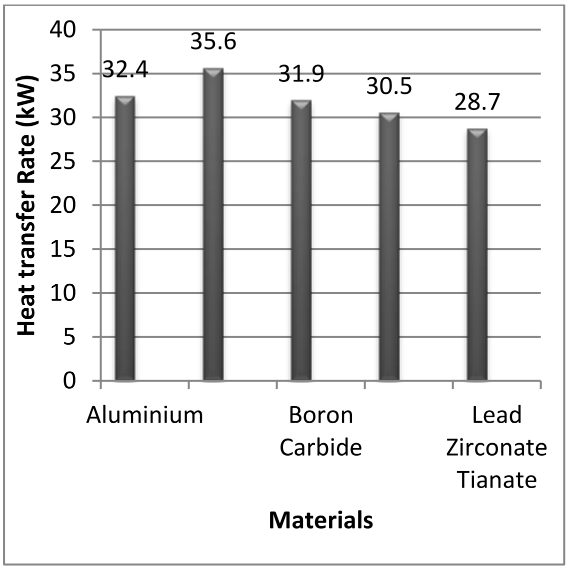


Fig.7: Heat Analysis Process of New Design (Lead Zirconate Titanate)

From the CFD analysis we got the information of heat transfer rate of both new materials and existing material, by which we can choose the best suitable material for our design. We have compared heat transfer rates of four materials with the existing radiator material aluminium. Material lithium niobate showed best heat transfer rate compared to that of aluminium. Boron carbide did not show a good heat transfer rate than aluminium. Barium titanate and lead zirconate titanate showed low heat transfer rate compared to aluminium as well. Barium titanate and lead zirconate titanate have less thermal conductivity hence resulted in low heat transfer rates. The below graph 1 shows us the heat transfer of the given materials ranging from (0-40 kW), we are replacing the existing material aluminium (32.4 kW) and have tested and analysed four new materials out of which barium titanate (30.5 kW) and lead zirconate titanate (28.7 kW) showed low heat transfer rates due to less thermal conductivity so we had to go with the selection of the best material from the analysis which is lead niobate (35.6 kW) as it showed better results.



Graph 1: Heat Transfer Rate of the Selected Materials

V.CONCLUSION

1. The heat analysis Fig 4 shows a temperature decrease and also shows a good thermal conductivity of 35.6 kW. When compared to that of the existing aluminium copper. Based on our study, here we can conclude that the newly proposed spiral design for radiator resulted in a compact configuration and also showed us an effective way by which we increase heat exchange in an automobile engine. Also, from the CFD analysis results we can say that Lithium niobate has an effective way to conduct heat transfer rate when compared to existing material like aluminium through our survey.
2. From the Table 5.1 we can observe that the newly proposed model has less volume occupied which is a clear sign of compactness and effective design for improved heat exchange. The spiral radiator space optimizes by 14.67% as compared to existing radiator design.

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