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Design, Analysis and Optimization of Automotive Radiator Using Different Material Combinations

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Abstract: ***In Internal Combustion Engine, large amount of heat is produced due to combustion of air-fuel mixture. Due to the high temperature of engine, this can damage or seize the engine components. Hence, for the safety of engine components there is need of cooling system. Generally there are two types of cooling systems that are used: 1) Air Cooling System 2) Water Cooling System. But the Water cooling system is very effective compared to the air cooling system. The radiator is the heart of water cooling system. In order to increase the efficiency of water cooling system, we should increase the performance of radiator. The performance of radiator can be increased by following methods : 1) By Changing construction of Radiator 2) By using Nano-fluids as working fluid in radiator 3) By changing material of tubes and fins of Radiator. In this paper, we are trying to increase the performance of existing radiator by changing the material of tubes and fins. By using ZnAlCu as a material of tubes and fins of Radiator instead of Copper-Brass and Aluminium, in order to achieve the better strength and cooling effect. Thus, the efficiency of ZnAlCu radiator increases when compared with existing Radiator.***
Keywords: Radiator, Water cooling system, Thermal and Flow analysis, NX 9.0, Performance

I. INTRODUCTION

In an automobile, the large amount of heat is generated due to the combustion of air-fuel mixture in combustion chamber of an IC Engine. As we know that total amount of heat produced by combustion is not converted into the useful work. The remaining heat which is not converted into work, must be removed from exhaust, this causes seize of the engine and damages the engine components. In order to prevent the overheating of an engine due to the excess heat, better cooling system is required. For heavy capacity engine, water cooling system is efficient compared with air cooling system. The water cooling system uses Radiator, Fan, Pump, Thermostat and the water is used as working fluid for cooling purpose. Here, we are designing the radiator for off-road vehicle like Tractor which is of better strength as well as better cooling. Nowadays, the Radiators are made from Copper-Brass and Aluminium. As per our requirement of better strength and cooling, Alloy material can be used like ZnAlCu.

A. Parts of Water Cooling System

The main parts in the water-cooling system are:

1) Water pump,
2) Fan,
3) Radiator
4) Pressure cap,
5) Water jacket,
6) Thermostat valve,
7) Hose pipes.

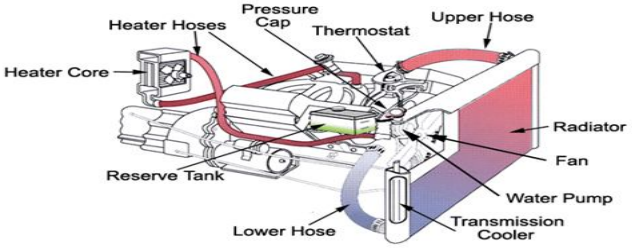

Fig. 1 Water Cooling System

B. Working of Water Cooling System

The system is so designed that the water will circulate because of the pump. The system consist of radiator having upper and lower tanks connected to upper and lower water jackets of the cylinder through the pipes.

The hot water in the jacket rises and flow into the upper tank due to lower density compared to cold water and the cold water from radiator flows to the lower water jacket to replace the hot water. The water will flow from the upper tank to the lower tank where in between travelling from tubes the air supplied by fan will cool down the water. To increase the efficiency of cooling system provide the fins around the tubes, hence due to fins the heat transfer area will increase and the overall performance will be increased.

II. LITERATURE REVIEW

A. R. Paul Linga Prakash [1] et. al. in their study revealed that if we want to increase the efficiency of cooling system of an IC Engine. It is necessary to increase the efficiency of Radiator and the efficiency of radiator can be increased by changing the parameter of radiator. The Nozzle effect provides the additional cooling to the engine because it decreases the pressure and increase the velocity thereby decreasing the temperature which is directly proportional to the pressure according to the ideal gas equation. Thereby, engine cooling and radiator efficiency is increased.

B. Ramesh T. [2] et. al. mentioned that the automotive radiator is key component of engine cooling system. This work has made a study and analysis of the thermal behaviour of the automobile radiators using the LMTD and ε-NTU methods of designing radiators for various parameters of mass flow rates of coolant and air with its specific geometrical parameters. By using these methods there is no need of designing of radiator for its analysis, proportionally it saves the time for designing the radiator. So that, result can be obtained directly by analytical methods.

C. Parshurama M. S. [3] et. al. said that the use of CuO- water Nano fluid as a coolant in a radiator of army tanker diesel engine. The heat transfer rate for CuO-Water Nano fluid at volume fraction 10% was studied. Their result indicates that the overall heat transfer coefficient of Nano fluid is greater than that of water alone and therefore the total heat transfer area of radiator can be reduced. However the considerable increase in associated pumping power may impose some limitations on the efficient use of this type Nano fluid in automotive diesel engine radiator.

D. Urvi Tushar Nagar and Bharatkumar Manharlal [4] Trivedi analysed that the most of automotive radiators are of rectangular or square shape but the air flow given to the Radiator for cooling purpose is in circular cross section. This circular cross section of air flow causes to cool down the central portion of the radiator but the four remaining corners will not be sufficiently cooled down. Hence, higher stress concentration on these four corners will occur. So instead of using rectangular or square radiator, the circular cross sectional radiator can be used for better performance. This circular cross sectional radiator have better performance, low weight, compact, easy to manufacture and less material requirement.

E. Vishal V. Kulkarni and Abhijeet S. Dhakane [5] presented work related to the different structures of tubes and core, which are used in automobile radiator how these are affected on radiator performance and improvement of shape and size of it is based on these one of the model of existing radiator which is normally used in air is studied. As focus is on developments in tubes and cores, fins arrangements are not much considered in this study. Then two case studies are discussed which are related to modification in tube structure. Geometrical specifications of such simplified prototypes are compared with reference radiator. This simple form of tubes structure is used to develop next radiator which is having concentric tubes structure. This second case of radiator provides flexibility to arrange multi fluid in the radiator with two tanks. This gives added advantage of using Nano fluids as coolants in the radiator with regular coolants.

III.PROBLEM IDENTIFICATION

Automotive engine cooling system takes care of excess heat produced during engine operation. It maintains the engine surface temperature for engine optimum efficiency. Recently, many researches have been done on engine cooling system to increase the efficiency of engine.

As we know that there is problem of leakage in the radiator which is used in off-road vehicle like tractor due to lack of strength. The tractors are used for farming application where there is high chances of leakage and corrosion of radiator because it works in dusty environment.

There is also problem of overheating in engine because it produces large amount of heat during farming application.

The proposed work focuses on how to overcome the disadvantages of current radiator system which is related to strength of radiator as well as better cooling.

IV. SIMULATION PROCEDURE

A. Existing Material of Radiator:

1) Aluminum

a) Advantages of using Radiator

i) Low weight compared to brass radiator.

ii) Low Cost.

iii) Good thermal conductivity.

b) Limitations of using Radiator

i) Difficult to Repair.

ii) Less life period.

iii) Low thermal conductivity than copper.

2) Copper and Brass

a) Advantages of using Copper & Brass:-

i) Higher Thermal Conductivity.

ii) Good Impact Strength.

iii) Long Life.

iv) Repairable.

b) Disadvantages of using Copper & Brass:-

i) Corrosion leads to serious failure in of radiator.

ii) Heavy in weight.

iii) Costly

TABLE I PROPERIES OF MATERIALS

Property	Aluminium	Copper	Brass	ZnAlCu	PVC	Water
Thermal Conductivity	176396 micro W/mm ◦C	387000 micro W/mm ◦C	116000micro W/mm ◦C	126W/m K	1731 micro W/mm ◦C	603 micro W/mm-◦C
Mass Density	2.794 e-006 kg/mm^3	8.92 e-006kg/mm^3	8.409 e-006kg/mm^3	5000kg/mm^3	1.4 e-006 kg/mm^3	1 e-006 kg/mm^3
Yield Strength	333762 kPa	30000 kPa	440000 kPa	370000 kPa	44500 kPa	-
Ultimate Tensile Strength	365974 kPa	207000 kPa	1.1 e+006 kPa	425000 kPa	-	-
Poisson's Ratio	0.33	0.31	0.35	0.34	0.4	-
Specific Heat	-	-	-	-	-	4.187 e+009 micro J/kg-K

B. Mesh Details

1) Total No. of Meshes in the Part: 62

2) Total No. of element in the Part: 1217254

3) Total No. of Nodes in the Part: 1915160

C. Boundary Conditions

1) Radiator Inlet:-

a) Volume Flow: 2 l/min

b) Heat Load: 0W

c) Temperature: 90◦

2) Air Flow Inlet:-

a) Velocity: 20 km/hr

b) Heat Load: 0W

c) Temperature: Ambient

d) Pressure: Ambient

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V. RESULT AND DISCUSSION

In this Paper, We have worked on Thermal and flow analysis of automotive radiator by using Unigraphics NX 9.0. The analysis of existing material and ZnAlCu alloy material radiator is done and compared their result with each other.
Here are the more details of Results of existing and implemented Radiator:

A. Result of Existing Radiator

1) *Aluminium Radiator:* Generally, in most of radiators aluminium is used in tubes and fins due to its properties of having light in weight, good heat transfer co-efficient, low cost, availability etc. That's why it is widely used in most of automotive radiator. In this radiator the tubes and fins are made of aluminium and upper tank and lower tank are made of PVC.

The results obtained from the analysis of radiator are:
Outlet Temp of Water: 73.5°
Yield Strength (Aluminium): 333762 kPa
Yield Strength (PVC): 44500 kPa
Ultimate Tensile Strength (Aluminium): 365974 kPa
Ultimate Tensile Strength (PVC): 52000 kPa
The Temperature variation on Aluminium Radiator is shown in below fig.

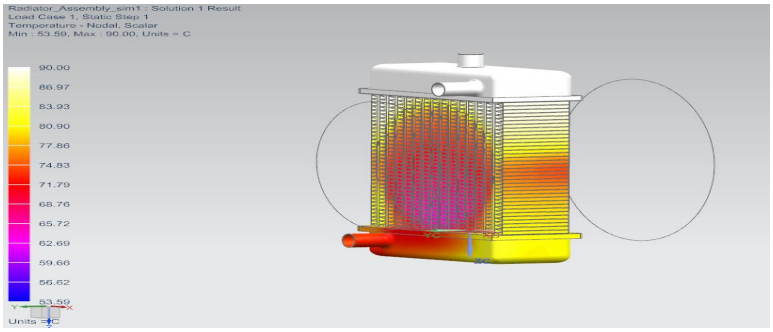

Fig. 1 Temperature Variation on Aluminum Radiator

2) *Copper-Brass Radiator:* Copper-Brass Radiators are mostly used in heavy vehicles like Truck, Bus, Tractor etc. It has advantage of having more thermal conductivity and strength compared to Aluminium Radiator. In Copper-Brass Radiator, tubes and fins are made of copper which provides better cooling effect due to its more thermal conductivity and upper tank and lower tank are made of brass which provides better strength.

The results obtained from the analysis of radiator are:
Outlet Temp of Water: 72.8°
Yield Strength (Copper): 30000 kPa
Yield Strength (Brass): 44000 kPa
Ultimate Tensile Strength (copper): 207000 kPa
Ultimate Tensile Strength (Brass): 345000 kPa
The Temperature variation on Copper-Brass Radiator is shown in below fig.

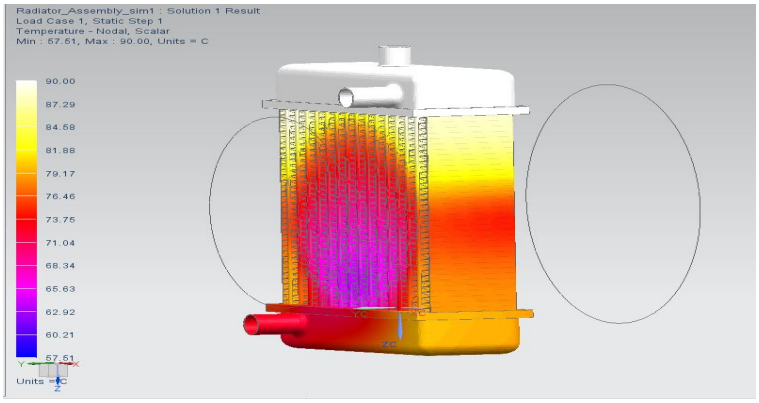

Fig. 3 Temperature Variation on Copper-Brass Radiator

B. Result of New Implemented Radiator

1) ZnAlCu: In this radiator, we have used the alloy material ZnAlCu in tubes and fins which provides better cooling due to its good thermal conductivity and also provides better strength. The upper tank and lower tank are made of PVC. This radiator has advantages of having good cooling as well as better strength which solves the problem of leakage.

The results obtained from the analysis of radiator are:

Outlet Temp of Water: 73°

Yield Strength (ZnAlCu): 370000 kPa

Yield Strength (PVC): 44500 kPa

Ultimate Tensile Strength (ZnAlCu): 425000 kPa

Ultimate Tensile Strength (PVC): 52000 kPa

The Temperature variation on ZnAlCu Radiator is shown in below fig.

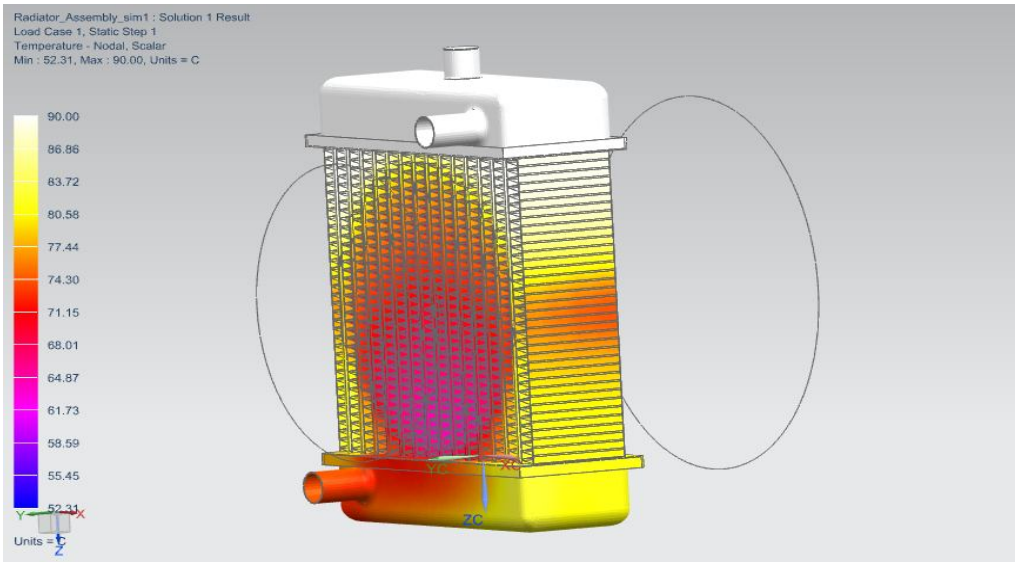

Fig. 4 Temperature Variation on ZnAlCu Radiator

VI. CONCLUSION

As we can see from the above results that, for the better cooling as well as better strength the New modified radiator is made of ZnAlCu alloy material which provides similar cooling effect like existing radiator. But the strength of ZnAlCu Radiator is so high when compared with Aluminium and Copper-Brass Radiator. Also it is cost effective than Copper-Brass Radiator. So by using ZnAlCu radiator, the problem of leakage which generally occurs in off-road vehicles like tractor is solved.

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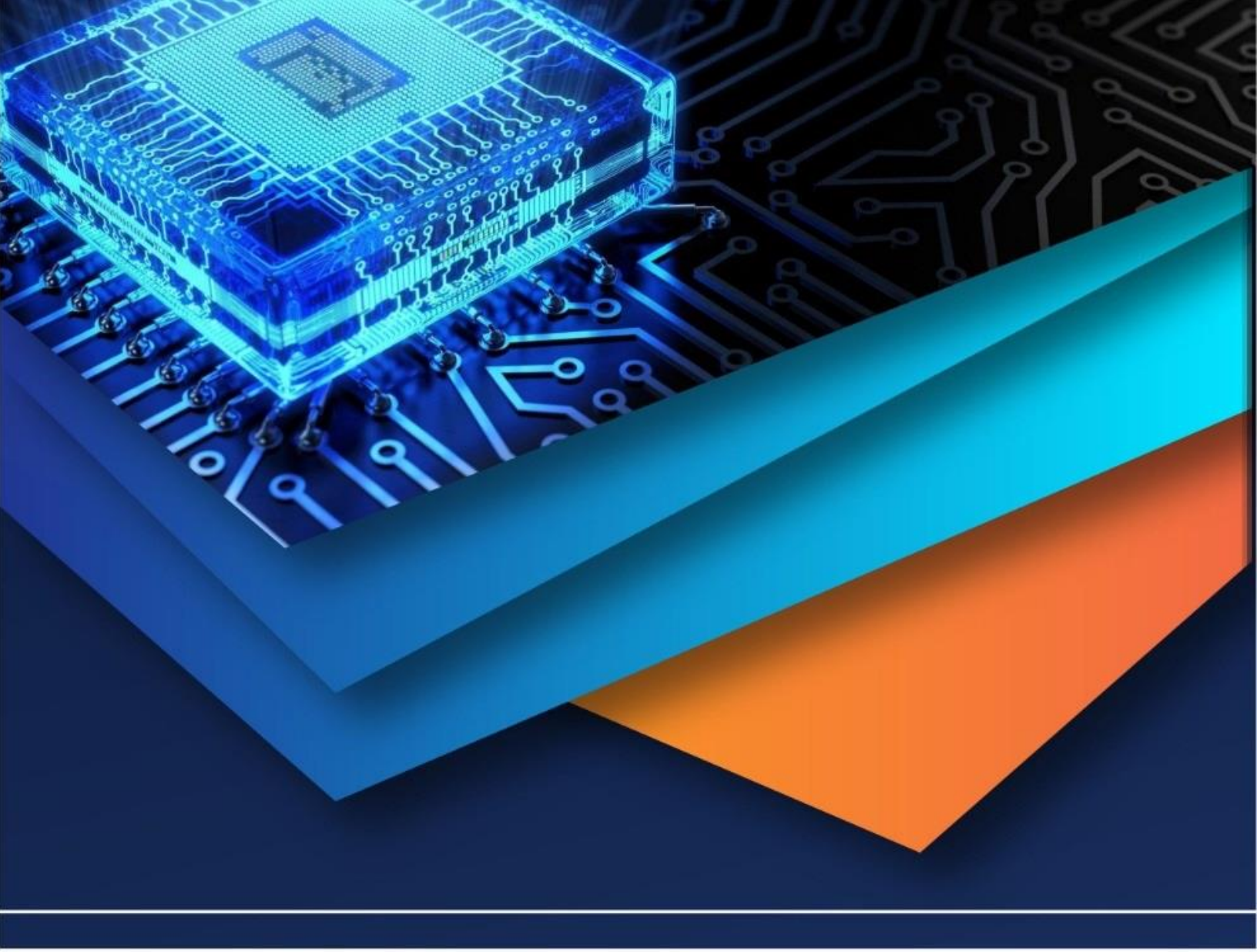

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