# Design and Analysis of Fluid Flow and Heat Transfer in a Crossflow Radiator as Changing the Fin and Tube Material

**C.Gopinath, L.Poovazhagan**

***Abstract:-The main purpose of this project is to identify the suitable radiator material for various working environments (such as coastal environment and desert-like high temperature environments) and applications. Hence in this project, the existing radiator is analyzed by changing its tube and fin material for evaluating the fluid flow and heat transfer characteristics. The materials chosen for analysis are Aluminium (Al), Al-Si-Mg alloy and Graphite flakes-metal alloy. Initially the required radiator model for analysis is designed and modelled using CREO Parametric 2.0. The overall pressure, temperature and mass flow rate distribution of the coolant and air in and around the tube-fin arrangement is evaluated using fluid flow (CFX) and steady state analysis systems of CFD. Stress Distribution over the radiator is evaluated using static structural analysis system of CFD. The fluid flow simulation is conducted using commercial software ANSYS. The heat transfer rate, heat flux and the pressure and temperature distribution along the tube length and tube width are presented and analyzed. The results obtained serve as good database for the future investigations.***

***Index Terms: Computational Fluid Dynamics, Materials, Radiators***

## I. INTRODUCTION

The push on car producers for creating smaller and vitality effective vehicles warrants a careful enhancement process in the plan of all motor segments, including radiators. Radiators are introduced in autos to expel warm from the under hood which incorporate motor cooling and warmth evacuation forms. The utilization of higher yield motors with firmly stuffed under hood bundling, the expansion of new emanation control parts and the necessity of streamlined front end styling with smaller openings are diminishing the space accessible for dissemination of under-hood cooling air.

These conditions request a superior comprehension of the mind boggling cooling liquid stream attributes and coming about warm execution of the radiator. About 30% of the warm vitality created because of burning of fuel is dispersed to the coolant that flows in the motor cooling coat. The hot coolant leaving motor cooling coat is to be cooled in a radiator and coursed again in the coat. In a vehicle, vitality scattered from the motor through radiator isn't used yet lost to the air. The motor execution, security and motor life relies upon viable motor cooling.

For breaking down the intricate cooling, wind stream qualities and coming about warm execution of the radiator and other warmth creating segments in the motor compartment can be effortlessly comprehended by using the savvy numerical apparatuses, for example, Computational Fluid Dynamics (CFD, which is a piece of ANSYS). The radiator of Maruthi 800 (MB308) vehicle is contemplated and displayed to decide the warmth exchange rates, temperature profiles and generally speaking effectiveness. The real radiator is estimated and a model is made local in CREO. All the features of the column including the empty water tubes and the blades are reproduced to guarantee the most precise model. The examination is finished with air, when traversing the radiator. ANSYS is utilized to compute the air speed circulation over the radiator. The goal is to demonstrate how CFD can be utilized as a pragmatic building instrument to supplement and upgrade the structure procedure. In this way, by utilizing these development business programming projects condition, we can enhance the adequacy and by and large execution of any part (radiator) of the vehicle. PC recreation is the way toward figuring a model of physical framework speaking to genuine procedures and examining the equivalent. Typically, the model is a numerical one speaking to the genuine procedures through arrangement of arithmetical, differential or indispensable conditions and the investigation is made utilizing a PC. In present day inquire about, PC recreation has turned into an incredible apparatus that spares time and is additionally practical when contrast with trial think about. A proposed hypothesis can be broke down rapidly utilizing a PC and the expense of setting up a trial mechanical assembly can be deferred until the point when the enhancement is accomplished. Notwithstanding, it might be noticed that reproduction is just a stage before experimentation and the outcomes got from reenactment considers must be approved with trial results to build up the unwavering quality. When approved, PC recreation can give a profound understanding into the execution attributes of the framework. This announcement is especially valid for the instance of radiator thinks about.

**Revised Manuscript Received on May 24, 2019.**

**C Gopinath**, Assistant Professor, Department of Mechanical Engineering St. Joseph College of Engineering, Sriperumbudur, Chennai.

**Dr.L.Poovazhagan** Professor, Department of Mechanical Engineering,SSN College of Engineering, Kalavakkam, Chennai



*Retrieval Number: A10570581C19/19©BEIESP*

*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

## II.RELATED WORK

Oliet et al. (2007) analyzed factors which effect radiator execution. It joins air, blade thickness, and coolant stream and air delta temperature. It is understand that warm exchange and execution of radiator unequivocally affected by means of air and coolant mass stream rate. As air and coolant stream builds cooling limit in like manner increases. Exactly when the air gulf temperature grows, the warmth exchange and cooling sum decreases. More diminutive equalization isolating and increasingly noticeable louver blade point have higher warmth exchange.blade thickness may be extended till it thwarts the wind current and warmth exchange rate decreased

Suleiman et al. (2009) use the computational Fluid Dynamics (CFD) showing proliferation of wind stream scattering from the vehicle radiator fan to the radiator. The task grasped the model the geometries of the fan and its surroundings is the underlying advance. The results exhibit that the outlet air speed is 10 m/s. The screw up of ordinary outlet air speed is 12.5 % in light of difference in the tip condition of the bleeding edges. This examination has exhibited that the CFD reenactment is a useful instrument in overhauling the structure of the fan cutting edge. In this paper this examination has exhibited a clear response for plan a barely streamlined condition of the fan center point

Chacko et al. (2005) used that the capability of the vehicle cooling structure unequivocally depend broadcasting live stream towards the radiator center. A sensible appreciation of the stream plan inside the radiator cover is required for upgrading the radiator cover shape to fabricate the stream toward the radiator center, thus improving the warm capability of the radiator. CFD examination of the gauge structure that was affirmed against test data showed that indispensable region of re-coursing stream to be inside the radiator cover

Vajjha et al. (2010) have been numerically considered a 3D laminar stream and warmth exchange with two particular Nano liquid, Al2O3 and CuO, in the ethylene glycol/water mix coursing through the dimension compartments of a vehicle radiator to survey their control over the base fluid. Convective warmth exchange coefficient along the level cylinders with the Nano liquid stream air impressive enhancement over the base fluid.

Peyghambarzadeh et al. (2011) have starting late investigated the utilization of Al2O3/water Nano liquids in the radiator by figuring the cylinder side warmth exchange coeffective They have recorded the interesting improvement of 45% veering from the unadulterated water application under exceedingly violent stream condition. Peyghambarzadeh et al. have used diverse base fluids including unadulterated water, unadulterated ethylene glycol and their twofold mixes with Al2O3 nanoparticles and eventually it was exhibited that Nano liquids redesign the cooling efficiency of the vehicle radiator comprehensively

Kim et al. (2009) Investigated effect of Nano liquids on the shows of convective warmth exchange coefficient of a round direct cylinder having laminar and tempestuous stream with predictable warmth transition. This considered have make that the convective warmth exchange coefficient of alumina Nano liquids improved interestingly with base fluid by 15% and 20% in laminar and tempestuous stream, independently.This showed as far as possible layer accepted a staggering activity in the laminar stream while warm conductivity expected an overwhelming activity in savage stream. Regardless no improvement in convection warm exchange coefficient was seen for nebulous atom Nano fluids.

Naraki et al. (2013) found that warm conductivity of CuO/water Nano liquids significantly higher than that of base liquid water. Maker found that the total warmth exchange coefficient increases with the upgrade in the Nano liquid focus from (0 - 0.4) vol. %. On the other hand, the foundation of Nano liquid forms the general warmth etrade coefficient up to 8% at Nano fluid point of convergence of 0.4 vol % in examination with the base fluid.

## III. THE HEART OF COOLING

A radiator is a warmth exchanger that expels warm from coolant going through it, in this way keeping up the motor temperature. This is finished by warmth exchange from hot coolant originating from motor cooling coat, streaming into the cylinders by means of the Inlet tank. Warmth rejected from coolant to the cylinder is exchanged to the smash air (surrounding) streaming over the blades.

The radiator is the most vital component of the cooling framework and has the basic capacity of decreasing temperature of the passing coolant. The "cooled" coolant keeps recycling all through the motor, evacuating heat squander. The coolant conveying the warmth squander from the motor moves into the radiator center by means of the delta hose.

- Radiator is a gadget which gives trade of warmth between two liquids are at various temperatures.
- The capacity of the radiator is to exchange warm from the boiling water coursing through the radiator cylinders to the air moving through the firmly separated thin plates outside connected to the cylinders.
- A radiator comprises of an upper tank, center and the lower (Collector) tank. Hot coolant from the motor enters the radiator at the best and is cooled by the cross stream of the air , while streaming down the radiator .The coolant gathers in the authority tank from where it is siphoned to the motor for cooling.
- Radiator is recuperator warm exchanger, for this situation the liquids trading heat are on either side of separating dividers (as channels or cylinders). These warmth exchanger are utilized when two liquids can't permit to blend. The blending is bothersome.

This distribution diminished the stream towards the radiator center, prompting a notoriety of sight-seeing pockets near the radiator surface and resulting disrespect of radiator warm productivity. The CFD make capable streamlining prompted radiator cover arrangement that dispensed with this distribution region and expanded the stream towards the radiator center by 34%. It is foreseen that this expansion in radiator center stream would vital to expand the radiator warm productivity. Jain et al. (2012) introduced a computational liquid elements (CFD) demonstrating of wind current to separate among a few from a radiator pivotal stream fan utilized in a corrosive siphon truck Tier4 Repower. CFD examination was executed for a zone weighted normal static weight is change at the gulf and outlet of the fan.

Weight shapes, way line and speed vectors were plotted for itemizing the stream attributes for different introductions of the fan cutting edge. This investigation indicated how the stream of air was irregular by the center point hindrance, along these lines bringing about undesirable switch stream districts. The distinctive introduction of sharp edges was likewise considered while working CFD investigation. The investigation uncovered that a left arranged sharp edge fan with counterclockwise revolution five played out the equivalent as a privilege situated edge fan with pivoting the clockwise heading. The CFD results were as per the exploratory information estimated amid physical testing.

Singh et al. (2011) learned about the issues of geometric parameters of a diffusive fan with in reverse and forward-bended sharp edges has been reviewed. Radiating fans are utilized for enhancing the warmth dispersal from the inside burning motor surfaces. The parameters examined in this investigation are number of sharp edges, outlet edge and measurement proportion. In the scope of parameters considered, forward bended cutting edges have 4.5% lower productivity with 21% higher mass stream rates and 42% higher power utilization contrasted with in reverse bended fan. Exploratory examinations propose that motor temperature drop is noteworthy with forward bended cutting edge fan with immaterial impact on mileage. MAAR (Mechanically Assembled Aluminum Radiator)

This innovation includes joining of Tubes, blades, header, side help all together utilizing mechanical activity in which a water driven press is utilized to extend the cylinders over the header, in this manner giving a locking, this mechanical locking is additionally guaranteed by giving epoxy gum cx which shape's a firm joint between the header and cylinders. It includes of:

• Round tubes
• Flat Contoured fins
• Sealing/joint obtained by mechanical interference, epoxy and rubber gaskets.

**MAAR Type Radiators includes:-**

• Maruthi 800
• YE2 (Zen)
• OMNI
• GYPSY 1L & GYPSY 1.3L
• 3BOX (Esteem)

A Heater Core is a Heat Exchanger that expels heat from coolant going through it, in this way keeping up the motor temperature. This is finished by Heat move from hot coolant originating from the motor cooling coat, streaming into the cylinders by means of the Inlet tank. Warmth rejected from coolant to the cylinder is moved to the slam air (encompassing) streaming over the blades.

## II. RADIATOR DESIGN

The structure information for Radiator in vehicle with the assistance of Creo Parametric was planned and gathered from Diesel motor vehicle. It is intended to exchange warm from the hot coolant that moves through it to the air passed up the fan. A superior route is to expand the radiator's frontal region either by making it greater or expanding the quantity of cylinders in the columns. The water stream rate through the cylinders will drop yet we have the preferred standpoint that more water is being presented to the coolest air hitting the front of the radiator. Hence the air will be cooler when it achieves the second column. This keeps up the temperature distinction between the cooling air and water.

## III. CREO PARAMETRIC

The radiator used in this work is exhibited using a showing programming called Creo Parametric2.0. Creo is a family or suite of plan programming supporting thing structure for discrete creators and is delivered by PTC. The suite includes applications, each passing on a specific game plan of capacities for a customer work inside thing improvement. Creo continues running on Microsoft Windows and offers applications to 3D CAD parametric part solid illustrating, 3D facilitate showing, 2D orthographic points of view, Finite Element Analysis (FEA) and reenactment, schematic arrangement, particular portrayals, and audit and observation. With Creo Parametric, you can faultlessly merge parametric and arrange showing

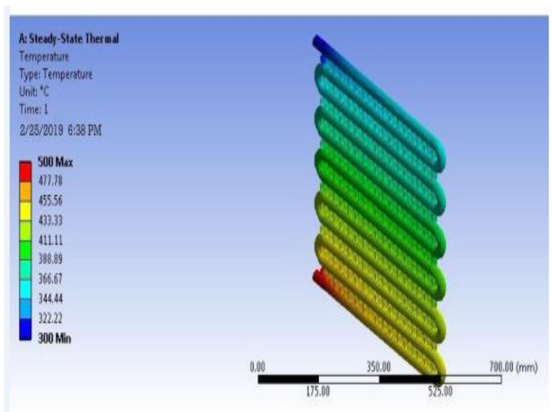


Fig.1. Heat transfer in Aluminium Radiator

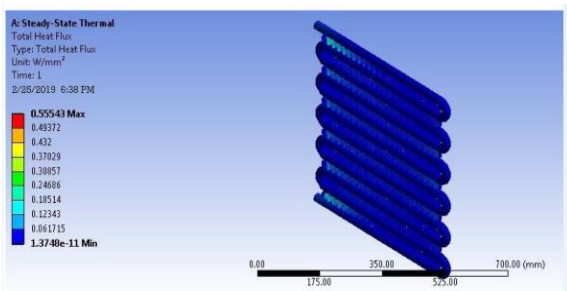


Fig.2.Heat Flux in Aluminium radiator

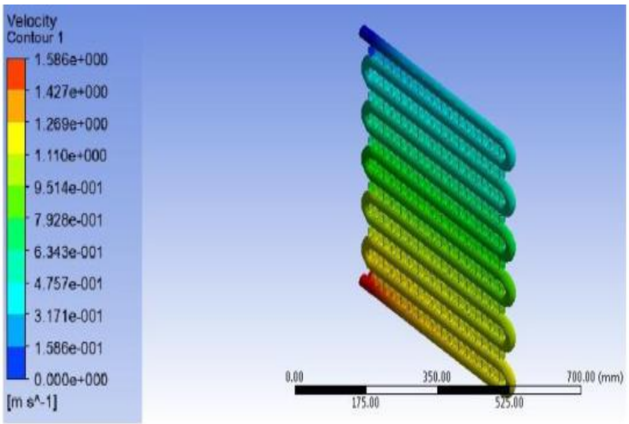


Fig.3.Fluid Velocity in Aluminium radiator

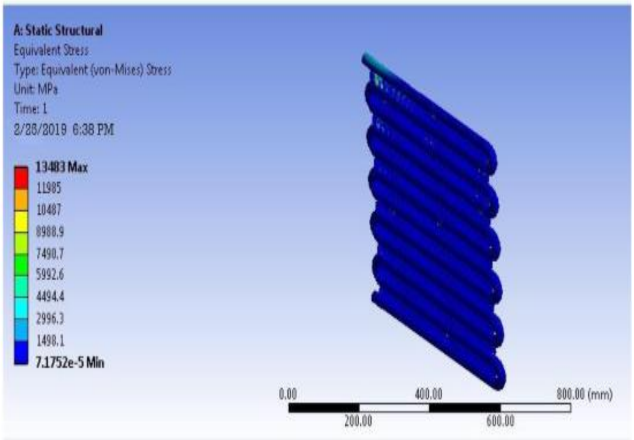


Fig.4. Equivalent stress analysis of Aluminium radiator

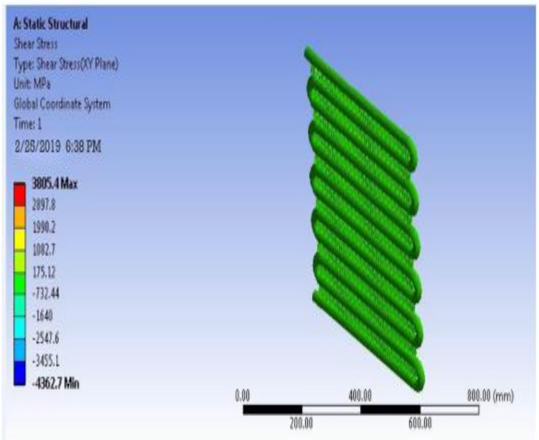


Fig.5. Shear stress in Aluminium Radiator

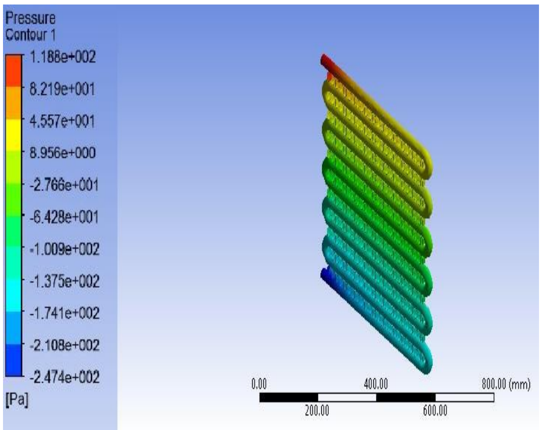


Fig.6.Pressure flow in Aluminium Radiator

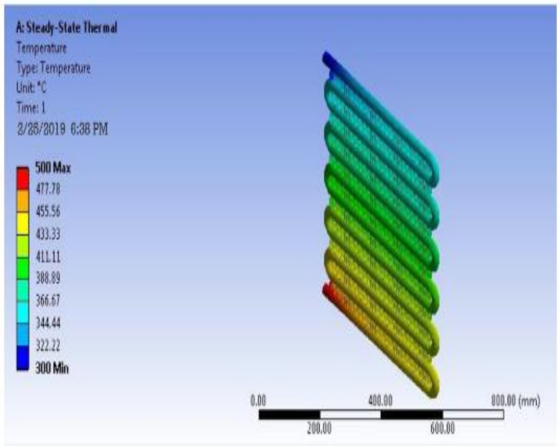


Fig.7.Heat Transfer in Al-Si-Mg Alloy Radiator

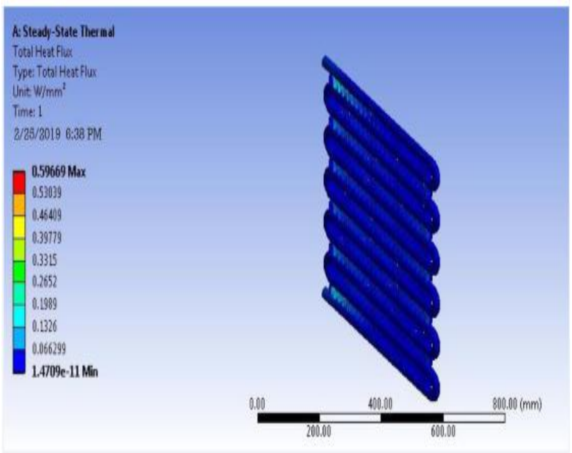


Fig.8.Heat Flux in Al-Si-Mg Alloy Radiator

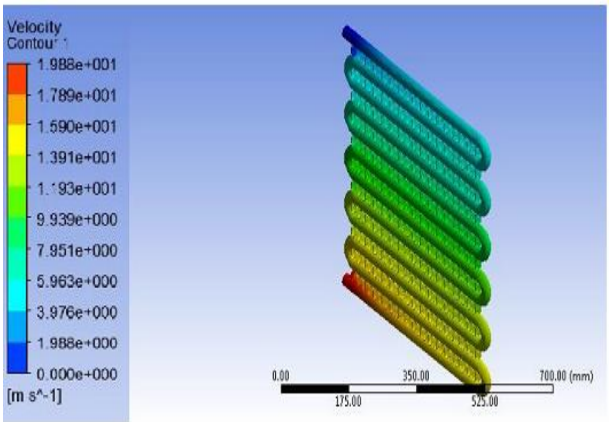


Fig.9. Fluid velocity in Al-Si-Mg Alloy

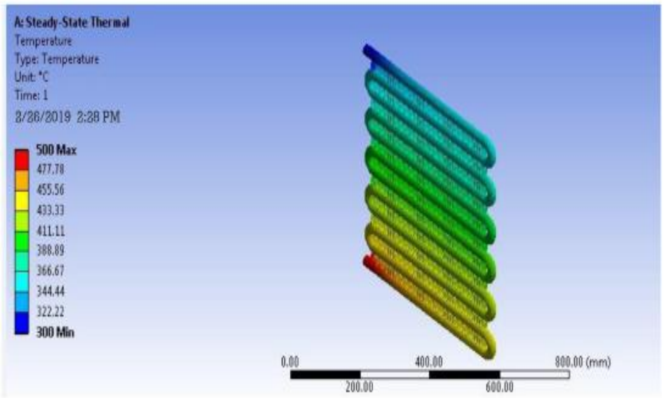


Fig.12.Heat Transfer in Graphite Flakes-Metal alloy Radiator

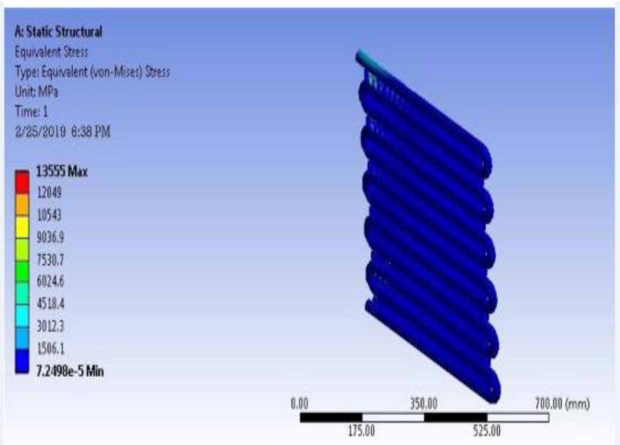


Fig.10. Equivalent Stress in Al-Si-Mg Radiator

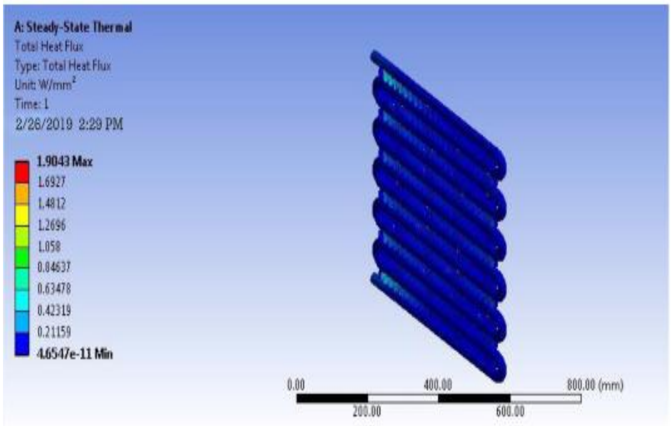


Fig.13.Heat Flux in Graphite Flakes-Metal alloy Radiator

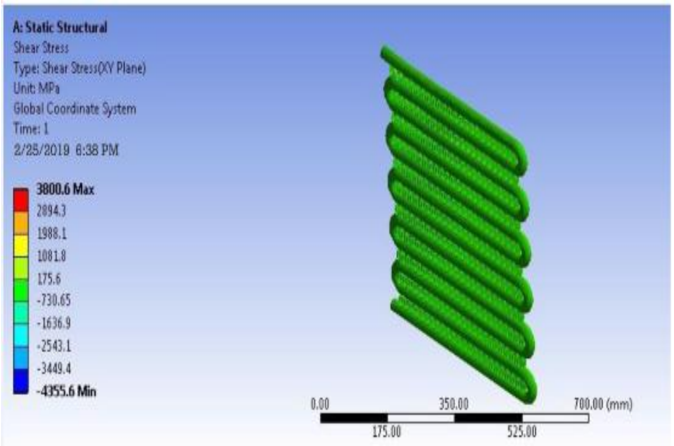


Fig.11. Shear Stress in Al-Si-Mg Radiator

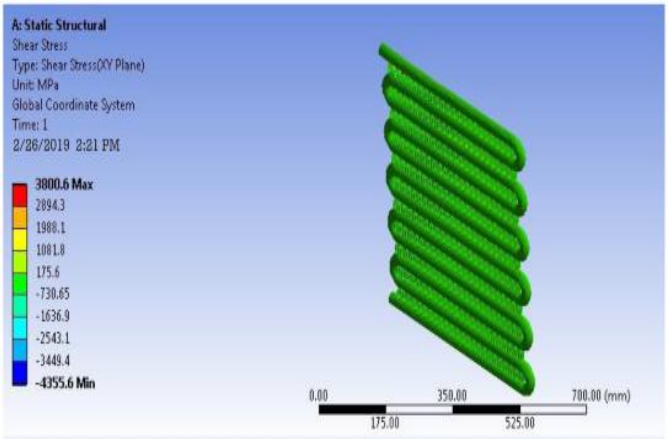


Fig.14. Shear Stress in Graphite Flakes-Metal alloy Radiator

## IV. RESULTS AND CONCLUSION

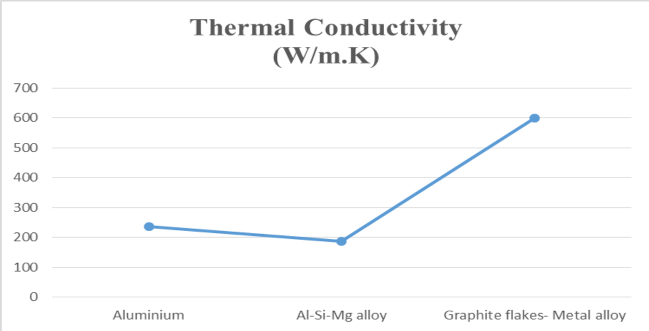


Fig.15. Thermal Conductivity Aluminium, A-Si Alloya and Graphite

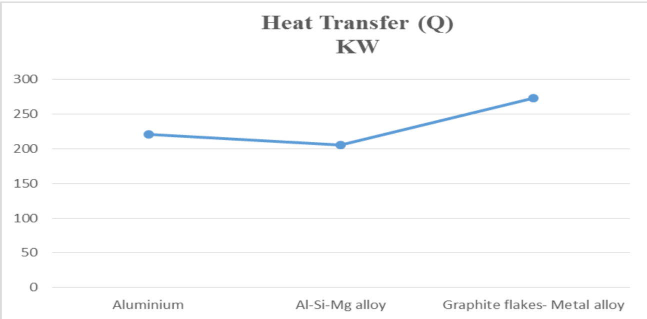


Fig.16. Heat Transfer(Q) Aluminium, A-Si Alloya and Graphite

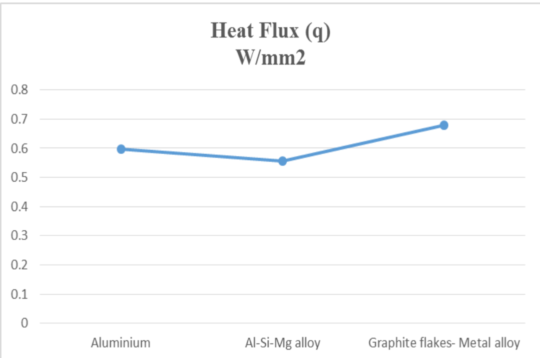


Fig.17. Heat Flux in Q Aluminium, A-Si Alloya and Graphite

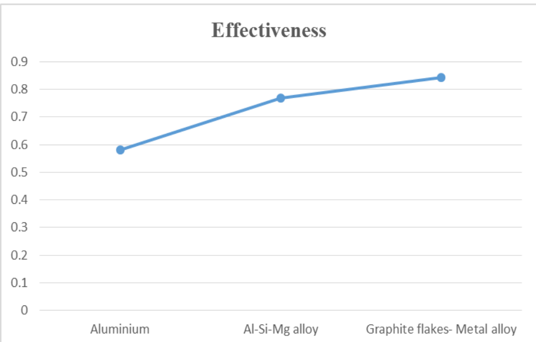


Fig.18. Effectiveness of Aluminium,A-Si Alloya and Graphite

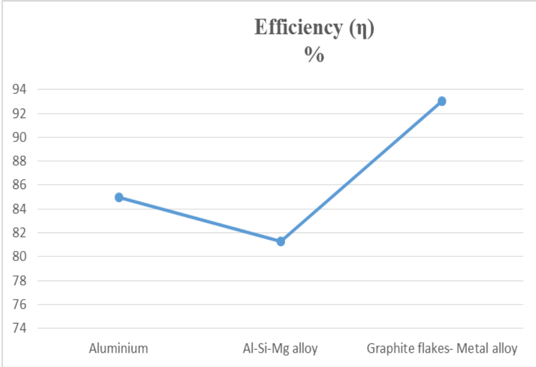


Fig.19. Eficiency of Aluminium, A-Si Alloya and Graphite

**Table 1** Model (B4) > Steady-State Thermal (B5) > Solution

| Domain | Nodes | Elements |
|---|---|---|
| Default Domain | 155098 | 852101 |
| Domain 1 | 70393 | 338717 |
| All Domains | 225491 | 1190818 |

**Table 2**Physics report domain physics for CFX Domain- default domain

| | |
|---|---|
| Type | Fluid |
| Location | B442 |
| *Materials* | |
| Air at 25 C | |
| Fluid Definition | Material Library |
| Morphology | Continuous Fluid |
| *Settings* | |
| Buoyancy Model | Non Buoyant |
| Domain Motion | Stationary |
| Reference Pressure | 1.0000e+00 [atm] |
| Turbulence Model | Isothermal |
| Fluid Temperature | 2.5000e+01 [C] |
| Turbulence Model | k epsilon |
| Turbulent Wall Functions | Scalable |
| **Domain - Domain 1** | |
| Type | Solid |



Retrieval Number: A10570581C19/19©BEIESP

*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

**Table 3: boundary physics for CFX**

| Domain | Boundaries | |
|---|---|---|
| Default Domain | **Boundary - inlet** | |
| | Type | INLET |
| | Location | F448.442 |
| | *Settings* | |
| | Flow Regime | Subsonic |
| | Mass And Momentum | Normal Speed |
| | Normal Speed | 1.0000e+01 [m s^-1] |
| | Turbulence | Medium Intensity and Eddy Viscosity |
| | **Boundary - outlet** | |
| | Type | OUTLET |
| | Location | F444.442 |
| | *Settings* | |
| | Flow Regime | Subsonic |
| | Mass And Momentum | Average Static Pressure |
| | Pressure Profile Blend | 5.0000e-02 |
| | Relative Pressure | 0.0000e+00 [Pa] |
| | Pressure Averaging | Average Over Whole Outlet |
| | **Boundary - Default Domain Default** | |
| | Type | WALL |
| | Location | F443.442, F445.442, F446.442, F447.442, F449.442, F450.442, F451.442, F452.442, F453.442, F454.442, F455.442, F456.442, F457.442, F458.442, F459.442, F460.442, F461.442, F462.442, F463.442, F464.442, F465.442, F466.442, F467.442, F468.442, F469.442, F470.442, F471.442 |
| | *Settings* | |
| | Mass And Momentum | No Slip Wall |
| | Wall Roughness | Smooth Wall |
| | Type | WALL |
| | Location | F168.157, F169.157, F170.157, F171.157, F172.157 |
| | *Settings* | |
| | Heat Transfer | Heat Transfer Coefficient |
| | Heat Transfer Coefficient | 1.0000e+01 [W m^-2 K^-1] |


*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

**Table-4:** Comparision of the resonator

| Sl. No | Material | Thermal Conductivity Heat Transfer Coefficient (K) (W/mK) | Heat Transfer (Q) (KW) | Heat Flux (q) (W/mm²) | Effectiveness (ε) | η % |
|---|---|---|---|---|---|---|
| 1 | Alumini | 237 | 221.16 | 0.59669 | 0.58 | 85 |
| 2 | Al-Si-Mg alloy | 188 | 205.86 | 0.55543 | 0.76 | 81 |
| 3 | Graphite flake | 600 | 273.14 | 0.67863 | 0.84 | 93 |

## VII. CONCLUSION

Vehicles are in recognized due to efficiencywithreducedcost.Scientistsarestilldevelopingcriticalcomponentswith most brief conceivable streamlining and brisk retention in advancement of cutting edge items. Here, in this task, we have explored different avenues regarding two unique materials for future radiators, which are contrasted and the most regularly existing aluminum radiators with the end goal to acquire their execution investigation and results.

### Al-Si-Mg Alloy Radiators

Though the thermal conductivity of Al-Si-Mg alloy (188 W/mK) is lower than that of Aluminium (237 W/mK), it has **higher corrosion resistance** than Aluminium. Hence Al-Si-Mg alloy can be used as the radiator material for coastal side running vehicles which results in longer life of the radiator.

- It has improved strength and greater stiffness when compared to the Aluminium radiators.
- The weight of Al-Si-Mg alloy is less than that of the Aluminium and thus it helps in reducing the weight of the radiator.
- It has higher thermal expansion coefficient.
- Al-Si-Mg alloy radiators can sustain longer at elevated temperatures.
- Due to the above said properties, Al-Si-Mg alloy radiators are well suited for coastal area vehicles and for vehicles that run on corrosive nature environments.

### Graphite Flakes Metal Alloy Radiators

- It has higher thermal conductivity (600 W/mK) than the Aluminium (237 W/mK). Hence it can be used in race cars and in other vehicle which generate lot of heat.
- It can work at high operating temperatures (up to 1500ºC) and its heat transfer rate is very much high compared to Aluminium radiators.
- It has higher efficiency (93%) and can be used in vehicles running on desert-like surroundings where there is high temperature environment.
- Graph alloy radiators are dimensionally stable, do not cold flow or deform under pressure.
- It is highly chemically resistant and so insoluble in most industrial liquids.
- This simplified approach to automobile engine cooling system analysis helps in the selection of material of radiator for various environments.

## REFERENCES


1. Giri, N. K., Automobile Technology, Khanna, pp. 456-504, 2008
2. Rising, F. G., Engine Cooling System Design for Heavy Duty Trucks, SAE 770023, pp. 78-87, 1978
3. Lukanin, V. N. (ed.), Internal Combustion Engines, Mir, Moscow, 1990
4. Rajput, R.K., Internal Combustion Engines, 2nded. Laxmi,
5. Pp.4 82-510, 2007 [5]. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, pp. 668-711, 1988
6. Prockter, C.E. (ed.), Kempe's Engineers Yearbook, 79th ed., Vol. 2, Morgan- Grampian, pp 303-305, 1974
7. Taylor, C. F., the Internal Combustion Engine in Theory and Practice, Vol. 1 & 2, MIT Press, 1985
8. Meziere and Saldana Racing Products, cooling System Principles, systemPrinciples.pdf.
9. Ibrahim Abdelfattah, A. I., Piston Temperatures, Automobile Engineer, Aug. 1954, pp. 335-339
10. Stone, R., Introduction to Internal Combustion Engines, 2nd ed., Macmillan, pp. 377-383 and pp 425-456, 1992
11. Ganesan, V., Computer Simulation of Spark-Ignition Engine Processes, Sangam, pp. 113-115, 1996
12. Robert Bosch GmbH, Bosch Automotive Handbook, 4thed ., Bosch, p.243and pp. 418-421, 1996
13. Yaws, C. L., Physical Properties, McGraw Hill, 1977
14. Pramuditya,S.,2011, www.engineeringtoolbox.com/ethylene-glycol
15. www.engineeringtoolbox.com/ethylene-glycol 49
16. Brace C. J, Burnham-Slipper H, Wijetunge R. S, Vaughan N. D., Wright K., Blight D., Integrated Cooling Systems for Passenger Vehicles, SAE O1HX-8, 2001
17. Robinson, K., Hawley, J G., Hammond, G P., Owen, N J., Convective coolant heat transfer in internal combustion engines, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 2003 217:133
18. Yimin Xuana, Wilfried Roetzelb: Conceptions for heat transfer correlation of Nano fluids conceptions for heat transfer correlation of Nano fluids.
19. Gunnasegaran, shuaib N.H., Abdul Jalala, M.F.ndSandhita {2012}„Numerical Study of Fluid Dynamic and Heat Transfer in a Compact Heat Exchanger Using Nano fluids‟, ISRN Mechanical Engineering , Vol.2012, Article ID 585496.
20. J. Koo and C. Kleinstreuer {2004} „A new thermal conductivity model for Nano fluids‟, Journal Nano particle Research, Vol. 6, pp. 577-588.
21. K.Y. Leong, R. Saidur, S.N. Kazi and A. H. Mamun, {2010}„Performance investigation of an automotive car radiator operated with Nano fluid–based coolants (Nano fluid as a coolant in a radiator)‟, Applied Thermal Engineering, Vol. 30, pp. 2685-2692.
22. S.M. Peyghambarzadeh, S.H. Hashemabadi, S.M. Hoseini, and M. Seifi Jamnani, {2011} „Improving the cooling performance of automobile radiator with Al2O3/water Nano fluid‟, Applied Thermal Engineering, Vol. 31, pp.1833-1838.

**AUTHORS PROFILE**

I**C Gopinath** based out of Chennai and current working as an Assistant professor (Department of Mechanical Engineering) In St.Joseph College of Engineering Sriperumbudur, Chennai. I have worked as design engineer in Webb India Pvt.Ltd Bangalore for a year, post that I have started worked as a lecturer in Thirumalai Engineering College Kancheepuram for 2 years and has over all experience is 10 years in the era of teaching. I am expertise in Machine design, Manufacturing technology and Finite element analysis. Coming to my educational background I am now pursuing my Ph.D. in the area of research Materials and Manufacturing from Anna University under the guidance of **Dr.L.Poovazhagan**, completed my Master of Engineering in Thiruvalluvar College of Engineering and Technology and have completed my Bachelor of Engineering in the course of Mechanical in Thirumalai Engineering College. I have filed two patents in the Official Journal of the patent office in India on the topics of Smart seat belt system and System and Method for Decomposing Organic and food waste. I have attended many faculty development programs, workshops and national conferences in various areas sponsored by Anna University. I have done my certifications in design software's like Auto CAD and CREO parametric.

**Dr.L.Poovazhagan** living in Chennai, presently I am working as an Associate professor (Department of Mechanical Engineering) in SSN College of Engineering, Kalavakkam, Chennai. I have an overall experience of 19.5 years in teaching. In 2014, I have completed my Ph.D. in the domain of Nano composites from Anna University-Chennai and completed my Master of Engineering in Manufacturing Engineering in 2004 from Annamalai University-Chidambaram. I have completed my Bachelor of Engineering in Mechanical Engineering from Coimbatore Institute of Technology-Coimbatore. I have published 19 papers in referred international journals and published a book. I have attended twenty national and international conferences and delivered 10 invited lectures. Under my Guidance, Seven Students are pursuing Ph.D. in the area of Nano composites and manufacturing. I am representing as doctoral committee members for many Ph.D. scholars. I have guided 25 UG/PG projects. Currently, carrying out two funded projects (DST SERB CRG –RS 2500000 and SSN Trust –RS 250000).



Retrieval Number: A10570581C19/19©BEIESP

*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*