DESIGN AND ANALYSIS OF THERMAL DISTRIBUTION OF COMPRESSOR FINS

K.M.Arunraja[1],S.R.Rajabalayanan[2], G.Kishoreraj[2] ,G.Madasamy[2], S.Naveenkumar[2]
[1]Department of Mechanical Engineering, Shree Venkateshwara Hi-Tech Engineering College, Gobichettipalayam, Erode, Tamilnadu-638455
[2]Department of Mechanical Engineering, Hindusthan Institute of Technology
Pollachi Main Road, Malumichampatti, Coimbatore– 641032
arunrajamurugan@gmail.com (corresponding author)

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ABSTRACT:

In air compressor heat can generated by two ways, heat produce by friction as well as by due to compress of air at high pressure, so this heat will transfer to atmosphere by fins. But normally circular fins are used in compressor cylinder. In our project we adopt different types of fins for experiment process and select most effective cooling fins.This project reports a study carried out using 3-D modeling and finite element analysis for cooling fin. Using unigraphics as a 3-D modeling softwarethe 3-D model of the various types of cooling fin created. Using Neutral file format the model was imported into Ansys. Here the solid model was converted into Finite Element model. Boundary conditions such as maximumtemperature of the cylinder, convective heat transfer coefficient,ambient temperature and materialproperties such as thermal conductivityof the material are used as set ofparameters fortheprogram. Heat flux and temperature profiles were used as measure ofefficiency.

INTRODUCTION:

Currently, many industries face problem of overheating in electronic components due to heat generation within them. The industries manufacture the appliances with compact design and low cost. But the heat needs to be disbursed at higher rate to maintain the temperature of the device so that the component remains within working temperature range. Therefore, devising efficient cooling is an answer to fulfill cooling requirement in devices. To overcome the problem of overheating, especially in thermal systems, fins are usually provided. Fins can be analyzed in design phase only using Computational Fluid Dynamics as tool and assuming uniform heat transfer coefficient model on its surface. However, research investigators prove that heat dissipation is not constant, however varies along the fin length. It is mostlydueto non-uniform resistance experienced by the fluid flow in the inter fin region. In order to dissipate highheat flux densities, the specified heat sink have to be larger than device. Consequently, the heat sink overall performance is decreased. The inter fin resistance can be decreased with the aid of adding the perforation to the fins. Adding a pass-fin in the middle enablesto increase the heat dissipation area, but it forms the stagnant layer of hotair at the fin bottom. The fluid drift motion at theunderside of the fin array may be improved by adding perforation to the fins.

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Heat Transfer:

Heat transfer is the transfer of thermal energy from a heated body to a colder body. Exchange of heat occurs till body and the surroundings reach at the same temperature. According to the second law of thermodynamics, 'Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped'; it can only be slowed down. Heat is the energy in transit between systems which occurs by virtue of their temperature difference when they communicate. Obviously, conditions of temperature disparity and communication must be fulfilled simultaneously for heat interaction between systems to occur. The finite temperature difference existing between the systems makes the process of heat exchange irreversible, i.e. flow of heat cannot be reversed.

Modes of Heat transfer:

Heat transfer usually includes three separate methods of heat transmission: conduction, convection and radiation. These three modes are similar in that a temperature difference must exist and the heat conversation is in the direction of reducing temperature.

Heat transfer is classified into three types. The first is conduction, which is defined as transfer of heat occurring through intervening matter without bulk motion of the matter. A solid has one surface at a high temperature and one at a lower temperature. This type of heat conduction can occur, for example, through a turbine blade in a jet engine. The outside surface, which is exposed to gases from the combustor, is at a higher temperature than the inside surface, which has cooling air next to it. The second heat transfer process is convection, or heat transfer due to a flowing fluid. The fluid can be a gas or a liquid; both have applications in aerospace technology. In convection heat transfer, the heat is moved through bulk transfer of a non-uniform temperature fluid.

The third process is radiation or transmission of energy through space without the necessary presence of matter. Radiation is the only method for heat transfer in space. Radiation can be important even in situations in which there is an intervening medium; a familiar example is the heat transfer from a glowing piece of metal or from a fire. Convective heat transfer is between the surfaces andsurrounding fluid can be increased byproviding the thin strips of metal called fins. Fins are also referred as extended surfaces. Whenever the available surfaces are inadequate to transfer the required quantity of heat, fins will be used. Fins are manufactured with different sizes and shape depends on the type of application. Air cooling for an IC Engine is well known example for Air cooling system in which air acting as a medium. Heat generated in the cylinder will be dissipated in to the atmosphere by conduction mode through the fins or extended surfaces are used in this system, which are incorporated around cylinder.

Conduction:

Thermal conduction is a process of heat transmission from a section of higher temperature to a section of low temperature with a medium (solid, liquid, or gases) or between several mediums in direct physical contact. Conduction does not include any transfer of macroscopic portions of matter relative to one another. The thermal energy may be transmitted by means of electrons which are free to move by the lattice structure of the material.

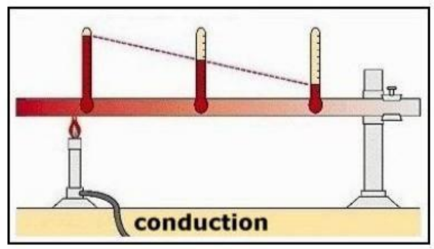


Fig. 1. Experiment explaining heat transfer by conduction

Convection:

The thermal convection is a process of energy, transference affected from the motion or mixing of a fluid medium. Convection is performing only in a fluid medium and is at once linked to the motion of medium itself. Macroscopic particles of a fluid movement in space cause the heat exchange, and for this reason convection constitutes the macroform of the heat transfer. The effectiveness of heat transfer through convection based largely upon the mixing movement of the fluid. With respect to the origin, types of convection are distinguished; forced and natural convection.

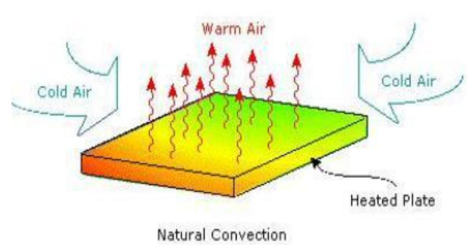


Figure 2: Heated Plate

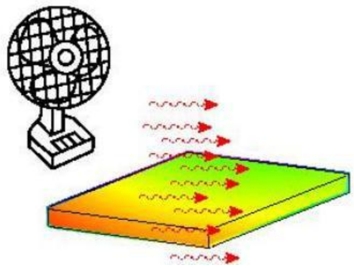


Figure 3:Forced Convection

Radiation:

Radiation is the energy transfer in the form of waves through space without any medium other than conduction and convection. Conduction and convection require a medium like solid or gas but radiation only happen in space through electromagnetic waves. The velocity of radiation which can be emitted from an outside at an absolute temperature T is governed by the Stefan-Boltzmann law as = ^{4}

Where, σ =5.670 ×10 -8 W/m 2 is the Stefan Boltzmann constant. The black body is ideal surface for emits radiation at maximum rate, and the radiation transferred by a black body is called black body radiation.Absorptivity α is another important property of a plane, is explained as the division of theradiation energy incident on a surface that is received by the surface. The entire radiationincident on it is absorbed by black body. That is, a blackbody is a perfect absorber (α=1) of radiation.

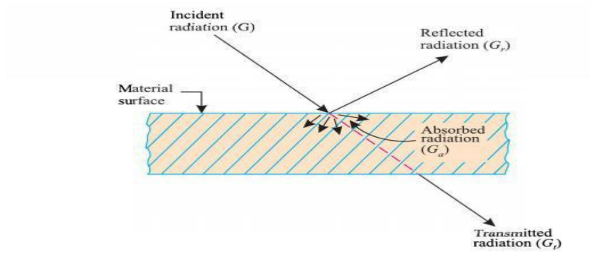


Figure 4: Transmission of Radiation

Natural Air Cooling:

In normal cause, larger parts of an engine remain exposed to the atmospheric air. When the vehicles run, the air at certain relative velocity impinges upon the engine, and sweeps away its heat.

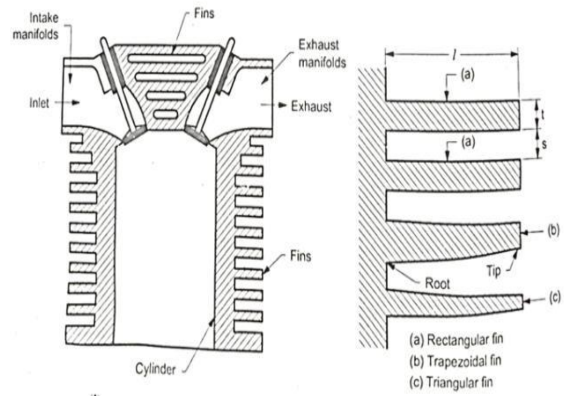
The heat carried-away by the air is due to natural convection, therefore this method is known as Natural air-cooling. Engines mounted on 2-wheelers are mostly cooled by natural air. As the heat dissipation is a function of frontal cross-sectional area of the engine, therefore there exists a need to enlarge this area. An engine with enlarge area will becomes bulky and in turn will also reduce the power by weight ratio. Hence, as an alternative arrangement, fins are constructed to enhance the frontal cross-sectional area of the engine. Fins (or ribs) are sharp projections provided on the surfaces of cylinder block and cylinder head. They increase the outer contact area between a cylinder and the air. Fins are, generally, casted integrally

Fins:

A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, radiation of an object determines the amount of heat it transfers.

Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options.

Adding a fin to the object, however, increases the surface area and can sometimes be economical solution to heat transfer problems. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples.



- Rectangular fin
- Triangular fin
- Trapezium fins
- Circular segmental fins.

Different shape and designs of fins are used in different situations.

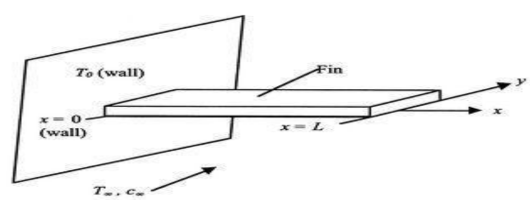


Figure 5:diagram of heat transfer fin

The fundamental modes of heat transfer are conduction or diffusion, convection and radiation.

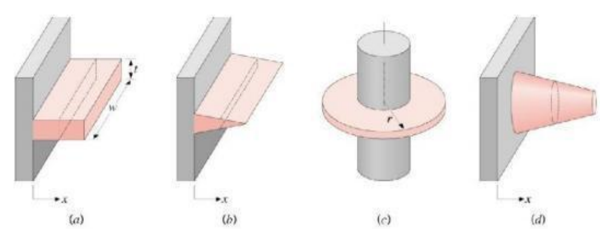


Figure 6: Use of extended surface or fin to enhance heat transfer.

Applications of Heat Sinks (Fins):

Natural Convection is caused by temperature variations in the fluid. Natural convection from heat sinks has long been used for thermal management of low-power-density devices. This cooling technique has many advantages such as the absence of moving parts, of power consumption, and of maintenance necessity. In addition, it offers quiet operation, high reliability, and low cost. For these reasons, natural convection heat transfer plays an important role in many types of cooling systems including electronic industry which has attracted constant researches for decades. Some applications can be listed as:

- Economizers for steam power plant
- Electrical transformers and motors
- Convectors for hot water and steam heating system
- Air cooled cylinders of aircraft engines, I.C. engines and air compressors
- Cooling coils and condenser coils in refrigerators and conditioners.

Advantages of Air Cooling System:

(a) Radiator/pump is absent hence the s ystem is light in weigHT

(b) In case of a water cooling system t here are leakages, but in this case of ai r cooling thereareno leakages.

(c) Coolant and antifreeze solutions are not required in air cooling systems.

(d) This system can be used in cold cli mates, where if water

Is used it may freeze.

INTRODUCTIONS TO CATIA:

CATIA which stands for computer aided three dimensional interactive applications is the most powerful and widely used CAD (computer aided design) software of its kind in the world. CATIA is owned/developed by Dassault system of France and until 2010, was marketed worldwide by IBM.

The Following general methodologies and best practices can be followed in the modeling of components in CATIA. The Below methodologies and Best practices followed will help in capturing the design intent of the Feature that is to be Modeled and will make the design robust and easy to navigate through.

- Specification tree structuring

- Renaming appropriate features & bodies in specification tree
- Handling input data & foreign bodies
- Dimensioning & constraining in sketches
- Parameters and relations.

Material used to fins :

Cast ron:

Cast iron is basically an alloy of carbon and silicon with iron. It is cont aining 2.4 – 3.7 % C, 1.1 – 2.8% Si, 0.3 1.1% Mn, 0.16% P and 0 .11% S. Cast iron possesses high fluidit y and hene it is cast into any complex shapes and thin sections. It has an exc ellent wear resistance of grey iron under lubricating sliding conditions has been a ttributed to thepresence of graphite in th e microstructure It possesses high dampin g capacity in addition to that cast iron provided the working conditions are clea n. The material properties of cast iron a re given below

Aluminium:

Aluminum is a silvery white metal and it possess following characteristics:

Light metal, good conductivity, higher re sistance to corrosi

on and very ductile. The melting poi nt of aluminum alloy v

aries from 520 650oC. It is common to see aluminum fins on engine cylinders and heat exchangers.

In general, Aluminum is mostly used as fin material because:

- It has good thermal conductivity com pared to the cast iron
- Aluminum is lighter in weight.
- High corrosion resistance.
- High surface finish

Problem Definition:

In the present Project investigation on thermal issues on fins were carried out. Investigation yields the temperature behaviour and heat flux of the fins due to high temperature in the compressor chamber. Ansys work bench is utilized for analysis. The analysis is done for different models of fins that are commercially available now a days and a comparison is thus established between them. Also the material and design changed so that better heat transfer rate can be obtained.

Objectives of the project:

The following are the main objectives of the present work:

1) To design cylinder with fins by same

2) To determine steady state thermal properties of the proposed fin models.

3) To identify suitable alloy for the fabrication based on results obtained from finite element analysis and analytical method.

Methodology:

Step 1: Collecting information and data related to cooling fins.

Step 2: A fully parametric model of the cylinder with fin is created in catia software.

Step 3: Model obtained in igs is analyzed using ANSYS 14.5, to obtain the heat rate, temperature distribution

Step 4: Manual calculations theoretically and analytically are done.

Step 5: Finally, we compare the results obtained from ANSYS and compared different geometry and materials

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	2.0 mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	115.22 mm
Average Surface Area	978.41 mm²
Minimum Edge Length	2.e-002 mm
Quality	

Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium

Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on	No

Refresh	
Statistics	
Nodes	77938
Elements	17135

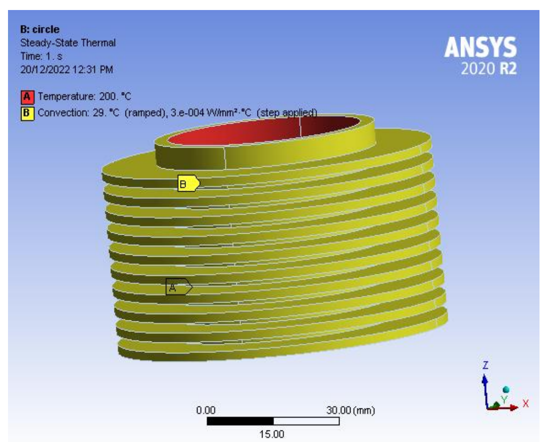


Fig 4.2.boundary condition

RESULT OF DIFFERENT SHAPES OF FINS:

Circle shape:

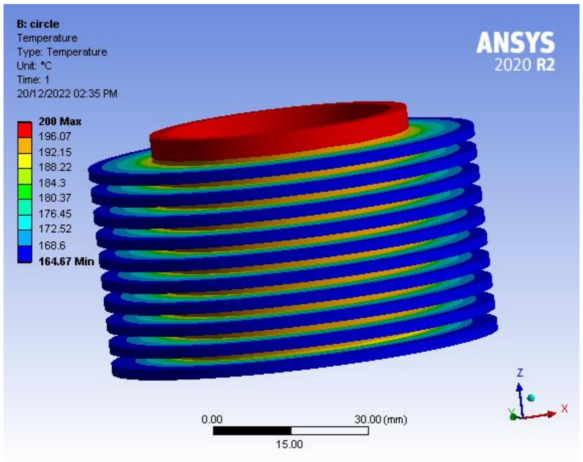


Fig 4.3.circular shape fin's temperature distribution

The temperature distribution of from 200 to 164 degree Celsius when using aluminium as base material

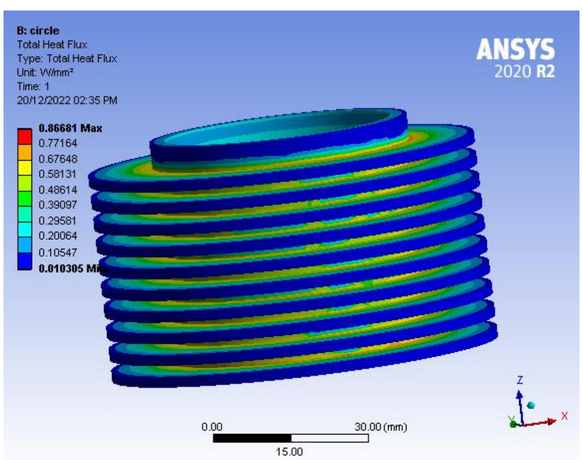


Fig 4.4. Heat flux of circular shape fins

The heat flow rate 0.866w/mm^2 the amount heat transfer through area when using rectangular cross shape fins

Triangular fins shape:

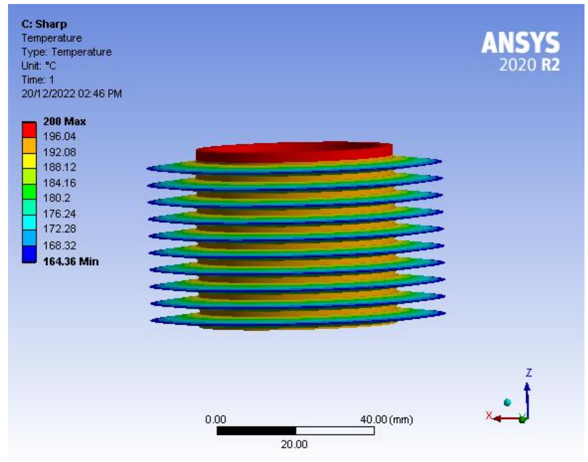
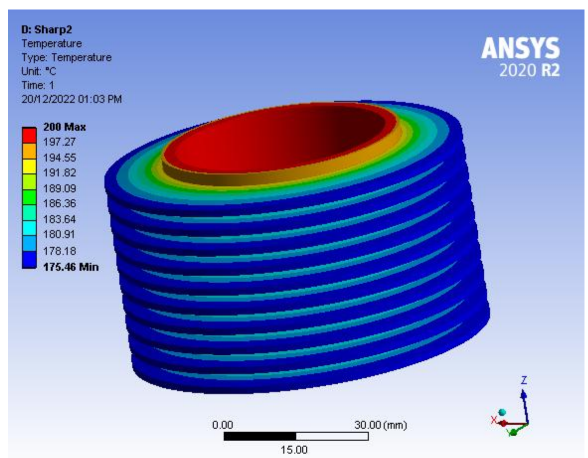
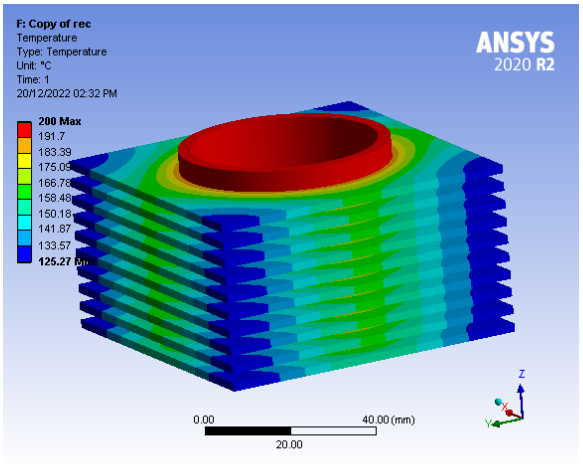


Fig 4.5. Triangular shape fin's temperature distribution

Trapezium fins:



Rectangular shape:



Result comparison

Result comparison :

S.no	Fin Shapes	Thermal Disruptions (^{0}C)		Heat Flux (W/mm^2)
		Max	Min	
1	Circular shape	**200**	164.67	**0.866**
2	Triangular shapes	200	164.36	0.587
3	Trapezium Shape	200	175.46	0.525
4	Rectangular Shape	200	125.27	1.175

Conclusion:

In present work, a cylinder fin body is modelled by using CATIA and thermal analysis is done by using ANSYS WORKBENCH-. These fins are used for air cooling systems. In present study, different shapes of fins analysis by Aluminium based material. The various parameters (i.e., geometry and thickness of the fin) are considered, by changing the shape of the fin to circular shape from the conventional geometry i.e., Rectangular, the weight of the fin body reduces there by increasing the heat transfer rate and efficiency of the fin. The results show, by using rectangular fin with material Aluminium Alloy is better since heat transfer rate of the fines more. Because comparing thermal distribution values circular shapes 18%,Triangular 17.82% ,trapezoidal shapes 12.4% and the rectangular shapes reducing 37.36 % of heat it s clearing explained that comparing with other shapes rectangular shapes covering more surface area .Each individual particle on the surface of an object is involved in the heat conduction process. An object with a wider area has more surface particles working to conduct heat. As such, the rate of heat transfer is directly proportional to the surface area through which the heat is being conducted.

REFERENCES:

1. Charan, Srivastav, Bharadwaj, "Thermal Analysis On Rectangular Plate Fin with Perforations Using Ansys", International Journal of Creative Research Thoughts, 2018.

2. Sangaj, Shinde, Shanediwan, Potdar, Suryawanshi, "Thermal and Parametric Analysis of Pin-Fin", International ResearchJournal of Engineering and Technology (IRJET), Volume 05, Issue 02, Feb-2018.

3. Kiran Beldar,AvinashPatil,"Design and Analysis of cylinder having longitudinal fins with rectangular notches", International Journal of Scientific Development and Research (IJSDR), 2017.

4. Rajesh, Rahamathullah, MalleswaraRao, "design and optimization of engine cylinder fins by varying Geometry and material with thermal analysis", International Journal of Core Engineering & Management, 2017.

5. Mayankjain, MahendraSankhala, KanhaiyaPatidar,"heat transfer analysis and optimization of fins by Variation in geometry", International Journal of Mechanical and Production Engineering, Volume- 5, Issue-7, Jul.-2017.

6. Kummitha, Reddy, "Thermal Analysis of cylinder block with fins for different materials using ANSYS", ICAAMM, Elsevier, 2016.

7. S.Ravikumar, Chandra, Harish, "Experimental and Transient Thermal Analysis of Heat Sink Fin for CPU processor for better performance", Materials Science and Engineering, 197, 2017.

8. Sandeep Kumar, NitinDubey, "Investigation and Thermal Analysis of Heat Dissipation Rate of Single Cylinder SI Engine", IJEDR, Volume 5, Issue 2, 2017.

9. Mogaji, Owoseni, "Numerical Analysis of Radiation Effect on Heat Flow through Fin of Rectangular Profile", American Journal of Engineering Research (AJER), Volume-6, Issue-10, pp-36-46, 2017.

10. Arefin, "Thermal Analysis of Modified Pin Fin Heat Sink for Natural Convection", 5th International Conference on Informatics, Electronics and Vision, 2016.

11. Balendra Singh, Satish Singh, "A Research Paper on Heat Transfer in Notch Fin and UN Notch Fin", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 4 Issue IX, September 2016.

12. Kongre, Barde, "A Review Paper on Thermal Analysis and Heat Transfer of

Single Cylinder S. I. Engine Fins", International Journal of Engineering Research & Technology (IJERT), Volume 4, Issue 30, 2016.

13. Natrayan, Selvaraj, Alagirisamy, "Thermal Analysis of Engine Fins with Different Geometries", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 5, May 2016.

14. Laad, BAkhare, Chaurasia, "Thermal Analysis of Heat Sink with Fins Of Different Configuration Using Ansys Workbench 14.0", International Journal Of Engineering Sciences & Research Technology, volume 5, Issue 6, 2016.

15. SaurabhPathak, Ravikant, "Thermal Analysis of Fins with Varying Geometry of Different Materials", IJSRD - International Journal for Scientific Research & Development, Vol. 4, Issue 03, 2016.

16. Alshabbani, "CFD Simulation of Unsteady State Thermal Analysis for Circular Fins", Industrial Engineering Letters, Vol.5, No.12, 2015.

17. Prabisha, Ramesh, "Thermal Performance Evaluation of Heat Sink for Various Fin Profiles", International Journal of Science, Technology & Management, Volume No 04, Special Issue No. 01, March 2015.

18. SantoshKansal, PiyushLaad, "Performance & Thermal Analysis of Heat Sink with Fins of Different Configuration Using CFD", International Journal of Scientific & Engineering Research, Volume 6, Issue 6, June-2015.

19. Oswal, Jagtap, Mane, "Factors Affecting on Thermal Performance of Fins & Analysis of Fins with ANSYS Icepak", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 6, June 2015.

20. Shrivastava, Upadhyay, "Thermal Analysis of IC Engine Cylinder Block with Fins Perpendicular to the Axis of Piston Movement", International Journal of Mechanical and Industrial Technology, Vol. 3, Issue 2, pp: 139-149,2016.

21. M. S. Patel, N.M. Vora, "Thermal Analysis of I C Engine cylinder fins array using CFD", International Journal of Advance Engineering and Research Development (IJAERD) Volume 1, Issue 5, May 2014.

22. N. B. Rairker, A. V. Karmankar, R. E. Thombre, "Thermal Analysis of Fin and Tube Heat Exchanger", International Journal of Engineering Research and Applications, Vol. 4, Issue 6, June 2014, pp.01-05.

23. Chaitanya, Suneela Rani, Vijaya Kumar, "Thermal Analysis of Engine Cylinder Fin by Varying Its Geometry and Material", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 11, Issue 6, 2014, PP 37-44.

24. Chakrabortya, Luharuka, A. Sirkar, "Thermal Analysis of Semicircular Fins Considering Temperature-dependent Thermal Conductivity and Heat Transfer Coefficient", Indian Chemical Engineer, Taylor and Francis, Vol. 56 No. 3 September 2014, pp. 281–293.

25. LaxmikantChavan, NiranjanPurane, "Thermal Analysis of Pin Fin using Different Materials and Forms", International Journal of Science and Research (IJSR), Volume 4 Issue 12, December 2015.

26. Mohsen Torabi, Yaghoobi, "Thermal Analysis of the Convective-Radiative Fin with A Step Change In Thickness And Temperature Dependent Thermal Conductivity", Journal Of Theoretical And Applied Mechanics, 51, 3, pp. 593-602, Warsaw 2013.

27. Heat and Mass Transfer. 7 th edition, S. K. Kataria&Sons.

28. Heat and Mass Transfer. Revised edition, R. K. Rajput, S. Chand Publications.

29. Ravikumar M, Radhakrishnan B, Arunraja K M, and Pandiyarajan K, (2022) “Heat Transfer Analysis of Fin and Tube Exchanger using CFD”, Materials Today Proceeding, Elesvier Publications, Vol.52, 3, pp:1603-1605.

30. Yasin, J., Selvakumar, S., Kumar, P. M., Sundaresan, R., &Arunraja, K. M. (2022). “Experimental study of TiN, TiAlN and TiSiN coated high speed steel tool”. Materials Today: Proceedings.

31. Ponmurugan, M., M. Ravikumar, R. Selvendran, C. Merlin Medona, and K. M. Arunraja. "A review on energy conserving materials for passive cooling in buildings." Materials Today: Proceedings (2022).

32. P Thangavel, V Selladurai (2008), “An experimental investigation on the effect of turning parameters on surface roughness”, Int. J. Manuf. Res. 3 (3), 285-300.

33. Alwarsamy, T. &Palaniappan, Thangavel&Selladurai, Vini. (2007). Reduction of machining vibration by use of rubber layered laminates between tool holder and insert. Machining Science and Technology. 11. 135-143. 10.1080/10910340601172248.

34. Prakasam, S &Palaniappan, Thangavel. (2013). Springback effect prediction in wipe bending process of sheet metal: A GA-ANN

approach. Journal of Theoretical and Applied Information Technology. 55.

35. M. Viswanath and K.M.Arunraja, “A Literature Review on Hybrid Electric Vehicles”, International Journal of Engineering Research & Technology, Vol.6 Issue 04,Special Issue on 2018.

36. Mathivanan, S., K. M. Arunraja, and M. Viswanath. "Experimental Investigation on Aluminum Metal Matrix Composite." International Journal of Engineering Research & Technology, ISSN (2018): 2278- 0181.