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Thermal Analysis of I C Engine Fins using ANSYS Software

Nitesh Vaishnav
M.Tech. Research Scholar
Department of Mechanical Engineering,
Oriental University
Indore, (M.P.) [INDIA]
Email: niteshvai2012@gmail.com

Satya Narayan Dubey
Assistant Professor
Department of Mechanical Engineering,
Oriental University
Indore(M.P.), [INDIA]
Email: satyanarayan.hcet@gmail.com

Abstract— *In order to cool the engine, fins are provided on the cylinder to increase the rate of heat transfer. Present research work is based on investigations on fin thickness and improved material selection for an internal combustions engine assembly. For this purpose simulation approach was adopted in which dimensions of fins from a standard engine were taken, model is prepared and analysis of model was conducted on a well-known simulation software ANSYS 15.0. The main purpose of analysis thermal properties, three criteria namely, heat flux; thermal gradient and average temperature were selected. The varying parameters were fin thickness, and fin materials. Heat flux show varied results, and therefore on this criterion rankings of different materials with fin thicknesses were investigated. Results show the suitability of Al alloy 204 with fin thickness of 3 mm for the purpose.*

Keywords:— *Cooling Fins, Heat transfer, extended surfaces, Simulation, ANSYS.*

1. INTRODUCTION

We know that in the case of internal combustion engines (petrol engines), combustion of air and fuel takes place within the engine cylinder and hot gases are generated. Combustion with small capacity engine the temperature of gases reached around 1000-1500°C. This can be a really high and can result in burning of oil film between the moving elements and result into seizing of piston too. So, this temperature should be reduced to regarding 150-200°C at which the engine can work satisfactorily. An excessive amount of cooling is additionally not fascinating as it reduces the thermal efficiency of the system. So, the purpose of cooling system is to stay the engine running at its most effective operating temperature. If cooling system cools the engine below satisfactory working temperature, it shall be overcooled and not work properly; therefore, cooling system requires maintaining the minimum temperature of the engine.

There are two main types of cooling systems; water cooled and air cooled systems. In water cooled systems, cooling water is used to carry away the heat generated from the system. Air cooled systems are used in the engines with the small capacity of around 10-20 kW. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion within the engine cylinder is conducted to the fins and when the air flows over the fins, heat gets dissipated by air. The quantity of heat dissipated to air depends upon many factors, but the important factors are quantity of air flowing through the fins, surface area of the fins exposed to the air, and thermal conductivity of the material used to make fins.

Considering above mentioned facts

present research is devoted to investigations on IC engine fins. The basic reason of choosing an IC engines is its wide applicability. For this purpose a simulation approach is being adopted. For the research a standard engine is targeted and effects of variation of changes in material and fin width are analysed.

1.1 Objective of the Research

Following are the objectives of the research:

1. To analyze the effect of material changes on thermal characteristics of IC engine; and
2. To analyze the effect of changes of fin dimensions on the thermal characteristics of IC engine.

2. LITERATURE REVIEW

Present Section tells about the details of research contributions of different researchers on extended surfaces associated with internal combustion engines and gaps in the research, the details of which are presented in upcoming sub-sections.

2.1 Research contributions from Researchers

Following are the details of research contributions from different researchers in the field of I C Engine fins.

1) Naman Sahu (2018)

According to researcher, 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 mostly due to non-uniform resistance experienced by the fluid flow in the inter fin region. In order to dissipate high heat 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 enables to increase the heat dissipation area, but it forms the stagnant layer of hot air at the fin bottom. The fluid drift motion at the underside of the fin array may be improved by adding perforation to the fins. Also we can develop a model for the values of total heat flux and temperature distribution by using ANSYS.

2) Deepak Tekhre (2017)

In this research studied to investigate heat dissipative effect of fins made up of different materials and different geometries. It’s necessary to analyze the heat transfer rate of fins. Study will lead to the different experiments which have been made to increase fin efficiency by changing fin material properties, climatic condition around fins, using perforations and notches in fins and fin geometry. The main thermal analysis tool is CFD analysis with the help of computer modeling software. The main study is focused on a two wheeler engine (Honda unicorn 150cc). It also founded that change in environmental condition causes great change in heat transfer coefficient and in its efficiency.

3) K. Sathishkumar and S. Balamurugan (2017)

This paper provides that The fins with various configurations were modeled using CREO 2.0 and analyses are done by using CFD – Fluent in order to find out the heat transfer rate. It is clear that the results from software and theoretically says that the fins with rectangular notch have greater heat transfer rate compared to that of the fins without holes, fins with holes and V shaped fins. Since the heat dissipation rate is more in rectangular notch so we conclude that the rectangular notch fins are most efficiency and best heat transfer notch among all types of notch.

4) Piyush Laad, Bhushan Akhare et al. (2016)

According to researcher, the impact of the pin-fin shapes on the general performance of the heat sink with inline and staggered arrangement is studied during this research. Six totally different shapes of fins square, trapezoidal, rectangular interrupted, rectangle, circular inline and staggered are subjected to study during this research. The optimization processes are allotted using computer simulations performed using ANSYS bench 14.0. Heat transfer was analysed in natural air and aluminum 6063 as a pin fin material. to review of thermal performance of different heat sink of fin profile at different velocities 5, 10 & 12 m/s and simulation is completed at totally different heat load of 15W, 20W & 25 W and air inlet temperature is taken as 295 K. the aim of this study is to look at the effects of the configurations of the various pin-fins design. It is determined from the results that optimum cooling is achieved by the heat sink design that contains Circular pin fins. After the choice of correct heat sink by CFD simulations the steady state thermal performance is allotted at different fin height of circular pin fin heat sink. The result shows that the temperature is increasing by reducing the fin height. At totally different loads the performance of all chosen fin profiles is allotted and located that at & 25 W load the maximum temperature is maximum for interrupted rectangular fin and minimum for circular pin fin. And therefore the price of Nusslet number is additionally maximum for circular pin fin design.

5) Deepak Gupta and Wankhade (2015)

This paper provides the cooling mechanism of the air cooled engine is mostly enthusiastic about the fin design of the cylinder head and block. Cooling fins are accustomed increase the heat transfer rate of specific surface. Engine life and effectiveness will be improved with effective cooling. The main aim of the research is to check and examination with 100 cc Hero Honda motorbike fins and analyzes the thermal properties by varied geometry, material and thickness. Parametric models of cylinder with fins are developed to predict the transient thermal behavior. The models are created by varied the geometry like rectangular, circular shaped fins and conjointly by varied thickness of the fins 3mm and 2.5mm. The 3D modeling software used is Pro/Engineer. The analysis is completed using ANSYS. Presently Material used for producing the models is gray cast iron that has thermal conductivity of 53.3 W/mk and aluminum alloy 6063 that has thermal conductivity of 200W/mk. Researchers designed models by taking the thermal temperature of 1100^{0}C.

6) Sachin Kumar Gupta, Harishchandra Thakur (2015)

Engine performance depends on varied parameters like kinds of material use for making engine, numbers of fins used, thickness of fins, and fins shape that escort thermal result thereon. In this project our main aim is to analyses the thermal properties by using differing kinds of materials for the fins with variable sizes slots to improve its performance and scale back its price. The 3D modeling of engine with different slot sizes keeping fin size and number of fin same designed on Solid works and therefore the analysis on the ANSYS steady state. Presently Material used for manufacturing fin body (shape is cylinder) is aluminum Alloy A204 and that we are examination its performance using completely different material like aluminum alloy 6061, Aluminum alloy C443 and aluminum alloy 2014 that having higher thermal conductivities. The result shows that 75mm slotted fins of aluminum alloy 2014 having most heat transfer rate and additionally discovered that because the slots size increase higher than 75mm there will decrease in heat transfer rate.

7) Thammala Praveen and Sampath Rao (2015)

A model of the cylinder fin body was created using Pro/Engineer software. Then the model will be imported to analysis using FEA in this connection ANSYS software is used. ANSYS to complete thermal analysis for determining maximum heat transfer rate and minimum heat transfer rate in W/mm2. The temperature is maximum inside the cylinder with value in 'K' and decreasing to outside still reducing on the fins. A cylinder fin body for a 150cc motorcycle is modeled using parametric software Pro/Engineer. The original model is changed by changing the thickness of the fins. The thickness of the original model is 3mm, it has been reduced to 2.5mm. By reducing the thickness of the fins, the overall weight is reduced.

2.2 Gaps in the Research

On the basis of literature survey, following research gaps are being investigated.

1. There is very limited research based on effect of materials change on fin performance;

2. There is very limited research which compares different thermal properties of fins.

3. SOLUTION METHODOLOGY

Present Section tells about the details of software used in the research work. In the present research work ANSYS R 15.0 simulation software was used for the purpose of simulation, and obtainment of results. Details of software are presented in succeeding section.

3.1 ANSYS

ANSYS is considered as one of the renounced tools in the field of simulation, developed by ANSYS Inc., USA. It can be used successfully for the purpose of simulating problems of thermal analysis, structural analysis, computational fluid dynamics, harmonic analysis, modal analysis, transient dynamics, buckling, and other categories. In addition to this, software also offers the facility to develop simple models. With the help of inbuilt library, one can find out the properties of materials, and even add the desired properties or new materials with the known values of properties. ANSYS also include a set of models to solve complex problems of engineering, architecture, physical sciences, mathematical models and other applications. Following are the salient features of the software:

Offers excellent simulation facility;

- Easy modules for different types of complex analysis like modal, transient, etc;
- Offers different theoretical perspective to solve a problem with different inbuilt models;
- Simple parts can be easily created;
- Inbuilt library to offer material properties; and
- Better graphics facilities.

The following points describe the setup and solution steps used in ANSYS.

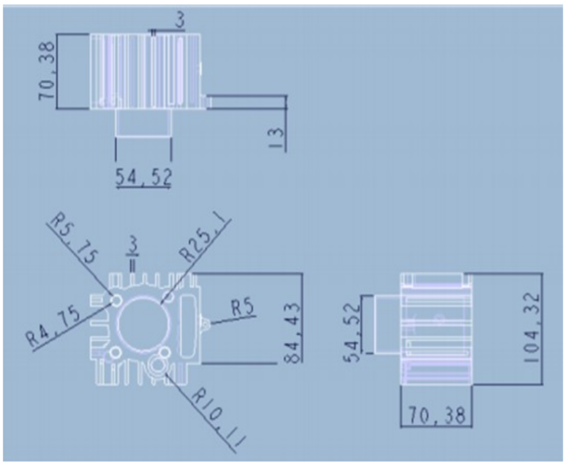
- Preparation;
- Creating a Fluent Fluid Flow Analysis System in ANSYS Workbench;
- Creating the Geometry in ANSYS Design Modeler;
- Meshing the Geometry in the ANSYS Meshing Application;
- Setting Up the CFD Simulation in ANSYS Fluent;
- Displaying Results in ANSYS Fluent and CFD-Post;
- Duplicating the Fluent-Based Fluid Flow Analysis System;
- Changing the Geometry in ANSYS Design Modeler;
- Updating the Mesh in the ANSYS Meshing Application;
- Calculating a New Solution in ANSYS Fluent; and
- Comparing the Results of both systems in CFD-Post.

4. CASE STUDY

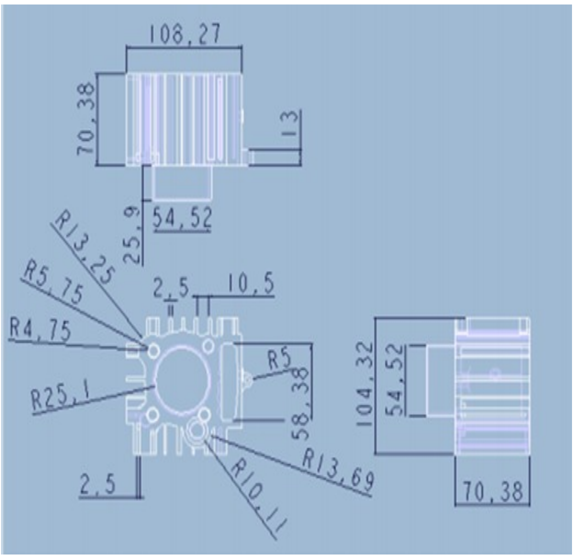
Present Section is devoted to the details of solution methodology adapted to for solving the research problem, and explains in details about problem formulation, development of fin system, and different properties used for simulation of model with the applications of materials.

4.1 Model Formulation

First step in the research work was the formulation of model of fin system for an internal combustions engine system. For this purpose dimension of standard dimensions of a hero Honda 100 cc engine system are used. Following are the details of dimensions.



(a)



(b)

Figure 1: Dimensions of an IC Engines consisting Fins (Praveen and Rao, 2015)

With the help of dimensions shown in Figure 1, first of all, a Model of engine was prepared using ANSYS R 15.0, as shown in Figure 2.

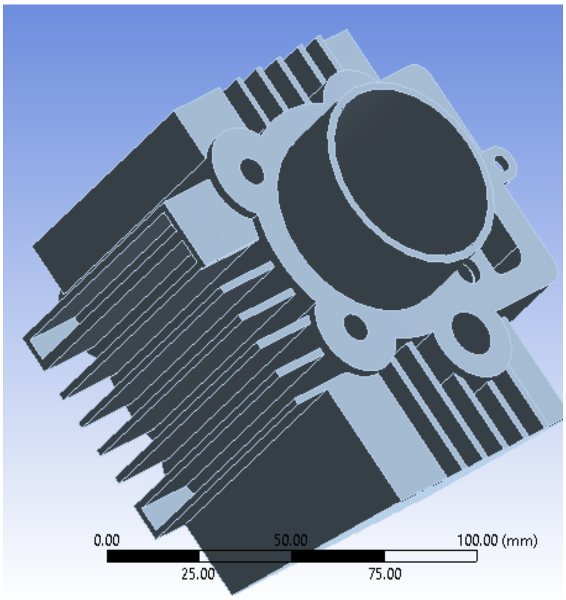


Figure 2: Model of IC Engine

4.2 Solution of the Model

After formulation of model, its solution was derived. For this purpose, first of all meshing of the model was carried out. With the help of meshing, a body can be made deformable due to which, it can show changes in its properties, dimensions, stress levels, etc. Figure 3 shows the mesh diagram for the engine.

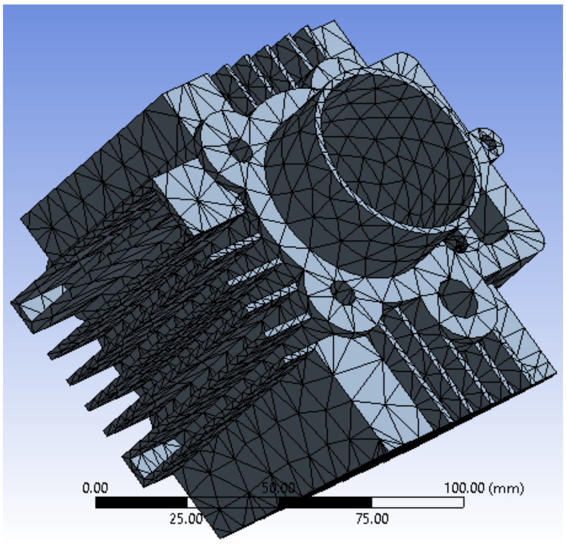


Figure 3: Mesh structure of Engine

In next step values of heat flux and thermal gradient for different combinations of materials were calculated. For this purpose, based on literature survey, following parameters were used.

Table 1: Parameters used in Finding Values of Heat Flux and Thermal Gradient

S.No.	Parameter	Value
1.	Inner temperature of Engine	558 K
2.	Film Coefficient	25 W/m^2
3.	Bulk temperature	313 K

Table 2: Properties of IC Fin Materials (Rajesh and Kumar, 2014) (Thakur and Gupta, 2015)

S.No.	Material	Property	Value
1.	Al2014	Density (g/cc)	2.8
		Sp. Heat (J/g°C)	0.88
		Thermal Conductivity(W/mK)	192
2.	Al6061	Density (g/cc)	2.7
		Sp. Heat (J/g°C)	0.896
		Thermal Conductivity(W/mK)	180
3.	Al Alloy A204 (existing)	Density (g/cc)	2.8
		Sp. Heat (J/g°C)	0.963
		Thermal Conductivity(W/mK)	120
4.	Al Alloy C443	Density (g/cc)	2.69
		Sp. Heat (J/g°C)	0.936
		Thermal Conductivity (W/mK)	142

5. RESULTS AND DISCUSSION

Present Section tells about results and discussions about the research work, the details of which are presented in upcoming sub-sections.

5.1 Results

Following are the results obtained from the application of simulation approach to the research problem.

5.2 Discussion

Table 5.1 Shows following noteworthy points.

1. Values of thermal gradient for different slots are almost the same for different materials;
2. There is similarity of results in average temperatures for the fins of materials irrespective of fin thickness;
3. Values of heat fluxes for thickness 3 mm fins are greater, and temperature gradients are less in 3 mm fins; and
4. There is no trend of similarity of results in the three criteria.

In order to investigate the best selection out of the available combinations, the criteria heat flux can be chosen because of the similarity of results and less spreading of results obtained from other two criteria.

On following the heat flux criteria, one can finds that the material Al alloy A204 shows maximum value of heat flux 0.17302 W/mm2.It shows the thermal gradient of 1.4492e16 K/mm and average temperature of 521K. The thickness of fin is 3 mm.

For the second rank material Al2014 is proposed due to heat flux value of 0.16114 W/mm2 It shows the thermal gradient of 1.4492e16 K/mm and average temperature of 522.5K. The thickness of fin is 3 mm.

For the third rank material Al6061 is proposed due to heat flux value of 0.16097W/mm2 It shows the thermal gradient of 1.4492e16 K/mm and average temperature of 522.5K, with the fin thickness of 3 mm. In the similar manner, other rankings can also be investigated.

Form the observations, one can also find that if one chooses the combination of criteria and places thermal gradient at first place along with the combination of heat flux, materials, AlA204, Al2014, Al6061, and Al

Table 5.1: Combined Results for Different Parameters

S.No	Thickness of Fin	Material	Thermal Gradi-ent	Heat Flux	Temperature
1.	2.5 mm	Al2014	2.4358e16	0.048185	522.5
2.		Al6061	2.4358e16	0.048138	522.5
3.		Al Alloy A204	2.4354e16	0.051787	521
4.		Al Alloy C443	2.4356e16	0.047938	521.5
5.	3 mm	Al2014	1.4492 e16	0.16114	522.5
6.		Al6061	1.4492 e16	0.16097	522.5
7.		Al Alloy A204	1.4492 e16	0.17302	521
8.		Al Alloy C443	1.4492 e16	0.16022	521.5

Table 5.2: Rankings of Fins

S.No	Thickness of Fin	Material	Thermal Gradient	Heat Flux	Temperature	Ranking
1.	2.5 mm	Al2014	2.4358e16	0.048185	522.5	VI
2.		Al6061	2.4358e16	0.048138	522.5	VII
3.		Al Alloy A204	2.4354e16	0.051787	521	V
4.		Al Alloy C443	2.4356e16	0.047938	521.5	VIII
5.	3 mm	Al2014	1.4492e16	0.16114	522.5	II
6.		Al6061	1.4492e16	0.16097	522.5	III
7.		Al Alloy A204	1.4492e16	0.17302	521	I
8.		Al Alloy C443	1.4492e16	0.16022	521.5	IV

Alloy A204 will secure I, to IV ranks respectively, in order of their heat flux scores. There may be rankings obtained on the basis of average temperature, but due to very less differences between scores of alternatives, it shall be of nil worth.

On the basis of these results one can analyze that in spite of varying fin thickness materials are showing the same rankings, and 3 mm fin shows better results as compared to 2 mm results from heat flux point of view.

Table 5.2 shows the details of rankings obtained by fins.

6. CONCLUSION, LIMITATIONS, AND FUTURE SCOPE OF THE RESEARCH

Present Section is contains the conclusion of research work, and limitations and future scope of the research work, details of which are presented in upcoming sub-sections.

6.1 Conclusion

Present research work is based on investigations on fin thickness and improved material selection for an internal combustions engine assembly. For this purpose simulation approach was adopted in which dimensions of fins from a standard engine were taken, model is prepared and analysis of model was conducted on a well-known simulation software ANSYS 15.0. For the purpose of analysis, three criteria namely, heat flux; thermal gradient and average temperature were selected. The varying parameters were fin thickness, and fin materials. The selected materials were Al2014, Al6061, and Al Alloy C443, and Al Alloy A204 (existing material), and fin thickness was changed from 2.5 mm to 3 mm. From simulation results, it was found that out of the *three* criteria, heat flux show varied results, and therefore on this criterion rankings of different materials with fin thicknesses were investigated. *Following* points represent the conclusion drawn from the research work.

- Al Alloy A204 shows the maximum heat transfer and secures *first* rank;
- Al 2014 secures *second* rank from heat transfer view point;
- Al 6061 secures *third* rank from heat transfer view point;
- At thickness of 3 mm all the materials show improved heat flux; and
- At the thickness of 2.5 mm all the materials show improved thermal gradient.

6.2 Recommendations

On the basis of above research work, it is recommended that for the enhanced performance, combination of Al Alloy A204 with 3 mm thickness can be adopted.

6.3 Limitations and Future Scope of the Research

Following are the limitations of the present research work:

- The research work is limited to a specific set of materials;
- The research work is limited to a specific set of fin thickness; and
- The work is also made limited by the analysis of fins on the parameters thermal gradient, heat flux, and average temperature.
- Following points represent the future scope of the research work:
- An detailed analysis consisting of broader set of materials is still pending;
- A extensive research, considering a broader set of fin dimensions can be conducted; and
- A detailed research highlighting a broader set of properties is still awaited.

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