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Thermal Analysis and Optimization of Two-Wheeler Engine Cylinder Fins

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Abstract - *Fins are the extended surfaces which help to dissipate heat generated in the engine. Various automobile industries work to increase this heat dissipation rate by which engine efficiency can be increased. The heat generated during combustion in IC engine should be maintained at higher level to increase thermal efficiency, but to prevent the thermal damage some heat should remove from the engine. In air-cooled engine, extended surfaces called fins are provided at the periphery of engine cylinder to increase heat transfer rate. That is why the analysis of fin is important to increase the heat transfer rate. The main aim of the paper is to analyse the thermal properties by varying geometry and thickness of cylinder fins. To improve the rate of heat transfer thermal analysis of two designs providing slot, reducing the fin thickness and increasing no. of fins is carried out in this paper. The cylinder block with fins are modelled and analysis is done in CAD and FEA software.*

Key Words: **Thermal Analysis, Fins, Engine, FEA, Cylinder Block, Steady state thermal analysis, Two Wheeler**

1. INTRODUCTION

In smooth function of I C engine. Fins are extended surface which are used to cool various structures via the process of convection. Generally heat transfer by fins is basically limited by the design of the system. But still it may be enhanced by modifying certain design parameters of the fins. The cooling system is an important engine subsystem. The air cooling mechanism of the engine is mostly dependent on the fin design of the cylinder block and head. Fins are the extended surfaces purposely provided at a place from where heat is to be removed in to surrounding. The amount of conduction, convection or radiation of an object determines the amount of heat it transfers. By increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient or increasing the surface area of the object in turns increases the heat transfer rate. In this paper attempt has been made to increase rate of heat transfer by varying geometry of the fins. Design of cylinder block was modelled by using 3D modelling software by considering actual dimensions of cylinder block, heat transfer analysis were carried out by using FEA software. The rate of heat transfer that will distribute depends on the no. of fins, thickness of fins and material of the fins.

1.1 Technical Specifications of Cylinder Block Used to Study

In the survey we have collected the information about the existing model by using sources like garages, service centers, research papers and web sources and we collected the all specifications of the existing design of the cylinder block. And the information collected in this survey is given below in table 1.1.

Table-1.1: Technical Specifications

Sr. No.	Model Name	Hero Honda Splendor
1.	**CC**	97.2mm^3
2.	**Stroke (mm)**	49.5
3.	**Bore (mm)**	50
4.	**No. of Fins**	11-08-11
5.	**Fin Pitch (mm)**	9
6.	**Fin Material**	Cast Iron
7.	**Position of fins w.r.t. cylinder axis**	Parallel
8.	**Position of cylinder in vehicle**	Horizontal
9.	**Fin Height (mm)**	Max = 36 Min = 08

Figure 1.1: Photographic View of Existing Cylinder Block with fins

2. LITERATURE REVIEW

Masao YOSHIDA [1] Effects of the number of fins, fin pitch and wind velocity on air-cooling were investigated using experimental cylinders for an air-cooled engine of a motorcycle.

B.V.R. Reddy [2] In this paper an attempt has been made to find out the thermal analysis of cylinder block with fins for different materials by using ANSYS, and the results has been analysed to find out the best material that gives the better heat transfer rate and consists of light weight.

Divyank Dubey [3] In this paper they tried to increase the heat dissipation rate through these extended surfaces by increasing engine fin tip thickness about 3mm and also providing slots of 50mm, 75mm, and 100mm.

Shubham Shrivastava [4] In this thesis report two model were created in software and modified design of the same model were analyzed, and comparison of two models according to geometry and material wise analyzed.

Vijayaraghavan Srinivasan [5] In this paper study of the various methods available for calculating fin efficiency in practical fin configurations with condensation, moist air cooling, and boiling on the extended surfaces done.

3. PROBLEM DEFINATION AND METHODOLOGY

A. Problem Definition:

The current design of the cylinder block is widely used in Hero bikes and the material used for cylinder block is cast iron which has good thermal and mechanical properties but it is very heavy assembly. The main aim of our project is to analyse the thermal properties of fins of cylinder block by varying geometry of fins and thickness of cylinder fins using finite element method to improve the heat transfer rate for more cooling of engine. We are going to change the geometry of fins and thickness of fins of the cylinder block in two case studies to improve the rate of heat transfer.

B. Objectives:

- To study the current design of cylinder block fins with its specification and all required consideration.
- Modify fin design to in such a way that it will cools engine more effectively.
- To design the modified fin cylinder block
- To design various models of cylinder block with different fin geometry, fin thickness and varying material.
- Thermal analysis of modified fins geometries and obtaining results.

C. Methodology

The proposed work involves the following steps:

- Detailed study of existing cylinder block presently used in bike.
- Modelling of existing cylinder block taking actual dimension from actual part which was in application by using 3D modelling software and import into FEA software for further analysis.
- Thermal analysis of Existing Cylinder block.
- To improve the rate of heat transfer by selecting suitable design parameter such as change in geometry of fins, changing thickness and no. of fins and by changing the material of the model create different geometries.
- Carry out Thermal analysis for newly designed cylinder block models using FEA software.
- Validation of Existing Model Analytically and Experimentally.

4. DESIGN AND ANALYSIS OF CYLINDER BLOCKS:

For all the models the material used is same which is Cast Iron and properties of this material is given in the table- 4.1

Material used: Cast Iron

Table- 4.1 Material Properties

Isotropic Thermal Conductivity	8.3e-002 W/mm^{0C}
Density	7.2e-009 tonne/mm^3
Specific Heat Constant Pressure	1.65e+008 mJ/tonne^{0}C

Also the boundary conditions applied for the thermal analysis of all the models are same which are shown in the table- 4.2

Table- 4.2 Boundary Conditions

Boundary Conditions		
Type	Temperature	Convection
Magnitude	150. °C	
Suppressed	No	
Film Coefficient		Tabular Data
Coefficient Type		Average Film Temperature
Ambient Temperature		35. °C (ramped)
Convection Matrix		Program Controlled
Edit Data For		Film Coefficient

A. DESIGN AND ANALYSIS OF EXISTUING MODEL

I. MODELLING OF EXISTING MODEL

3D model of existing cylinder block with fins is modelled on 3D modelling software which is shown in figure 4.1.

Figure-4.1: 3D Existing model

II. THERMAL ANALYSIS OF EXISTING MODEL

The Existing 3D model of existing cylinder block is imported to the parasolid format for the further thermal analysis.

i. Imported Model

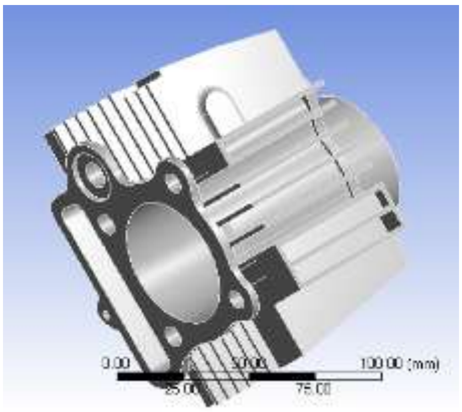

Figure-4.2 Imported Existing Model

ii. Meshing

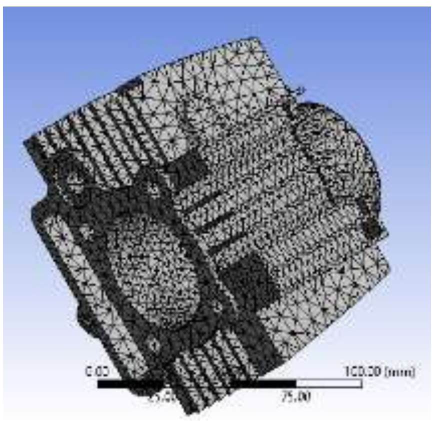

Figure-4.3 Meshing of Existing Model

No. of Nodes = 80378
No. of Elements= 43635

iii. Results of Existing Model

From thermal analysis of the existing model we obtained the results of Temperature Distribution, Total Heat Flux and Directional Heat Flux which are shown in Figure-4.4, Figure-4.5 and Figure-4.6 Respectively,

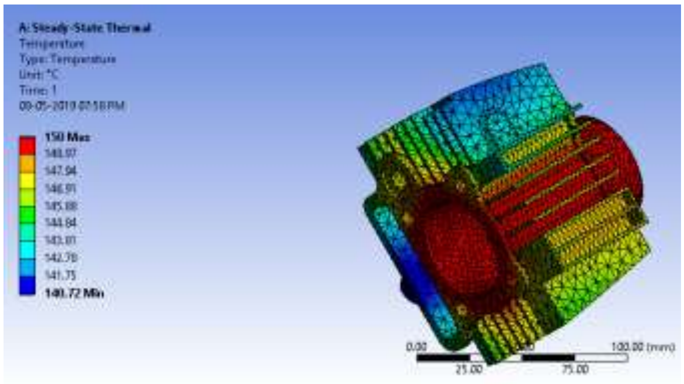

Figure-4.4 Existing Model Temperature Distribution

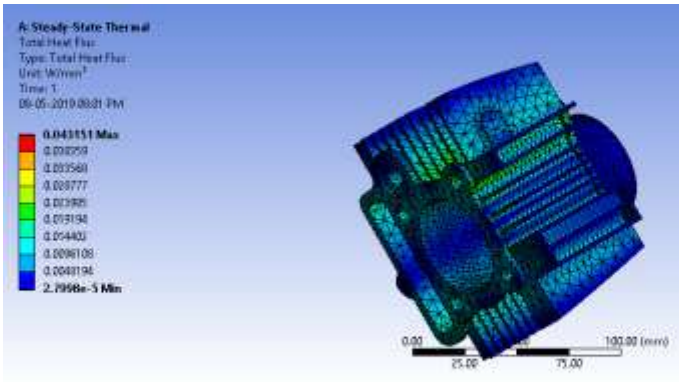

Figure-4.5 Existing Model Total Heat Flux

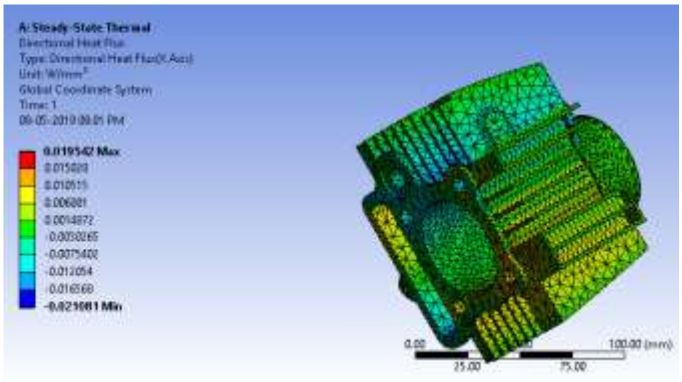

Figure-4.6 Existing Model Directional Heat Flux

RESULTS:

Max. Temperature: 150^0C, **Min Temperature**: 140.72^0C

Total Heat Flux:

Min: $2.7998\text{x}10^{-5}$W/mm^2 **Max:** 0.043W/mm^2

Directional Heat Flux:

Min.: -0.0210W/mm^2, **Max.:** 0.0195W/mm^2

B. DESIGN AND ANALYSIS OF MODIFIED-1 MODEL

I. MODELLING OF MODIFIED-1 MODEL

3D model of Modified-1 cylinder block with fins is modelled on 3D modelling software which is shown in figure 4.7.

Figure-4.7: 3D Modified-1 Model

II. THERMAL ANALYSIS OF MODIFIED-1 MODEL

The 3D model of modified-1 cylinder block is imported to the parasolid format for the further thermal analysis.

i. **Imported Model**

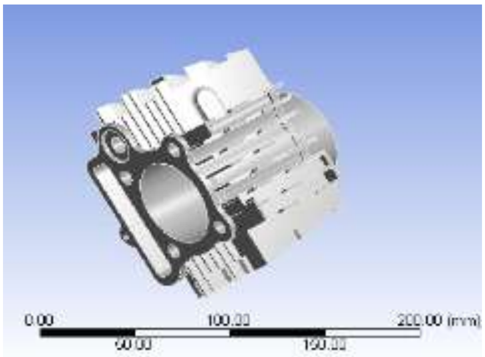

Figure-4.8 Imported Modified-1 Model

ii. **Meshing**

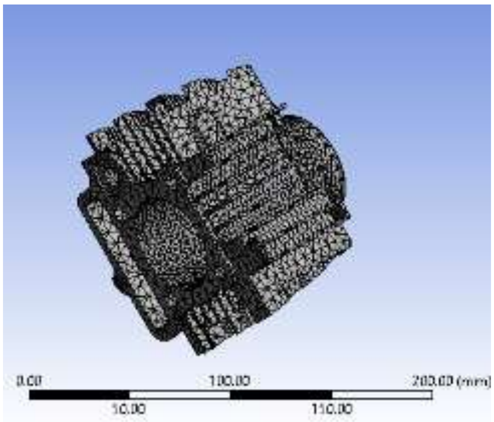

Figure-4.9 Meshing of Modified-1 Model

No. of Nodes = 88653
No. of Elements= 47626

iii. **Results of Modified-1 Model**

From thermal analysis of the Modified-1 model we obtained the results of Temperature Distribution, Total Heat Flux and Directional Heat Flux which are shown in Figure-4.10, Figure-4.11 and Figure-4.12 Respectively,

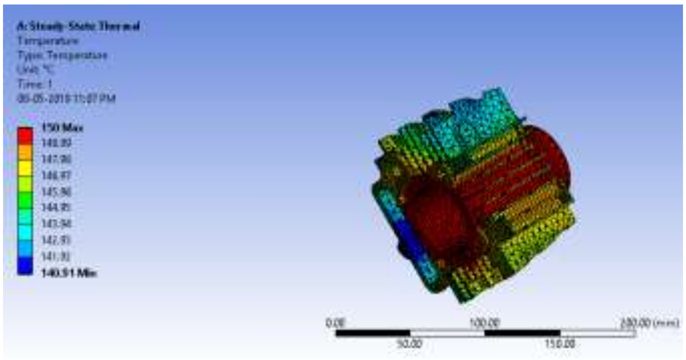

Figure-4.10 Modified-1 Model Temperature Distribution

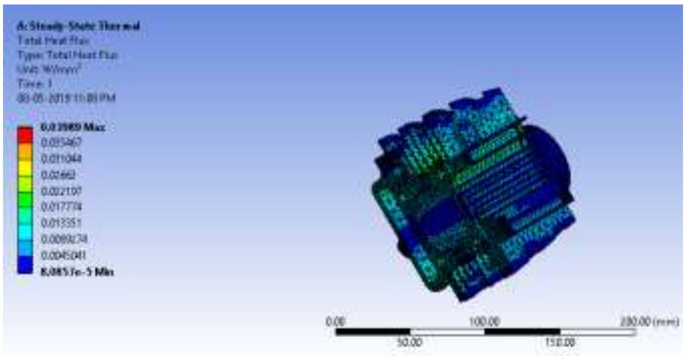

Figure-4.11 Modified-1 Model Total Heat Flux

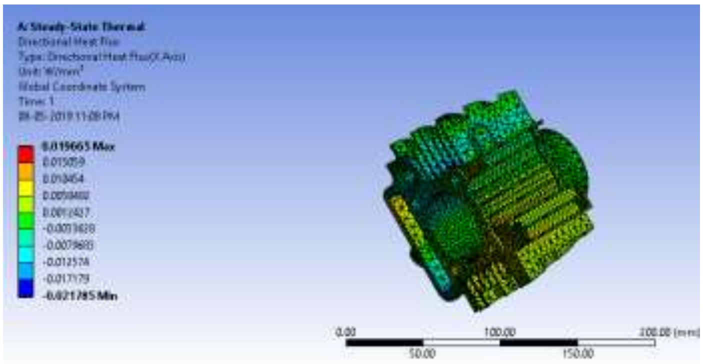

Figure-4.12 Modified-1 Model Directional Heat Flux

RESULTS:

Max. Temperature: 150^0C, **Min Temperature**: 140.91^0C

Total Heat Flux:

Min: 8.0857×10^{-5}W/mm^2 **Max:** 0.03989W/mm^2

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Directional Heat Flux:

Min.: -0.0217W/mm^2, **Max.:** 0.01966W/mm^2

C. DESIGN AND ANALYSIS OF MODIFIED-2 MODEL

I. MODELLING OF MODIFIED-2 MODEL

3D model of Modified-2 cylinder block with fins is modelled on 3D modelling software which is shown in figure 4.13.

Figure-4.13: 3D Modified-2 Model

II. THERMAL ANALYSIS OF MODIFIED-2 MODEL

The 3D model of modified-2 cylinder block is imported to the parasolid format for the further thermal analysis.

i. Imported Model

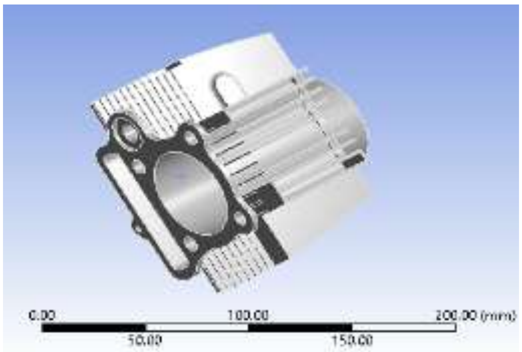

Figure-4.14 Imported Modified-2 Model

ii. Meshing

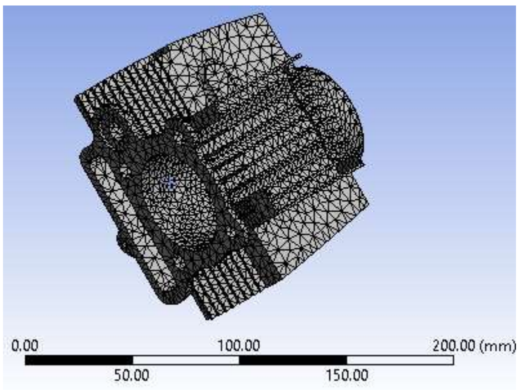

Figure-4.15 Meshing of Modified-2 Model

No. of Nodes = 88162
No. of Elements= 47381

iii. Results of Modified-2 Model

From thermal analysis of the Modified-2 model we obtained the results of Temperature Distribution, Total Heat Flux and Directional Heat Flux which are shown in Figure-4.16 Figure-4.17 and Figure-4.18 Respectively,

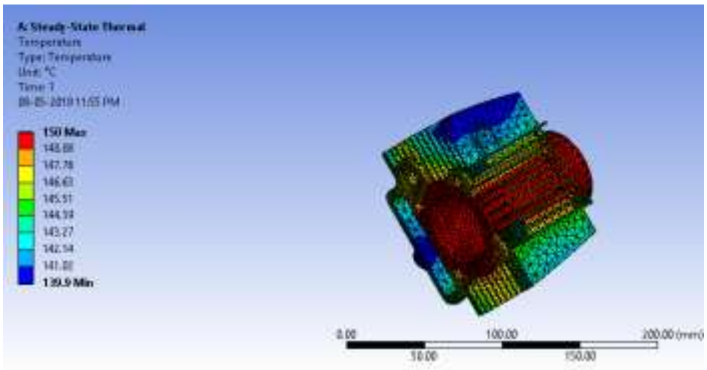

Figure-4.16 Modified-2 Model Temperature Distribution

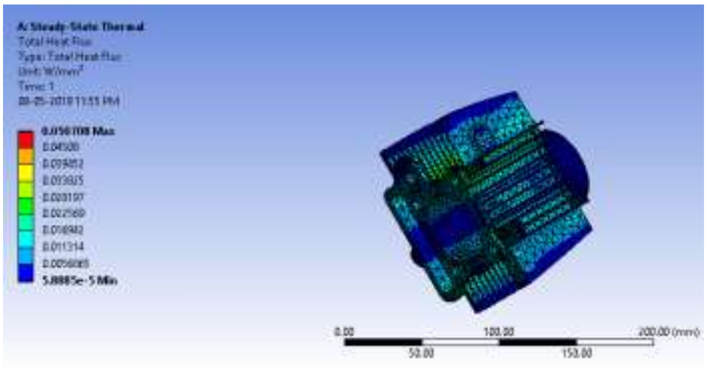

Figure-4.17 Modified-2 Model Total Heat Flux

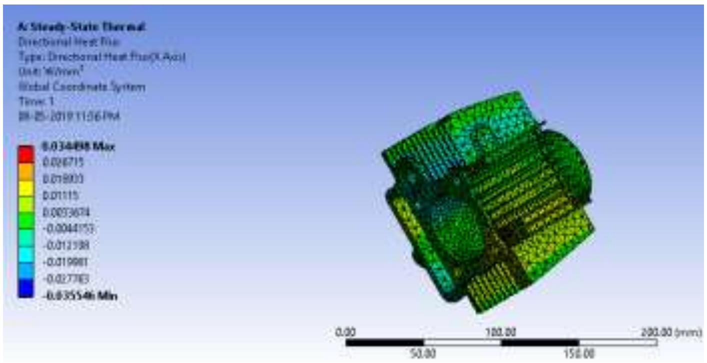

Figure-4.18 Modified-2 Model Directional Heat Flux

RESULTS:

Max. Temperature: 150^{0}C, **Min Temperature**: 139^{0}C

Total Heat Flux:

Min: 5.8885x10^{-5}W/mm^2 **Max:** 0.0507W/mm^2

Directional Heat Flux:

Min.: -0.0355W/mm^2, **Max.:** 0.03449W/mm^2

5. EXPERIMENTAL SETUP FOR VALIDATION

In the experimental method we are prepared experimental setup to get the approximate temperature generated within the cylinder block and to take reading of temperature distribution over the fins we are prepared experimental setup. Temperature at the end of each fin is recorded and the comparison of that readings are done with the analytical readings taken at end of the tip by providing temperature probe at point of fin. The experimental setup is shown in the figure-5.1.

Figure-5.1: Experimental Setup

Experimental Procedure:

- We have created the support for the engine assembly and mounted engine on the structure.
- All the components are assembled properly line silencer, filter and accelerator cable etc.
- All the assembly is kept in the room which has room temperature of 35^{0}C.
- First of all we checked the working of engine after the completion of testing of engine we started the engine.
- The fuel petrol is filled in the bottle which is connected to the carburettor through pipe.
- By using starting kick we started the engine.
- For measurement of the temperature at fin root we used the instrument electronic thermostat and infrared thermometer.
- The temperature found at the fin root is about 144^{0}C to 149^{0}C so that we are taken the temperature inside the cylinder wall 150^{0}C. The temperature at the tip of the fin is recorded by measuring it by using thermostat and infrared thermometer.
- The observation is taken five times and compared it with the FEA software results.

Table-5.1 Comparison of analytical and Experimental observations

Fin No.	Analytically Temperature at tip of fins ^{0}C	Experimentally Temperature at tip of fins ^{0}C Observations				
		1	2	3	4	5
1	144.52	143	144	143	144	143
2	145.65	144	144	143	143	144
3	146.57	145	145	144	145	145
4	147.18	146	146	146	145	146
5	147.48	146	146	146	146	146
6	147.35	146	147	146	146	146
7	146.78	145	145	145	144	145
8	146.1	145	145	146	145	145
9	145.79	144	144	145	144	145
10	146.23	146	146	144	145	145
11	146.59	145	145	145	144	144
1	146.51	145	145	144	145	145
13	146.53	145	145	146	145	146
14	145.87	144	144	145	145	145
15	144.1	142	143	143	143	144
16	143.87	142	142	143	143	142
17	142	141	141	140	141	142
18	142.31	141	141	142	142	141
19	142.63	141	142	142	142	141
20	143.96	142	142	143	142	142
21	144.68	144	143	143	143	143
22	144.93	143	143	143	144	144
23	146.26	145	145	144	145	145
24	146.15	145	145	145	145	145
25	145.49	145	144	144	144	145
26	144.33	144	143	144	143	144
27	144.23	143	143	143	144	143

The temperature obtained in FEA analysis and experimental methods are nearly equal and so that it validate the results of FEA software results

In the modified-1 model the inclined 45^0 slots with 10 mm depth and 10 mm wide are created on the fins, and the pitch of the slots is 20mm. The slots will cause trapping of flowing air and cooling of engine is carried out.

In the modified-2 model the thickness of the fin is reduced to 1.5mm and pitch reduced to 6mm also the no. of fins in the array of the fins is increased from 11-08-11 to 13-10-13. Increasing convection area we can increase the rate of heat transfer.

6. RESULTS AND DISCUSSION

In the above analysis of all the model we got the result as temperature distribution over the fins, Total heat flux and directional heat flux in FEA software. In which the modified-2 model gives us more cooling as compare to existing and modified-1 model. Modified-2 model is very good and it has more rate of heat transfer and it provide more cooling to the engine to work efficiently. The results of all the models obtained from FEA software are listed in table-6.1.

Table-6.1 Results of all models

Sr. No.	Geometry	Temperature (^0C)		Total Heat Flux (W/mm^2)		Directional Heat Flux (W/mm^2)	
		Max.	Min.	Max.	Min.	Max.	Min.
1	Existing Model	150	141	0.043	2.7998 $x10^{-5}$	0.019	-0.021
2	Modified-1	150	140.9	0.039	8.0857 $x10^{-5}$	0.019	-0.0217
3	Modified-2	150	139	0.050	5.885 $x10^{-5}$	0.034	-0.0355

7. CONCLUSIONS

Steady state thermal analysis of the two wheeler engine cylinder block with fins is carried out in this project. Analysis of existing model, Modified-1 model and Modified-2 model is carried out. Varying the geometry of the cylinder block fins and changing thickness of the fins and increasing no. of fins this analysis carried out. By providing slots on fins we can trap the air flow over it and due to the swirl of the air into slots it will cause more heat transfer and cools engine more effectively. As we increase the area under the convection the cooling of engine improves and due to which engine cools effectively.

The benefits of modified fin geometries:

- Engine parts cools moderately and avoid damage of engine component
- Due to slots the weight of the engine reduces
- Engine work efficiently.
- Improving the fins in cylinder block can be used for increasing the heat transfer from the fins.

8. FUTURE SCOPE

In present work we studied the thermal effect of fins modification so there is scope to work on the structural effect analysis on working of cylinder block after modification of fins, and also we can use CFD tools to study the fin performance.

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