Heat Transfer Analysis And Optimisation Of 2-Wheeler Engine Cylinder Head Fins Using FEA

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Abstract. This research describes about the thermal analysis of fins by FEA method. Fins are extended surfaces which help to increase the heat transfer rate[1]. In this research we observe that when heat is produced in IC engine when fuel is burned, will have to be at higher level so that thermal efficiency increases, but to fend off from damages like thermal damage, useless or excess heat have to be removed from the engine. In air cooled engine, fins are placed at upper layer or on boundary of engine cylinder to increase heat transfer rate, because of this analysis of fins is very important and help to enhance the performance of engine and also increase the life span of the engine parts. The main aim of this research is to analyse the thermal properties of fins by varying certain conditions i.e. doing some modifications in conventional model, in our research work we have done two modifications in the fins geometry. In modified model-1 we have increased the number of fins, to achieve this we decreased the gap between the fins of conventional model. And in modified model-2 we have done circular perforation of 4mm diameter on the faces of all the fins of the conventional model. The cylinder head with fins are modelled on Solidworks software 2019 version and all model’s analysis is performed on Ansys software. We have used Steady State Thermal of Ansys mechanical to perform our analysis. And as per the analysis the results showed that modified model-1 has the maximum heat transfer rate as compared to other models.

KEYWORDS: Thermal analysis, Fins, FEA, cylinder block, steady state thermal analysis

1. Introduction
Fins are extended surfaces which are used to increase the heat transfer from the surface and then cool various surfaces through convection process[4]. In general heat transfer by Fins having limitations because of system's design though this problem is to be rectified by doing some modifications in design framework of fins. In engine, cooling part is very important also cooling mechanism is depend upon fin design of cylinder head. In this paper we tried to increase the heat flow rate by changing the different properties in existing model such as by increasing no of fins by decreasing gaps between the fins and by doing circular holes in fin. Through 3 D modelling software solid works we design a cylinder block by considering the data of existing model and then the thermal analysis is done on ANSYS.
1.1 Technical Specifications
In this research, we have bought a cylinder head from the market and measured all its dimensions with the help of measuring instruments, and all the information about the material and boundary conditions of this cylinder block is taken from a published research paper\cite{5}, the technical specifications are given below in Table 1.1

| S.no | Model Name       | Details           |
|------|------------------|-------------------|
| 1    | Swept Volume     | 97.2 mm$^3$       |
| 2    | Stroke           | 49.5 mm           |
| 3    | Bore             | 50 mm             |
| 4    | Fin Material     | Cast Iron         |
| 5    | No. of fins      | 11-8-11           |

**Figure 1.1** Photo of existing model.

1.2 Equations And Assumptions used in analysis using Steady State Thermal of ANSYS Mechanical:
For a steady-state (static) thermal analysis in Simulation, the temperatures $\{T\}$ are solved for in the matrix below:

$$[k(T)]\{T\}=\{Q(T)\}$$

This results in the following assumptions:
- No transient effects are considered in a steady-state analysis
- $[K]$ can be constant or a function of temperature
- Temperature-dependent thermal conductivity can be input for each material property
- $\{Q\}$ can be constant or a function of temperature
- Temperature-dependent film coefficients can be input for convective boundary conditions

Fourier’s Law provides the basis of the previous equation:
- This means that the thermal analysis Simulation solves for is a conduction-based equation.
- Heat flow within a solid (Fourier’s Law) is the basis of $[K]$
- Heat flux, heat flow rate, and convection are treated as boundary conditions on the system $\{Q\}$
- No radiation is currently considered
- No time-dependent effects are currently considered
- Heat transfer analysis is different from CFD (Computational Fluid Dynamics)
Convection is treated as a simple boundary condition, although temperature-dependent film coefficients are possible. If a conjugate heat transfer/fluid problem needs to be analysed, one must use ANSYS CFD tools instead.

2. Design and analysis of cylinder blocks:
For all the models there are only one material is used i.e cast iron$^{[5]}$ and their properties are given in table – 2.1

| Thermal property          | Cast iron  |
|---------------------------|------------|
| Isotropic thermal conductivity | 8.3e-002 W/mm$^o$C |
| Density                   | 7.2e-009 tonne/mm$^3$ |

Also, the boundary condition$^{[1]}$ applied for all the models are same as shown in table 2.2

| Parameter          | specification                  |
|--------------------|--------------------------------|
| Base temperature   | 150$^o$C (ramped)              |
| Ambient temperature| 35$^o$C                        |
| Film coefficient   | 5e$^-6$ w/mm$^2$ °C (step applied) |
| Convection matrix  | Program controlled             |

2.1 Design and analysis of existing model

2.1.1 Modelling of existing model.
3D Model of existing cylinder block with fins is modified on 3D modelling software which is shown in fig 2.1
2.1.2 Thermal analysis of existing model.
The existing 3D model of existing cylinder block is imported to the Parasolid format for the further thermal analysis.

A. Imported model

B. Meshing

**Figure 2.1** 3D existing model.

**Figure 2.2** Imported existing model.

**Figure 2.3** Meshing of existing model.
No. of nodes = 524151
No. of elements = 296649

C. Temperature distribution

![Figure 2.4](image)

Figure 2.4 Temp. distribution of existing model.

D. Total heat flux

![Figure 2.5](image)

Figure 2.5 Existing model total heat flux.

E. Directional heat flux

![Figure 2.6](image)

Figure 2.6 Existing model directional heat flux.

Results:
max temp: 150$^\circ$C, min. temp: 140.77$^\circ$C
Total heat flux:
min: $1.74e^{-005}$ W/mm$^2$, max: $7.02e^{-002}$ W/mm$^2$
Directional heat flux:
Max: $4.9e^{-002}$ W/mm$^2$, Min: $-3.32e^{-002}$ W/mm$^2$
2.2 Design and analysis of modified model-1

2.2.1 Modelling of modified model-1.
In this model no. of fins are increased by reducing the gap between fins of existing model. 3D model of modified – 1 cylinder block with fins is modelled on 3D modelling software which is shown in fig 4.13. No. of fins= 15-12-13, thickness = 3mm, gap=3mm

![Figure 2.7 3D modified 1 model.](image)

2.2.2 Thermal analysis of modified model-1.

A. Imported model

![Figure 2.8 Imported modified model-1.](image)

B. Meshing

![Figure 2.9 Meshing modified model-1.](image)

No of nodes = 635363
No. of elements = 360479
C. Temperature distribution

![Figure 2.10 modified model-1 temp. distribution.](image)

D. Total heat flux

![Figure 2.11 modified model-1 total heat flux.](image)

E. Directional heat flux

![Figure 2.12 Modified model-1 directional heat flow.](image)

Results:
Max temp. = 150°C, min temp. = 130.24°C
Total heat flux:
Max = 0.120w/mm², min = 5.2e⁻⁰⁰⁵ w/mm²
Directional heat flux:
Max = 6.08e⁻⁰⁰² w/mm², min = -6.99e⁻⁰⁰² w/mm²
2.3 Design and analysis of modified model-2

2.3.1 Modelling of modified model-2.
In this we have created circular penetration of diameter 4mm on the faces of fins of the conventional model and keeping all other parameters same as the conventional model and this became our modified model-2. The sketch of the circular perforation done on conventional model is shown in Figure 2.13.

![Figure 2.13 Sketch of circular perforation on fins modified model-2.](image)

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

A. Imported model

![Figure 2.14 Imported modified model-2.](image)

B. Meshing

![Figure 2.15 Meshing of modified model- 2.](image)
No. of nodes = 799456  
No. of elements = 447266

C. Temperature distribution

![Figure 2.16 Temp. distribution of modified model-2.](image)

D. Total heat flux

![Figure 2.17 Total heat flux modified model-2.](image)

E. Directional heat flux

![Figure 2.18 Modified model-2 directional heat flux.](image)

**Results:**  
Max temp. = 150°C, Min. temp. = 140.6°C  
Total heat flux  
Max = 6.18e^002 w/mm², min = 1.24e^005 w/mm²  
Directional heat flux  
Max = 5.93e^002 w/mm², min = -3.43e^002 w/mm²
3. Results and discussion
In the above analysis of all the model we have got the result as temperature distribution over the fins, Total heat flux and directional heat flux in the ANSYS software. In which the modified model-1(no. of fins increased by decreasing the gap between the fins of exiting model) model gives us more cooling as compare to existing conventional model and modified model-2. Modified model-1 showed good results 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 ANSYS software are listed in table 3.1 below

| Property                  | Before modification | After modification |
|---------------------------|---------------------|--------------------|
|                          |                     | Modified-1         |
|                          |                     | Modified-2         |
| Material                  | Cast iron           | Cast iron          |
| No of fins                | 11-8-11             | 15-12-13           |
| Circular perforation      | Not used            | Not used           |
|                           |                     | Used               |
| Fin gap                   | 6 mm                | 3 mm               |
|                           |                     | 6 mm               |
| Temp distribution max (°C)| 150                 | 150                |
|                           | 140.77              | 130.24             |
|                           | 140.60              |                    |
| Temp distribution min (°C)|                     |                    |
| Total heat flux max. (W/mm²)| 7.02e -2            | 12.0e -2           |
|                           | 1.74e -5            | 5.2e -5            |
| Total heat flux min. (W/mm²)| 4.9e -2            | 6.08e -2           |
| Directional heat flux max. (W/mm²)| -3.32e -2     | -6.99e -2           |
| Directional heat flux min. (W/mm²)|                     | -3.43e -2           |
| Maximum fin length        | 25mm                | 25mm               |
| Minimum fin length        | 8mm                 | 8mm                |

Table 3.1 Result of complete analysis of all the models.
Figure 3.1 Total Temperature drop variations

Figure 3.2 Total Heat flux maximum

Figure 3.3 Directional Heat flux maximum

Table 3.2 Heat flux increase as compared to exiting model.

| Type of Model | HEAT FLUX (in w/mm²) | Increase in heat flux (in w/mm²) | Percentage Increase in heat flux (in %) |
|---------------|----------------------|----------------------------------|---------------------------------------|
| Modified - 1  | .120                 | .0498                            | 70.94                                 |
| Modified - 2  | .0618                | -.0084                           | -11.96                                |
4. CONCLUSION
Steady state thermal analysis of the two-wheeler engine cylinder block with fins with cast iron is carried out in this research. Analysis of existing model of cast iron fins in which the no of fins are 11-8-11 each side respectively and the gaps between them are 6mm. Modified-1 model of cast iron carried out in which we reduce the gaps between fins from 6mm to 3mm due to which no of fins increases from 11-8-11 to 15-12-13 each side respectively. Modified-2 model of cast iron is carried out in which we created two holes of 4mm diameter on the face of the fins. This analysis carried out in which Modified-1 model give us more cooling as compare to Modified-2 model and conventional models due to increases in the surface area. Fins which 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.

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