Design Modification and Analysis of Cooling Fins in Motor Cycle Engine

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Abstract : Engine life and effectiveness can be improved with effective cooling. The cooling mechanism of the air cooled engine is mostly dependent on the fin design of the cylinder head and block. Insufficient removal of heat from engine will lead to high thermal stresses and lower engine efficiency. The cooling fins allow the wind and air to move the heat away from the engine. Low rate of heat transfer through cooling fins is the main problem in this type of cooling. The main aim of the project is to analyze the thermal properties and to increase the air flow efficiency of two wheeler engines by varying geometry of the fins. The material of fin body is Aluminum alloy 6061. The shape of the fin is rectangular, I have modified the thickness of fin and another one changed the shape with rectangular concave shaped. The models are created by 3D modeling software used is Pro/ENGINEER. The analysis is done using ANSYS 15.0. The maximum heat transfer has occurs at rectangular concave shaped.

Index Terms – **cooling mechanism, fin design, analyze thermal properties, varying geometry of fins.**

I. INTRODUCTION

In engine when fuel is burned heat is produced. Additional heat is also generated by friction between the moving parts. Only approximately 30% of the energy released is converted into useful work. The remaining (70%) must be removed from the engine to prevent the parts from melting. for this purpose engine have cooling mechanism in engine to remove this heat from the engine some heavy vehicles uses water-cooling system and almost all two wheelers uses air cooled engines, because air-cooled engines are only option due to some advantages like lighter weight and lesser space requirement. 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.

1.1 Introduction to heat transfer

Heat transfer is the movement of thermal energy from one thing to another thing of different temperature. Heat transfer occurs when the temperatures of objects are not equal to each other and refers to how this difference is changed to an equilibrium state. There are different ways the heat can transfer.

1. Conduction (through direct contact)
2. Convection (through fluid or gas movement)
3. Radiation (through electromagnetic waves)

1.2 Basic relationship for heat transfer by convection

There is heat transfer occur in the different medium.

The basic relationship for heat transfer by convection is

$$Q = h\,A(T_a - T_b)$$

Q is the heat transferred per unit time in W
A is the area of the object in m^2
h is the heat transfer coefficient in W/m^2K
T_a is the object surface temperature in K
T_b is the gas or fluid temperature in K

II. COOLING FINS IN AUTOMOBILES

An air cooled motorbike engine dissipates waste heat from the cylinder through the cooling fins to the cooling air flow created by the relative motion of moving motorbikes. 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 head and block. It also depends on the velocity of the vehicle and the ambient temperature.

This heat transfer from the fin is influenced by many fixed and variable constraints such as fin array, fluid flow velocity, fin geometry; shape and material etc. many experimental methods are available in literature to analyze the effect of these factors on the heat transfer rate. The effect of cooling of internal combustion engine cylinder in free air is studied.

The analysis of fin is important to increase the heat transfer etc. Computational Fluid Dynamic (CFD) analysis and flow simulation analysis have shown improvements in fin efficiency by changing fin geometry, fin pitch, number of fins, fin material and climate condition. Of these, wavy fins are particularly attractive for their simplicity of manufacture, potential for enhanced thermal-hydraulic performance and ease of usage in both plate-fin and tube-fin type exchangers.

2.1 Types of cooling system in automobiles

There are two types of cooling systems

1. Water cooling systems
2. Air cooling systems

2.1.1 Air cooling systems

Air cooled system is generally used in small engines, upto15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. the amount of heat dissipated to air depend upon

1. Amount of air flowing through fins.
2. Fin surface area.
3. Thermal conductivity of metal used for fins

III. MODELING OF FINS

The parametric modeling approach uses parameters, dimensions, features, and relationships to capture intended product behavior and create a recipe which enables design automation and the optimization of design and product development processes. This powerful and rich design approach is used by companies whose product strategy is family-based or platform driven, where a prescriptive design strategy is critical to the success of the design process by embedding engineering constrains and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform. These capabilities, include Solid Modeling, Surfacing, Rendering, data interoperability, routed systems design, simulation, tolerance analysis and NC and tooling design.

3.1 Pro/E modeling of cooling fins

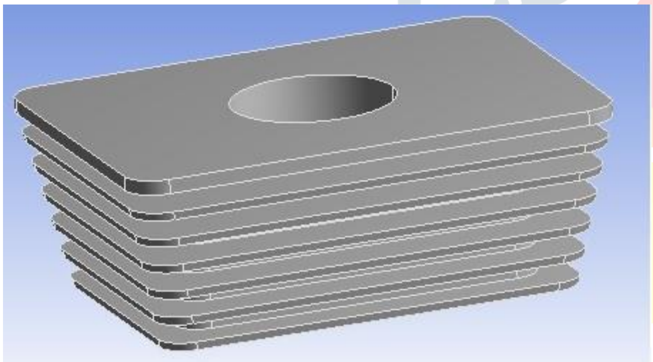

Figure 1: temperature distribution – conventional cooling fin

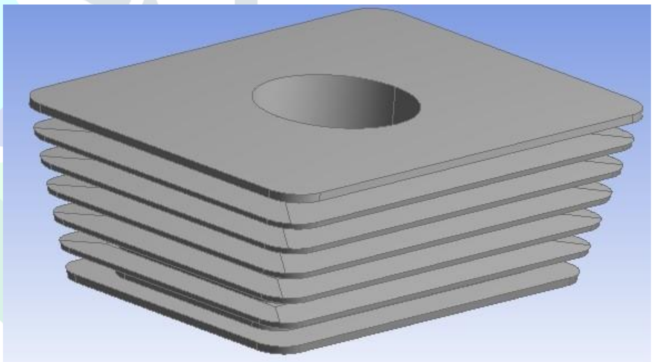

Figure 2: Temperature distribution- optimized cooling fins modification of fins thickness

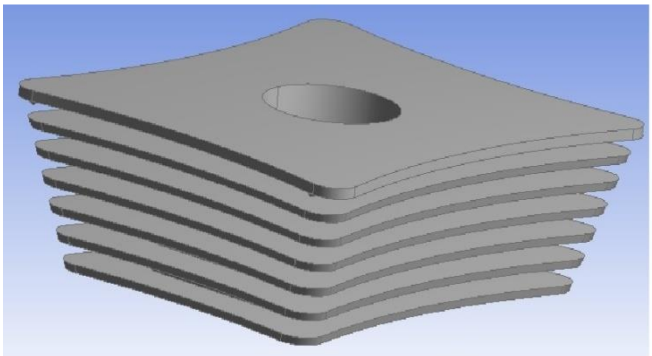

Figure 3: Temperature distribution - optimized cooling fins modification of concave shape

IV. ANALYSIS USING ANSYS

4.1 Material used in cooling fins

Aluminium alloy 6061 is a precipitation hardening, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S ", it was developed in 1935. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of Aluminium for general purpose use.

4.1.1 Physical properties

Density : 2.7 g/cm^3
Melting point : 580^o c
Modulus of elasticity : 70-80 G Pa
Poisson's ratio : 0.33

4.1.2 Thermal properties

Co-Efficient of thermal expansion (20-100^{o}c) : 23.5x10^{-6}
Thermal conductivity : 173 W/(m.K)
Melting temperature : 585^o C
Specific heat capacity : 897 J/(kg.k)

4.2 Thermal analysis

The thermal analysis of the various modeling of cooling fins are done by using ANSYS in steady state thermal analysis. The input parameter of the cylinder has applied at 200^{o}C. and the convection heat transfer occurs in the steady state thermal analysis. Then the results kept for the temperature distribution, total heat flux and directional heat flux from the x axis.

Temperature distribution

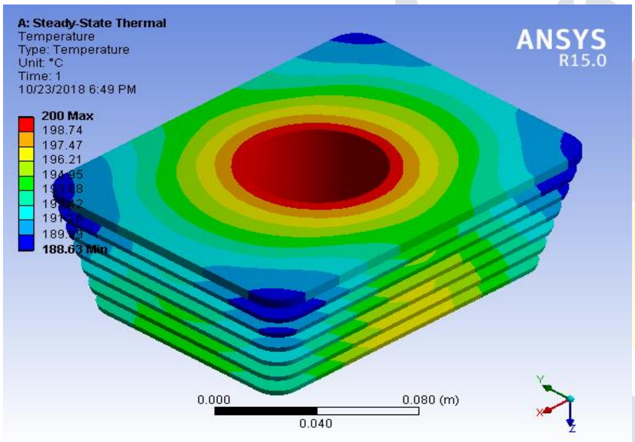

Figure 4: temperature distribution – conventional cooling fin

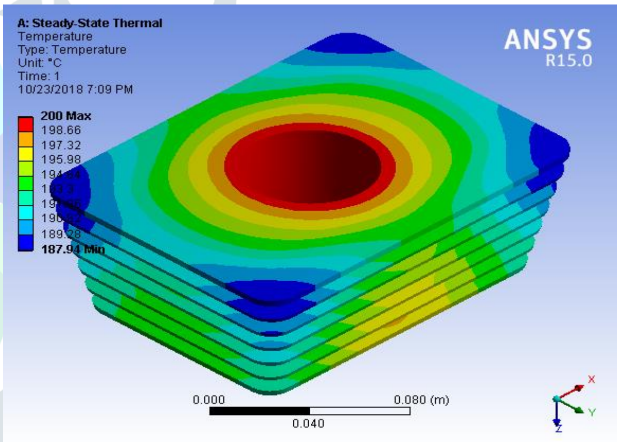

Figure 5: Temperature distribution- optimized cooling fins modification of fins thickness

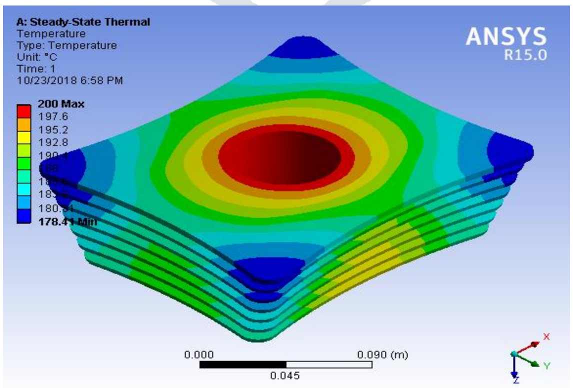

Figure 6: Temperature distribution - optimized cooling fins modification of concave shape

Total heat flux

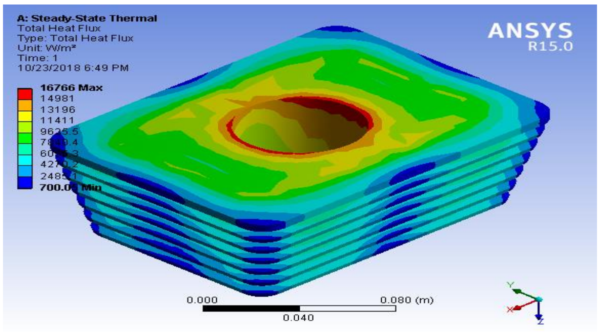

Figure 7: Total heat flux - conventional cooling fins

Directional heat flux

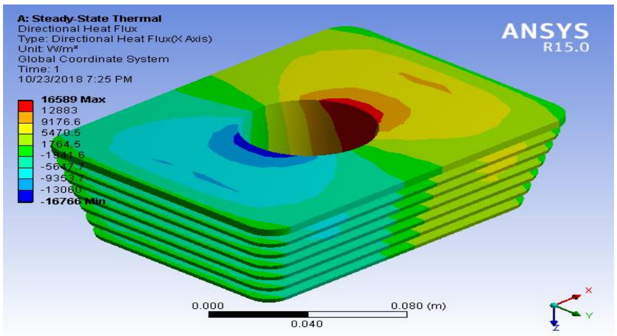

Figure 8: Directional heat flux- conventional cooling fins

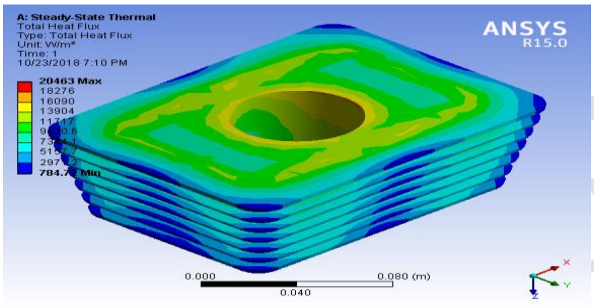

Figure 9: Total heat flux -optimized cooling fins modification of fins thickness

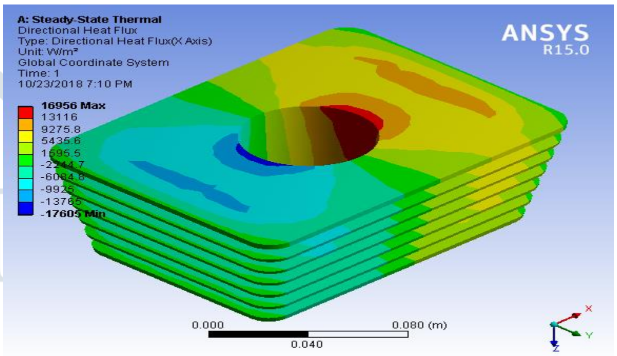

Figure 10: Directional heat flux- optimized cooling fins modification of fins thickness

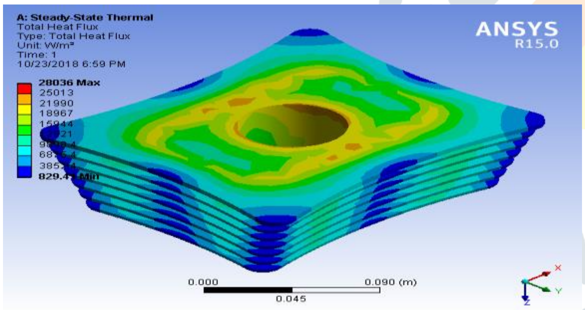

Figure 11: Total heat flux-optimized cooling fin modification of concave shape

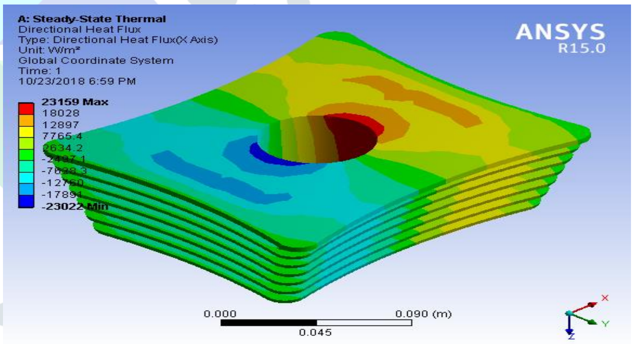

Figure 12: Directional heat flux- optimized cooling fins modification of concave shape

CFD Analysis from ANSYS

The air velocity on the fin surfaces of the various modeling of cooling fins are shown by ANSYS Fluent.

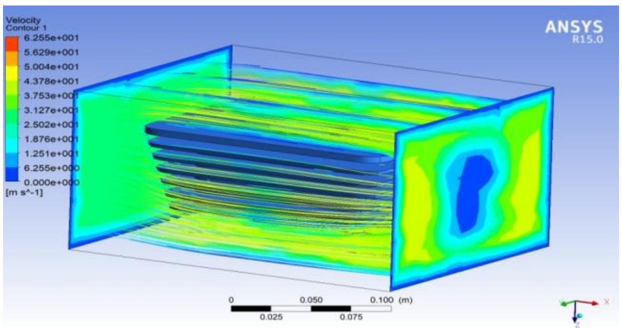

Figure 13: Air flow velocity - conventional cooling fins

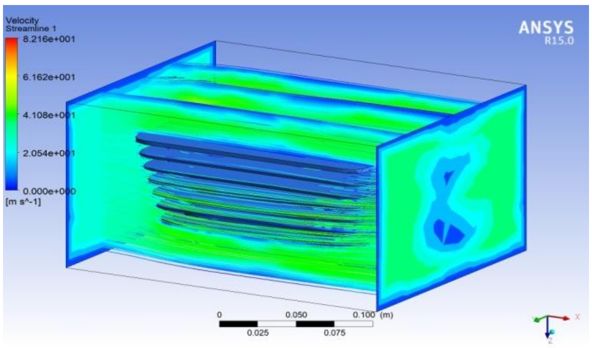

Figure 14: Air flow velocity -optimized cooling fins modification of fins thickness

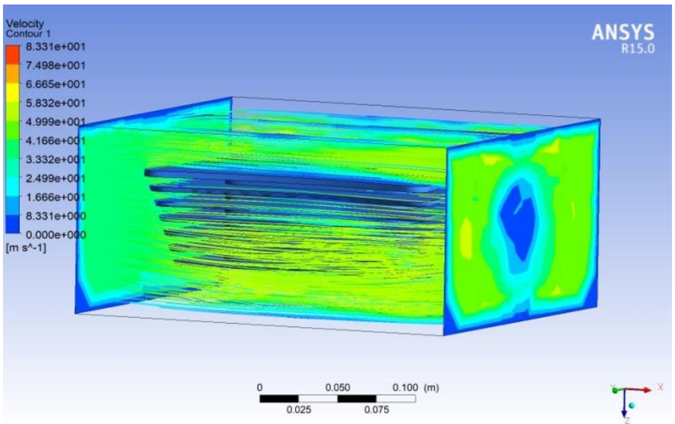

Figure 15: Air flow velocity - optimized cooling fin modification of concave shape

V. RESULTS AND DISCUSSION

Thermal analysis and CFD results from ANSYS

Table 1: Thermal analysis and CFD results from ANSYS

	SURFACE TEMPERATURE IN (^{O}C)		TOTAL HEAT FLUX IN (W/m^2)		DIRECTIONAL HEAT FLUX IN (W/m^2)		AIR FLOW VELOCITY IN (m/s)
VARIOUS COOLING FINS	**Maximum (Applied value)**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Conventional cooling fins	200	188.63	16766	700.05	16589	16766	62.55
Optimized cooling fins modification of fin thickness	200	187.94	20463	784.72	16956	17605	82.16
Optimized cooling fins modification of concave shape	200	178.41	28036	829.41	23159	23022	83.31

- The temperature distribution of the various cooling fins has calculated by thermal analysis using ANSYS. the inside temperature of cylinder applied at 200^o c and its distributed through the fins. The conventional cooling fins distributes the minimum surface temperature at188.63^{o}c. and the optimized cooling fins for modification of fin thickness distributes the minimum surface temperature at 187.94^{o}c in this temperature distribution reduced form conventional at 0.69^{o}c. The optimized cooling fins for modification of concave shape distributes the surface temperature at 178.41^{o}c in this temperature distribution reduced at 10.22^{o}c from the conventional one.
- Heat flux is the thermal energy transferred from one substance to another per unit time and unit area .the total heat flux of the various cooling fins calculated by steady state thermal analysis. the total heat flux of the conventional cooling fins varies from 16766 W/m^2 to 700.05 W/m^2.The optimized cooling fins for modification of fin thickness varies from 20463 W/m^2 to 784.72 W/m^2. there is increase the total heat flux value from conventional at 3697 W/m^2 to 84.67 W/m^2. The another one of optimized cooling fins for modification of concave shape varies from28036 W/m^2 to 829.41W/m^2.in this total heat flux increased from conventional at 11270 W/m^2 to 129.36 W/m^2.The total heat flux compare from optimized cooling fins modification of fins thickness the total heat flux increased to optimized cooling fins modification of concave shape at 7573 W/m^2 to 44.69 W/m^2.So, the maximum heat flux occur in the optimized cooling fins for modification of concave shape.
- The directional heat flux has to applied in direction of x axis and the heat transfer can calculated. the conventional cooling fins transfer the heat in the x direction at 16589 W/m^2 to 16766 W/m^2. The optimized cooling fin for modification of fin thickness transfer the heat in x axis at16956 W/m^2 to 17605 W/m^2. there is increased in the heat flux

range from 367 W/m^2 to 839 W/m^2. Then the another one of optimized cooling fins for modification of concave shape transfers the heat flux in x axis at 23159 W/m^2 to 23022 W/m^2. in this heat flux has to increased from the conventional one at 6570 W/m^2 to6256 W/m^2. the maximum of directional heat flux occur in the optimized cooling fins for modification of concave shape.

- The air flow velocity has calculated by CFD Fluent in ANSYS. In this material properties has applied as Aluminium alloy 6061. And the initial value of air flow velocity has applied in 30 m/s . the maximum output of air flow velocity in conventional cooling fins has calculated in 62.55 m/s, the optimized cooling fins for modification of fin thickness is 82.16 m/s, and the optimized cooling fins for modification of concave shape has calculated in 83.31 m./s. the comparison of above values of air flow velocity in various cooling fins the maximum air flow velocity occurs in the optimized cooling fin for modification concave shape.

VI. CONCLUSION

In this project designed a rectangular fin body and modeled in parametric 3D modeling software Pro/ENGINEER. Material of fin body is Aluminum alloy 6061. The shape of the fin is rectangular, I have modified the thickness of fin and another one model changed the shape with rectangular concave shaped. From all the research and experiment can be conclude that contact time for the air flow over the fin is also important factor in heat transfer rate. if we can increase the turbulence of air by changing the design and geometry of the fins it will increase the heat transfer rate. Thermal analysis of the fin body done by varying geometry and thickness. by observing the result from the ANSYS. The minimum of surface temperature occurs at optimized cooling fins for modification of concave shape at 178.63^{o}Cand the maximum heat flux at 28036 W/m^2 to 829.41 W/m^2. And maximum of directional heat flux in x axis at 23159 W/m^2 to 23022 W/m^2 also occurs at the optimized cooling fins for modification of concave shape. The air flow velocity with rectangular concave fin profile higher than the conventional rectangular fin and optimized cooling fins for modification of fin thickness. Amount of heat transfer increase with decreasing the surface temperature or increasing air velocity, So conclude that the rectangular concave shape is better for increasing the heat transfer rate.

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