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Enhancement of Natural Convection of IC Engine by Replacing Triangular Fins instead of Rectangular Fins

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ABSTRACT: Heat transfer by convection between a surface and the fluid surrounding can be increased by attaching to the surface called fins. The heat conducting through solids, walls, or boundaries has to be continuously dissipated to the surroundings or environment to maintain the system in a steady state condition. In many engineering applications large quantities of heat needed to be dissipated from small areas. The fins increase the effective area of a surface thereby increasing the heat transfer by convection. Rectangular fin and triangular fins are straight fins numerically and using comsolsoftware. Triangular fins are attractive, since for an equal heat transfer it requires much less volume than rectangular fin. Hence the fins have practical importance because it gives maximum heat flow per unit mass with ease of manufacture. In an air-cooled engine, rectangular and triangular fins are provided on the periphery of engine cylinder. Heat transfer analysis is carried out by placing rectangular and then triangular fins. Analysis is carried out by varying temperatures on the surface of the cylinder from 200 °C to 600°C and varying length from 6 cm to 14 cm. Input parameters such as density, heat transfer coefficient, thermal conductivity and thickness of fin are taken and output parameters such as rate of heat flow, heat flow per unit mass, efficiency and effectiveness are determined. Comparisons are presented with rectangular fins.

KEYWORDS: Rectangular fin, Triangular fin, Heat flow rate, Heat Transfer coefficient, Efficiency and Effectiveness, Comsol.

I. INTRODUCTION

Heat transfer is a thermal energy which occurs in transits due to temperature difference. The modes of heat transfer are conduction, convection and radiation. Fin is a thin component or appendage attached to larger body or structure. Based upon the cross sectional area type, straight fins are of different types such as rectangular fin, triangular fin, trapezoidal fin parabolic fin or cylindrical fin. Fin performance can be measured by using the effectiveness of fin, thermal resistance and efficiency. Triangular fins have applications on cylinders of air cooled cylinders and compressors, outer space radiators and air conditioned systems in space craft. Several authors paid attention in analysing and using comsolthe performance of fins.

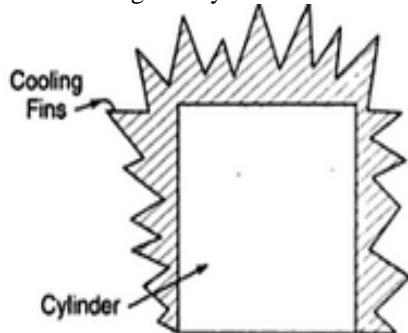
As fins are introduced to enhance heat transfer from a base which is at high temperature, rectangular fins and triangular fins are considered for analysis on two stroke air cooled engine. Engine life and effectiveness can be improved with effective cooling. The cooling mechanism of the air cooled engine is mostly dependent on the fin size. The heat is conducted through the engine parts and convicted to air through the surfaces of the fins. Insufficient removal of heat from engine will lead to high thermal stresses and lower engine efficiency. As air-cooled engine builds heat, the cooling fins allow the wind and air to move the heat away from the engine.

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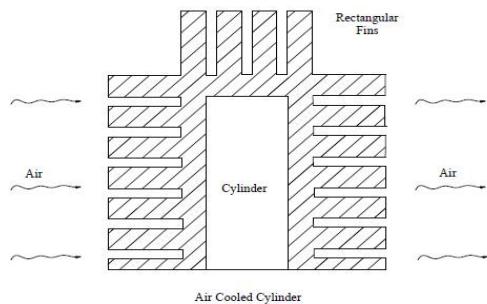
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Considering an air cooled petrol engine with two stroke, at no load condition engine does not generate power. When load increases on an engine, the upward movement of a piston causes compression of the previously available charge inside the cylinder. Thus, during upward stroke, suction and compression of charge takes place simultaneously, and both transfer port and exhaust port remain closed. At the end of compression stroke, the charge is ignited by a high voltage electric spark. After ignition of charge, hot high pressure gases expand. The piston goes downwards and compresses the charge drawn in the crank case. At the end of expansion stroke, exhaust port which is slightly placed higher than the transfer port, opens releasing the burnt gases from cylinder to the atmosphere. Fins are provided on a periphery of Engine. Exhaust heat is exposed to outside of engine cylinder. Air cooled engines have fins to radiate heat to surrounding air. Cylinder is made of cast iron and fins are made of stainless steel



Air cooled cylinder with triangular fins



Air cooled cylinder with rectangular fins

II. LITERATURE REVIEW

Made an attempt to simulate the heat transfer using CFD analysis, Heat transfer from the surface of the engine is modelled in GAMBIT and simulated in FLUENT software. In their paper an expression of average fin surface heat transfer coefficient in terms of wind velocity is obtained. From their analysis, it is observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine. Heat transfer through extended surfaces and the heat transfer coefficient is affected by changing cross-section, climatic conditions and materials etc. From a thus analysis they concluded that the heat transfer of the fin can be augmented by modifying fin pitches, geometry, shape, material and wind velocity

Pradeep Singh [1] in this paper, the heat transfer performance of fin is analysed by design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions. The heat transfer performance of fin with same geometry having various extensions and without extensions is compared. Near about ranging 5% to 13% more heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions. Fin with various extensions design with the help of software AutoCAD. Analysis of fin performance done through the software Autodesk® Simulation Metaphysics. In this thermal analysis, temperature variations w.r.t. distance at which heat flow occur through the fin is analysed. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. On comparison, rectangular extensions provide on fin gives the greatest heat transfer than that of other extensions having the same length and width attached to finned surface. The effectiveness of fin with rectangular extensions greater as compare to other extensions on fin. Moitsheki and Harley [2] in their paper transient heat transfer through a longitudinal fin of various profiles. Thermal conductivities and heat transfer coefficients are assumed to be temperature dependent. The effects of realistic fin parameters such as the thermos geometric fin parameter and the exponent of the heat transfer coefficient on the temperature distribution are studied.

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Kang [3] in his paper a triangular fin with variable fin base thickness is analysed and optimized using a two-dimensional analytical method, for fixed fin volumes, the maximum heat loss, the corresponding optimum fin effectiveness, fin base height and fin tip length as a function of the fin base thickness, convection characteristic number and dimensionless fin volume are represented. From the analysis, results shows that the optimum heat loss increases whereas the corresponding optimum fin effectiveness decreases with the increase of fin volume.

Teerakulpisut [4] in his paper presented application of modified Bessel functions in the analysis of extended surface heat transfer and differential equations formulated from the fundamentals of conduction and convection heat transfer

Khaled and Gan [5] in their paper analysed heat transfer through a wall containing triangular fins partially embedded in its volume. Coupled heat diffusion equations governing each constituent are solved numerically using an iterative finite volume method. Numerical and the analytical results are attained in their paper. It is found that the fin-root can act simultaneously as a heat sink and heat source for the wall. The heat transfer rate through the combined system is clearly seen to be maximized at a specific fin-root length. The maximum reported heat transfer rate through the triangular rooted-finned wall is recommended to utilize the triangular rooted-fin as a heat transfer enhancer for high mechanical strength structures exposed to highly convective fluid streams.

III. ANALYSIS OF TRIANGULAR AND RECTANGULAR FINS

Fig.1 shows rectangular fins placed around the cylinder. These fins are made of stainless steel of thickness 2.5 cm. Fig.2 shows a single cylinder fitted with triangular fins of thickness 2.5 cm. As the heat developed inside a two stroke engine cylinder is more, the heat has to be dissipated to surroundings by fins. These fins fitted are having an appropriate surface area to take away the heat to surroundings.

Rectangular Fin:

The rectangular fin as shown in Fig.2 with L as the length of the fin, 2δ as thickness of the fin and W width of fin and assuming the heat flow is unidirectional and it is along length and the heat transfer coefficient (h) on the surface of the fin is constant.

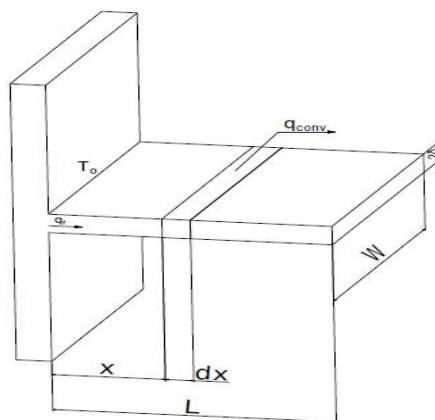


Fig.1 Rectangular fin attached to cylinder

Heat lost by fin,

$$Q = -KA_c m \theta_0 \frac{h \cos hmL + km \sin hmL}{km \cos hmL + h \sin hmL} \quad \dots \dots \dots \quad (1)$$

Where,

k = thermal conductivity, W/mK

Ac= cross section area of fin, m²

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$m = \text{fin parameter, } (\sqrt{hP/kA_c})$

$P = \text{perimeter of fin, } (2W+4\delta)$, m

$\theta_0 = \text{temperature difference, K}$

$h = \text{heat transfer coefficient, W/m}^2\text{K}$

Mass of rectangular fin, $(mr) = 2\delta \times \rho \times L$

where,

$\rho = \text{density of fin material, kg/m}^3$

Rate of heat flow per unit mass through rectangular fin,

$$q^r = \frac{KA_c m \theta_0 \frac{h \cos hmL + km \sin hmL}{km \cos hmL + h \sin hmL}}{2\delta \times \rho \times L} \dots \quad (3)$$

Efficiency of rectangular fin, $(\eta_r) = \frac{\text{Heat lost with fin}}{\text{Heat lost from the fin}}$
 if entire surface maintained at room temperature

$$= \frac{-KA_c m \theta_0 \frac{h \cos hmL + km \sin hmL}{km \cos hmL + h \sin hmL}}{2WL \cdot h \theta_0} \dots \quad (4)$$

Effectiveness of rectangular fin, $(\epsilon_r) = \frac{\text{Heat lost with fin}}{\text{Heat loss without fin}}$

$$= \frac{-KA_c m \theta_0 \frac{h \cos hmL + km \sin hmL}{km \cos hmL + h \sin hmL}}{h A_c \theta_0} \dots \quad (5)$$

Triangular Fin:-

For a triangular fin representing length of fin L, thickness, 2δ and width of fin, W and assuming the heat flow is unidirectional and it is along length and the heat transfer coefficient (h) on the surface of the fin is constant.

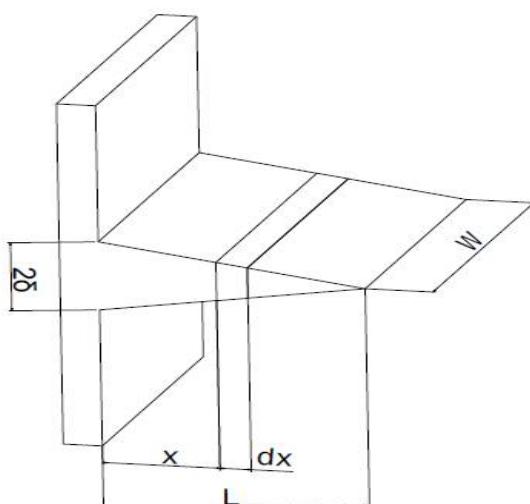


Fig.2 Triangular fin attached to cylinder

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Heat lost by triangular fin,

$$Q = 2W\theta_0 \sqrt{(hk\delta)} \left[\frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})} \right] \dots \quad (6)$$

where,

θ_0 = temperature difference, K
 k= thermal conductivity, W/mK
 B= fin parameter, ($\sqrt{hL/\kappa}$)

I_1 = Bessel function of first kind

I_0 =Bessel function of first kind

$$\text{The mass of triangular fin, } (m_t) = \frac{1}{2} \times 2\delta \times L \times W \times \rho \quad \dots \dots \dots \quad (7)$$

ρ = Density of fluid kg/m³

$$\text{Rate of heat flow per unit mass (q)} = \frac{\text{Heat flow through fin}}{\text{mass of fin}} = \frac{2W\sqrt{hk\delta}t_0 \frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})}}{\frac{1}{2} \times 2\delta \times L \times W \times \rho} \quad \dots \quad (8)$$

$$\text{Efficiency of triangular fin } (\eta_t) = \frac{2W\sqrt{hk}\delta\theta_0 \frac{I_1(2B\sqrt{l})}{I_0(2B\sqrt{l})}}{2WL_h\theta_0} \dots \quad (9)$$

$$\text{Effectiveness of triangular fin, } (\epsilon_t) = \frac{\text{Heat lost with fin}}{\text{Heat loss without fin}}$$

$$= \frac{2W\sqrt{hk\delta}\theta_0}{\hbar A_b\theta_0} \frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})} \dots \quad (10)$$

where,

A_b = base area of triangular fin, ($W \times 2\delta$), m^2

IV. MODELLING AND ANALYSIS

The main product is COMSOL Desktop which is an integrated user interface environment designed for cross-disciplinary product development with a unified workflow for electrical, mechanical, fluid, and chemical applications. The add-on modules blend into COMSOL Desktop, and the way of operation of the software remains the same no matter which add-on products are engaged. The Application Builder is also available with the COMSOL Desktop environment and allows for creating specialized applications, based on a physics model, with a user interface that avoids the details of the simulation model from the perspective of the end user. Two editors are available for designing applications; using drag-and-drop tools, in the Form Editor, or by programming using the Method Editor. There is scope to include specific features from the model or introduce new ones through programming using the Method Editor. COMSOL metaphysics also provides application programming interfaces (APIs). The COMSOL API for use with Java comes included with COMSOL metaphysics, and provides a programmatic way of driving the software through compiled object oriented code. This API is also used in the Method Editor of the Application Builder. LiveLink for MATLAB allows to work with COMSOL metaphysics in combination with the MATLAB

Consider is base temperature (T_b) = 600°C, ambient temperature (T_a) = 30°C, Length of fin= 14 cm, Thickness= 2.5 cm, Density (ρ) =8055 kg/m³, Heat transfer coefficient (h) = 60 W/m²K and Thermal conductivity (k) = 23.749W/Mk

Assumptions:

1. Properties such as density of a fin (ρ), thermal conductivity (K) of the fin is taken at base temperature.

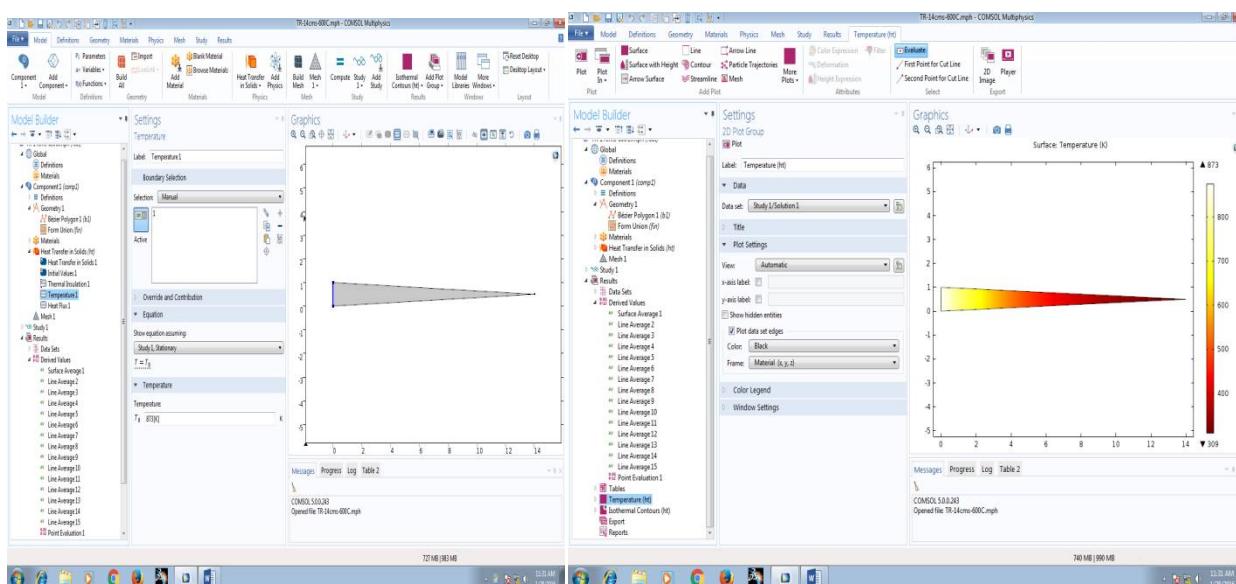
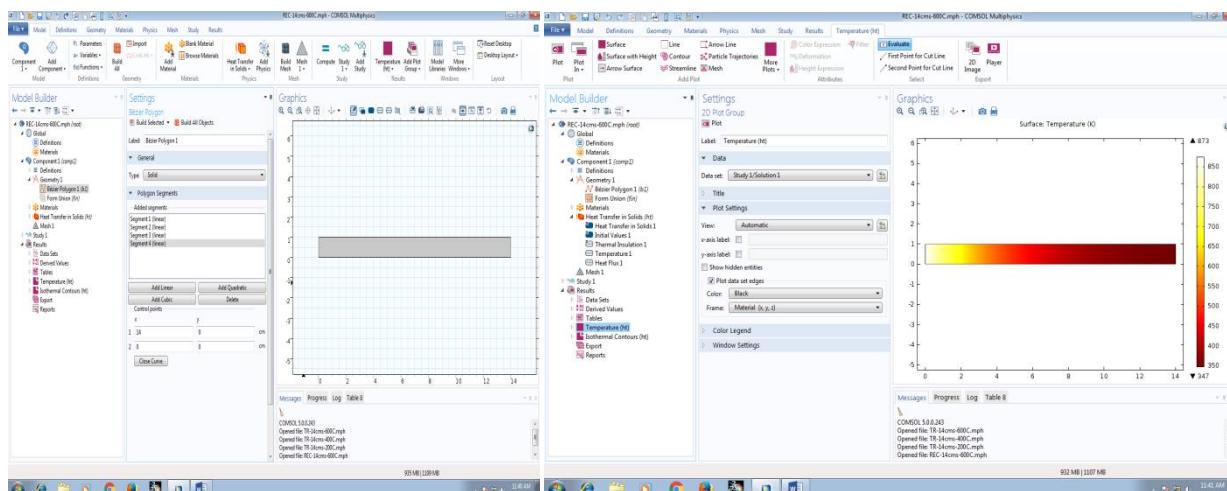
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- Heat transfer coefficient is found to be varied as 14cm with increase in base temperature.

Geometry and heat dissipation of rectangular and triangular fins



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Rectangular and Triangular Fin Heat Dissipation comparison chart

temperature in k	length in cms	Heat dissipation w/m2		Increasing percentage of triangular fin %
		Rectangular	Triangular	
873	6	306.46	514.23	40
873	8	256.788	443.06	42
873	10	219.7	383.85	42
873	12	189.85	335.04	43
873	14	165.45	293.43	43
473	14	23.5	44.56	47
573	14	48.42	93.6	48
673	14	80.9	143.58	43
773	14	128.5	266.5	42.8
873	14	165.5	293.4	43

Comparison of effective heat dissipation at Engine cylinder using the triangular in place of rectangular fin:-

Base temperature in k	length in cms	Effective cooling		Increasing percentage of triangular fin
		Rectangular	Triangular	
873	6	305	374	22.6
873	8	395	468	18.48
873	10	457	519	12.44
873	12	470	514	9.54
873	14	526	564	7.22
473	14	157	169	7.64
573	14	248	267	7.66
673	14	340	366	7.64
773	14	431	465	7.88
873	14	526	564	7.22

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V.RESULTS & DISCUSSIONS

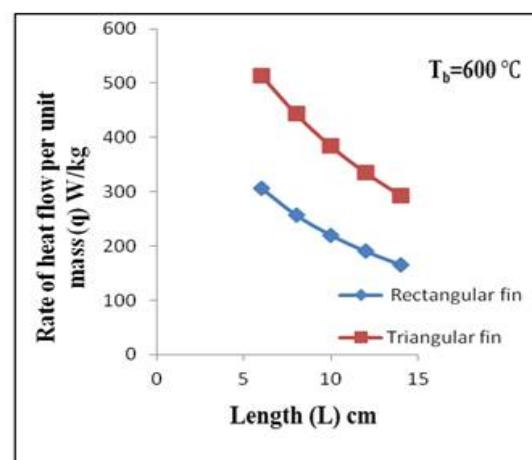
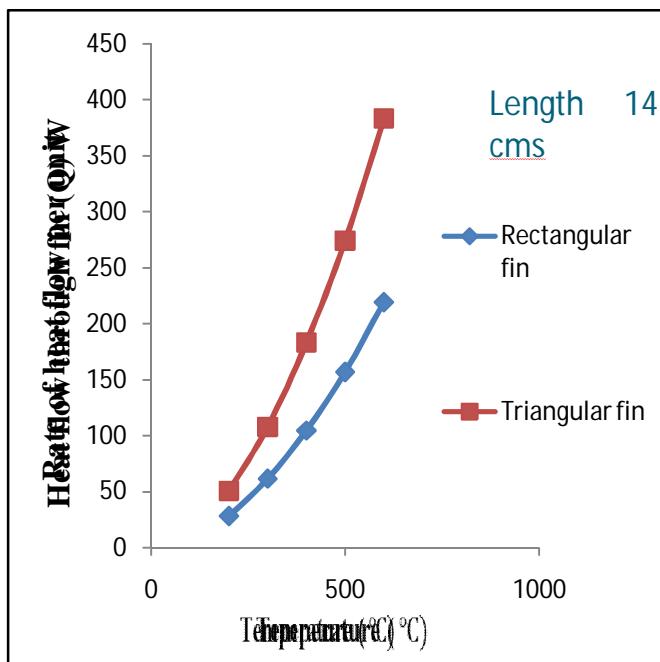


Fig. Variation of rate of heat flow per unit mass of fin (q) with length (L)

Above Fig. shows a variation between rates of heat flow per unit mass to the length of fin. It is observed that the heat flow of a triangular fin is more when compared to rectangular fin at any point of length hence it is utilising most of the material for dissipation of heat.

VI. CONCLUSION

The following conclusions are arrived when the air cooled petrol engine is fitted with rectangular and triangular fins.

1. Varying the length of fin from 6 cm to 14 cm and maintaining base temperature at 600 Degree Centigrade.
 - a) Heat Dissipation of triangular fin is increased by 42.9% compare to Rectangular fin.
2. Varying base temperature of a fin from 200 to 600 Degree Centigrade keeping the length fixed at 14 cm.
 - a) Heat Dissipation of triangular fin is increased by 43 % compare to rectangular fin.

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