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Increase the Efficiency of Internal Combustion Engine Fin by Replacing the Conventional Fin with Parabolic Fin

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Abstract: - **Energy conservation and efficiency have always been the quest of engineers concerned with IC engines. In 1882, Sir Dugald Clerk showed the efficiency of the Otto cycle to depend solely upon the expansion ratio. As we know, if excess heat is not removed, engine components fail due to excessive temperature. Only approximately 25-30% of the energy released is converted into useful work. The remaining (70%) must be removed from the engine to prevent the parts from melting. This paper is related to increase the efficiency of fins used in two wheeler four stroke internal combustion engine.**

Index Term: -Internal combustion engine, Finite element analysis, Parabolic fin.

I. INTRODUCTION

Energy conservation and efficiency have always been the quest of engineers concerned with IC engines. In 1882, Sir Dugald Clerk showed the efficiency of the Otto cycle to depend solely upon the expansion ratio [1]. As we know, if excess heat is not removed, engine components fail due to excessive temperature. Only approximately 25-30% of the energy released is converted into useful work. The remaining (70%) must be removed from the engine to prevent the parts from melting [2]. These same higher temperatures can also cause the cylinder to fluctuate in size, preventing proper conforming and sealing of the piston rings. Excessive oil consumption and smoking result. Since metal expands with increased temperatures, the excessive heat generated Loss of compression. Extended parts are used to dissipate the excess heat into atmosphere. The extended part is termed as fin.

Fins are seen every day in daily life like in Auto-mobile, electronics items (which need heat rejection), heat sinks etc. The importance to heat transfer is because the heat generation due to combustion in internal combustion engine. Commonly, these devices need additional cooling in order to avoid extreme temperatures inside it. Heat sinks allow this supplementary cooling, so they are universal in motor bikes.

Heat sink can work by forced convection, natural convection or liquid cooling. Normally in engine assemblies they are made of materials with good thermal conduction such as aluminium. The heat transfer in sinks is especially by convection, but also by radiation. Radiation heat transfer can represent up to 30% of heat rate in natural convection heat sinks [3].

Fins are commonly used in extended surface exchangers. Conventional fin type automobile engine often characterize the heat exchanger. In a gas-to-gas exchanger (engine of motor bike), the heat transfer coefficient on the inside is generally one order of magnitude higher than that on the air side. To minimize the size of heat exchangers fins are used on the air side to increase the surface area and the heat transfer rate between the heat exchanger surface and the surroundings. Both the conduction through the fin cross section and the convection over the fin surface area take place in and around the fin. When the fin is hotter than the fluid to which it is exposed then the fin surface temperature is generally lower than the base (primary surface) temperature. If the heat is transported by convection to the fin from the ambient fluid, the fin surface temperature will be higher than the fin base temperature, which in turn reduces the temperature differences and the heat transfer through the fin. The temperature value is limited by the type of material and production technique. All above causes that auto mobile engine are used in different thermal systems for applications where heat energy is exchanged between different media.

There are a lot of geometries available and they are generally adapted to each specific requirement. However, a very common heat sink profile is the rectangular parallel fin one. The radiation process is almost a geometric problem; the heat transfer rate to the wall of engine block can be enhanced by the use of fins.

II. VALIDATION OF WORK

A. C. Alkidas et al. (1982) [4] has been obtained Heat-flux at several locations on the cylinder head and liner of a four stroke single cylinder spark ignition engine. The magnitude of the heat flux was found to be highest at near stoichiometric composition. The calculated amount of heat transferred to the walls of the combustion chamber during the closed portion of the engine cycle (intake valve losing to exhaust valve opening) agreed with the corresponding values obtained from the heat-flux measurement.

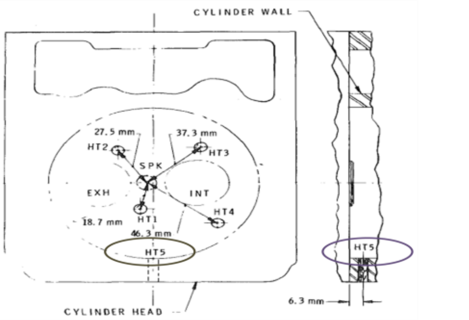
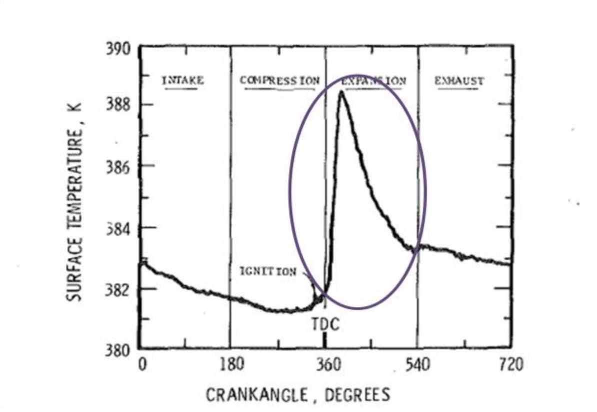


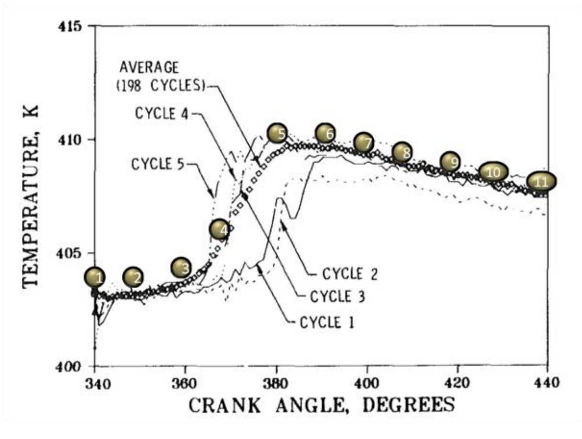
Figure1. Location of heat flux probe (HT) (Alkidas et al.,1982) [4]

In figure1, the arrangement of heat flux probe is shown, current work is concern with the heat flux probe HT5, at this location Alkidas et al., (1982) noted the flux. This measured flux is used to find out the temperature outside the fin surface on the tip. The initial high rate of increase of the heat flux is caused by the arrival of the flame at the location of measurement. Thus it may be concluded that the cycle-to-cycle variation of the heat flux is primarily caused by the cycle-to-cycle variation of flame propagation. This, in turn, is believed to be due to mixture velocity variations that exist in the cylinder near the spark plug at the time of ignition

Temperature curve shown in figure 2a, 2b is the average of 198 cycles. Experiment was focused only on the closed portion of the engine cycle (intake valve closing to exhaust valve opening).



(a) [5]



(b)

Fig2a,2b. Measured surface temperature variation with crank angle (Alkidas et al., 1980-82) temperature at HT 5 [4]

In table 1 the closed portion of the cycle is shown, the values of numerical and experimental results are much closed to each other, means the model is validate for the numerical analysis.

The various cases are the nomenclature against the crank angle. Case-1 denotes the temperature against the crank angle 340 and so on up to Case-11 equally divided the angle between 340 to 440 degree.

Table: - 1 Data of Thermal Analysis

Case-No.	**Crank Angle**	**Experiment (**Alkidas et al., 1982**)**	**Numerical**
		Temperature in K	
Case-1	340	403.236	402.644
Case-2	350	403.138	403.282
Case-3	360	403.568	403.931
Case-4	370	406.469	407.4
Case-5	380	409.395	409.032
Case-6	390	409.673	409.542
Case-7	400	409.265	408.382
Case-8	410	408.804	408.395
Case-9	420	408.324	408.382
Case-10	430	407.916	407.119
Case-11	440	407.600	406.864

The calculated amount of heat transferred to the walls of the combustion chamber during the closed portion of the cycle using the first law of thermodynamics agreed well with the corresponding values obtained from the transient heat-flux measurements. Significant cycle-to-cycle variations in the surface temperature history, and consequently in the heat-flux history, were observed at each location of measurement. These cycle-to-cycle variations were primarily associated with corresponding variations of the propagation of the flame through the combustion chamber. I have used the data of HT5 only the temperature abstained by Alkidas et al.

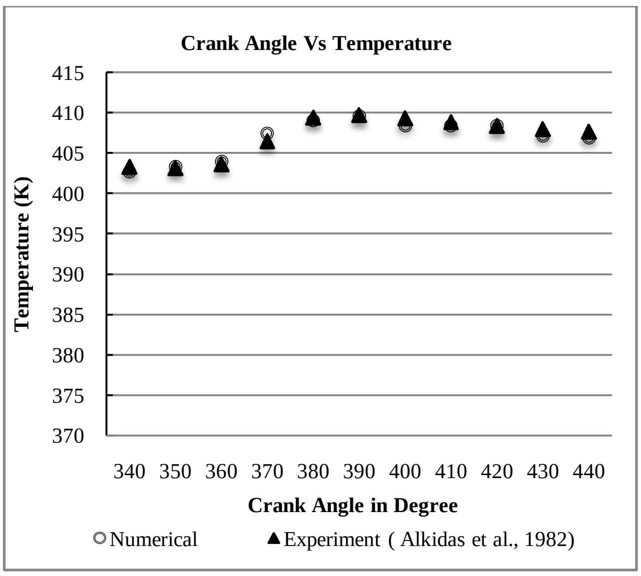


Figure3. Graph between Crank Angle Vs Temperature

Graph in figure 3 shows the variation between data obtained by numerical and experiment, it is much closed, and the numerical model is validated.

III. COMPUTATIONAL ANALYSIS

Finite element analysis was adopted to carry out the 3D simulations, after getting the data from simulation find out the efficiency of various conditions.

A. Finite Element Analysis

In this research finite element code ABAQUS is taken in use for 3D modelling and simulations for temperature propagation. Finite element method has vast approach to sort out complex discrete problems which consist of thousands of elements and nodes; analytically it is not possible for a human to solve. Besides this, finite element method holds well when dealing with thermal analysis that's the reason it was employed in this research.

B. 3D Modelling and Simulations

Complete modelling and simulation of parabolic was done in two segments, at first modelling was performed through different modules of ABAQUS including part which creates a 3D axis- symmetric parabolic fin.

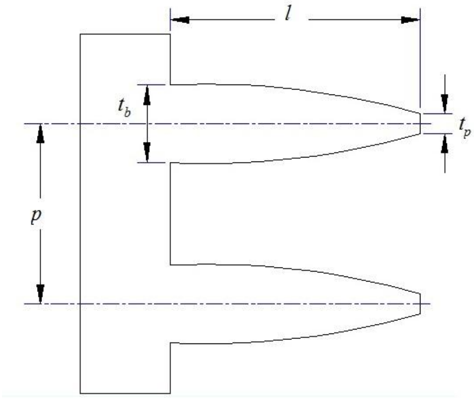


Figure4. Description of Parabolic fin

Where

l = Length of fin
t = thickness of fin
p=pitch of fin
T = temperature
A = area of fin
w = width of fin
h = convection heat transfer coefficient
η = efficiency of fin
ε = effectiveness of fin

Subscript

s = surface
b = base
p = tip
∞ = surrounding
atm = atmospheric

Table2. Mechanical Properties of Aluminium-6061[6]

S.No.	Specification	Value
01	Conductivity	167 W/m^2 K
02	Density	2700 kg/m3
03	Specific Heat	896 J/kg K
04	Young modulus	68.9 GPa
05	Poisson's Ratio	0.33

The fin part is created in Abaqus after that material properties is defined.

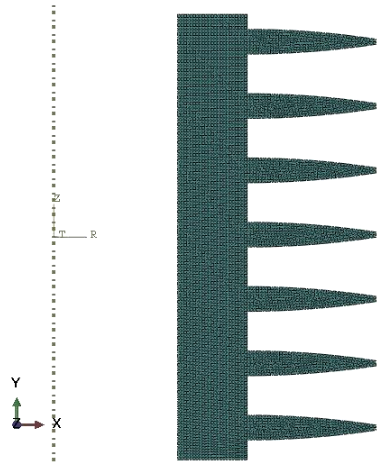


Figure5. Meshed specimen of parabolic fin

Total Number of Nodes = 23916
Total Number of Elements = 22116

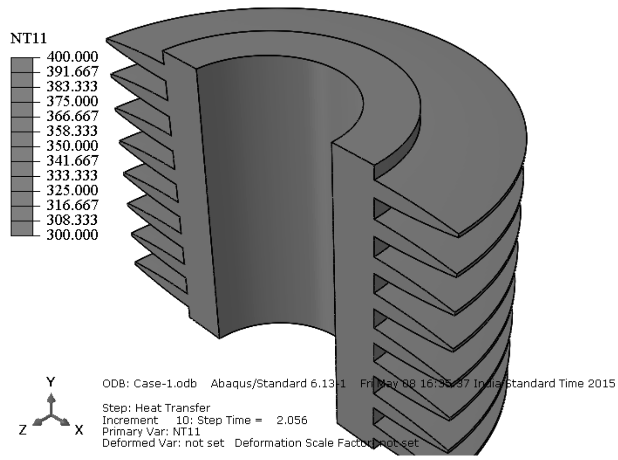


Figure6. Cut section model of fin arrangement

C. Various cases

Table3. Detail of Cases

Case	Base Width	Tip Width	Pitch Length	No of Fins
A	4 mm	2 mm	11 mm	8
B	4 mm	2 mm	13 mm	7
C	4 mm	2 mm	15 mm	6
D	5 mm	1 mm	11 mm	8
E	5 mm	1 mm	13 mm	7
F	5 mm	1 mm	15 mm	6

D. Formula used

$\eta_{fin} = \frac{Q_{fin}}{Q_{fin,max}}$

Q_{fin} = Actual heat transfer rate from the fin

$Q_{fin,max}$ = Ideal heat transfer rate from the fin, if the entire fin were at base temperature

$Q_{fin,max} = hA_s (T_b - T_\infty)$

Heat transfer from surface area A_s of parabolic fin

$$Q = hA_s (T_s - T_\infty)$$

$$A_{s,fin} = wl [C + (l/t) \ln(t/l + C)]$$

$$C = [1+ (t/l)^2]^{1/2}$$

$\varepsilon_{fin} = \frac{Q_{fin}}{Q_{n0\ fin}}$

$Q_{no\ fin} = hA_b (T_b - T_\infty)$

Q_{fin} = Heat transfer rate from the fin of base area A_s

$Q_{no\ fin}$ = Heat transfer rate from the surface A_b

IV. RESULT AND DISCUSSION

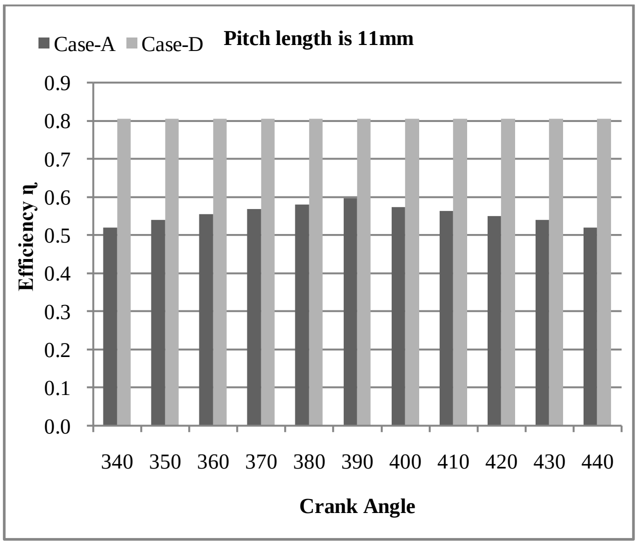


Figure7. Graph of efficiency of Case-A v_s Case-D, having pitch length 11mm

In figure7 the efficiency of fin having 5mm base width is greater than the base width 4mm.

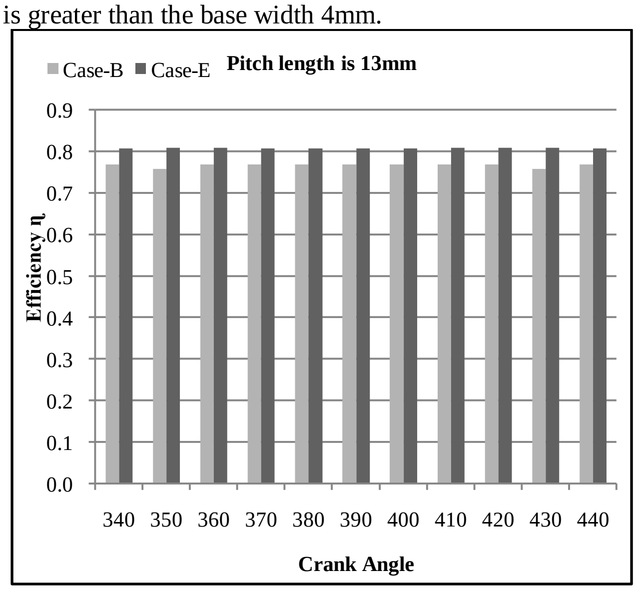


Figure8. Graph of efficiency of Case-B v_s Case-E, having pitch length 13mm

In figure8 the efficiency of fin having 5mm base width is greater than the base width 4mm.

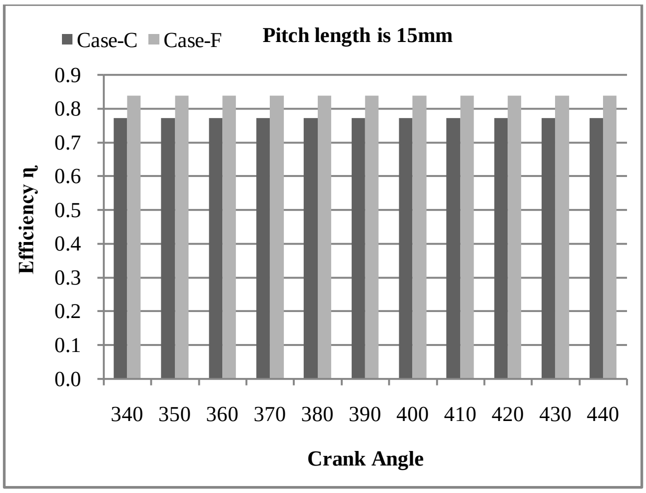


Figure9. Graph of efficiency of Case-C v_s Case-F, having pitch length 15mm

In figure9 the efficiency of fin having 5mm base width is greater than the base width 4mm.

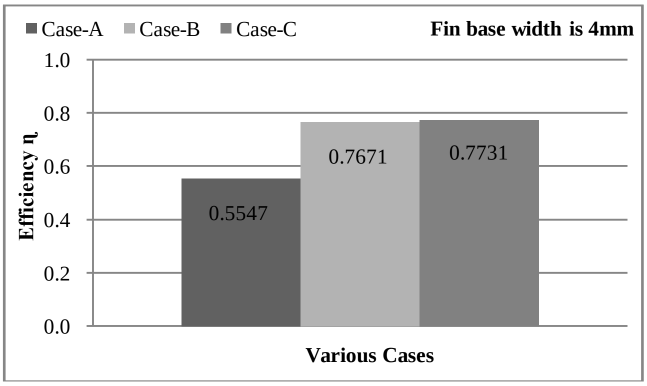


Figure10. Graph of efficiency of Case-A vs Case-D, having pitch length 11mm

The efficiency of fin having p=15 is greater than the p=11 & p=13.

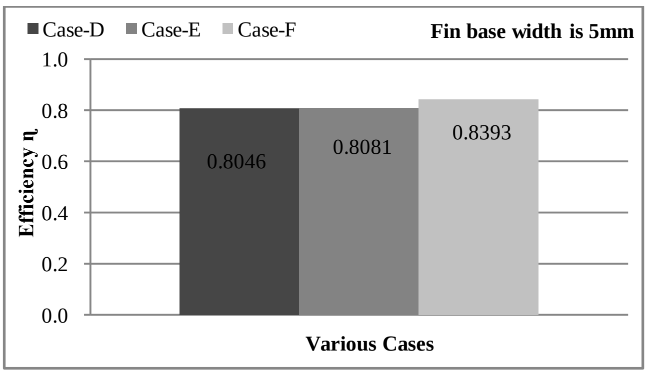


Figure11. Graph of efficiency of Case-A vs Case-D, having pitch length 11mm

The efficiency of fin having p=15 is greater than the p=11 & p=13

CONCLUSION

When pitch length is 11 mm, the efficiency of fin with 5 mm base width is greater than the fin having base with 4mm by 30.92 %.

When pitch length is 13 mm, the efficiency of fin with 5 mm base width is greater than the fin having base with 4mm by 5.07 %.

When pitch length is 15 mm, the efficiency of fin with 5 mm base width is greater than the fin having base with 4mm by 7.89 %.

When base width is 4 mm, the efficiency of fin having 15 mm pitch length is greater by 1 % of fin having pitch length 13 mm & greater by 28.24 % of fin having pitch length 11 mm.

When base width is 5 mm, the efficiency of fin having 15 mm pitch length is greater by 3.7 % of fin having pitch length 13 mm & greater by 4.13 % of fin having pitch length 11 mm.

The overall conclusion, the efficiency of fin having 5 mm base width with 15 mm pitch length is greater among the six cases.

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