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Design Modification and Analysis of Two Wheeler Engine Cooling Fin

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Abstract: **Today our world runs in this condition only because of invention of internal combustion engine. In internal combustion engine chemical energy of fuel is converted to thermal energy to give a mechanical work output. There is large amount of heat liberated during the combustion of fuel, In which only few amount of energy is converted in to useful work (60 to 80%) and the remaining heat energy is wasted. This heat is first conducted to engine cylinder and convected to air through surface called fins. In an air cooled engine low rate of heat transfer is the main problem. Excess temperature developed in the engine causes thermal stresses on the engine parts and piston sizing. In order to avoid this effect, the heat should be sufficiently removed, for this issue in this paper we discussing the heat transfer of different fin geometry under different forced convection conditions. The efficiency of heat transfer can increase by increasing the heat transfer coefficient. Motorcycle engine releases heat to the atmosphere through the mode of force convection. To solve this, fins are provided on the outer of the cylinder. The heat transfer rate is defined depending on the velocity of vehicle, fin geometry and the ambient temperature. Many experimental methods are available in literature to analyse the effect of these factors on the heat transfer rate. However, different fin geometries are modelled in CATIA V5 software and CFD analysis will be used to simulate the heat transfer of the engine block. The result from the software is compared with the existing geometries. The material used for the manufacturing of fin is aluminium alloy**

***Index Terms*—** **footwear, piezoelectric devices, power generated, weight.**

I. INTRODUCTION

Fins are the extended surfaces designed to increase the heat transfer rate of the body by increasing the convective surface area. Fins find their application from the small computer chips to the huge engines. The enormous application of the fins makes it an interesting and important field. Optimizing the heat transfer rates reflects the saving in power supplied and increased efficiency in case of the automobile engines. Natural convection from cylinder block may be used to simulate wide variety of engineering applications as well as provides better insight into more complex systems of heat transfer such as heat exchangers, refrigerators, electric conductors etc. Convection may be enhanced by using the Non uniform fins instead of the conventional fins. 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 as described by R.K. Rajput [1]. The equation (1.1) represents conduction heat transfer from inner wall to fin surface,

$q = K (T_b - T_{fin})$ W/m2

q = Heat transfer rate

K = Conductive heat transfer coefficient

T_b = Boundary temperature

T_{fin} = Fin temperature

The convection heat transfers from fin surface to atmosphere air by free and forced air is given by equation (1.2),

$$q = h (T_b - T_a) \text{ W/m2}$$

h = Convective heat transfer coefficient.

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 analyse 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 rate. Computational Fluid Dynamic (CFD) analysis and Flow Simulation Analysis have shown improvement in fin efficiency by changing fin geometry. Non uniform fins are particularly attractive for their simplicity of manufacture, potential for

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enhanced heat transfer rate.

Heat transfer augmentation from a horizontal rectangular fin by sinusoidal perforations whose bases parallel and towards the fin base under natural convection has been studied. It has concluded that the heat transfer rate increases with perforation and the change in the fin geometry and the configuration as compared to fins of similar dimensions. The temperature and heat transfer coefficient values from fin base to tip are not uniform which shows the major advantage of CFD for analysis of heat transfer. Curve and Zig-zag fin shaped cylinder block can be used for increasing the heat transfer from the fins by creating turbulence for upcoming air.

A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, radiation of an object determines the amount of heat it transfers. Fig 1.2 represents conventional fin geometry. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to the object, however, increases the surface area and can sometimes be economical solution to heat transfer problems. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples

Material selection

Aluminium is selected for fin and cast iron for engine cylinder material. The thermal conductivity of aluminium is higher. Aluminium is the best material to manufacture many components because of its unique properties. Good strength and ductility with excellent corrosion resistance and superb machinability.

Assumptions

The following assumptions are considered for solving the problem,

i.Fin material is assumed as homogeneous.

ii.Thermal conductivity of material is same in all direction and assumed to be constant.

iii.Ambient temperature surrounds the fin uniformly.

iv.Thickness of fin very small compared to its length and width, so temperature distribution across the fin thickness and heat transfer through edge of fin neglected.

v.Temperature at the base of cylinder is uniform.

vi.The thermal resistance between cylinder and fin contact is neglected.

vii.Radiation heat transfer of fin neglected

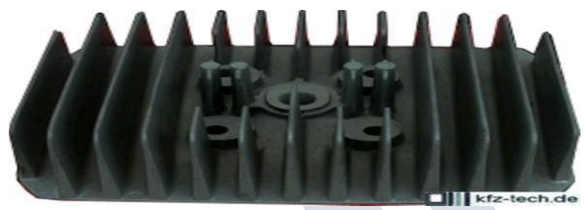

Fig.1.Conventional fin geometry

In Engine when fuel is burned heat is produced. Additional heat is also generated by friction between the moving parts. Engine have cooling mechanism in engine to remove this heat from the engine some heavy vehicles use water-cooling system and almost all two wheelers use 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 be removed 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.

Kumbhar D.G. [4] Heat transfer augmentation from a horizontal rectangular fin by triangular perforations base under natural convection has been studied using ANSYS. They have concluded that the heat transfer rate increases with perforation as compared to fins of similar dimensions without perforation. The perforation of the fin enhances the heat dissipation rates at the same time decreases the expenditure for fin materials also.

N. Nagarani et.al. [5] Analyzed the heat transfer rate and efficiency for circular and elliptical annular fins for different environmental conditions. If space restriction is there along one particular direction while the perpendicular direction is relatively unrestricted elliptical fins could be a good choice. Normally heat transfer co-efficient depends upon the space, time, flow conditions and fluid properties. If there are changes in environmental conditions, there

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is changes in heat transfer co-efficient and efficiency also.

Ashok Tukaram Pise and Umesh Vandeorao Awasarmol [7] conducted the experiment to compare the rate of heat transfer with solid and permeable fins. Permeable fins are formed by modifying the solid rectangular fins with drilling three holes per fin inclined at one half lengths of the fins of two wheeler cylinder block. Solid and permeable fins block are kept in an isolated chamber and effectiveness of each fin of these blocks were calculated. Engine cylinder block having solid and permeable fins were tested for different inputs (i.e. 75W, 60W, 45W, 30W, 15W). It was found that permeable fins block average heat transfer rate improves by about 5.63% and average heat transfer coefficient 42.3% as compared to solid fins with reduction of cost of the material by 30%.

G. Raju, Dr. Bhramara Panitapu, S. C. V. Ramana Murty Naidu. [8] “Optimal Design of an I C engine cylinder fin array using a binary coded genetic algorithm”. This study also includes the effect of spacing between fins on various parameters like total surface area, heat transfer coefficient and total heat transfer. The aspect ratios of a single fin and their corresponding array of these two profiles were also determined. Finally, the heat transfer through both arrays are compared on their weight basis. Results show the advantage of triangular profile fin array. Heat transfer through triangular fin array per unit mass is more than that of heat transfer through rectangular fin array. Therefore, the triangular fins are preferred than the rectangular fins for automobiles, central processing units, aero-planes, space vehicles etc… where weight is the main criteria. At wider spacing, shorter fins are more preferred than longer fins. The aspect ratio for an optimized fin array is more than that of a single fin for both rectangular and triangular profiles.

R.P. Patil and H.M. Dange [9] conducted CFD and experimental analysis of elliptical fins for heat transfer parameters, heat transfer coefficient and tube efficiency by forced convection. The experiment is carried for different air flow rate with varying heat input. The CFD temperature distribution for all cases verifies experimental results. At air flow rate of 3.7 m/s, the heat transfer rate decreases as heat input increases. Also h is higher at above atmospheric temperature and lower at below atm. Temperature. At air flow rate of 3.7 m/s the efficiency increases as heat input increases.

Magarajan U., Thundil karrupa Raj R., Elango T. [10] “Numerical study on heat transfer I C Engine cooling by extended fins using CFD” [4] In this study, heat release of an IC engine cylinder cooling fins with six numbers of fins having pitch of 10 mm and 20 mm were calculated numerically using commercially available CFD tool ANSYS Fluent. The IC engine is initially release heat from the cylinder is analysed at a wind velocity of 0 km/h. It is observed from the CFD result that it takes 174.08 seconds (pitch=10 mm) and 163.17 secs (pitch =20 mm) for ethylene glycol domain to reach temperature of 423 K to 393 K for initially. The experiment results show that the value of heat release by the ethylene glycol through cylinder fins of pitch 10 mm and 20 mm are about 28.5W and 33.90 W.

Heat Transfer Augmentation of Air Cooled 4 stroke SI Engine through Fins- A Review Paper. [14] The author had studied number of research papers and concluded that the phenomenon by which heat transfer takes place through engine fins must frequently be improved for these reasons. 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. Hence the aim of this paper is to study from different literature surveys that how heat transfer through extended surfaces (fins) and the heat transfer co-efficient are affected by changing cross-section, climatic conditions, materials etc. It is to be noted that heat transfer of the fin can be augmented by modifying fin pitches, geometry, shape, material and wind velocity. As per available literature surveyed there is a little work available on the wavy fins geometry pertaining to current research area to till date. So there is a scope of research in the field of heat transfer study on wavy fins on cylinder head – block assembly of 4 stroke SI engine.

In this project focusing mainly to improve the heat transfer rate of the existing rectangular fin by modifying its design and the new design is intended to reduce the amount of material required for manufacturing the fin. The desired outcome of this project is briefly described as follows,

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1.Introduce two new fin designs.
2.Numerically investigate the effect of different fin geometries on total heat transfer from the air cooled fin array mounted on the cylindrical surface.

II. GEOMETRY

Cylinder along with fin was modelled in CATIA V5. The dimensions of the cylinder along with fin were taken from literatures available. Fins with different geometries (Rectangular, Wavy and Zig-Zag) were modelled using CATIA V5.

Modification of model

The normal structure of fin available in the market for two wheelers is flat structured. Our idea is that to modify the existing shape without changing material and area of fin. Our main aim is to increase heat transfer rate in engine, then only we can cool the engine easily and increase the thermal efficiency. In this paper, we are discussing the heat transfer and heat transfer coefficient of 3 fin models. The structures were modelled in CATIA V5 software and thermally analyzed by using ANSYS fluent software. Fig 3.1 and 3.2 stands for modified fin geometry.

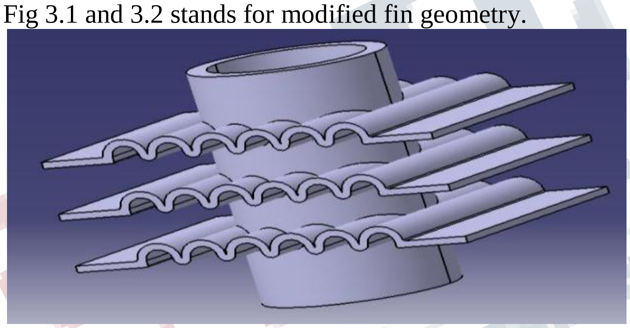

Fig.2. Wavy Fin Geometry Modeled In CATIA V5

1. Length of wavy fin=220mm
2. Width of wavy fin=150mm
3. Thickness of wavy fin=1mm

Cylinder with three numbers of fins which was used for CFD analysis. The dimensions of cylinder And fins are similar to the model in literature. The outer diameter of the cylinder is Ø72 mm, inner diameter Ø70 mm and the thickness of 1mm. The cylinder is of a length of 80 mm. The hollow cylinder, three fins along with the outer air domain is created separately in CATIA V5 and is then assembled. The output assembly design is created in IGS format file for grid generation in ANSYS

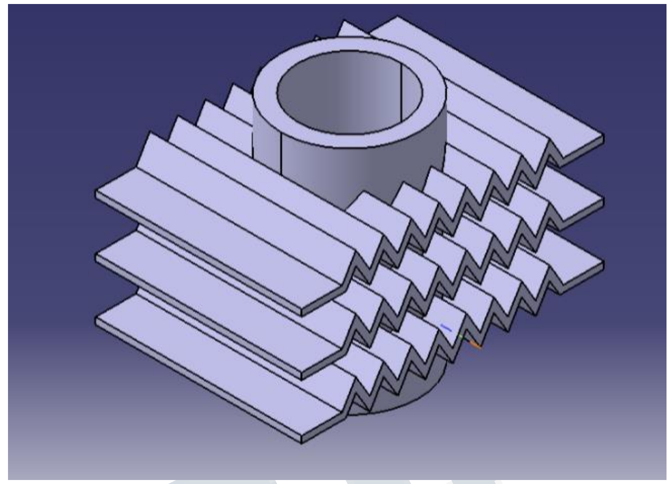

Fig.3. Zig Zag Fin Geometry Modeled In CATIA V5

1. Length of zig-zag fin=220mm
2. Width of zig-zag fin=150mm
3. Thickness of zig-zag fin=1mm

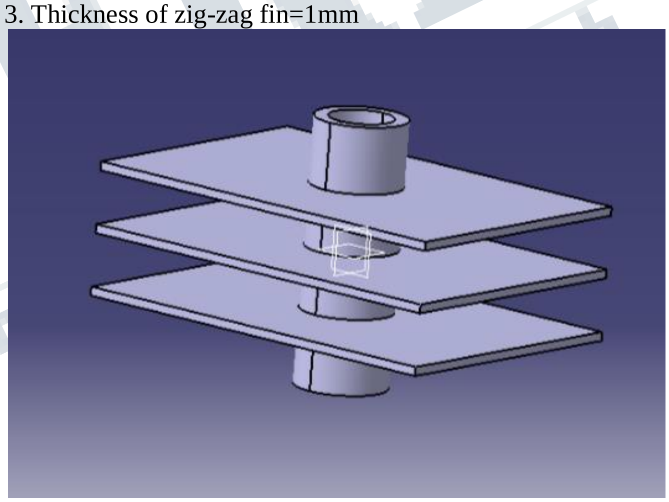

Fig.4. Conventional fin geometry modelled in CATIA V5

III. GRID GENERATION

The 3-D model is then discretized in CFD meshing tool. In order to capture both the thermal and velocity boundary layers the model is discretized using tetrahedral mesh and the domain is discretized using hexahedral mesh elements which are accurate and involve less computation effort. Fine control on the hexahedral mesh near the wall surface allows capturing the boundary layer gradient accurately. The entire geometry is divided into three domains

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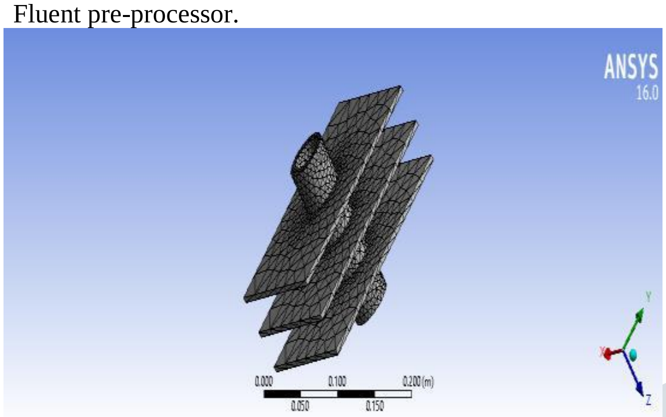
FLUID_AIR, FLUID_ AIR_ SOLID_FINS SURROUNDING, and SOLID_CYLINDER. The discretized model is checked to have a minimum angle of 27°and min determinant quality of 65 %.Once the meshes are checked for free of errors and minimum required quality it is exported to ANSYS Fluent pre-processor.



IV. GOVERNING EQUATIONS

The 3-dimensional heat flow through the cylinder and fins were simulated by solving the appropriate governing equations viz. conservation of mass, momentum and energy using Ansys Fluent code which work by finite volume approach. Turbulence is taken care by Shear Stress Transport (SST) k-ω model

Conservation of mass:

$\nabla.(\rho \vec{V}) = 0$

ρ = Density of fluid

$\vec{V}$ = Velocity vector

X-momentum:

$$\nabla.(\rho u\vec{V}) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}$$

p = Pressure in the fluid flow

τ_{xx} = Shear stress in x plane x direction

τ_{xy} = Shear stress in x plane y direction

τ_{xz} = Shear stress in x plane z direction

u = Velocity in x direction

Y-momentum:

$$\nabla.(\rho vV) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z}$$

v = Velocity in y direction

τ_{yy} = Shear stress in y plane y direction

Z-momentum:

$$\nabla.(\rho wV) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}$$

Energy: $\nabla.\left(\rho e \vec{V}\right) = -p\nabla.\vec{v} + \nabla.(k\nabla T) + q + \varphi$

V.BOUNDARY CONDITION SETUP

The fluid air is assumed to be incompressible fluid. Ambient temperature and pressure are assumed as 298 K and 101325 Pa respectively. The values of the boundary conditions like operating temperature, velocity of air are taken from the literature review. Other boundary conditions like density, specific heat, thermal conductivity and other material properties are considered as constants throughout the analysis. The mesh is imported to ANSYS-Fluent and then the domains are initialized. The boundary conditions and the interface cylinder, fins and air are set in the solver. The top and bottom of the cylinder surface are assumed to be adiabatic. The cylinder base temperature is initialized at 373 K as the initial temperature of the domain. The analysis is carried out with velocity conditions.

VI. RESULTS AND DISCUSSION

The following graph is the comparison of convective heat transfer coefficient of different geometries at different velocities.

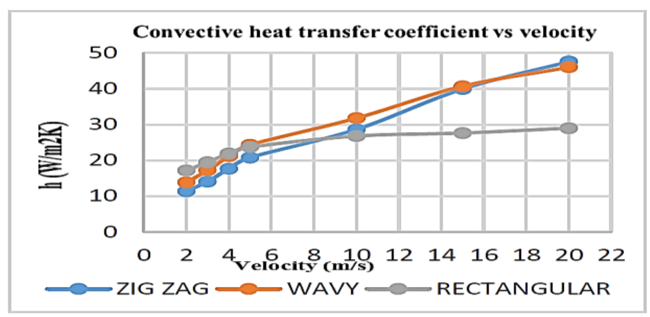


Fig.6. convective heat transfer coefficient Vs velocity when actual convective area is taken in to consideration

The heat transfer rates of different geometries are compared. It is seen that at lower velocities, flat fin have higher heat transfer rate and heat transfer coefficient. And if we goes on increasing, we can see that zig zag have higher heat transfer rate followed by

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wavy and then flat fins.

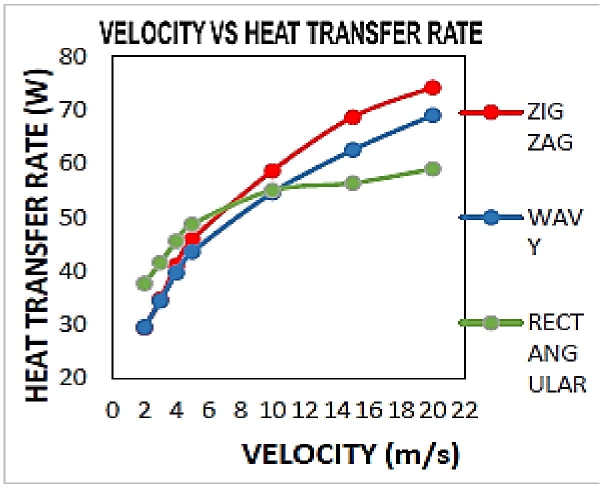

Fig. 7. Heat transfer rate Vs velocity

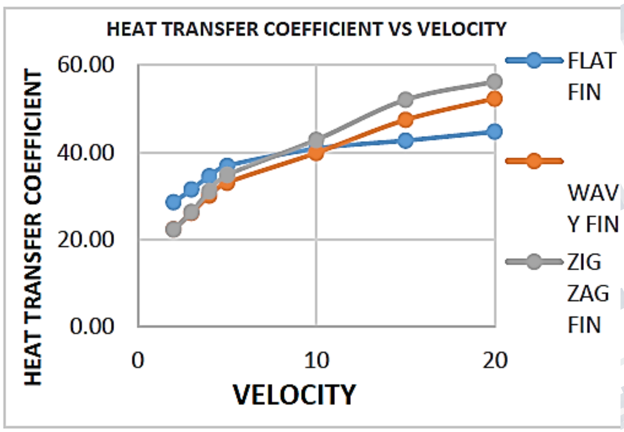

Fig.8. heat transfer vs velocity when cylinder base area is considered

VII. CONCLUSION

1. The difference of heat transfer rate for conventional fin are greater for low velocity with respect to that of newly developed wavy fin and zig zag fin.
2. The heat transfer rate increases for zig zag and wavy fin compared to that of conventional flat fin as we go on increasing the speed.
3. Due to the development of curved and zig zag shape it can generate swirl between two fins which induces turbulences and hence higher heat transfer.
4. Design of fin plays a crucial role in heat transfer. Thus by changing the fin geometry from the convention flat fin the heat transfer rate can be improved greatly, which leading to less thermal stress development.
5. Zig zag and wavy fin thus can be preferred over conventional fins for higher speed vehicles as it induces greater turbulence and thus greater heat transfer rate.
6. Also uniform as well as faster cooling can be possible by this modified fin. More turbulence and vorticity cause further improved heat transfer rate. This helps to improve the engine efficiency and effectiveness.

VIII. SCOPE FOR FUTURE WORK

Investigate the fin performance by varying the fin geometry under various fin spacing and obtain an optimal fin design under normally operating air velocities.

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