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Review Paper on Effect of Cylinder Block Fin Geometry on Heat Transfer Rate of Air-Cooled 4S SI Engine

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***Abstract*— Indian two-wheeler market is the world's second biggest market. Among the 3 segments (motorcycles, scooters and mopeds) of the Indian two wheeler market, major growth trends have been seen in the motorcycle segment over the last four to five years due to its resistance and balance even on bad road conditions. In Indian motor-cycles, Air-cooling is used due to reduced weight and simple in construction of engine cylinder block. As the air-cooled engine builds heat, 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 of aim of this work is to study various researches done in past to improve heat transfer rate of cooling fins by changing cylinder block fin geometry, climate condition and material.**

***Keywords*—Air Cooling, ANSYS, CFD, Cylinder block, Engine Performance, Fins, Heat Transfer, Internal Combustion Engine.**

I. Introduction

Air-cooling and Water cooling are the main type of the 4S-SI engine cooling system. Water cooling system efficiency is more than air cooling system, but due to some advantages like reduced weight, lesser space requirement and cheaper over water cooling system, most of the Indian Motor-cycles are air-cooled[25].

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 to increase the heat transfer rate. Computational Fluid Dynamic (CFD) analysis and Wind tunnel experiments have shown improvements in fin efficiency by changing fin geometry, fin pitch, number of fins, fin material and climate condition.

II. Literature Review

Arnold E. Biermann and Benjamin Pinkel[1] obtained heat transfer coefficient over a range of air speeds from 30 to 150 miles per hour from tests in a wind tunnel of a series of electrically heated finned steel cylinder, which covered a range of fin pitches from 0.10 to 0.60 inch, average fin thickness from 0.04 to 0.27 inch, and fin width from 0.37 to 1.47 inch.

They concluded that the value of surface heat transfer coefficient varies mainly with air velocity and the space between fins. The effect of the other fin dimensions is small.

J.C. Sanders et.al. [2] carried out the cooling tests on two cylinders, one with original steel fins and one with 1-inch spiral copper fins brazed on the barrel. The copper fins improved the overall heat transfer coefficient from the barrel to the air 115 percent. They also concluded that in the range of practical fins dimensions, copper fins having the same weight as the original steel fins will give at least 1.8 times the overall heat transfer of the original steel fins.

Denpong Soodphakdee et.al [3] compared the heat transfer performance of various fin geometries. These consist of plate fins or pin fins, which can be round, elliptical, or square. The plate fins can be continuous (parallel plates) or staggered. The basis of comparison was chosen to be a circular array of 1mm diameter pin fins with a 2mm pitch. The ratio of solid to fluid thermal conductivity for aluminium and air is quite high, around 7000, permitting the fins to be modelled as isothermal surfaces rather than conjugate solids. The CFD simulations were carried out on a two-dimensional computational domain bounded by planes of symmetry parallel to the flow. The air approach velocity was in the range of 0.5 to 5m/s. the staggered plate fin geometry showed the highest heat transfer for a given combination of pressure gradient and flow rate.

Fernando Illan [4] simulated the heat transfer from cylinder to air of a two-stroke internal combustion finned engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analyzed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition.

Starting from a zero-dimensional combustion model developed in previous works, the cooling system geometry of a two-stroke air cooled internal combustion engine has been optimized in this paper by reducing the total volume occupied by the engine. A total reduction of 20.15% has been achieved by reducing the total engine diameter D from 90.62 mm to 75.22 mm and by increasing the total height H from 125.72 mm to 146.47 mm aspect ratio varies from 1.39 to 1.95. In parallel with the total volume reduction, a slight increase in engine efficiency has been achieved.

Bassam A and K Abu Hijleh [5] investigated the problem of cross-flow forced convection heat transfer from a horizontal cylinder with multiple, equally spaced, high conductivity permeable fins on its outer surface numerically. Permeable fins provided much higher heat transfer rates compared to the more traditional solid fins for a similar cylinder configuration. The ratio between the permeable to solid Nusselt numbers increased with Reynolds number and fin height but tended to decrease with number of fins. Permeable fins resulted in much larger aerodynamic and thermals wakes which significantly reduced the effectiveness of the downstream fins, especially at $\theta < 90°$. A single long permeable fin tended to offer the best convection heat transfer from a cylinder.

Masao YOSIDHA et.al. [6] investigated effect of number of fin, fin pitch and wind velocity on air-cooling using experimental cylinders for an air-cooled engine of a motor-cycle in wind tunnel. Heat release from the cylinder did not improve when the cylinder have the more fins and too narrow a fin pitch at lower wind velocities, because it is difficult for the air to flow in to the narrower space between the fins, so the temperature between them increased. They have concluded that the optimized fin pitches with the greatest effective cooling are at 20mm for non-moving and 8mm for moving.

Han-Taw Chen and Wei Lun Hsu [7] used the finite difference method in conjunction with the least-squares scheme and experimental temperature data to predict the average heat transfer coefficient and fin efficiency on the fin of annular-finned tube heat exchangers in natural convection for various fin spacing. The results show that the h value increases with increasing the fin spacing S, and the fin efficiency decreases with increasing the fin spacing S. However, these two values respectively approach their corresponding asymptotical values obtained from a single fin as $S \rightarrow \infty$.

The fin temperature departs from the ideal isothermal situation and decreases more rapidly away from the circular center with increasing the fin spacing.

A. Mohammadi et.al. [8] applied computational fluid dynamics (CFD) code to simulate fluid flow, heat transfer and combustion in a four-stroke single cylinder engine with pent roof combustion chamber geometry, having two inlet valves and two exhaust valves. Heat flux and heat transfer coefficient on the cylinder head, cylinder wall, piston, intake and exhaust valves are determined with respect to crank angle position. It was found that the local value of heat transfer coefficient varies considerably in different parts of the cylinder, but they have equivalent trend with crank angle. Based on the results, new correlations are suggested to predict maximum and minimum convective heat transfer coefficient in the combustion chamber of a SI engine.

Kumbhar D.G et.al. [9] Heat transfer augmentation from a horizontal rectangular fin by triangular perforations whose bases parallel and towards the fin 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. [10] Analyzed the heat transfer rate and efficiency for circular and elliptical annular fins for different environmental conditions. Elliptical fin efficiency is more than circular fin. 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 is changes in heat transfer co-efficient and efficiency also.

Ashok Tukaram Pise and Umesh Vandeorao Awasarmol [11] 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 fins incline at one half length of the fins of two wheeler cylinder block. Solid and permeable fins block are kept in 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 30%.

Pulkit Agarwal et.al [12] simulated the heat transfer in motor-cycle engine fins using CFD 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. It is observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine. They have concluded that overcooling also affects the engine efficiency because of overcooling excess fuel consumption occurs. This necessitates the need for reducing air velocity striking the engine surface to reduce the fuel consumption. It can be done placing a diffuser in front of the engine which will reduce the relative velocity of the air stream thus decreasing the heat loss.

S.H. Barhatte et.al. [13] natural convection heat transfer from vertical rectangular fin arrays with and without notch at the center have been investigated experimentally and theoretically. In a lengthwise short array where the single chimney flow pattern is present, the central portion of fin flat becomes ineffective due to the fact that, already heated air comes in its contact. In the present study, the fin flats are modified by removing the central fin portion by cutting a notch.

Matkar M.V et.al. [14] calculated the heat transfer rate and the temperature behaviour for the same object with the different material (like copper and aluminium). They have concluded that observe that heat flow rate of copper fin (19.2W) is less than the heat flow rate of the aluminum fin (56.99 W). The copper gets stable at the lowest temperature. And hence here conclude that the copper is best material suitable for fin than the aluminum.

G.Raju et.al. [15] investigated maximization of heat transfer through fin arrays of an internal combustion engine cylinder, under one dimensional, steady state condition with conduction and free convection modes. They used non-traditional optimization technique, namely, binary coded Genetic Algorithm to obtain maximum heat transfer and their corresponding optimum dimensions of rectangular and triangular profile fin arrays. They concluded

1. 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 where weight is the main criteria.
2. At wider spacing, shorter fins are more preferred than longer fins.

Magarajan U et.al. [16] have studied heat release of engine cylinder cooling fins with six numbers of fins having pitch of 10 mm and 20 mm, and are calculated numerically using commercially available CFD tool Ansys Fluent. The engine was at 150 C and the heat release from the cylinder was analyzed at a wind velocity of 0 km/h. Their CFD results were mostly same as that of the experimental results. So, they concluded that, it is possible to modify the fin geometry and predict those results, changes like tapered fins, providing slits and holes in fins geometry can be made and the optimization of fins can be done with the help of CFD results.

A.K. Mishra et.al. [17] carried out transient numerical analysis with wall cylinder temperature of 423 K initially and the heat release from the cylinder is analyzed for zero wind velocity. The heat release from the cylinder which is calculated numerically is validated with the experimental results. To increase the cylinder cooling, the cylinder should have a greater number of fins. However, the cylinder cooling may decrease with an increased number of fins and too narrow a fin pitch. The is because the air could not flow well between the fins, thus the overlapping of thermal boundary layers occurs at the upper and lower fin surfaces.

J. Ajay Paul et.al. [18] carried out Numerical Simulations to determine heat transfer characteristics of different fin parameters namely, number of fins, fin thickness at varying air velocities. A cylinder with a single fin mounted on it was tested experimentally. The numerical simulation of the same setup was done using CFD. Cylinders with fins of 4 mm and 6 mm thickness were simulated for 1, 3, 4 &6 fin configurations. They concluded that

1. When fin thickness was increased, the reduced gap between the fins resulted in swirls being created which helped in increasing the heat transfer.
2. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence and hence higher heat transfer.

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The heat transfer from the outside portion of the fin is found to be less.

G. Babu and M. Lavakumar [19] analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. The models were created by varying the geometry, rectangular, circular and curved shaped fins and also by varying thickness of the fins. Material used for manufacturing cylinder fin body was Aluminum Alloy 204 which has thermal conductivity of 110-150W/mk and also using Aluminum alloy 6061 and Magnesium alloy which have higher thermal conductivities. They concluded that by reducing the thickness and also by changing the shape of the fin to curve shaped, the weight of the fin body reduces thereby increasing the efficiency. The weight of the fin body is reduced when Magnesium alloy is used and using circular fin, material Aluminum alloy 6061 and thickness of 2.5mm is better since heat transfer rate is more and using circular fins the heat lost is more, efficiency and effectiveness is also more.

S.S. Chandrakant et.al.[20] conducted experiments for rectangular and triangular fin profiles for air velocities ranging from 0 to 11 m/s. Experimental and CFD simulated result proves that annular fins with rectangular fin profiles are more suitable for heat transfer enhancement as compared to triangular fin profiles. Surface temperature of triangular fin profile is higher than rectangular fin profile at different air velocity. Heat transfer coefficient increase with increases with increases in velocity in both profiles. In comparison of both profile rectangular fin profile have higher heat transfer coefficient than triangular fin profile. In comparison of both profile rectangular fin profile transfer large amount of heat than triangular fin profile.

A. Rajkumar et.al [21] carried out the transient analysis with assumption that the engine is running at 6000 rpm for 60 seconds. First thermal analysis was done and analyzed the temperature distribution over the fin area. In the second stage structural analysis was carried out using the thermal loads obtained in the first stage. They found that for material A413.0, the maximum stress was 386.094 MPa. For material C443.0, the maximum stress was 363.354 MPa.

For material B390.0, the maximum stress was 242.236 MPa and calculated the factor of safety for all three materials was 0.3367 for A413.0, 0.266 for C443.0 and 1.032 for B390. They concluded that the B390.0 was the best material among all because it has more Factor of Safety than other two and the FOS should always more than one.

R.P. Patil and H.M. Dange [22] 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.

N. Phani Raja Rao et.al. [23] analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. Different material used for cylinder fin were Aluminum Alloy A204, Aluminum alloy 6061 and Magnesium alloy which have higher thermal conductivities and shown that by reducing the thickness and also by changing the shape of the fin to circular shaped, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin. The results shows, by using circular fin with material Aluminum Alloy 6061 is better since heat transfer rate, Efficiency and Effectiveness of the fin is more.

S.M. Wange and R.M. Metkar [24] have done, experimental and computational analysis of fin array and shown that the heat transfer coefficient is more in notch fin array than without notch fin array. Geometric parameters of fin affects on the performance of fins, so proper selection of geometric parameter such as length of fin, height of fin, spacing between fins, depth of notch is needed.

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III. Survey On Four Stroke Spark Ignition Air Cooled Engine Cylinder Fins, Commercially Available In India

Model	CC	Stoke (mm)	Bore (mm)	No Of Fins	Pitch (mm)	Thickness (mm)	Height		Fin Material	Position of Fins W.R.T. Cylinder Axis
							Max (mm)	Min (mm)		
Hero Passion 	110	55.6	50	11-8-11	9	2	36	8	Aluminium alloy	Parallel
Courtesy by RAJDEEP AUTOMOBILES, CTM, AHMEDABAD,GUJARAT, INDIA										
Honda Sine 	125	57.9	52.4	6	10	2	22	7	Aluminium alloy	Perpendicular
Courtesy by APEX HONDA, MANINAGAR, AHMEDABAD, GUJARAT, INDIA										
Bajaj Pulsar 	135	54	59	6	10	2	35	10	Aluminium alloy	perpendicular
Courtesy by BAJAJ SERVICE, BAPUNAGAR, AHMEDABAD,GUJARAT,INDIA										
Bajaj Pulsar 	150	56.4	58	6	11	2	35	10	Aluminium alloy	Perpendicular
Courtesy by BAJAJ SERVICE, BAPUNAGAR, AHMEDABAD,GUJARAT,INDIA										
Honda Unicorn 	149	57.8	57.3	6	7	3	13	9	Aluminium alloy	Perpendicular
Courtesy by APEX HONDA, MANINAGAR, AHMEDABAD, GUJARAT, INDIA										
Yamaha Fazer 	153	57.9	58	7	10	3	24	5	Aluminium alloy	Perpendicular
Courtesy by YAMAHA SERVICE CENTER ,MANINAGAR,AHMEDABAD, GUJARAT, INDIA										
Hero Karizma 	225	66.2	65.5	8	10	2	23	12	Aluminium	perpendicular
Courtesy by RAJDEEP AUTOMOBILES, CTM, AHMEDABAD,GUJARAT, INDIA										

IV. Conclusion

Design of fin plays an important role in heat transfer. There is a scope of improvement in heat transfer of air-cooled engine cylinder fin if mounted fin’s shape varied from conventional one. Contact time between air flow and fin (time between air inlet and outlet flow through fin) is also important factor in such heat transfer. Wavy fin shaped cylinder block can be used for increasing the heat transfer from the fins by creating turbulence for upcoming air. Improvements in heat transfer can be compare with conventional one by CFD Analysis and Wind Tunnel experiment.

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