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Review on Enhanced Heat Transfer Techniques using Modern Technologies for 4S Air Cooled Engines

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Abstract: Engine performance is a biggest challenge and a vital area of concern when it comes to automobiles. Researchers across the globe have been working decades together meticulously improvising the performance of engine in terms of efficiency. The durability of the engine components mainly depends on the thermal stress it undergoes over the period of operation. Air cooling of engine is the simplest and most desirous technique that has been adopted for ages. In this regard fins or extended surfaces are employed for effective cooling of the cylinder while in operation. The conductive and convective heat transfer rate from the cylinder to the fins and in turn from the fins to surrounding ambience determines the effective performance of the engine. In this paper an attempt is made to review and summarize the various researches that were conducted on the Fins in terms of profile geometry, number of fins, size, thickness factor, material used etc., and to bring about a long term solution with the modern technologies like nano coatings and nano materials.

1. Introduction
Automobiles are a fascinating and most attractive industry around the world. The competitiveness in developing new technologies with modern innovations for meeting the standards and expectation of the user has reached varied horizons. Performance of the automobile mainly depends on the efficiency of the engine. The thermal stresses developed on the engine have great impact on all the components that is associated with the combustion chamber. To increase the durability of the engine components and there by an efficient performance of the engine it become very essential to quickly dissipate the heat generated during combustion. Typical air cooled engines use fins or the extended surfaces along its periphery for this purpose.[1] Heat is removed from the inside of the cylinder through conductive heat transfer to the fins and from fins to the surrounding through convective heat transfer. Hence the heat transfer rate plays a very important role in maintaining the required engine temperature. Extensive works carried out in the past shows significant results in achieving better heat transfer rate. The availability of software like Pro-E ANSYS, MATLAB, has greatly helped in understanding the thermal distribution for various fin geometry with different material compositions enabling effective optimization of fins for a particular engine. In addition, the recent advancements in nano materials and its suitability to extend its application for engine has opened a new dimension for the researchers working on the engine cooling systems.

2. Literature Review
G. Babu and M. Lavakumar [2], have worked on a heat transfer analysis for optimization of engine cylinder fins by varying the geometry and material. Experimentation has been conducted by designing a cylinder fin for the 100cc Hero Honda Motorcycle and modeling was done in parametric 3D modeling software Pro/Engineer. The fin material Aluminum alloy 204 was replaced with Aluminum alloy 6061 and magnesium alloy. The profile of the fin

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was modified from rectangular to circular and curve shaped. The default thickness of fin was reduced from 3mm to 2.5mm. It is found that efficiency is increased by reducing the thickness and the fin profile is changed to curve shape, thereby reducing the weight of the fin body. The weight of the fin body is said to have reduced further with the use of Magnesium alloy. Thermal analysis on the fin is made by varying materials, geometry and thickness. From the analysis results it was observed that circular fin made of Aluminium alloy 6061 and thickness of 2.5mm is better since heat transfer rate is more. But by using circular fins the weight of the fin body was found increasing. In terms of weight reduction curved fins are found effective than other geometries. So it was concluded that aluminium alloy 6061 with reduced thickness of 2.5 mm and curved shape fins are very suitable for the increased heat transfer rate of the selected engine. The Figure1&2 shows the variation of the temperature distribution over the rectangular and circular fin profile for the same engine configuration.

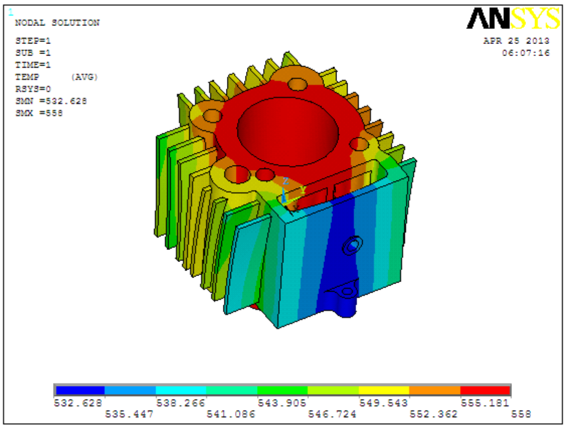

Figure 1. Temperature distribution over a rectangular fin

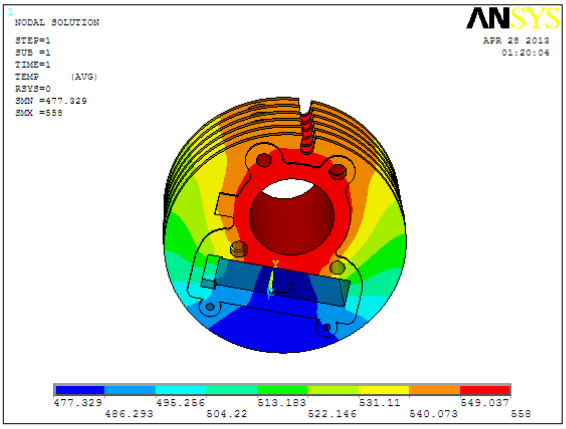

Figure 2. Temperature distribution over a circular fin

Mohsin A .Ali, Prof. S.M Kherde [3] have concluded from their review on design modification of two wheeler fins that, design of fin plays an important role in heat transfer between the cylinder to the surroundings. The fin geometry and the area of cross section affect the heat transfer coefficient to a larger extent.

In high speed vehicles, thicker fins produced swirls which increased the heat transfer and thereby increasing the efficiency of the fin. Also large number of fins with lesser thickness in high speed engines than thick fins with lesser number helped in higher heat transfer by inducing greater turbulence. Contact time between air flow and fin is also found to be an important factor for such heat transfer.

Denpong Soodphakdee et.al **[4]** has compared the heat transfer performance by adopting various fin geometries. The fin geometry taken for study is plate fins or pin fins. The plate fins can be continuous parallel plates or staggered. A circular array of 1mm diameter pin fins with a 2mm pitch is taken as a basis for comparison. It is observed that the ratio of solid to fluid thermal conductivity for aluminium and air is greater, this led to modeling of fins as isothermal surfaces than the conjugate solid. The two-dimensional CFD simulations were conducted on planes having symmetry parallel to the flow. The air approach velocity is in the range of 0.5 to 5m/s. It has been observed that the staggered plate fin geometry has higher heat transfer for the given combination of pressure gradient and flow rate.

N. Phani Raja Rao et.al. [5] typically analyzed the thermal properties by varying thickness, geometry and material of cylinder fins. From the results the thickness is reduced and the fin shape is changed to circular which increased the efficiency and heat transfer rate of fin. By using Aluminum Alloy 6061 as circular fin material the heat transfer rate is better with higher fin efficiency and effectiveness.

S.S. Chandrakant et.al.[6] has made extensive experiments on rectangular and triangular fin profiles with a varied air velocities ranging from 0 to 11 m/s. Experiments carried out and CFD simulation result proves that annular fins with rectangular fin profiles have optimal heat transfer when compared to triangular fin profiles. It is observed that at different air velocity the triangular fin surface temperature is greater than rectangular fin. The rectangular fin has higher heat transfer coefficient than triangular fin. The comparison resulted in rectangular profile being more efficient than the triangular profile.

Pulkit Agarwal et.al [7] in their experimental investigation has simulated the heat transfer in motor-cycle engine fins using CFD analysis. During investigation it was found that, the surrounding ambient temperature played a important role in engine efficiency. The heat transfer rate was very higher at low ambient temperatures, which in turn increased the heat transfer to a larger extent which caused over cooling of the. This resulted in excess fuel consumption and hence need to reduce the air velocity striking the engine surface. In this aspect a diffuser is placed in front of the engine to reduce the relative velocity of the air stream thus decreasing the heat loss.

Bassam A and K Abu Hijleh [8] has made investigation of a cross flow forced heat transfer for a horizontal cylinder that has permeable fins which are equally spaced multiple layout on the outer surface. These fins exhibit higher heat transfer rate than the traditional fins of similar structure. The aerodynamic and thermal wakes caused in permeable fins is reduced by downstream fins, when θ is below 90°. A better convection heat transfer from the cylinder can be obtained by using a long permeable fin.

L. Dialameh et. al. [9] have conducted a numerical study to predict natural convection from an array of aluminum horizontal rectangular thick fins of 3 mm < t < 7 mm with short lengths (L 6 50 mm) attached on a horizontal base plate. Finite volume scheme is used to solve the three-dimensional elliptic governing equations of laminar flow and heat transfer. Two types of flow patterns in the channel of the fin arrays were observed based on the model verified, fluid flow and thermal structure. Effect of various fin geometries and temperature differences on the convection heat transfer from the array was determined for Rayleigh numbers based on fin spacing of 192–6784. Then correlations were developed to predict the Nusselt numbers with reference to non-dimensional parameters. It is concluded that natural convection heat transfer coefficient increases with increasing temperature differences and increases with fin spacing and decreases with fin length.

Mr. A. Raj Kumar et. al. [10] has made an investigation in which the transient analysis is performed for a engine running at 6000rpm for a minute. In the initial stage temperature distribution in the fin area is analyzed and thermal analysis is done. In the next stage the obtained thermal load is used for doing the structural analysis. It is found that the maximum stress of 386.094 MPa for the material A413.0 and maximum stress of 363.354 MPa for the material C443.0. The material B390.0 has more Factory of Safety better than the other two materials, so it is the best material.

Wladyslaw Mitianiec et. al. [11] have dealt with calculation of the thermal loads and temperature distribution of the cylinder and cylinder head of the two-stroke engine 115 cm^3 capacity cooled by air at mean engine load. The meshing is done in CATIA and simulation is carried out in ANSYS program. The simulation results were verified with the experimental results. The results showed that the cooling heat in the air-cooled two-stroke engine increases with the engine speed and cooling energy amounts above 30% of the total energy delivered with fuel. Also, spark plug and the outer ribs which experience the highest temperature in SI two-stroke can be lessened in order to decrease the weight of the parts.

Mohd Faizal Mohideen Batcha et. al. [12] in their investigation on Mist cooling, have found dissipating heat fluxes with low coolant mass fluxes. The temperature distribution is analyzed for plate fins. The fins are analyzed by giving actual conditions on a cylinder head by subjecting to constant heat flux and there by cooling by applying airflow at velocities in the range of 21.5 m/s to 40.4 m/s. The amount of heat transferred is measured from the temperature distribution in the fin at different locations. On repeated experimentation with the injection of mist a comparison is made for the augmentation of heat transfer. The heat transfer coefficients increased between 200 and 400%, the surface temperatures were depressed. Therefore it is concluded that during critical conditions mist-cooling is adopted to enhance the heat transfer and lower the temperatures in air-cooled systems.

Benjamin pineel [13] in his experimental investigation have analyzed the heat-transfer processes of an air-cooled engine for the purpose of determining the manner in which the various engine and cooling conditions combine to determine the cylinder temperature. Investigation was conducted on the cylinders of Pratt & Whitney 1535 and a Pratt & Whitney 1340H. It is concluded that the values of the effective gas temperatures were practically independent of the engine speed and brake mean effective pressure. The normal range of operation were equal to 1,150° F. for the head and 600° F for the barrel for both the Pratt & Whitney 1535 and the 1340-U cylinders. A suggestion to incorporate turbulence devices in front of the cylinder to increase in the heat-transfer coefficient of the order of 30 percent for the same pressure drop is made.

S. Pashah, Syed et al [14] have studied the effect of coating layer on variable profile composite annular fins using a non-dimensional finite element formulation. The non-linear relationship between the temperature and relative humidity is done by piecewise linear approximation. The coating effects are completely governed by a single dimensionless parameter Bic. A limiting value of Bic ¼ 1 is identified for which the coating effects become negligible. Bic 1 results show a minor increase in fin thermal performance. Further, finite element formulation can be used to study any arbitrary fin profile and fin type under fully or partially wet condition.

S. Pashah , A.F.M. Arif ,et al [15] have studied the effects of coating layer and interface resistance on thermal performance of variable thickness composite annular fins. The obtained results are in dimensionless form, by using the governing parameters for dimensionless system the coating layer effect is governed by single dimensionless parameter. This dimensionless parameter groups important material and geometry parameters of coating and fin substrate. The coating degrading effects is insignificant for contact Biot number. The interface resistance effects are governed by a single dimensionless parameter Bi which groups the important material and geometry parameters of interface and fin substrate. For identical value of Biot number the interface resistance effect is more important than the coating layer resistance effect.

3. CONCLUSION

From the literature review done it is very predominant that the conductive and convective heat transfer rate of the fins varies with the material, profile geometry, number of fins, pitches, coating provided etc., in other hand changing the existing fin profiles with complicated geometry involves tedious techniques. No significant research has been conducted so far with the fins coated with nano materials. The complexity in design and inadequate technology in the past to enable nano coating on the fins could be a reason for the researchers to keep away from this aspect. With recent advancements in the field of nano technology, the plasma spray coating techniques have come as a solution for such complex applications. The nano coated fins with suitable high thermal conducting material could thus become a long standing solution and a most effective means of enhanced heat transfer method for air cooled engines.

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