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INVESTIGATION OF EFFECTIVENESS OF DIFFERENT SHAPES OF FINS ON SINGLE CYLINDER PETROL ENGINE

Engineering

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ABSTRACT

Fins are necessary for an air-cooled internal combustion engines to dissipate heat generated during combustion.The geometry of these fins is very important to determine the cooling efficiency and thermal stability [1,2]. This study investigated the thermal effectiveness of rectangular, circular(annular), and triangular fin geometries applied to a single cylinder, four stroke, 220cc gasoline engine. The total heat generated by the engine was calculated based on fuel-consumption data and heat balance sheet method, with these process, the estimation of heat removed by the fins was approximately 4.2 kW [3] . The design of the three-dimensional models of the finned cylinder were created on Onshape CAD and were simulated and analyzed under steady-state thermal analysis by using ANSYS Workbench 2025 R1. The material of the fin selected was Aluminium alloy[4]. The convective heat-transfer coefficient was calculated using the Hilpert correlation method [5]. The result showed that the rectangular fins had the highest heat-transfer performance with approximately 3.12 kW on simulated and 3.6 kW on theoretical calculations. Even if the triangular fins provided higher fin efficiency with its tapered tip, its overall heat removal was lower, while the circular fins had less thermal effectiveness. The study concluded that the rectangular fins were the most suitable for an air-cooled motorcycle engines.

KEYWORDS

Air-cooled Engine, Engine Cooling Fins, Fin Geometry, Heat Transfer Analysis, Rectangular Fins, Thermal Effectiveness, ANSYS Workbench, Gasoline Engine

1. INTRODUCTION

Air cooling is the mostly used in thermal management for gasoline engines especially in motorcycles due to its simplicity, low cost and maintenance[1,6]. In an air-cooled engine around 30-35% of the energy is converted into useful mechanical work, while the remaining is dissipated through the exhaust, friction, cylinder walls and fins[7]. If the heat is not removed efficiently, excessive temperature can cause thermal stresses and components failure [2,8]. To provide a efficient cooling, fins are added to the cylinder to have more effective area for convective heat transfer. Fins performance was influaenced by multiple parameters like material properties, spacing, fins geometry and airflow condition [4,9]. Although circular or annular fins are mostly used because of its simple manufacturing [6], some studies show that alternative geometries can affect temperature distribution and heat removal capacity [10,11]. Rectangular fins have uniform heat conduction due to its constant cross-section, while triangular fins use less materials with its tapered thickness it can produce higher conduction near the tip [12]. However direct comparative studies of the fin geometries under the same engine specific conditions are limited. This work addresses to that gap by performing a comparative steady-state thermal analysis of the rectangular, circular, and triangular fins for a 220 cc single-cylinder gasoline engine and evaluating their performance on heat flux, temperature distribution, fin efficiency and thermal effectiveness under the same boundary conditions.

2. Litterature Review

Heat tranfer in an internal combustion engines has been deeply studied because of thermal managemement affects directly engine efficiency, durability and performance. For an air cooled engine, fins play a very important role for dissipating heat to the surroundings. The following literatures gives both theoritical, numerical and experimental basis.

- **Incorpoera et al. [1]** presented the principles of heat and mass transfer in thermal analysis of mechanical systems, which explained the mechanism of conduction, convection and radiation on cylindrical bodies. The concept is to evaluate heat dissipation from engine cylinder and fins, especially on an air cooled engines where convection is dominant.
- **Heywood [2]** Provided a treatment of internal combustion engine fundamentals, with thermal environment inside the cylinder, heat flow paths and consequences of combustion on engine component temperatures. It also gave importance of effective cooling in maintaining thermal stresses in engine component.
- **Tejaswee et al. [3]** Studied the design and simulation of pistons of a 220cc engine. The work focused primarly on structural thermal analysis, showing the importance of proper material selection. The study showed that a carefully design of the piston was necessary to withstand temperature rise and stress.
- **Rajam and Sathiskumar [4]** studied thermal analysis of cooling fins in internal combustion engines. The study focused on role of fin geometry in enhancing heat dissipation and showed that fin dimensions and surface area affected thermal performance of an engine. So the results suggested optimized fins configurations.
- **The classical work of Hilpert [5]** For a cylinder, an empirical correlation was required for convective heat transfer under external flow conditions. The correlations was very used for engineering calculation in cylindrical surface exposed to the air.
- **Varghes et al. [6]** The study investigated enhancement of heat transfer for an air cooled engine fins. Their study showed that by modifying fin design, the cooling effectiveness would improve. With the calculations mades by the authors they concluded that fin optimization was effective for thermal management.
- **Tandon [7]** Provided a heat balance analysis for an air cooled gasoline engines to determine the distribution of heat during operation. The study showed the heat pathways which were exhaust gas, cooling surfaces, and other engine components to understand the thermal behavior of an air cooled engine.
- **Sisodia and Tandon [8]** Analyzed the thermal performance of an internal combustion engine cooling fins and highlighted the relation between fin geometry and temperature reduction. The results showed a lower cylinder temperature for a well configured fins.
- **Chavan and Kulkarni [9]** Made a comparative study of fin geometries for an air cooled cylinder. By comparing different fin profiles they determined which provided better thermal performance. Their results showed that variation of fins profiles could strongly influence cooling effectiveness and fin shapes increased surface area which gave better airflow.
- **Sisodia and Chavan [10]** Performed numerical analysis of different fin geometries to enhance heat transfer. The work supports the idea that thermal efficiency could improve by selecting suitable fins shapes and arrangements. The numerical simulations showed the temperature distributions and heat flux of each design.
- **Varghese and Thomas [11]** Studed that thermal behavior of an air cooled fins engine cylinder with modified fins. It demonstrated that fins modifications could improve heat rejection and produce more uniform temperature distribution over the cylinder surface.

3. METHODOLOGY:

The methodology in this study consisted on four essential steps:

theoretical design of the cylinder, theoretical analysis of the cylinder, CAD model design of the cylinder, Simulation analysis of the cylinder. Following these steps led to comparison results of thermal performance of different fin geometries under the same conditions.

3.1 Material Used

The finned cylinder analyzed in this study was for a single-cylinder, four stroke, air-cooled gasoline engine with a displacement of 220 cc. The material used for the cylinder and the fins was Aluminium alloy due to its high thermal conductivity, low density, and corrosion resistance [4,9]. Aluminium alloys were known to have good properties for heat-transfer and strucutral weight that led them the most suitable for air-cooled engines for a rapid heat dissipation requirement.

The material properties for the analysis are:
Material: Aluminium alloy
Thermal conductivity: 180W/mK
Density: 2700 kg/m^3
Specific heat capacity: 900 J/kg.K
These properties were kept to be the same for all fin geometries for an accurate comparison for thermal performance and to isolate the effect of fin shape on heat dissipation.

3.2 Theoretical Design of the Cylinder

The engine used in this study was a Bajaj Pulsar 220 cc petrol engine with the following specification based on Tejaswe et al[3].

Table 1: Engine Specification

Engine type	Four stroke, petrol engine
Induction	Air coole type
Number of cylinders	Single cylinder
Bore(D)	67mm
Stroke(L)	62.4mm
Length of connecting rod	124.8mm
Displacement volume	220cm3
Compression ration	9.5+/-0.5:1
Maximum power	15.51 kW at 8500 rpm
Number of revolution/cycle	2
Maximum torque(T)	19.12N-m at 7000rpm(N)

- Thickness of the cylinder wall: t= 0.045D+1.6
- Length of the cylinder: L=1*1.15
- Thickness(acc R.K Rajput "Thermal engineering")
- "For a small to mid size (220cc), fin thickness for air cooled IC engine is approximately 2 to 3mm"
- Number of fins: N= 15

3.3 Theoretical Analysis of the Cylinder

Multiple calculations were necessary for this comparative study of different geometries of fins: Determination of the convective heat transfer, heat generation due to fuel combustion, required area of the cylinder fins, and thermal performance of the fins in effeciency and effectiveness.

- Heat Transfer Coefficient

In this step to calculate the convective heat transfer of the finned cylinder the Hilpert correlation for forced convection [1,5]. The Hilpert correlation formula is:
$Nu = C.Re^{m}.Pr^{1/3}$
Where:
Nu: Nusslet number
Re: Reynolds number
Pr: Prandtl number
C and m: empirical constant depending on Reynolds number range [1].
The convective heat transfer was then obtained with the following formula:

$$h = \frac{Nu.k_{air}}{D}$$

The convective heat transfer obtained with the previous conditions was 61W/m^2.K, which was consistenly used in theoretical calculation and numerical simulations[6,9].

- Fuel Consumed and Heat Generated

To determine the total of heat generated inside the engine cylinder, fuel consumption and heat balance were needed [2,7]. The heat rate was calculated as the following formula:
Q= mf . CV
Where:
mf: mass flow rate of fuel
CV: calorific value of gasoline[2]
Based on brake thermal efficiency of small gasoline engine, only a fraction of the fuel energy is converted into mechanical work while the remaining is rejected by the exhaust gases, friction [2,7]. From the heat balance sheet around 4.2kW of heat needed to be removed by the fins [3,10]

- Area Required for Heat Dissipation

The total surface area required to remove the heat, the convective heat transfer was needed [1,4].

$$A_{req} = \frac{Q}{\eta.h.(Ts - T\infty)}$$

Where:
Q: heat to be removed
η: efficiency of the engine
h: convective heat transfer coefficient
Ts: cylinder surface temperature
T : ambient air temperature
With this formulation the area required was 0.563m^2.

- Fin Efficiency, Effectiveness and Heat Removed by the Fins

Fin efficiency and fin effectiveness were the necessary standard performance of the engine [1,4]. The following data are the same and required to evaluate this step for each fin geometry:
- Number of fins: 15
- Do= 0.07162m
- Fin base thickness tb= 0.002m
- Fin axial length aliong the cylinder La(rectangular fins)= 0.152m, La(triangular fins) = 0.170m, La(circular fins) = 0.168m
- Thermal conductivity Al Alloys k= 180W/mK
- Convective coefficient air h= (44.537+76.098)/2 = 61W/m2K
- Base temperature= 150°C = 423K
- Ambient Temperature= 30°C = 303K

Fin efficiency was defined as

$$\eta = \frac{\tanh(m.L)}{m.L}$$

where:

$$m = \sqrt{\frac{2h}{k.t}}$$

Fin effectiveness was defined as

$$\varepsilon = \frac{Q\ with\ fins}{Q\ without\ fins}$$

Heat removed by the fins was defined as

$$Q_f = \eta.h.A_f.\Delta T$$

Where:
Qf: heat removed by the fins
Af: Area total of fins

3.3 CAD Model Design of the Cylinder

The three dimensional CAD model of the finned cylinder was made using Onshape CAD software. The base of the cylinder was modeled based on the calculated dimensions and specified dimensions [3]. For each geometry of fins a single profile was created then patterned uniformly along the cylinder wall for constant spacing.With the variation of the geometry while keeping other parameter constant, the comparative study was consistent [9,10].

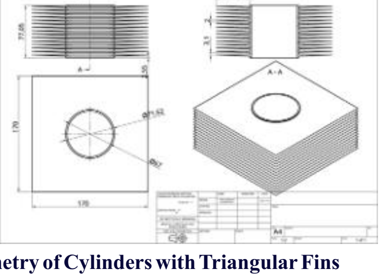

Fig 1: Geometry of Cylinders with Triangular Fins

Figure 1 presented the CAD geometry of the cylinder with triangular fins including orthographic and isometric views along with the appropriate principal dimensions. The tapered fin profile reduced the thickness which saved materials while maintaining heat conduction from cylinder wall.

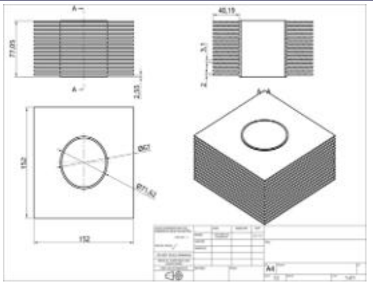

Fig 2: Geometry of Cylinders with Rectangular Fins

Figure 2 showed the CAD model of the cylinder with rectangular fins, Each fins had uniform thickness providing a constant conduction and large surface area for convection.

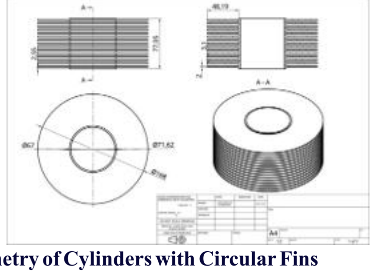

Fig 3: Geometry of Cylinders with Circular Fins

Figure 3 showed the CAD geometry of the cylinder with circular/ annular fins, the configuration follows the cylindrical form of the cylinder of the engine with uniform heights of the fins.

3.4 Simulation Analysis of the Cylinder

The simulation analysis was performed using ANSYS Workbench 2025 R1 software to evaluate the steady state thermal of the finned cylinder [6,10,11]. The CAD models were imported in .IGES format. The material was Aluminium alloy which was selected on the library of the software along its properties:

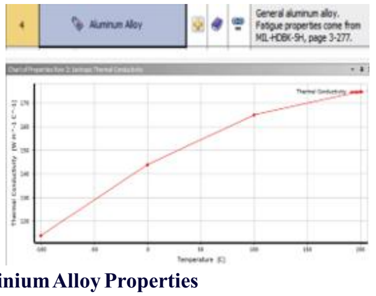

Fig 4: Aluminium Alloy Properties

Figure 4 illustrated the aluminium alloy material used in ANSYS, with the thermal conductivity variation with temperature. The same material was used for all three fins configuration, for a accurate comparison.

Boundary conditions were the same for each fin geometries then applied on the surface of the finned cylinder where:

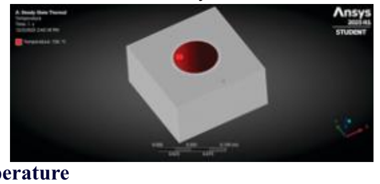

Fig 5: Temperature

Figure 5 presented the temperature boundary condition applied in the steady state thermal analysis. A temperature of 150°C was applied on the inner cylinder surface to show the thermal load transferred from combustion to the cylinder body.

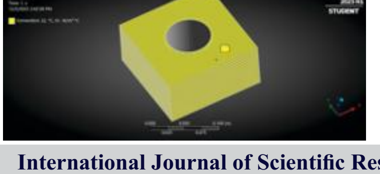

Fig 6: Convection

Figure 6 showed the convection boundary condition applied to the external surfaces of the finned cylinder. This condition simulates the heat loss from the cylinder and fins to the surrounding air through external convection.

Meshing was then applied to the finned cylinder using the same meshing methods and each geometry has different number of nodes and elements.

Table 2: Result of Meshing

	Cylinder with rectangular fins	Cylinder with triangular fins	Cylinder with circular fins
Element Size(m)	0.004	0.004	0.004
Number of nodes	111928	115163	119371
Number of element	53911	55596	58149
Methods	Tetrahedrons	Tetrahedrons	Tetrahedrons

4. RESULTS AND DISCUSSION

During the steady-state thermal analysis under the same boundary conditions, the rectangular fins had the mostly better performance than the other geometries on uniform temperature distribution, lower thermal gradients and reaction probe [1,4]. The rectangular fins had a heat removal of 3.12kW which exceeded to the others cooling load , the circular fins showed medium heat dissipation and the triangular fins, even with higher efficiency due to the tapered fins removed less heat because of its smaller effective surface area [9,10] .

The theoretical calculation had similar results for the rectangular fins which validated the methodology [1,6]. The following table was the summary results of both theoretical and simulation analysis.

- **Temperature Distributions:**

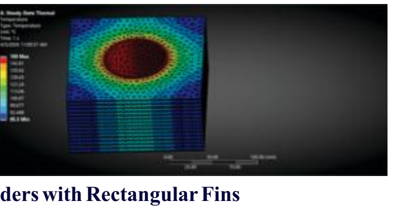

Fig 7: Cylinders with Rectangular Fins

Figure 7 showed the temperature distribution for the cylinder with rectangular fins under steady state conditions. The highest temperature is concentrated at the cylinder wall and it decreased progressively to the outer fins surfaces. The uniform contour of the fins provided good thermal performance for a rectangular fins.

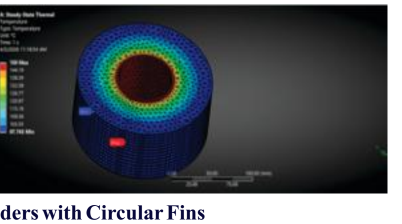

Fig 8: Cylinders with Circular Fins

Figure 8 showed the temperature distribution for the cylinder with circular fins under steady state conditions. The hotter region is from the cylinder wall and decreasing while the heat was spread to the circular fins. The circular arrangements provided a stable cooling even though its thermal performance is lower that the best performing shape.

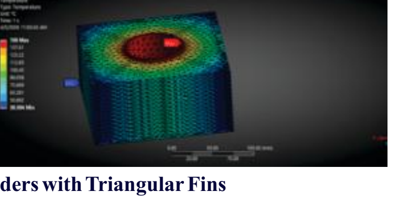

Fig 9: Cylinders with Triangular Fins

Figure 9 showed the temperature distribution for the cylinder with triangular fins. The heat is conducted from the inner heated region to the tapered fins, the figure showed a larger temperature drops compared to the others.

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- **Total Heat Flux**

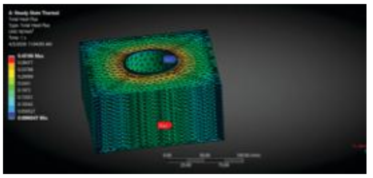

Fig 10: Cylinders with Triangular Fins

Figure 10 presented the total heat flux of the cylinder with triangular fins. The maximum heat flux is near the hotter region of the inner cylinder , and it decreased outward through the fins. The figure showed that triangular fins are capable of transferring heat effectively.

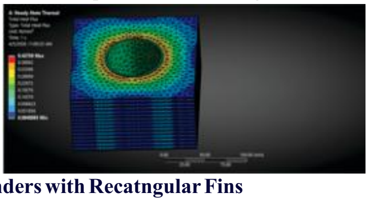

Fig 11: Cylinders with Recatngular Fins

Figure 11 presented the total heat flux of the cylinder with rectangular fins. The figure showed high heat flux around the inner region and decreasing through the fins. The cylinder with rectangular fins had the higher maximum heat flux which showed good heat removal and thermal performance.

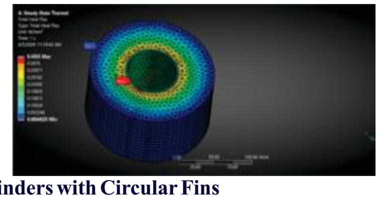

Fig 12: Cylinders with Circular Fins

Figure 12 presented the total heat flux distribution for the cylinder with circular fins. The maximum heat flux is concentrated around the inner cylinder wall and decreased through the circular fins. Compared to the rectangular fins, the circular had lower maximum flux which means lower heat dissipation capability.

- **Directional Heat Flux**

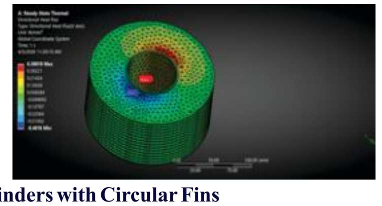

Fig 13: Cylinders with Circular Fins

Figure 13 showed the directional heat flux of the cylinder with circular fins, unlike total heat flux, the result showed the heat transfer capability on a selected axis, the positives and negatives values are from the directional variation of heat flow around the geometry.

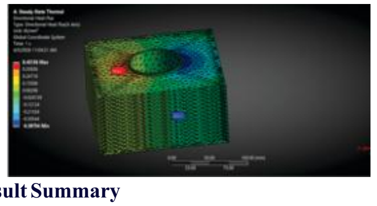

Fig 14: Cylinders with Triangular Fins

Figure 14 showed the directional heat flux of the cylinder with triangular fins. The figure showed that the tapered fin profile affects both values and direction of the heat conduction.

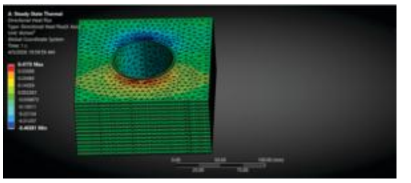

Fig 15: Cylinders with Recatangular Fins

Figure 15 showed the directional heat flux of the cylinder with rectangular fins. The figure showed a more organized heat flow path from the heated region. And the results showed that the cylinder with rectangular fins had the most effective thermal conduction among the geometries studied.

- **Heat Transfer Rate**

Fig 16: Cylinders with Recatangular Fins

Figure 16 presented the reaction probe of the cylinder with rectangular fins, used to determine the heat transfer rate. The results simulated approximately 3121.4W which is the highest among the other three geometries studied which proved more that the rectangular fins had the suitable cooling performance under the selected boundary conditions.

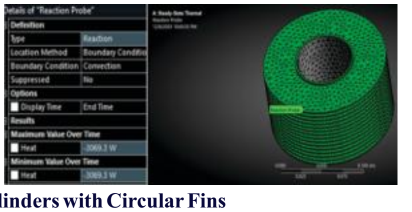

Fig 17: Cylinders with Circular Fins

Figure 17 presented the reaction probe results of cylinder with circular fins. The measured heat transfer rate is approximately 3069.3W, which is lower than the rectangular fins and showed that even if the circular had a stable heat removal it was lower under the same boundary conditions.

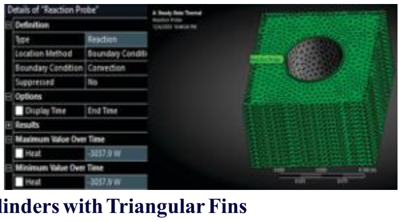

Fig 18: Cylinders with Triangular Fins

Figure 18 presented the reaction probe results for the cylinder with triangular fins. The result was approximately 3037.9W which is higher than circular fins but lower than the rectangular fins. That proved that the triangular fins provided moderate cooling performance under the same boundary conditions.

Table 2: Result Summary

Cylinder Type	Temp. Max (°C)	Temp. Min (°C)	Total Heat Flux Max (W/mm²)	Total Heat Flux Min (W/mm²)	Directional Heat Flux Max (W/mm²)	Directional Heat Flux Min (W/mm²)	Simulated Heat Transfer (W)	Calculated Heat Transfer (W)	Efficiency (%)	Effectiveness
Cylinder with Circular fins	150	97.74	0.4355	0.0044	0.39019	-0.4016	3069.4	3477.58	85.6	21.00
Cylinder with Triangular fins	150	38.504	0.43166	0.0096	0.4313	−0.3975	3037.9	3588.26	86.0	20.91
Cylinder with Rectangular fins	150	85.3	0.4275	0.00488	0.4173	−0.4038	3121.4	3674.87	85.0	29.59

5. CONCLUSION

This study analyzed thermal performance of the rectangular, circular and triangular fin on an air-cooled sing cylinder gasoline engine using theoretical analysis and simulation analysis. The results showed that the rectangular fins cylinder had the most effective cooling performance with high heat dissipation with uniform temperature distribution [6,10]. Even if the triangular fins had good efficiency the overall heat removal was limited due to less effective surface area, and the circular fins had the lowest thermal effectiveness [9,11]. Based on heat flux, temperature distribution, fin efficiency and effectiveness, rectangular fins were the most suitable for air cooled motorcycle engines. This study proved that the optimization of fin geometry could improve the engine cooling performance without changing the material properties or operating conditions.

6. REFERENCES

[1] F.P Incropera, D.P.Dewitt, T.LBergman, A.S Lavine, "Fundamentals of heat and mass transfer", 7th ed., John Wiley & Sons, New York, USA, 2011.

[2] J.B Heywood, "Internal combustion engine fundamentals", McGraw-Hill Education, New York, USA, 1988.

[3] Tejasve, Y., Dhamecha, Y., and Patel, K., "Design and Analysis of Piston Cylinder Assembly of 220 cc Engine," International Research Journal of Engineering and Technology (IRJET), Vol. 7, Issue 8, pp. 1055–1060, 2020.

[4] V.Rajam and M.Sathiskumar, "Thermal analysis of cooling fins used in internal combustion engines", International journal of Engineering Research, vol. 6, no. 2, pp. 97-102, 2016.

[5] R.Hilpert, "Heat transfer from cylinders", Forschungsarbeiten auf dem Gebeite des Ingenieurwesens, vol. 4, pp. 215-224, 1993.

[6] A.Varghese, J.Mathew and R.Thomas, "Numerical investigation of heat transfer enhancement in air-cooled engine fins", International journal of Mechanical Engineering and Technology, vol. 8, no. 6, pp. 456-463, 2017.

[7] J.Tandon, "Heat balance analysis of air-cooled gasoline engines", International journal of Automative Engineering, vol. 4,no. 1, pp. 34-39, 2015.

[8] S.Sisodia and P.Tandon, "Thermal performance analysis of IC engine cooling fins", International Journal of Scientific and Research Publications, vol. 6, no. 5, pp. 120-126, 2016.

[9] R.Chavan and S.Kulkarni, "Comparative study of fin geometries for air-cooled engine cylinders", International Journal of Engineeering Research and Technology (IJERT), vol. 4 no. 6, pp. 512-517, 2015.

[10] S.Sisodia and R.Chavan, "Numerical analysis of different fin geometries for enhancing heat transfer", International Journal of Engineering Sciences & Research Technology, vol. 6, no. 4, pp. 289-295, 2017.

[11] A.Varghese and R.Thomas, "Thermal behavior of air-cooled engine cylinder with modified fins", International Journal of Engineering Research in Mechanical and Civil Engineering, vol. 3, no. 2, pp. 85-91, 2018.