" CFD ANALYSIS OF FINNED CYLINDER FOR HEAT TRANSFER RATE BY CHANGING FIN PROFILES "

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ABSTRACT

Heat dissipation is probably one of the most important considerations in engine design. An internal combustion engine creates enough heat to destroy itself. Without an efficient cooling system, we would not have the vehicles we do today. The original radiators were simple networks of round copper or brass tubes that had water flowing through them by convection. Engine life and effectiveness can be improved with effective cooling. The cooling mechanism of the air cooled engine is mostly dependent on the fin design of the cylinder head and block. Insufficient removal of heat from engine will lead to high thermal stresses and lower engine efficiency. 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 and climate condition. Based on the research done, a model is selected to perform heat transfer analysis and identify possible increase in the rate by changing the fin profile. To perform the study, virtual simulation by CFD approach is proposed.

Keywords:- *Experimental cylinder, Fin profile, Heat transfer rate, Simulation, ANSYS*

1 INTRODUCTION

In the study of heat transfer, fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Heat transfer between a solid surface and a moving fluid is governed by the Newton's cooling law. Increasing the temperature gradient 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 feasible or economical to change the first two options. Thus, adding a fin to an object, increases the surface area.

The conduction heat transfer from inner wall to fin surface is given as:
$q = k (T_w - T_{fin})$
The convection heat tansfer from fin surface to atmosphere air by free and forced air is given as:
$q = h_f (T_{fin} - T_{air})$

Experiments has been made to increase fin efficiency by Changing fin material and fin geometry. The cooling mechanism of the air cooled IC engine is generally dependent on the fin design of the cylinder, cross-section area of fin, pitch of the fin, thickness of fin, air velocity, air exposed angle and weather conditions. 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. [1]

Masao YOSIDHA et.al. [2] investigated effect of number of fin, fin pitch and wind velocity on air-cooling using experimental cylinders for an air-cooled engine of a motorcycle 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. The average fin surface heat transfer coefficient can be obtained using the following equation at the speed from 0 to 60 km/h.

$$\alpha_{avg} =(2.47-2.55/p^{0.4})u^{0.9\ 0.087\ 2p+4.31}$$

Pulkit Agarwal et al. [3] made an attempt to simulate the heat transfer using CFD analysis. The heat transfer surface of the engine is modeled in GAMBIT and simulated in FLUENT software. An expression of average fin surface heat transfer coefficient in terms of wind velocity is obtained. It is observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine. A number of experimental studies have been done on cooling of air-cooled engine fins. Air cooled cylinders were tested at wind velocities from 7.2 to 72 km/hr to design fins for motorcycle engines and an experimental equation for the following fin surface heat transfer coefficient was derived.

$\alpha= 2.11u^{0.71} \text{ x } s^{0.44} \text{ x } h^{-0.14}$ Where, α: Fin surface heat transfer coefficient[$W/m^{20}C$], h: Fin length [mm], u: Wind velocity[km/hr], s: fin separation at middle length[mm]

Table 1 Experimental cylinder and wind velocity by Thornhill et al., Gibson and Bierman et al.

	Thornhill et al.	Gibson	Bierman et al.
Cylinder Diameter[mm]	100	32-95	118.364
Fin Pitch [mm]	8-14	4-19	1.448-15.240
Fin Length mm]	10-50	16-41	9.398-37.338
Material	Aluminium alloy	Copper, Steel, Aluminium	Steel
`Wind Velocity [km/hr]	7.2-72	32-97	46.8-241.2

2 OBJECTIVE OF PRESENT WORK

- To study the various researches done in past and from the researchers data to take the experimental cylinder.
- To increase heat transfer rate by change fin profile and varying wind velocity.
- To perform the study , simulation by CFD approach is proposed.
- Finally compare the fin profiles by heat transfer rate.

3 MODEL SELECTION

The finned cylinder geometry is selected based on the research and experiments conducted by Masao Yoshida and Pulkit Agarwal as described below. Cylinder model with dimension is shown following figure. A model is validated with researchers experimental data for surface heat transfer co-efficient.

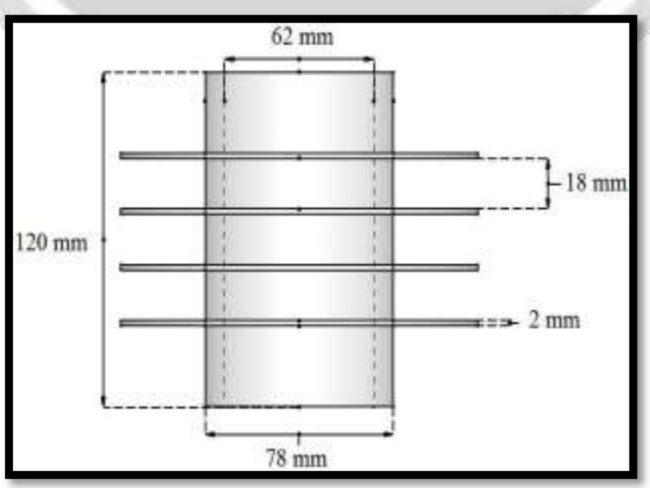

Fig. 1 Cylinder modeled with dimension

3.1 Fin profile and material selection

With varying the fin profile to increase the heat transfer rate so here the figure of different types of rectangle fins such as

i. straight fin ,
ii. offset strip fin and
iii. sine fin.

Aluminium is selected as a fin material for further analysis by ANSYS. Aluminium is a very light metal with a specific weight. The use of Al in vehicle reduces dead weight and energy consumption while increasing load capacity. Aluminium is a good reflector of visible light as well as heat. Aluminium properties better corrosion resistance, thermal conductivity, reflectivity, ductility, odourless, recyclability.

Table 1 Boundary conditions

Wind velocity	30,40,50,60 & 70 km/hr
Air Temperature	Ambient Temperature 300K
Atmospheric Pressure	101.325 kPa
Flow Direction	Left to Right
Outer Cylinder Surface	Wall Boundary Condition
Cylinder Inside Wall Temperature	150 ^{0}C

CFD Methodology :

- Import finned cylinder geometry to ANSYS Design Modeler.
- Develop fluid domain around the cylinder geometry to capture flow physics.
- Generate mesh and create name selection for relevant faces in the geometry.
- Setup model details in Fluent environment.
- Select material (Air and Aluminum).
- Apply velocity inlet, pressure outlet and cylinder wall temperature as boundary conditions.
- Initialize the solution.
- Calculate the solution by gradually increasing the number of iterations while monitoring the residuals.
- Determine the results through CFD Post-processing.

4 ANALYSIS BY ANSYS

The analysis is carried out by ANSYS-FLUENT 15.0 which optimize to increase heat transfer rate by change the fin profiles (straight,step,sine) and varying wind velocity from 30 to 70km/hr.

4.1 Straight fin profile

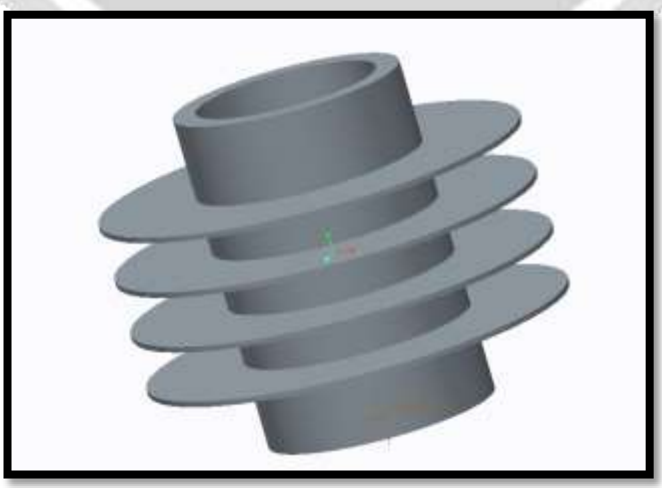

Fig. 2 CAD model of cylinder with straight fin profiles

As above shown methodology, the finned cylinder geometry is imported to ANSYS environment for CFD simulation. A fluid domain around the cylinder is developed to capture air flow physics and a symmetry plane is used to reduce the size of solution domain, utilizing less computational power and providing results faster. Inlet boundary is applied to one end of the fluid domain for the purpose of applying inlet velocity boundary conditions. Outlet boundary is applied at other end of the fluid domain for the purpose of applying pressure outlet boundary conditions. Mesh is generated for the entire domain with advanced sizing option to obtain finer mesh near proximity and curvature of the finned cylinder geometry.

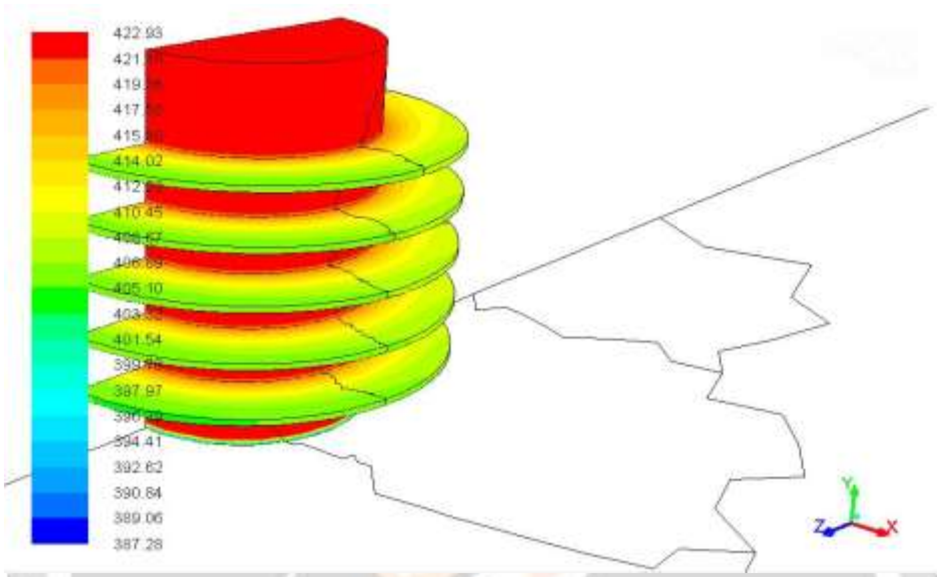

Fig. 3 Contours of static temperature for straight fin at 40 km/hr

In above fig.3 the temperature distribution obtained at wind velocity of 40 km/hr through CFD simulation shows the effect of heat conduction across the fins attached to the cylinder. Now, we see the convection heat transfer from fin surface to atmospheric air passing at 40 km/hr.

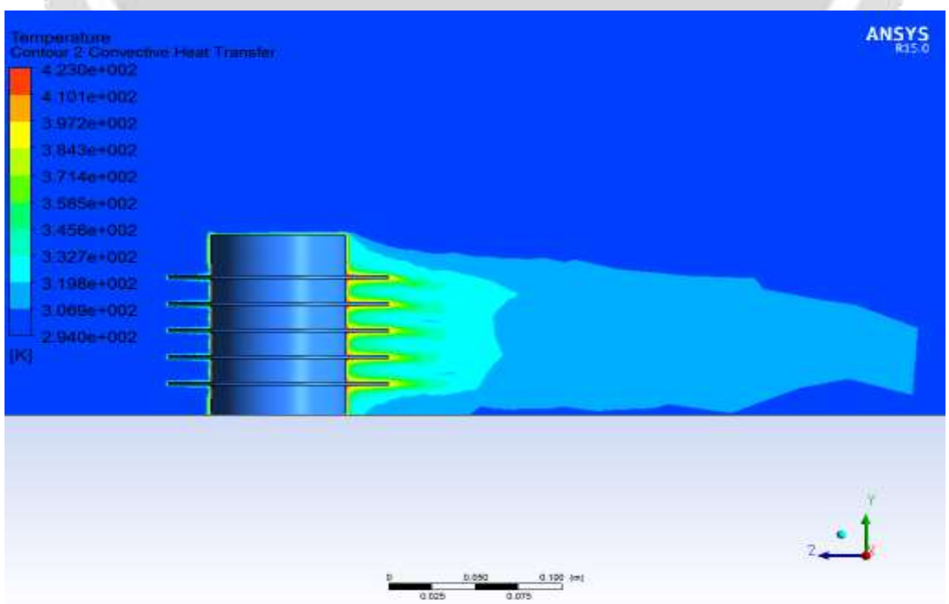

Fig. 4 Convective heat transfer from fins to passing air for straight fin at 40 km/hr

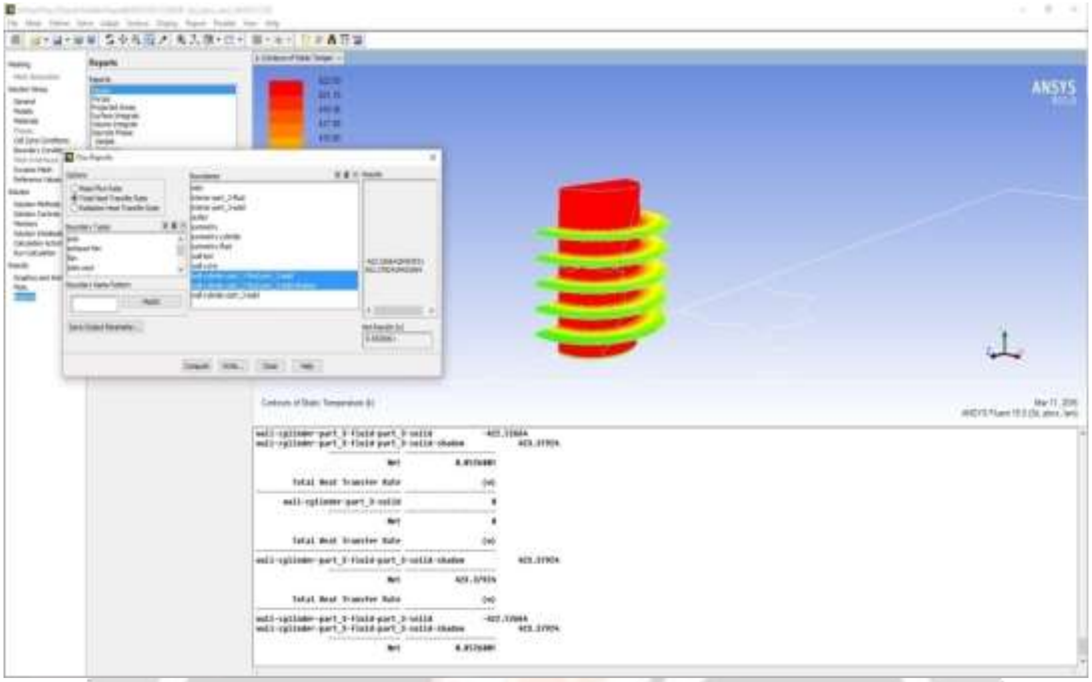

Fig. 5 computed heat transfer rate for straight fin at 40 km/hr

As shown in the fig.5 the heat transfer rate for straight fin at 40 km/hr is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 375.01 W. Similar CFD simulations were performed for different wind velocities of 60km/hr and 70km/hr and values of temperature distribution, convective heat transfer and heat transfer rate were computed as shown below.

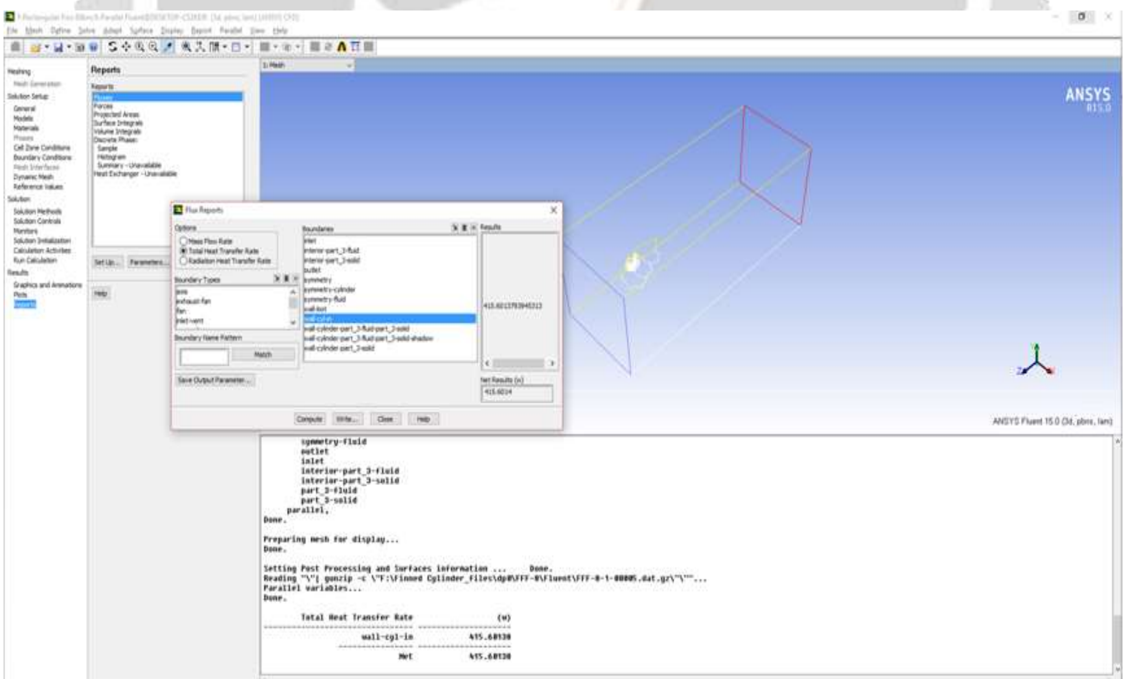

Fig. 6 Computed value of heat transfer rate for straight fin at 60km/hr

As shown in the fig.6 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 415.60 W.

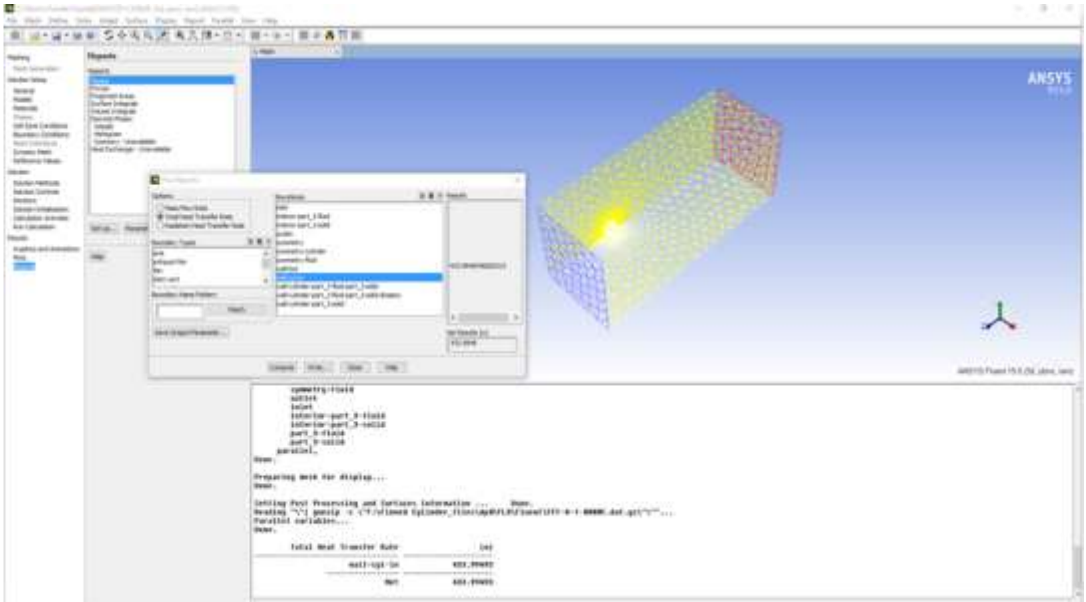

Fig. 7 Computed value of heat transfer rate for straight fin at 70km/hr

As shown in the fig.7 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 433.99 W.

4.2 Step fin profile

To increase the heat transfer from fins to surrounding air, it is important to increase the surface area of the fins. As such, a different fin profile is developed with steps which allow more surface area for air to carry heat from the fins.

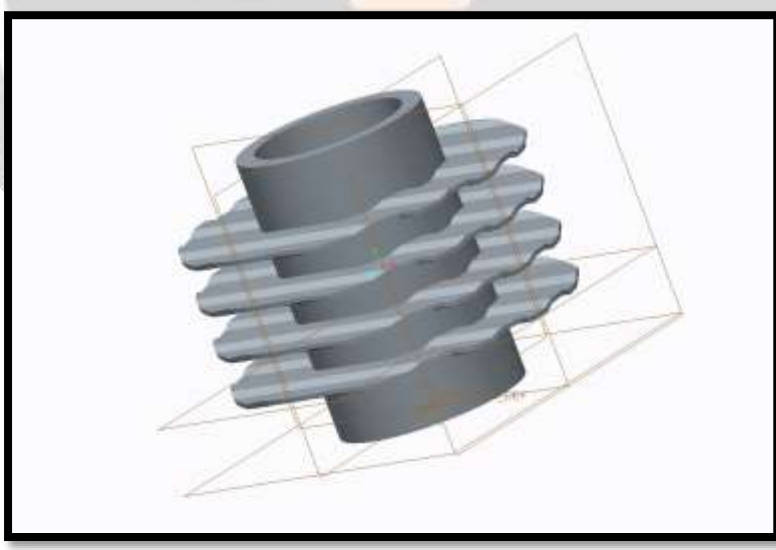

Fig. 8 CAD model of step fin profile

CFD simulations are further carried out for the new stepped fin profile to compute heat transfer rate, temperature distribution and convective heat transfer at different wind velocities of 30km/hr, 40km/hr, 50km/hr, 60km/hr and 70km/hr respectively with same procedure which shown above for straight fin profile. Here's only describe CFD simulation for the value of heat transfer rate.

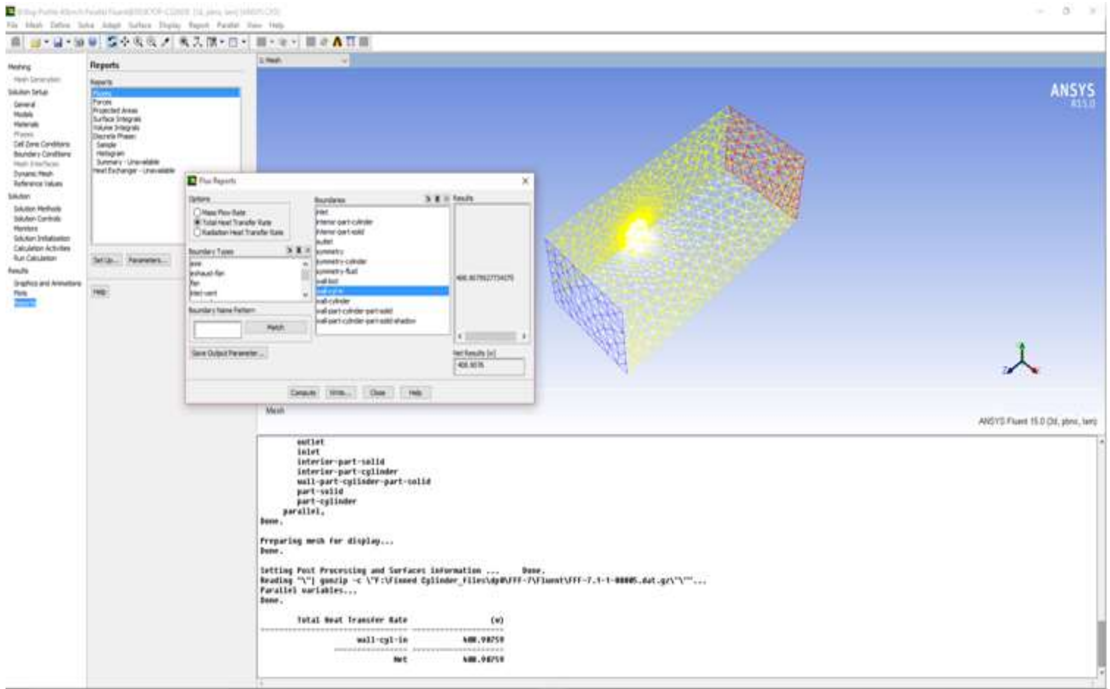

Fig. 9 Heat transfer rate for step fin at 40km/hr

As shown in the fig.9 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 408.90 W.

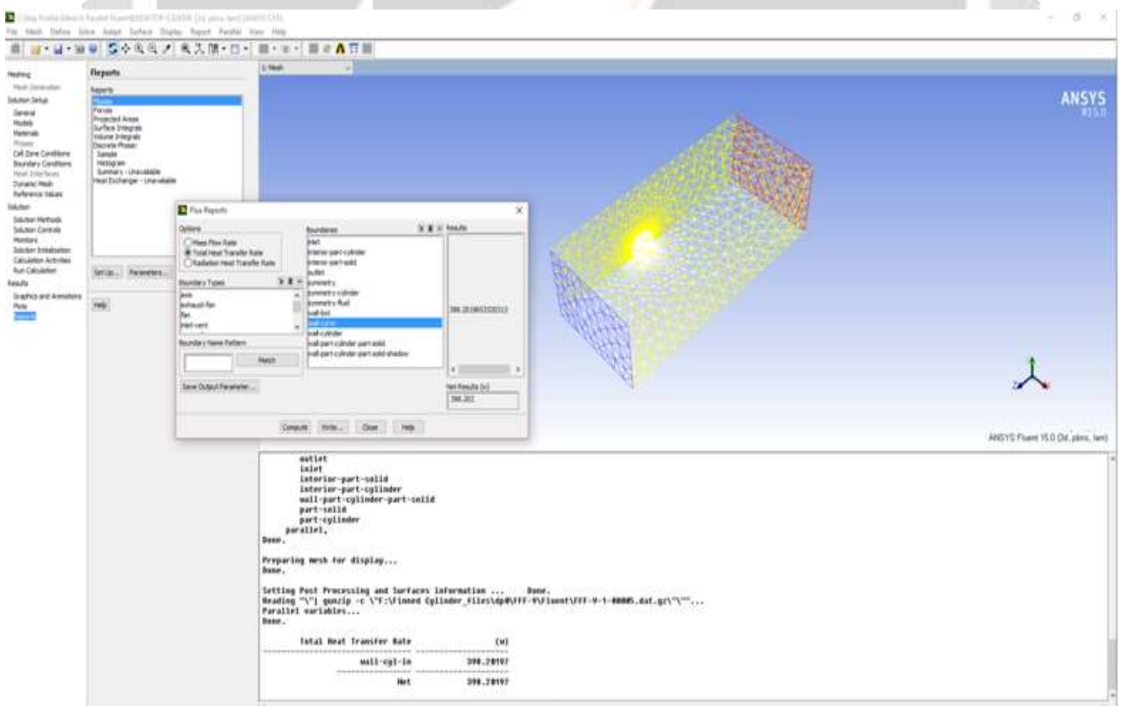

Fig.10 Heat transfer rate for step fin at 60km/hr

As shown in the fig.10 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 398.20 W.

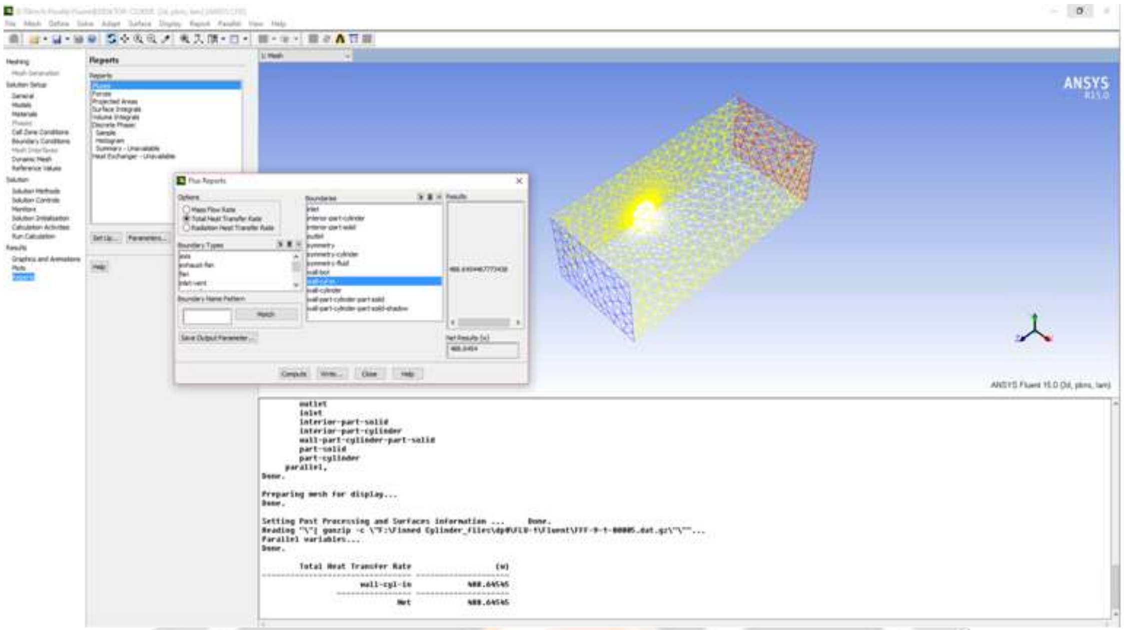

Fig. 11 Heat transfer rate for step fin at 70km/hr

As shown in the fig.11 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 488.64 W.

4.3 Sine fin profile

To increase the heat transfer from fins to surrounding air, it is important to increase the surface area of the fins. As such, a different fin profile is developed with sine curve which allow more surface area and smooth surface for air to carry heat from the fins.

Fig. 12 CAD model of sine fin profile

CFD simulations are further carried out for the new sine fin profile to compute heat transfer rate, temperature distribution and convective heat transfer at different wind velocities of 30km/hr, 40km/hr, 50km/hr, 60km/hr and 70km/hr respectively. with same procedure which shown above for straight fin profile. Here's only describe CFD simulation for the value of heat transfer rate.

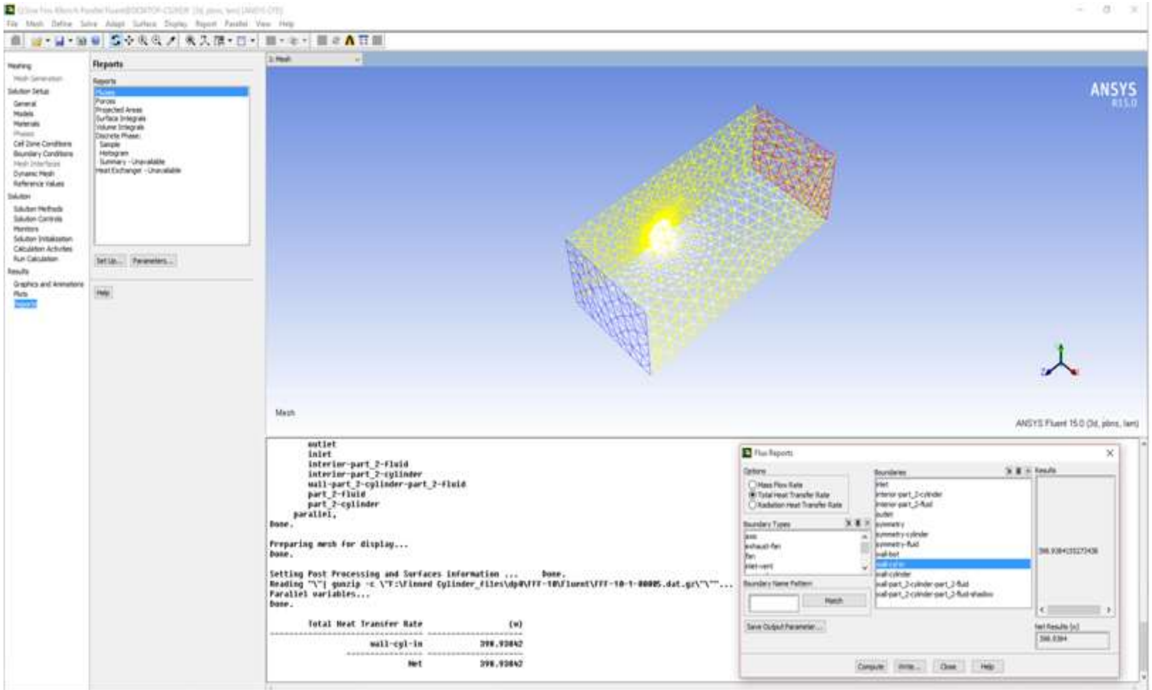

Fig. 13 Heat transfer rate for sine fin at 40km/hr

As shown in the fig.13 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 398.93 W.

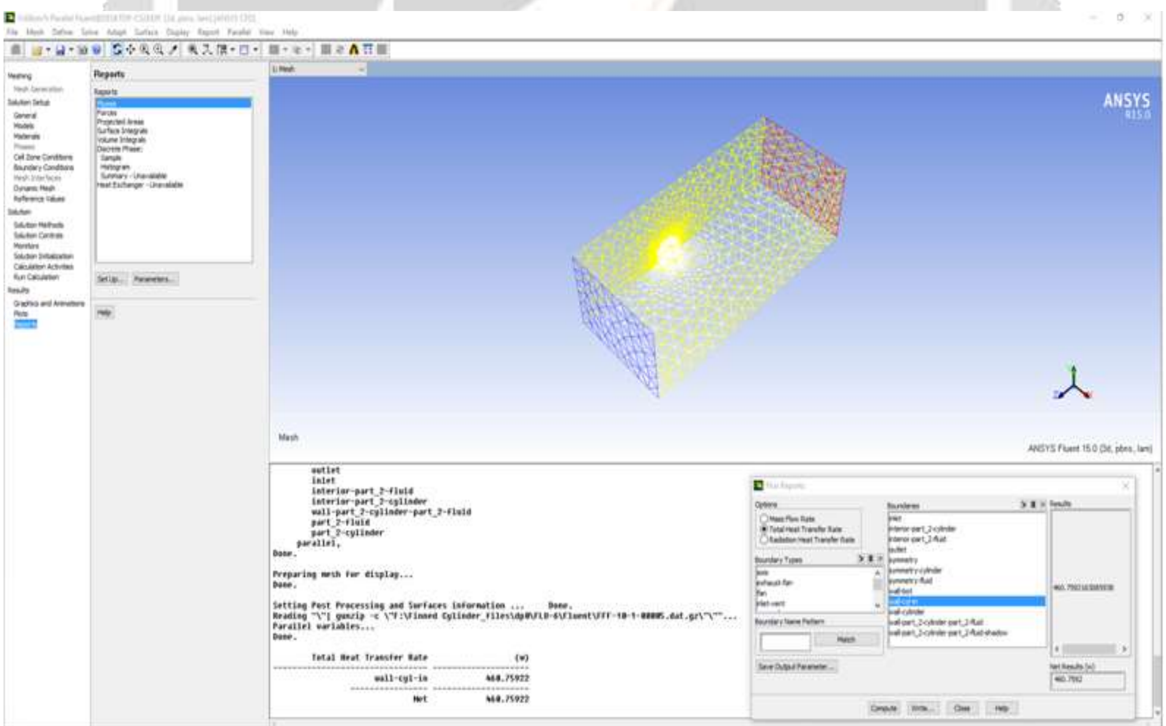

Fig. 14 Heat transfer rate for sine fin at 60km/hr

As shown in the fig.14 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 460.75 W.

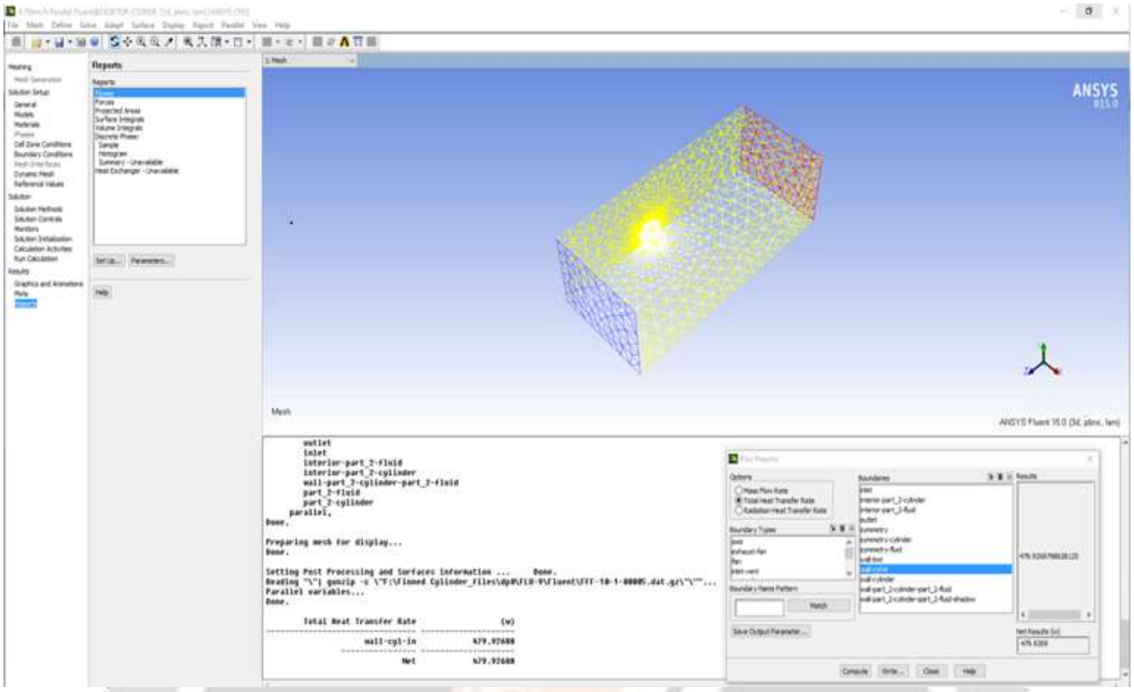

Fig. 15 Heat transfer rate for sine fin at 70km/hr

As shown in the fig.15 the heat transfer rate is computed directly from the CFD flux reports for inside cylinder wall and it is found to be 479.92 W.

5 RESULT AND DISCUSSION

Simulations are performed for different fin profiles such as straight , step and sine curve profile at the wind velocity of 30km/hr, 40km/hr, 50km/hr, 60km/hr and 70km/hr respectively and the results are compared by computed value of heat transfer rate as shown in the table below:

Table 2 Result comparison between straight, step and sine fin profiles

Fin Profile	30km/hr	40 km/hr	50km/hr	60 km/hr	70 km/hr
Straight	528.47 W	375.01 W	162.61 W	415.60 W	433.99 W
Step	367.81 W	408.90 W	437.65 W	398.20 W	488.64 W
Sine	359.36 W	398.93 W	428.45 W	460.75 W	479.92 W

6 CONCLUSION

The summary of present work is as follows:

1. Heat transfer rate and heat transfer coefficient can be increased with the increase surface area and wind velocity.
2. To accomplish the thesis objective, the cylinder geometry is selected based on the research work carried out by previous scholars and change the fin profile (straight,step,sine) for increasing surface area then CFD simulations are performed for all of them at different wind velocities to find heat transfer rate for each fin configuration.
3. It is found from the results that Step and Straight fins behave differently at different wind speeds and hence heat transfer rates are found to be random.

4. Sine fin profile is a good candidate to increase heat transfer from the cylinder to surrounding air, since it follows a continuous curve at different wind speeds. The chances of recirculation are less in sine profile due to smooth surface, allowing air to pass around the cylinder easily and carry the heat from the fins.
5. Overall the possibility of heat transfer augmentation can be ascertained with the new sine profile without altering the fin length and pitch. The thesis thus opens up new avenues for engine designers to improve the heat transfer from air cooled engines.

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