“ FIN ANALYSIS FOR HEAT TRANSFER RATE AUGMENTATION OF AIR COOLED IC ENGINE ”

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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:- *Cooling fin, Experimental cylinder, Heat transfer co-efficient, Simulation, ANSYS*

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1 INTRODUCTION

Almost all two wheelers uses Air cooled engines, because Air-cooled engines are only option due to some advantages like lighter weight and lesser space requirement. Internal combustion engines at best can transform about 25 to 35 % of the chemical energy in the fuel in to mechanical energy. About 35 % of the heat generated is lost in to the surroundings of combustion space, remainder being dissipated through exhaust and radiation from the engine. The IC Engine fins are made from Aluminum alloy and it is provided for better cooling effect. 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. There are mainly two types of cooling systems: [1]

(a) Air cooled system, and

(b) Water cooled system

The use of air cooled system is generally restricted to small engines churning power up to 15-20 kW and is also utilized in aircraft engines. In this system, fins or extended surfaces are attached on the engine cylinder walls or cylinder head. The heat generated during combustion is conducted by the fins and is dissipated to surrounding air through convection. The amount of heat dissipated to air depends upon:

(a) Amount of air flowing through the fins

(b) Surface area of the fin

(c) Thermal conductivity of metal used for fins

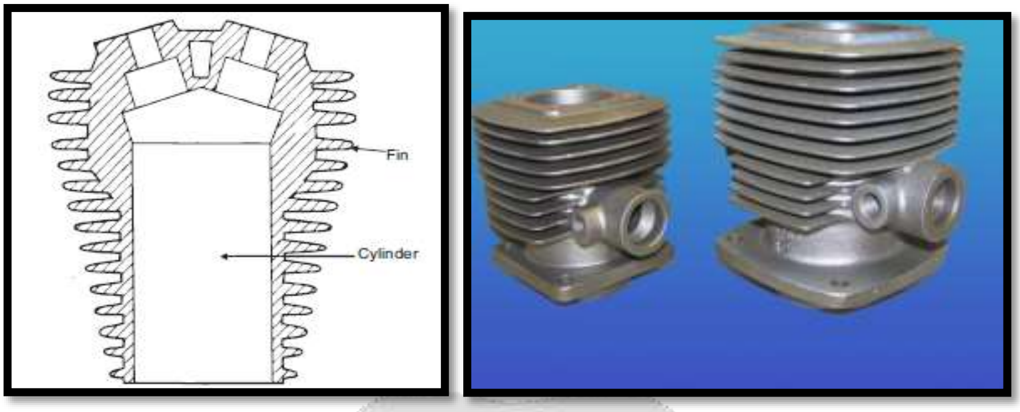


Fig.1 Engine with fins [1]

In air-cooled engine to increase the heat transfer rate, fins are provided at the periphery of engine cylinder so that the analysis of fin is important. 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.

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

Arvind S.Sorathiya et al [4] conducted study on various researches done in past to improve heat transfer rate of cooling fins by changing cylinder block fin geometry, climate condition and material. Their research showed that 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 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 compared with conventional one by CFD Analysis and Wind Tunnel experiment.

Mahendran.V*,Venkatasalakumar.A [5] their work based on Analysis of ic engine air cooling of varying geometry and Material. To increase heat transfer rate from extended fins modifying geometry of circular fins with curvature shape and Aluminium alloy 6061. In this thesis, thermal analysis is done for all the two materials Cast Iron and Aluminum alloy 6061. The Analysis is carried out by Ansys Workbench 14.0 optimize which material will maximum heat transfer rate By observing the thermal analysis results, Aluminum alloy its weight is less, so using Aluminum alloy 6061 is better heat transfer material . And also by reducing the thickness of the fin, the heat transfer rate is increased. Mishra A.K., Nawal S. and Thundil Karuppa Raj R [6] they described to study the effect of fin parameters on fin array performance which includes variation in pitch and fin material. In addition, the current paper considers the effect of air flow velocity on different fin pitch. CFD could be used to determine optimal values of fin parameters before actual design. To increase the cylinder cooling, the cylinder should have a greater number of fins. The study reveals that the optimized fin material with the greatest effective cooling is copper. Mohsin A. Ali1, Prof. (Dr.) S.M Kherde [7] their pioneer work is a review on design modification and analysis of two wheeler cooling fins. They shows the fin geometry and cross sectional area affects the heat transfer co efficient. In High speed vehicles thicker fins provide better efficiency. Increased fin thickness resulted in swirls being created which helped in increasing the heat transfer. Heat transfer coefficient can be increased by increasing the surrounding fluid velocity by forced convection.

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 surface heat transfer co-efficient by varying wind velocity.
- To perform the study , simulation by CFD approach is proposed.
- Simulation result is compared with experimental data derived by researchers.

3 MODEL SELECTION

The finned cylinder geometry is selected based on the research and experiments conducted by researchers as described below. Cylinder model is created in CREO with straight fin profile. Wind velocity- 40,60,70 km/hr is taken for further simulation by ANSYS.

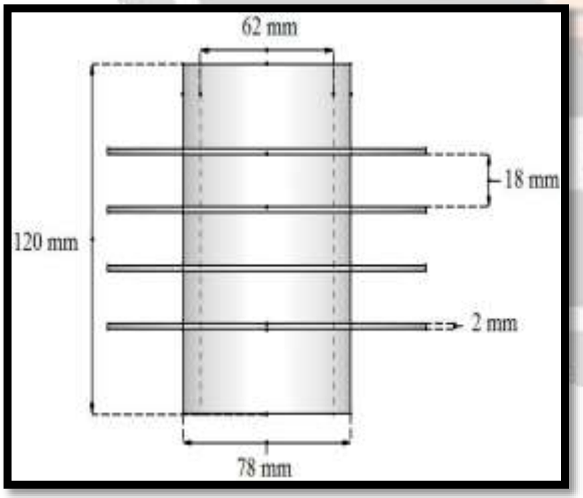


Fig. 2 Cylinder modeled with dimension

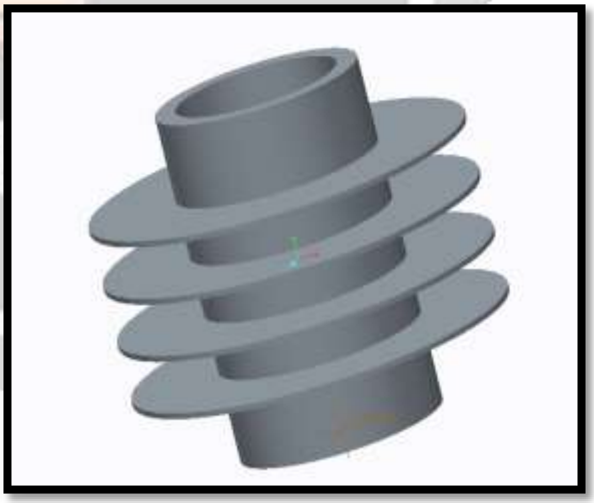


Fig. 3 CAD model with straight fin profile

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 2 Boundary conditions

Wind velocity	40, 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 increasing surface heat transfer co-efficient at different wind velocity. 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.

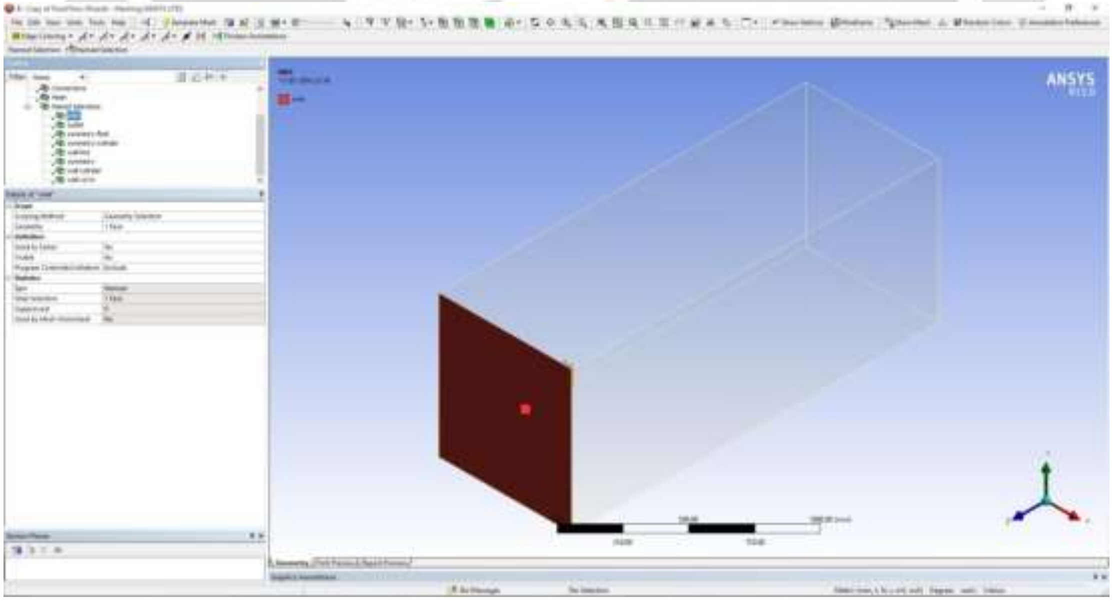


Fig. 4 Inlet boundary conditions

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.

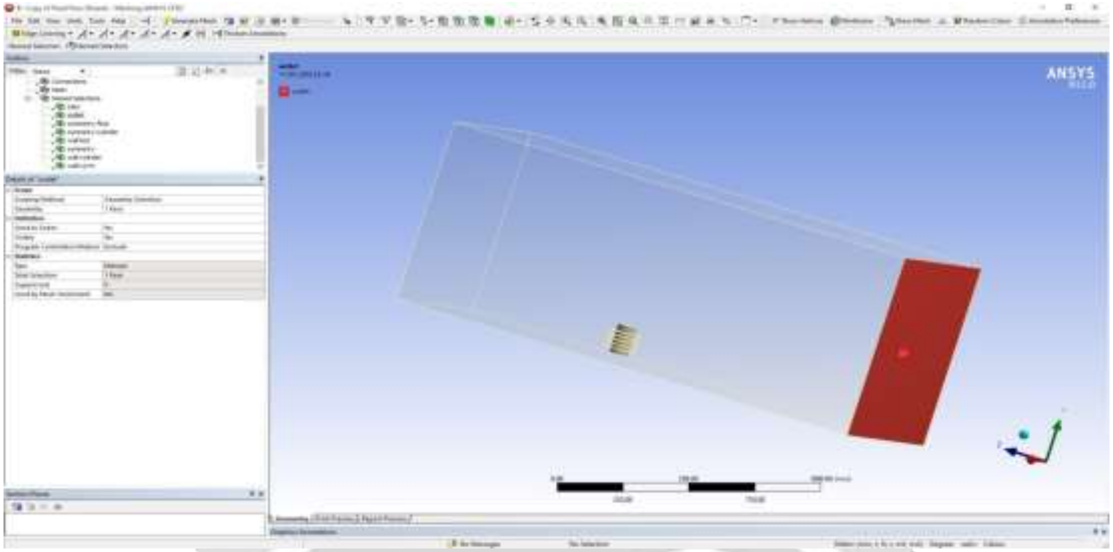


Fig. 5 Outlet boundary conditions

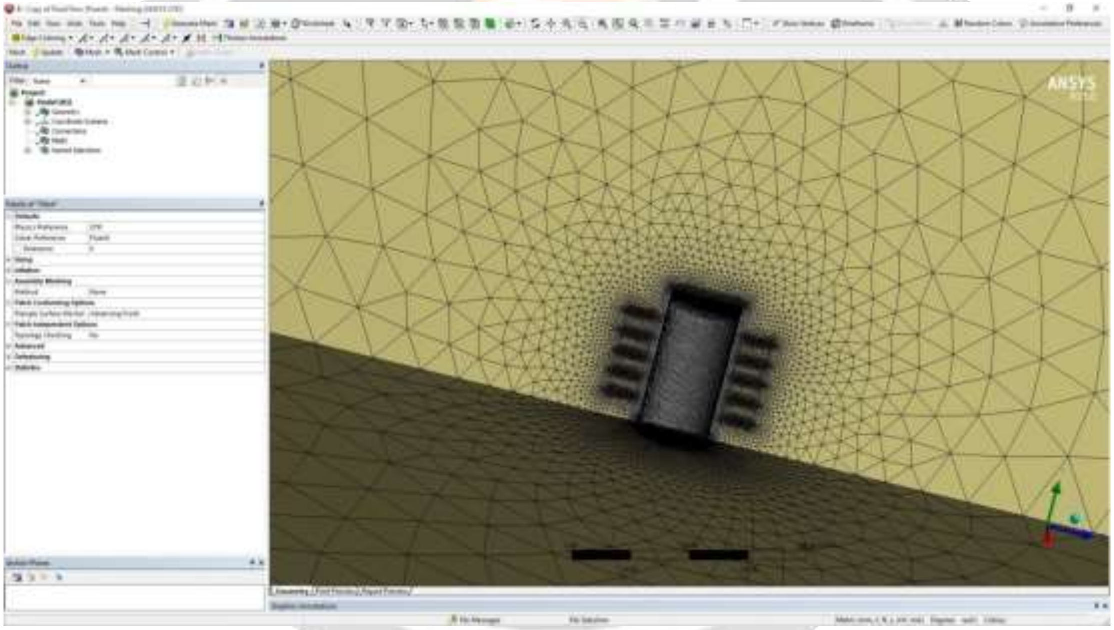


Fig. 6 Meshing applied on the fluid and solid domain

Mesh is generated for the entire domain with advanced sizing option to obtain finer mesh near proximity and curvature of the finned cylinder geometry.

Table 3 Mesh details

Domain	Nodes	Elements	Tetrahedra
Fluid Domain	223809	1182733	1182733
Solid Domain	96775	411350	411350
All Domains	320584	1594083	1594083

To calculate surface heat transfer co-efficient, contours of wall fluxes are selected from reports and the surface between solid and fluid is selected which accounts for the convective heat transfer from cylinder fins to the surrounding air flow.

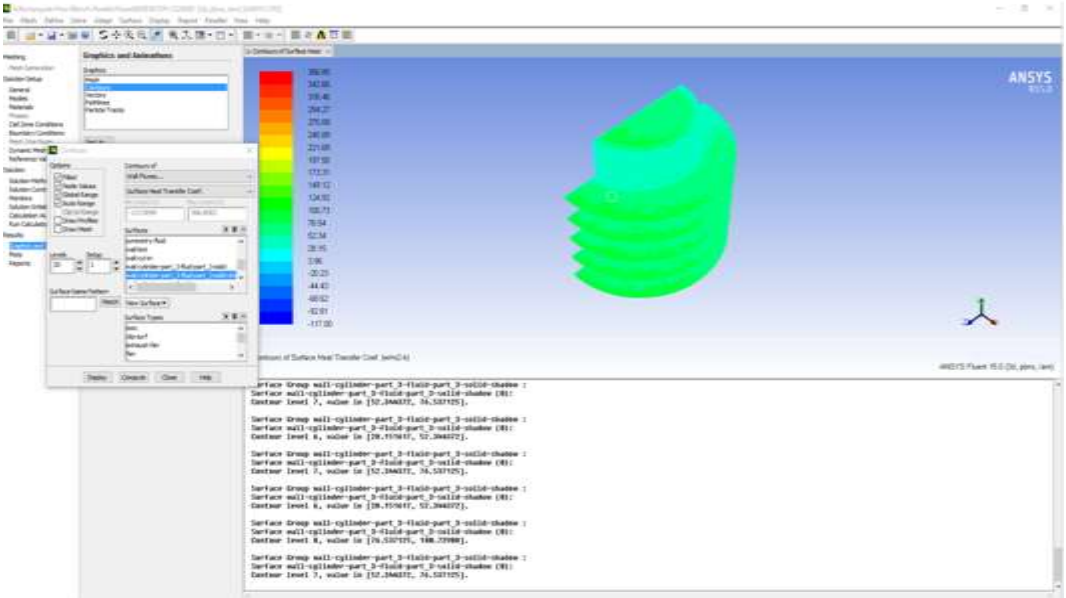


Fig. 7 Surface heat transfer co-efficient for straight fin at 40km/hr

As shown in fig.7 the average heat transfer co-efficient at wind velocity of 40km/hr typically lies between 50-70 W/m^{2}K.

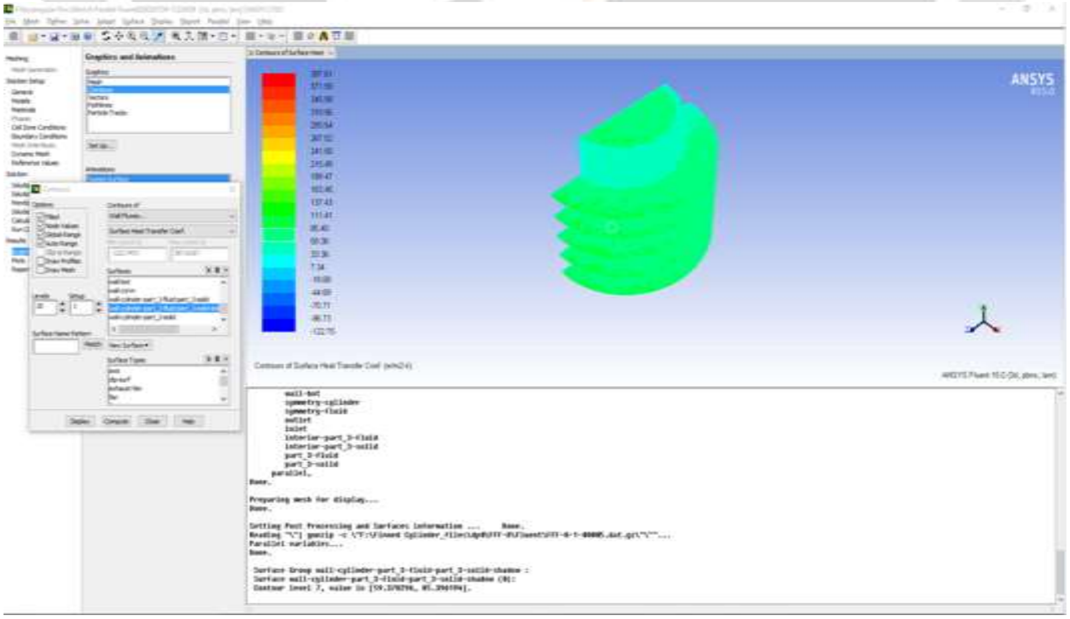
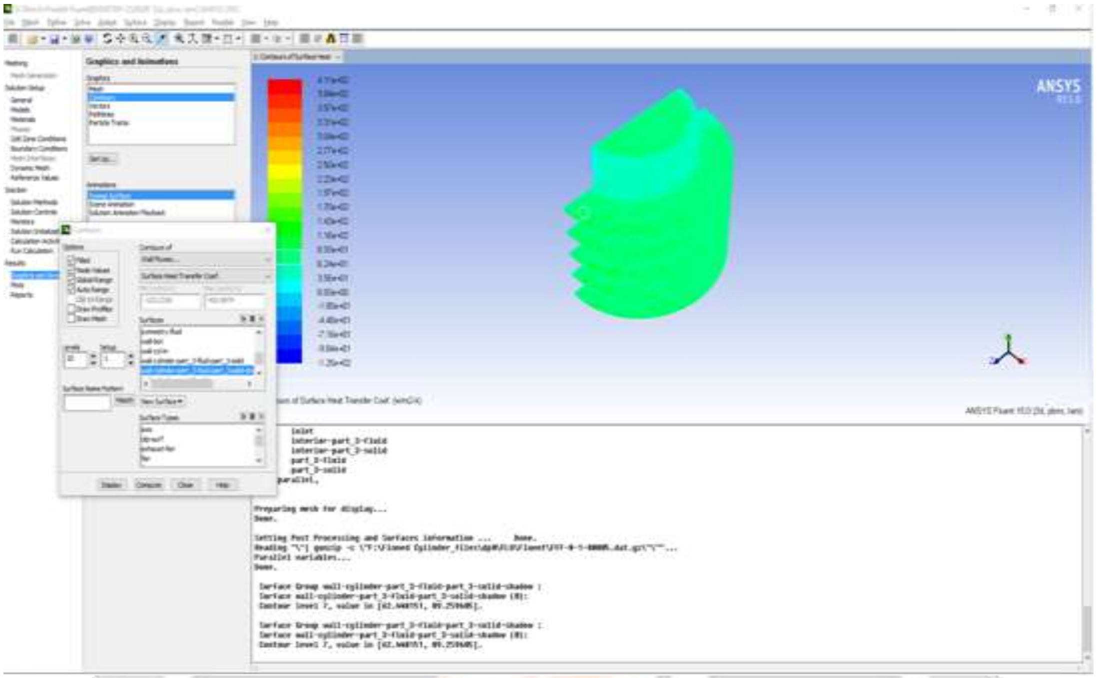


Fig. 8 Surface heat transfer co-efficient for straight fin at 60km/hr

As shown in fig. 8 the average heat transfer co-efficient at wind velocity of 60km/hr typically lies between 60-80 W/m^{2}K.



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        inlet
        interior-part_3-fluid
        interior-part_3-solid
        part_3-fluid
        part_3-solid
    parallel,

Preparing mesh for display...
Done.

Setting Post Processing and Surfaces information ...     Done.
Reading [illegible] ...
Parallel variables...
Done.

 Surface Group wall-cylinder-part_3-fluid-part_3-solid-shadow :
 Surface wall-cylinder-part_3-fluid-part_3-solid-shadow (8):
 Contour level 7, value in [62.448751, 89.259685].

 Surface Group wall-cylinder-part_3-fluid-part_3-solid-shadow :
 Surface wall-cylinder-part_3-fluid-part_3-solid-shadow (8):
 Contour level 7, value in [62.448751, 89.259685].
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Fig. 9 Surface heat transfer co-efficient for straight fin at 70km/hr

As shown in fig.9 the average heat transfer co-efficient at wind velocity of 70km/hr typically lies between 60-90 W/m^{2}K..

5 RESULT AND DISCUSSION

Here's the obtained surface heat transfer coefficient at the different wind velocity is validated with the experimental data derived by Yoshida et al and Thornhill et al. It is observed that the CFD results are in close relation and hence the simulation can be considered validated.

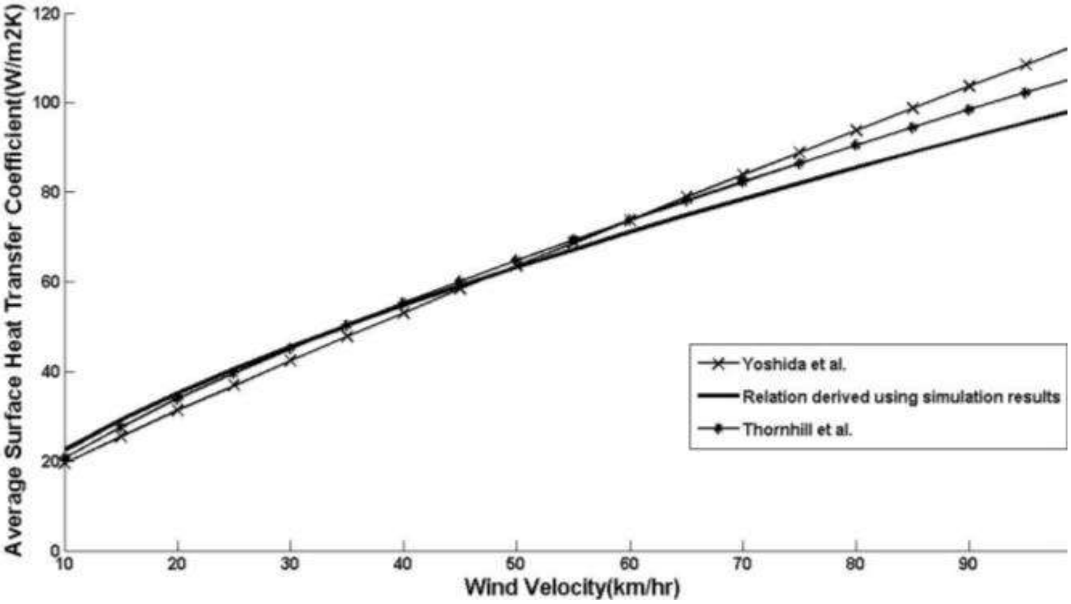

Chart 1 Wind velocity Vs Avg. surface heat transfer co-efficient for experiments conducted by Yoshida et al, Thornhill et al and PulkitAgarwal et al

Table 4 Result comparison with experimental data

Wind Velocity (km/h)	**Avg. Heat Transfer Co-efficient (W/m^{2}K)**		
	CFD	**Yoshida et al**	**Thornhill e al**
40	52.34 - 76.53	45-50	45-50
60	59.37 - 85.39	60-65	60-65
70	62.44 – 89.25	75-80	78-80

The results obtained through CFD simulation for the experimental cylinder are in close co-relation to the results obtained by the experiments conducted by Thornhill et al and Yoshida et al. Thus, heat transfer augmentation can be performed using the same cylinder with different fin profiles. The fin profile selected for heat transfer augmentation is developed using CAD software and further simulation is carried out in similar fashion as performed for the experimental cylinder.

6 CONCLUSION

The summary of present work is as follows:

1. Heat transfer rate and heat transfer coefficient can be increased with the wind velocity.
2. To accomplish the thesis objective, the cylinder geometry is selected based on the research work carried out by previous scholars and is validated using CFD for different heat transfer co-efficient at different wind velocities.
3. By comparing simulation result with experimental data for surface heat transfer co-efficient, it is clearly observed that the results are found to be in close agreement with their findings.
4. Thus, heat transfer enhancement can be performed using the same cylinder with different fin profiles and different fin pitch.

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