Fins Material Optimization of CNG Fueled SI Engine by CFD Analysis

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Abstract— Depletion of ozone layer and increase in global warming due to petroleum product is the need to switch for alternative fuels. Today all major automobile industries are in way to launch their CNG bikes. In this research 125cc CNG fuelled SI engine is optimized for different fins material using CFD analysis. Model of engine cylinder block is design in CATIA V5. Two different materials of fin one of aluminium alloy 6061 and other of cast iron is analyzed in ANSYS 15.0 fluent Software. It is observed that aluminium alloy 6061 has more heat loss than that of cast iron. All the trials are performed at 4500C cylinder temperature. Heat transfer coeffient is calculated using ANSYS Fluent software at different climatic condition for vehicle speed of 15 km/hr.

Key words: CFD, CNG, Heat Flux, Fins, Heat Transfer, SI Engine

I. Introduction

Fins are the extended surfaces provided on engines for enhancing rate of heat transfer. In IC engine due to combustion inside the cylinder high heat is generated. Due to this high heat there is knocking, melting of lubrication and Sezure of parts of engine takes place so to avoid this fins are provided on outer surface of cylinder to dissipate the heat. Due to combustion inside cylinder heat generated not 100% heat utilize to increase power of engine some heat is absorbed by piston and cylinder. The heating of engine parts is not desired as it will damage the engine parts and burn the lubricants. So, cooling must be done

This research is carried out for optimizing material for fins of CNG engine two wheeler bike. As we know that auto ignition temperature of CNG gas 450℃ [10]so combustion inside the CNG engine is take place at 450℃ so high temperature generated inside cylinder but in case of petrol engine combustion takes place at 150℃ because auto ignition temperature of petrol is 150℃. High heat is generated inside CNG engine as compare to petrol engine. In this project we did analysis of this CNG engine fins at this high temperature of 450℃ in combustion chamber to find heat flux heat transfer coefficient, temperature distribution for aluminium alloy and cast iron fins.

In this project we are not manufacturing any engine. Engine which we are analyze are available in the market. We are doing analysis of these fin at high temperature of 723K and at velocity of wind 15km/hr to find how much heat transfer coefficient, heat flux dissipation and temperature distribution over surface of fins. Normally in two-wheeler engine fins are made of Aluminum alloy which is having good thermal conductivity and heat transfer rate as compare to cast iron. But in this case cost of aluminium alloy is seven times higher than that of cast iron. So it is necessary to do analysis of cast iron to find how much the value of heat flux is and heat transfer coefficient as compare to Aluminium alloy for CNG engine. The purpose of this research paper is to provide CFD analysis of CNG engine fins to automobile industry

A. Problem Statement

Many researchers had done CFD analysis of four stroke engine with petrol as fuel but no one did CFD analysis of Fins of four stroke SI engine of two-wheeler with CNG as fuel. There is no specific research work for two wheeler four stroke SI engine fins which are made up of Aluminium alloy and Cast iron for CNG operation and many automobile industry is on way to launch there CNG bike so this research work is important for them. In this project we are using rectangular fins made up different material like cast iron and Aluminium alloy. We can find how much heat transfer coefficient by use CFD analysis for Engine cylinder with cast iron fins and Engine cylinder with Aluminium alloy fins.

B. Objective

The objectives of this project is to compare Heat transfer coefficient from fins made up of aluminum alloy and cast iron of CNG motorcycle engine and to analyze CNG fuel Effect on different fin material. Heat Transfer coefficient for Al Alloy Fins and Cast Iron Fins at wind velocity of 15Km/hr and at ambient temperatures of 289K, 300K and 313K for CNG Engine of two wheeler for material optimization

II. Modelling and Design

Engine cylinder with rectangular fins is modelled in CATIA V5 software having stroke volume of 125cc. Piston cylinder consist of two parts one part is sleeve or liner and other part is Aluminium alloy fins block mounted over sleeve ANSYS FLUENT 15.0 software is used for pre-processing. Computation domain generated contains a fine mesh. Cut cell meshing is used here to generate the mesh. The computational domain consists of a rectangular volume of large dimensions containing the finned cylinder at its centre. It was focused on the fins and appropriate boundary conditions were applied at the domain ends to maintain continuity. The domain was made longer after the cylinder to allow for wake formation. A fine mesh has been created near the fins to resolve the thermal boundary layer which is surrounded by a coarse external mesh for better results, fast solution and accurate temperature distribution.

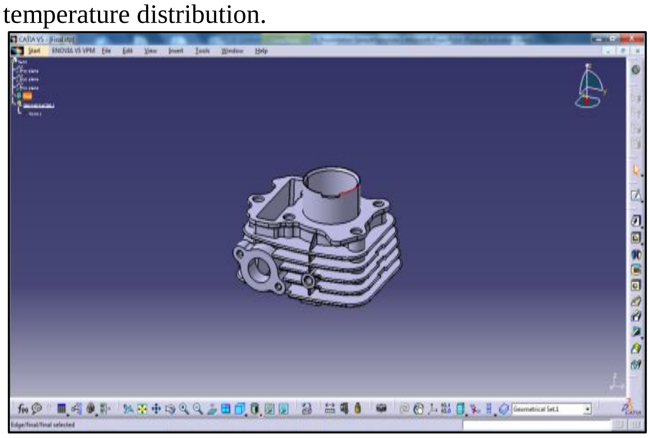

Fig. 1: Three dimensional Model of Piston cylinder with rectangular fins design in CATIA V5

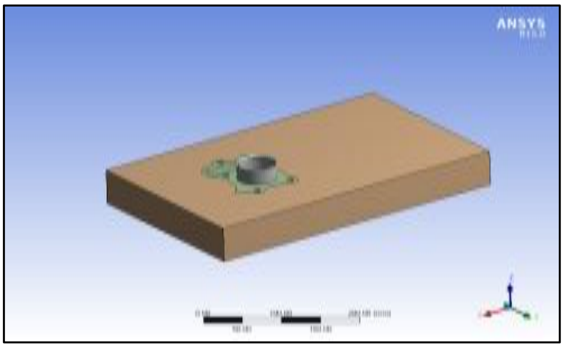

Fig. 2: Engine block fluid enclosure

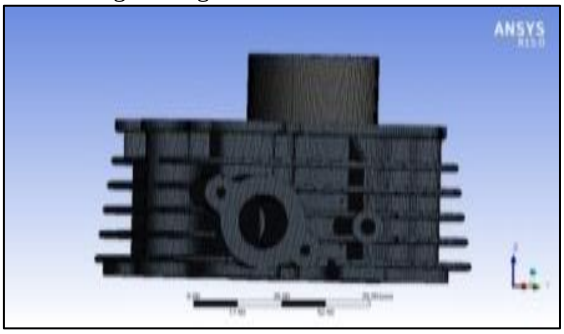

Fig. 3: Engine block After Meshing

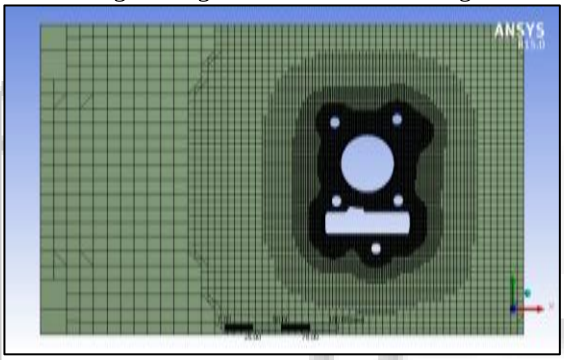

Fig. 4: Top view engine block with fluid after meshing

A. Problem Set Up In Fluent

ANSYS Fluent software is used here for analysis. In this project we are taking six cases. We Analyze Piston cylinder having Aluminium alloy fins at different ambient temperatures of 289k, 300k and 313k at wind speed of 15km/hr and Piston cylinder with cast iron fins with same boundary condition as Aluminium alloy 6061 fins block. In this piston cylinder there is sleeve which is made up of cast iron. On outer surface of sleeve there is rectangular block of Aluminium alloy 6061 fins is present as shown in figure. For analysis boundary condition we have to give inlet velocity, outlet pressure, Air temperature and inner temperature of sleeve. Turbulence model is used here is Standard k- εModel with standard wall function for CFD Analysis of Aluminium block and cast iron block. Discretization Technique for momentum, kinetic energy and Turbulent Dissipation rate is second order Upwind Scheme and coupled scheme used for Pressure-velocity for CFD Analysis of Aluminium block and cast iron block.

Sr.	Physics	Values
1	Inlet Velocity	15Km/hr
2	Outlet Pressure	101.325Kpa
3	Air Temperature	289 K
4	Sleeve Inner Wall Temperature	723 K

Table 1: Boundary Conditions for First case

Fin Material	Al. alloy 6061
No. of Cylinder	1
Engine Type	4-Stroke
Fin Pitch	10mm
Fin Thickness	3mm
Engine Displacement	125cc
Bore Diameter	50cm
Power	11Ps
Speed	5500RPM
Sleeve material	Cast Iron

Table 2: Engine Cylinder specification

Sr.	Properties	Values
1	Density	2700Kg/m^3
2	Specific heat (c_p)	900J/KgK
3	Thermal conductivity	200W/mK

Table 3: Properties of aluminium alloy 6061

Sr.	Properties	Values
1	Density	6900 Kg/m^3
2	Specific heat (c_p)	460 J/Kg K
3	Thermal conductivity	47.8W/mK

Table 4: Properties of Cast Iron

III. RESULT AND DISCUSSION

A. Flow Contour Over Fins

Flow pattern over fin surface is shown in Fig. 5. Flow separation occurs at fin surface resulting in wake formation in leeward direction so there is increase in velocity of air after flow separation shown in yellow shade

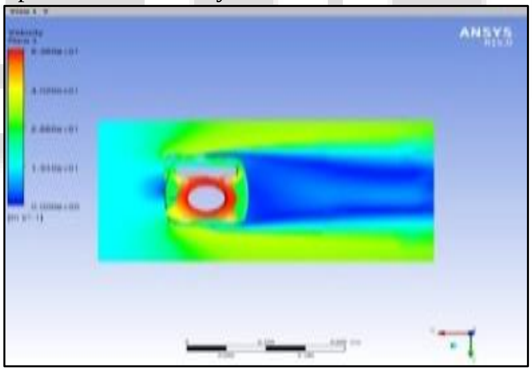

Fig. 5: Velocity vector plot for fin surface at velocity of 15km/hr

B. Tempreture Distribution over fins

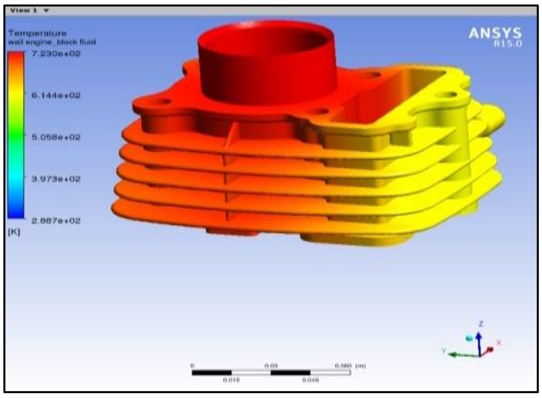

Fig. 6: Rear Contour plot of temperature (K) of Engine cylinder for Aluminium alloy fins at wind velocity of 15Km/hr and temperature 16℃

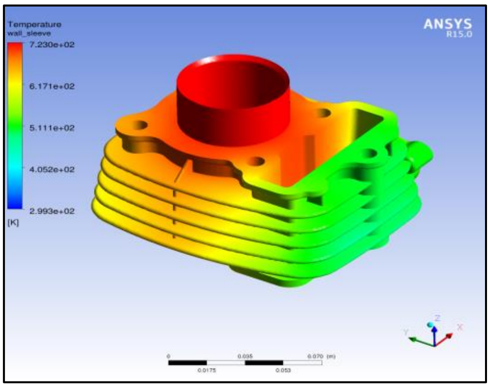

Fig. 7: Rear Contour plot of temperature (K) of Engine cylinder for Aluminium alloy fins at wind velocity of 15Km/hr and temperature 27℃

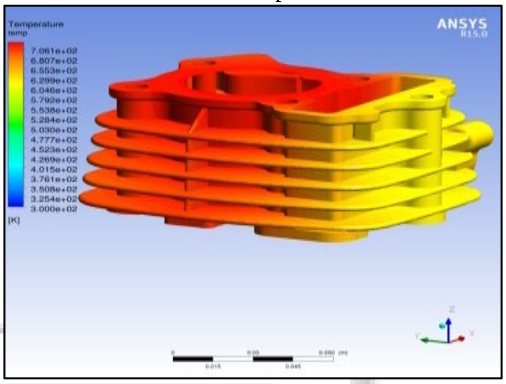

Fig. 8: Rear Contour plot of temperature (K) of Engine cylinder for Aluminium alloy fins at wind velocity of 15Km/hr and temperature 40℃

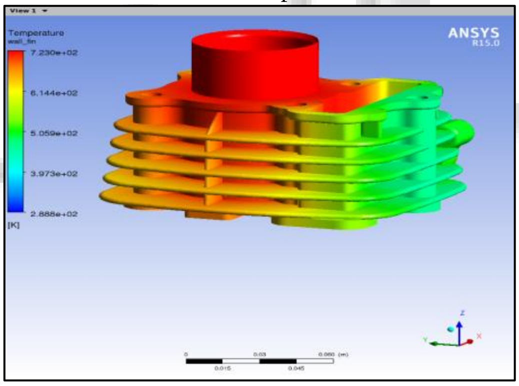

Fig. 9: Rear Contour plot of temperature (K) of Engine cylinder for Cast Iron fins at wind velocity of 15Km/hr and temperature 16℃

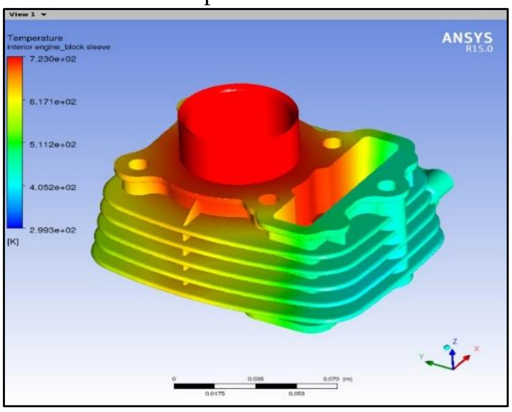

Fig. 10: Rear Contour plot of temperature (K) of Engine cylinder for Cast Iron fins at wind velocity of 15Km/hr and temperature 27℃

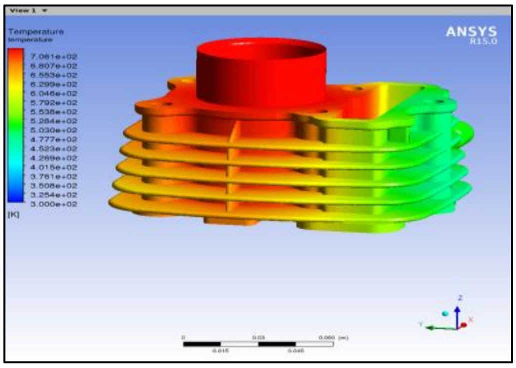

Fig. 11: Rear Contour plot of temperature (K) of Engine cylinder for Cast Iron fins at wind velocity of 15Km/hr and temperature 40℃

It is observed from above simulation that Heat transfer from Al. Alloy fins is greater than cast Iron fins at tem. of 300 K climate temp. as compare to 289 K and 313 K Climate Tem.

C. Heat Transfer Coefficient for fins

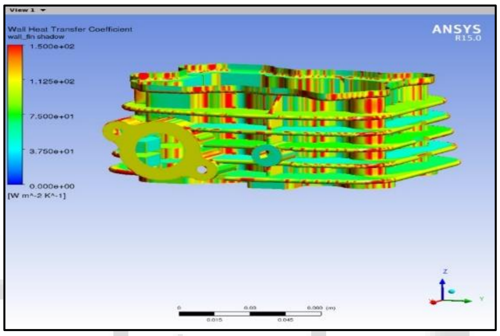

Fig. 12: Heat transfer coefficient of Aluminium Alloy fin surface at wind velocity of 15Km/hr and temperature 16℃

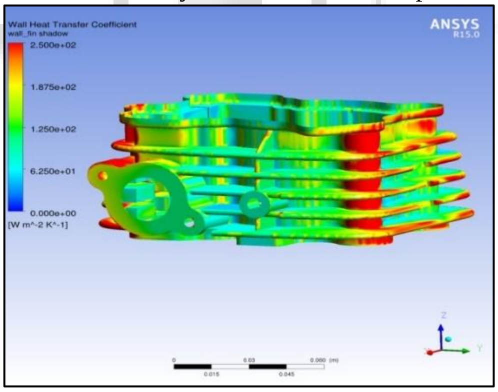

Fig. 13: Heat transfer coefficient of Aluminium Alloy fin surface at wind velocity of 15Km/hr and temperature 27℃

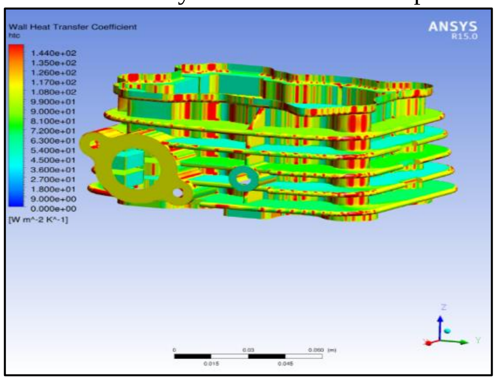

Fig. 14: Heat transfer coefficient of Aluminium Alloy fin surface at wind velocity of 15Km/hr and temperature 40℃

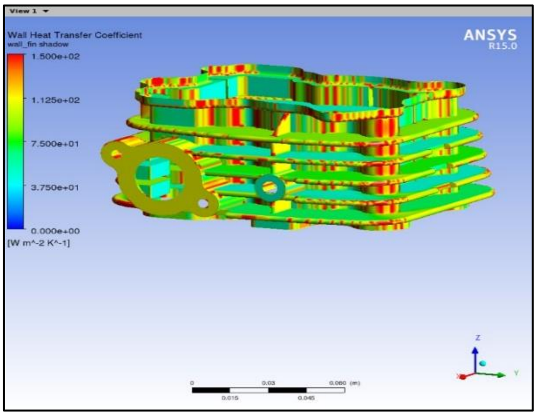

Fig 15- Heat transfer coefficient of Cast Iron fin surface at wind velocity of 15Km/hr and temperature 16°C

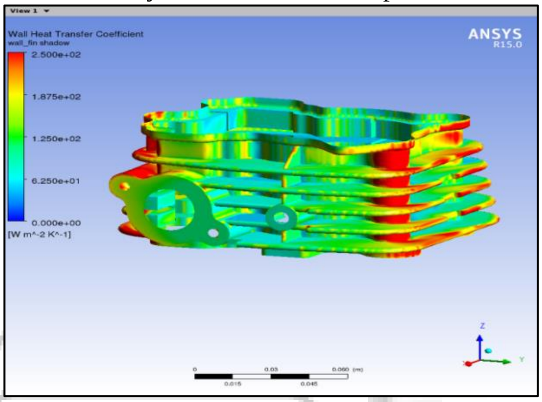

Fig. 16: Heat transfer coefficient of Cast Iron fin surface at wind velocity of 15Km/hr and temperature 27°C

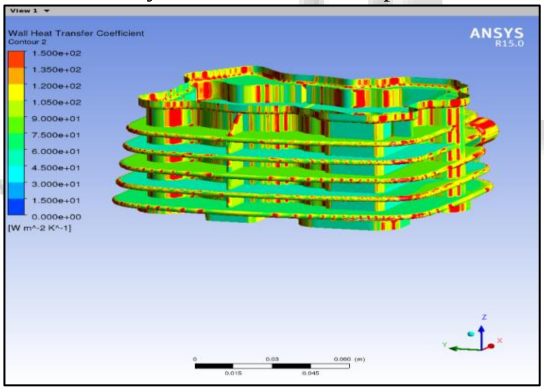

Fig. 17: Heat transfer coefficient of Cast Iron fin surface at wind velocity of 15Km/hr and temperature 40°C

Fig. 12, fig 13, fig 14, fig 15, fig 16 and fig 17 shows the variation heat transfer coefficient over fin surface. Front surface showing less heat transfer coefficient as compare to side surface due to flow separation sudden increase in velocity of wind due to this more heat loss takes place from side fins. It is found that max heat transfer coefficient is at temperature at 300k and minimum heat transfer coefficient at temperature of 313k because as there is increase in ambient temperature, temperature difference between fins surface and atmosphere is decreases so less heat dissipation takes place from fins. But at lower temp of 289k engine dissipate very less heat as compare to normal temperature of 300k due to high temperature difference between atmosphere and fin surface at operating condition. Table 5 showing heat transfer coefficient values for different climatic condition for Al. Alloy and Cast Iron fins at velocity of Air 15 Km/hr and Engine cylinder temperature of 723 K.

Material	Parameter	Climate temp.	Avg. Heat transfer coefficient
Al Alloy	Heat transfer co efficient (W/m^{2}K)	16°C	34.919308
		27°C	72.779
		40°C	31.623693
Cast Iron	Heat transfer coefficient(W/m^{2}K)	16°C	32.594166
		27°C	71.7
		40°C	30.797867

Table 5: Comparision Heat transfer Coefficient of Materials

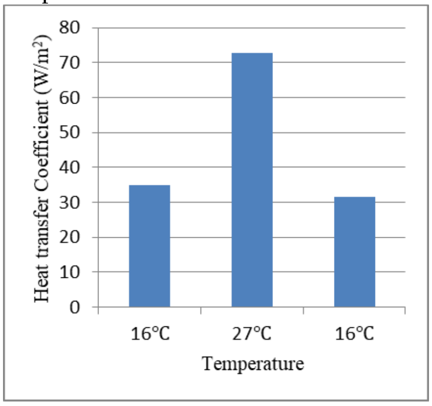

Fig. 18: Comparison of Heat Transfer Coefficient at Varying climatic Condition for Al. alloy 6061 fins cylinder

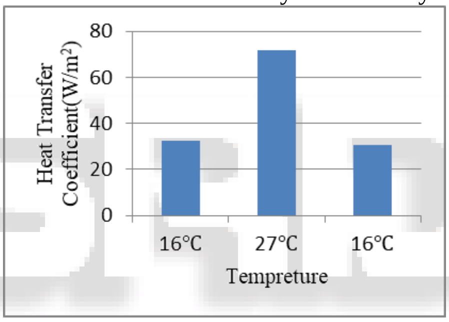

Fig. 19: Comparison of Heat Transfer Coefficient at Varying climatic Condition for Al. alloy 6061 fins cylinder

IV. CONCLUSION

Following conclusion is made from above work

- Steady state CFD analysis is performed on 125cc cylinder with rectangular fins for two material Aluminium Alloy 6061 Fins cylinder and Cast Iron Fins cylinder.
- By CFD Analysis, Temperature distribution, Heat transfer coefficient at wind velocity of 15Km/hr and Ambient temperature of 16°C , 27°C and 40°C are found for Al alloy 6061 and Cast iron fins for engine cylinder having CNG as fuel.
- It is found that 27°C is best temperature for cooling of engine as compare to 16°C and 40°C . More heat lost takes place at temperature of 16°C.
- High climate temperature 40°C and low climate temperature 16°C is not good for cooling of CNG Engine
- Research paper compare CNG engine fins of Aluminium Alloy 6061 and Cast Iron. It is found that Aluminium Alloy 6061 fin has 2% to 3% more heat transfer coefficient than cast iron cylinder for CNG fuel engine at 27°C. So more heat loss takes place through Al. Alloy 6061 fins than that of Cast Iron Fins for CNG Engine two wheeler bike.

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