IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.
www.ijiset.com
ISSN 2348 – 7968

Thermal Analysis and Comparison of Cylinder Blocks of 4S, SI Two Wheeler Engine Using Ansys

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Abstract

The aim of this project is to analyze cylinder blocks of 4S SI Engines of two wheelers from three different companies namely; HONDA, TVS, YAMAHA, in order to find out the thermal effects of combustion gases on them with respect to change in temperature and heat flux throughout the analysis time, and to also compare the three blocks. A replica of these blocks each is first designed using SolidWorks design software. These blocks are then analyzed using Ansys software to find the thermal effects when the engine is running on high speed, average speed, low speed, and also when the engine is exposed to variable conditions of the atmosphere during summer and winter in Greater Noida for 25mins. From the analysis it was deduced that Honda Activa always have higher amount of heat dissipated throughout the time span than TVS Wego and Yamaha Ray Z, but dissipates the least in the winter season, showing that temperature irrespective of the difference in thermal properties is a significant factor in heat dissipation.

Keywords: *Thermal Effects, Cylinder Blocks, Ansys, High speed, Average Speed, Low Speed.*

1. Introduction

An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid circuit. IC engines are classified under various categories but due to the scope of this project we will look at 4S spark ignition engines.

The energy released in the combustion chamber of an internal combustion engine is dissipated in three different ways. About 35 % of the fuel energy is converted to useful crankshaft work, and about 30 % energy is expelled with the exhaust. This leaves about one-third of the total energy that must be transmitted from the enclosed cylinder through the cylinder walls and head to the surrounding atmosphere. The temperature in the combustion chamber of an engine goes up to 2700 K, and the materials used in the engine cannot withstand this. Further, this high temperature destroys the lubricating properties of the oil film on the cylinder walls. At the same time, thermal stresses will be developed thereby distorting the cylinders, head and piston. Convection and conduction are the main heat transfer modes to remove energy from the combustion chamber to keep the cylinder walls from melting.

2. Literature Review

J. Ajay Paul and Sagar .C. (2012) conducted Parametric Study of Extended Fins in the Optimization of Internal Combustion Engine, where they found that for high speed vehicles engines with thicker fins provide better efficiency. When fin thickness increases, the gap between the fins reduces that resulted in swirls being created which helped in increasing the heat transfer. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence.

Pulkit Agarwal et.al (2011) simulated the heat transfer in motor-cycle engine fins using CFD analysis. It is observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine by excess fuel consumption. This necessitates the need for reducing air velocity striking the engine surface to reduce the fuel consumption. It can be done placing a diffuser in front of the engine which will reduce the relative velocity of the air stream thus decreasing the heat loss.

A.K. Mishra et.al. (2012) carried out transient numerical analysis with wall cylinder temperature of 423 K initially and the heat release from the cylinder is analyzed for zero wind velocity. The heat release from the cylinder which is calculated numerically is validated with the experimental results. To increase the cylinder cooling, the cylinder should have a greater number of fins. However, the cylinder cooling may decrease with an increased number of fins and too narrow a fin pitch. The is because the air could not flow well between the fins, thus the overlapping of thermal boundary layers occurs at the upper and lower fin surfaces.

Denpong Soodphakdee et.al (2001) compared the heat transfer performance of various fin geometries. These consist of plate fins or pin fins, which can be round, elliptical, or square. The basis of comparison was chosen to be a circular array of 1mm diameter pin fins with a 2mm pitch. The ratio of solid to fluid thermal conductivity for aluminium and air is quite high, around 7000, permitting the fins to be modelled as isothermal surfaces rather than conjugate solids. The CFD simulations were carried out on a two-dimensional computational domain bounded by planes of symmetry parallel to the flow. The air approach velocity was in the range of 0.5 to 5m/s. the staggered plate fin geometry showed the highest heat transfer for a given combination of pressure gradient and flow rate.

3. Project Methodology

[1]Choose three cylinder blocks whose engine specifications are closely related.
[2]Generate the CAD models for these cylinder blocks using Solidworks software.
[3]Define limitations, loading conditions, and assumptions in the analysis.
[4]Calculation of thermal loads the blocks are subjected to.
[5]Analysis of these blocks using Ansys software.
[6]Comparison of results from Ansys.

3. Properties of the Cylinder Blocks

Table 1: Engine specifications for the chosen 4S SI engines

	YAMAHA RAY-Z	***TVS WEGO***	***HONDA ACTIVA***
Engine type	Air-cooled 4s sohc, 2 valve engine	4s, sc, air-cooled ohc engine	Air-cooled, 4s, si engine
Displacement	113cc	109.7cc	109.2cc
Bore and stroke	52mm x 57.8mm	53.5mm x 48.8mm	50mm x 55.6mm
Max horse power	5.3kw / 7500rpm	5.88kw / 7500rpm	7.39kw / 7500rpm

According to ASTM coding system, the Aluminum alloys used in casting cylinder blocks are; Aluminum 319 T6, 356, and A356. Whereas there is only one Cast Iron alloy used in casting two wheeler cylinder blocks the ASTM A159 or SAE J431 Cast Iron of G2500 series.
According to Hadleigh Castings The Aluminum alloy A356 is made up of Aluminum 91.1 – 93.3 %wt, Copper 0.2max %wt, Iron 0.2 %wt, Magnesium 0.2 – 0.45 %wt, Manganese 0.1 %wt, Silicon 6.5 – 7.5 %wt, Titanium 0.2 %wt, Zinc and 0.1 %wt. it also has the following physical, mechanical and thermal properties.

According to ASTM Int'l (2011) The Cast Iron alloy G2500 series is made up of Iron 92.85 – 94.05 %wt, Carbon 3.2 – 3.5 %wt, Silicon 2 – 2.4 %wt, Manganese 0.6 – 0.9 %wt, Phosphorus 0.2max %wt, Sulphur 0.15max %wt. it also has the following physical, mechanical and thermal properties.

Table 1: Properties of Al356 and G2500 Cast Iron

Property	Al A356	G2500 Cast Iron
Density	2.685g/cc^3	7.15g/cc^3
Brinell hardness	80	170 - 229
Ultimate Strength	234MPa	173MPa
Yield Strength	165MPa	- -
Young Modulus	72.4GPa	117GPa
Poission ratio	0.33	0.26
Shear Strength	179MPa	260MPa
Compressive Strength	150MPa	636.6MPa
Specific Heat	963J/Kg.K	- -
Thermal Conductivity	167W/mK	46 - 49W/mK
Solidus temp.	557.2 °C	- -
Liquidus temp.	612.8 °C	- -
CTE	21.5-23 $\mu m/m°C$	10-12.5 $\mu m/m°C$

4. Results of Ansys Analysis

The following results were obtaineds after rigorous analysis of these three blocks under high, average, and low engine speeds both in summer and winter conditions separately, for a student riding in Greater Noida UP, India.

4.1 Assumptions in the Analysis

The analysis was done for a student of Sharda University riding to school for a maximum time of 25 mins.
The student is riding at a constant speed without using brakes, either high speed, average speed or low speed which is marked by 5000rpm, 3000rpm, and 1500rpm of the engine respectively.
The flywheel is perfect in maintaining uniform speed of the engine.
The average of the variations in gas temperatures during the four strokes was used for the purpose of calculations.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.
www.ijiset.com
ISSN 2348 – 7968

The heat transfer effect due to radiation from both gas molecules and the outer wall of cylinder block were neglected.
The same charge/gas was used in the engines and initial conditions of the engines are the same.

4.2 Specimen for the Analysis and Results

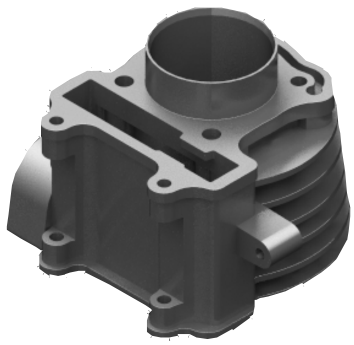

Fig. 1: CAD Model for Honda Activa Block

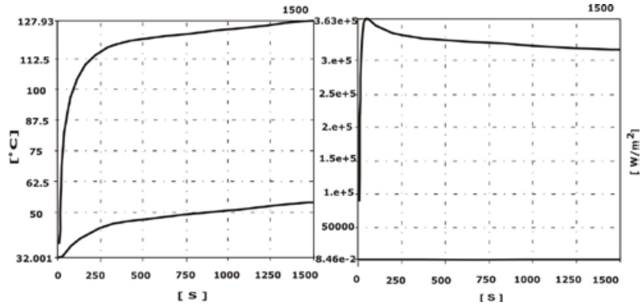

Fig. 4: Graph of low speed summer in Honda Activa

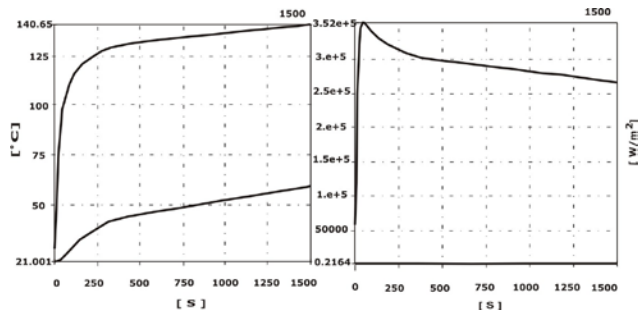

Fig. 5: Graph of low speed winter in Honda Activa

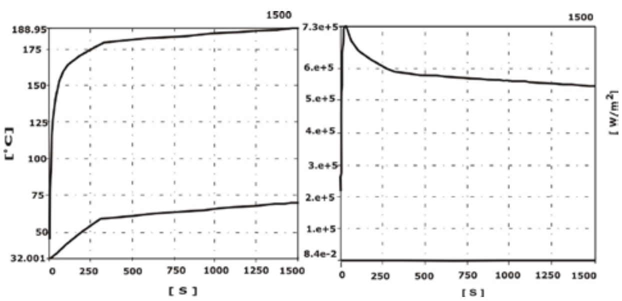

Fig. 2: Graph of high speed summer in Honda Activa

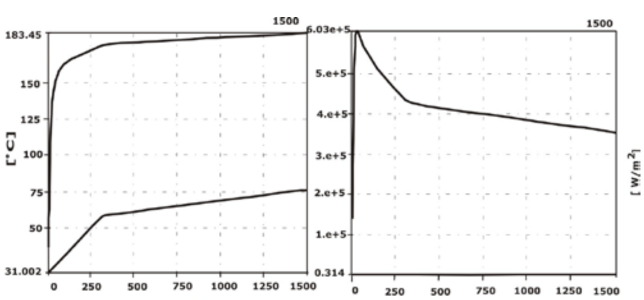

Fig. 3: Graph of high speed winter in Honda Activa

Fig. 6: CAD Model for Yamaha Ray Z Block

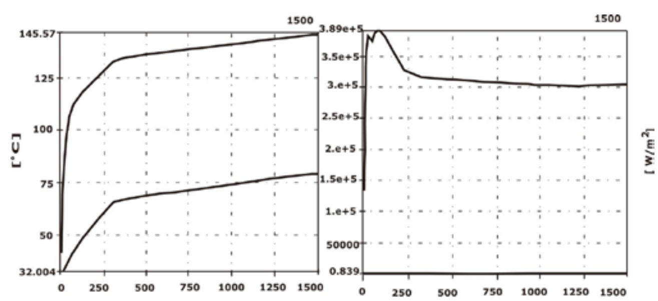

Fig. 7: Graph of high speed summer in Yamaha Ray Z

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.
www.ijiset.com
ISSN 2348 – 7968

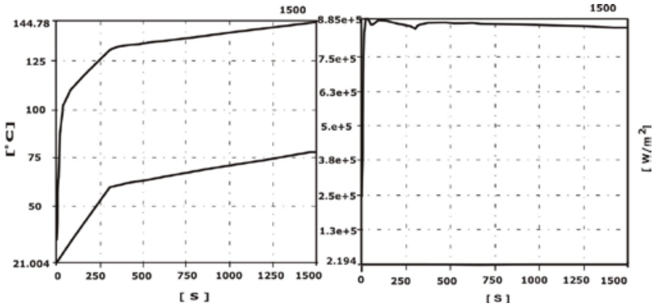

Fig. 8: Graph of high speed winter in Yamaha Ray Z

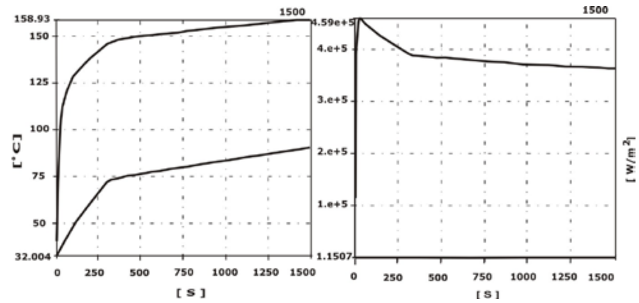

Fig. 12: Graph of high speed summer in TVS Wego

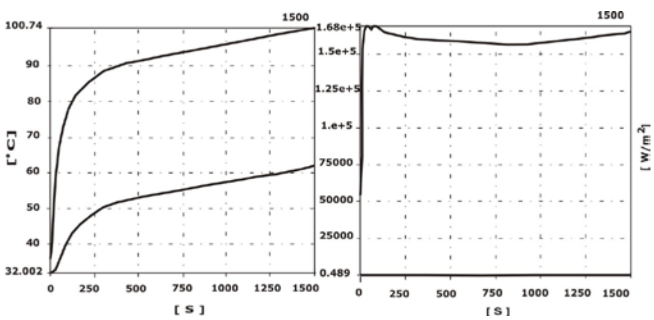

Fig. 9: Graph of low speed summer in Yamaha Ray Z

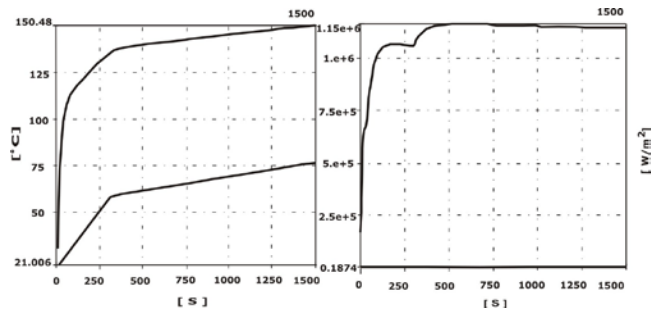

Fig. 13: Graph of high speed winter in TVS Wego

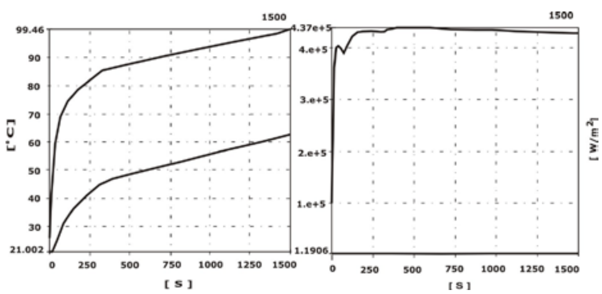

Fig. 10: Graph of low speed winter in Yamaha Ray Z

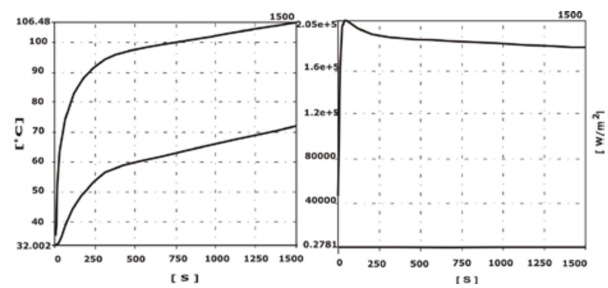

Fig. 14: Graph of low speed summer in TVS Wego

Fig. 11: CAD Model for TVS Wego Block

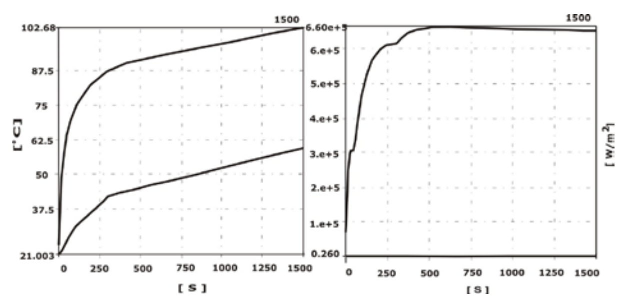

Fig. 15: Graph of low speed winter in TVS Wego

5. Discussions and Comparison of Results

The comparison is done based on maximum and minimum temperature, rate of increase in temperature with time, percentage of the body with the lowest temperature and heat dissipation. The grading is done on the scale of best, better, and good. Where best has “3” points and good has “1” point.

Table 2: Comparison of Cylinder Performance on Scale of 3 - 1

High Speed in Summer	***Honda Activa***	***Yamaha Ray Z***	***Tvs Wego***
Maximum Temperature	Good 1	Best 3	Better 2
Minimum Temperature	Best 3	Better 2	Good 1
Rate of increase of temperature with time	Good 1	Best 3	Better 2
Percentage of body with the lowest temperature	Good 1	Better 2	Best 3
Total heat dissipated	Best 3	Good 1	Better 2
Total	9	11	10
High Speed in Winter	***Honda Activa***	***Yamaha Ray Z***	***Tvs Wego***
Maximum Temperature	Good 1	Best 3	Better 2
Minimum Temperature	Best 3	Best 3	Best 3
Rate of increase of temperature with time	Good 1	Better 2	Better 2
Percentage of body with the lowest temperature	Best 3	Good 1	Better 2
Total heat dissipated	Good 1	Better 2	Best 3
Total	9	11	10
Low Speed in Summer	***Honda Activa***	***Yamaha Ray Z***	***Tvs Wego***
Maximum Temperature	Good 1	Best 3	Better 2
Minimum Temperature	Best 3	Better 2	Good 1
Rate of increase of temperature with time	Good 1	Better 2	Better 2
Percentage of body with the lowest temperature	Better 2	Better 2	Best 3
Total heat dissipated	Best 3	Good 1	Better 2
Total	10	10	10
Low Speed in Winter	***Honda Activa***	***Yamaha Ray Z***	***Tvs Wego***
Maximum Temperature	Good 1	Best 3	Better 2
Minimum Temperature	Better 2	Good 1	Better 2
Rate of increase of temperature with time	Good 1	Better 2	Best 3
Percentage of body with the lowest temperature	Best 3	Better 2	Good 1
Total heat dissipated	Good 1	Better 2	Best 3
Total	8	10	11

Maximum heat flux occurs within the first 90secs, but Yamaha Ray Z unlike others experienced a drop and increase again within the first 90secs, maybe due to its shape or ambient temperature. However, the lower the speed the Yamaha Ray Z drop and increase fades away. So it can be safely assumed that temperature and speed is what affects the slope of the heat flux irrespective of the shape of the block.

Thermal efficiency increases with increase in speed in all three models however it is observed that the increase in thermal efficiency is most in Honda Activa followed by Tvs Wego then Yamaha Ray Z, both in summer and winter conditions.

6. Conclusions

From the analysis it can be deduced that Honda Activa always have higher amount of heat dissipated throughout the time span than TVS Wego and Yamaha Ray Z, but dissipates the least in the winter season. This shows that temperature irrespective of the difference in thermal properties is a significant factor in heat dissipation. It is also observed that the rate at which heat is conducted from the inner to the outer surface is greatly affected by temperature as TVS Wego has highest percentage of body with low temperature in summer while Honda Activa dominated in the same field in winter. It is also observed that all the blocks are efficient in heat dissipation as they all reach high temperatures within 70secs and their thermal efficiencies all increase with increasing speed.

However, judging by the points gotten by each cylinder block on each scenario of the analysis, it is clear that cast iron cylinder blocks (Honda Activa) may be preferred only for its mechanical/ structural properties and higher thermal coefficient of expansion than aluminum alloys.

Acknowledgments

I want to acknowledge the help and support of the Almighty God (Jesus) who guided me throughout my stay for this program and guided me in this project. I also want to acknowledge my supervisor Asst. Prof Sunny Sharma, for his motivation and guidance before, during and presentation of this project, I couldn't have done it without you. I also want to thank every other faculty that guided me in this project, for all their support and teaching in one way or the other.

Finally, my parents Mr & Mrs Sam Okeke-Richard, who out of love and little, supported me financially and for their motivation throughout my stay for this program. I owe you all my sincere gratitude.

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First Author: Born on 10th September 1989, Chidi Okeke-Richard is one of the nine children of an Industrialist, so he had the chance to stay, observe and work with machines at a very tender age. This is where he developed a keen interest in how machines are put together for them to work in great harmony. This interest saw him through school, where he obtained BTech degree in Mechanical and Production Engineering in 2012, and also helping him pursue MTech degree in Machine Design, hopefully 2016. He is currently working in Samgoz Oil and Chemical Company Limited, a company that produces soap and also engages in fish farming as the production and maintenance manager. He also wants to head the extension of the company to producing machines used in soap industry. He is currently interested in improving the percentage of solar energy that can be converted to thermal energy for the purpose of heating and drying only. He belongs to Nigerian Society of Engineers (NSE), a body of professionals whose heads were joined together for the benefit of mankind through technology.