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CFD Analysis of light vehicle engine to increase heat transfer by using different types of fins

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Abstract

In internal combustion engine heat losses from combustion chamber through the cylinder wall strongly influences the thermodynamics of the engine cycle and an important part of the energy balance thatinfluences gas temperature and pressure, engine performance and emissions. The primary object of the present work to increase the heat transfer rate from existing cylinder block, for that three design is proposed in which one is actual design and other two is new proposed design. Mathematical and analytical studies were performed in order to optimize geometrical parameters for natural convective heat transfer from Actual cylinder block and proposed design of cylinder block for geometrical optimization. The transient thermal analysis in ANSYS v16.0 was performed on two different ambient temperatures; the first one is on 25oC & another one is on 45oC. Since the maximum temperature developed on all types of cylinder block design is same but the lower temperature is much below in proposed design-2 is attended. Hence the proposed design -2 of cylinder block has better performance and heat dissipation from the heating zone in the IC engine.

Keywords: Heat transfer, IC engine, Engine design, Transient thermal analysis etc.

INTRODUCTION

E Fins are commonly used for cooling of various components in industries like turbines, heat exchangers, engines etc. Now days there are a high require for light weight, compacted and economical heat sinks. Fins are the significant feature in geometry of heat sink. A fin is generally a flat surface extended from heat sink plane. It is used for increment in heat transfer to and from environment by growing the convective heat transfer surface area. Air-cooling also is accepted as a important method in the thermal design of electronic packages, because in addition to its accessibility, it is safe, does not contaminate the air and does not add vibrations, noise and humidity to the system in which it is used. Using fins is one of the inexpensive and common techniques to dissipate avoidable heat and it has been positively used for many engineering applications. Rectangular fins are the furthermost popular fin type because of their low fabrication costs and high thermal efficiency.

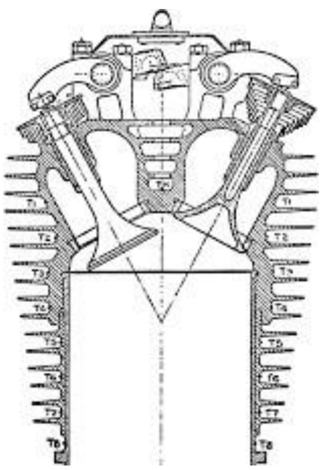


Figure 1.1: *Cylinder Fin*

Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant route through a heat exchanger (radiator) chilled by air. In air cooling system, heat is passed away by the air rolling over and around the cylinder. Here fins are cast on the cylinder head and cylinder barrel which provide additional conductive and radiating surface. In water cooling structure of cooling engines, the cylinder walls and heads are on condition that with jacket Cooling fins advantage keep Chevrolet volt battery at perfect temperature. It is known that in situation of Internal Combustion engines, Combustion of air and fuel proceeds inside the engine cylinder and subsequently hot gases are produced. The temperature of gases will be about

2300-2500°C. This is a quite high temperature and might results into burning of oil film amongst the mobile parts and possibly will result into clutching or welding of the same. So, this temperature necessity be reduced to about 150-200°C at which the engine will effort most proficiently. Too considerably cooling is also not necessary since it diminishes the thermal proficiency. So, the entity of cooling system is to keep the engine consecutively at its most functioning temperature. It is to be distinguished that the engine is pretty inefficient when it is cold and henceforth the cooling system is intended in such a way that it stops cooling when the engine is heating up and till it attain to extreme efficient functioning temperature, formerly it starts cooling

AIR COOLING SYSTEM

Air cooled system is normally used in minor engines say up to 15-20 kW and in aero plane engines. In such system fins or prolonged surfaces are on condition that on the cylinder walls, cylinder head, etc. The quantity of heat degenerate to air depends upon

- Quantity of air flowing through the fins.
- Fin external area.
- Used thermal conductivity of metal.

ADVANTAGES OF AIR COOLED SYSTEM

Subsequent are the advantages of air cooled system:

- Radiator/pump is absent henceforth the system is light.
- In situation of water cooling system there are leakages, but in this case there are no leakages.
- Coolant and antifreeze solutions are not required.
- This system can be used in cold climates, where if water is used it may freeze.

LITERATURE REVIEW

- Mahendran.V and Venkatasalakumar .A et al. [1] a cylinder fin body for Bajaj CT 100cc motorcycle is modeled using parametric software Solid Works 2012. The thickness of the original model is 3mm, in this thesis it is reduced to 2mm. The fin shape is Rectangular with curves at corner, in this paper Circular with curvature fin and radius of curvature is 0.5 mm. Present used material for fin body is Cast Iron. In this paper, thermal analysis is done for all the two materials Cast Iron and Aluminum alloy 6061. The material for the original model is changed by taking the consideration of their thermal conductivity and design of fins. 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.
- K. Parthiban, D. Senthilkumar and S. Maniamramasamy et al. [2] studied water cooling system is employed rather than air cooling system and analyzed with water as an operating fluid. Higher heat transfer constant of water could earn within the 2 wheeler 4-stroke engine performance and it reduces the evaporation of oil that lubricates the piston and cylinder wall. The constant circulation of the agent constantly cools the engine and might maintain high speeds for an extended time still because the performance isn't hampered. The liquid engine contains a longer life compared with an air cooled engine. The volumetrically efficiency of liquid cooled engine in any day is found to be higher than its air cooled counterpart. It's recommended that to boost

in cooling system for the continuous riding by continuous circulation and thereby stop overheating of the engine and reduction of the evaporation of oil.

• Abhishek Mote, Akshay Choukse, Atharva Godbole, Dr. Pradeep Patil and Avinash Kumar Namdeo et al. [3] found that higher air velocities around the extended surfaces increase the warmth transfer. The variation in vehicle speed considerably changes heat transfer rate. As a consequence fin efficiency additionally varies with vehicle speed. The physical dimensions of fin additionally impact the fin efficiency. it absolutely was found that the fin efficiency/heat transfer

• rate will increase once air speed was multiplied from 11.11m/s to sixteen.667 m/s. The flow pattern of air is ruled by physical pure mathematics of fins. CFD technique was found to be terribly helpful and quick. It eliminates the necessity of fabrication before experimental work. Each fabrication and experimental procedures are time overwhelming, dearly-won and sensitive to human errors. Using CFD technique produces fast and extremely correct results for a good vary of in operation conditions.

• KM Sajesh, Neelesh Soni and Siddhartha Kosti et al. [4] On the basis of the study carried out within the rectangular engine fin by Transient and Steady State Thermal Analysis in ANSYS work bench 16.0. Turbulence of flow of air is increased between the fins on creation of hole. Heat lost by the body may be increased by increasing the expanse i.e. increasing the diameter of the opening created on the fin. Temperature of the fin will be reduced by creation of holes. It's discovered from the results that before a fundamental quantity of four hundred seconds Transient temperature of all fins has reached to steady state temperatures. Fin with a hole of ten millimeter diameter has decrease the minimum temperature of 1036.5 K for an imperforated fin to a minimum temperature of 989.03 K.

• Mr. Manir Alam and Mrs. M. Durga Sushmitha et al. [5] a cylinder fin body for motorbike is sculptured exploitation parametric software system CATIA. The first model is modified by ever- changing the geometry of the fin body, distance between the fins and thickness of the fins. gift used material for fin body is forged iron. Thermal analysis is completed for the entire 3 materials forged iron, Copper and aluminum alloy 6082. The fabric for the first model is modified by taking the thought of their densities and thermal physical phenomenon. Density is a smaller amount for aluminum alloy 6082 compared with different 2 materials therefore weight of fin body is a smaller amount exploitation atomic number 13 alloys 6082. Thermal physical phenomenon is additional for copper than alternative 2 materials. By perceptive the thermal analysis results, thermal flux is additional for aluminum alloy than alternative 2 materials and additionally by exploitation aluminum alloy its weight is a smaller amount, therefore exploitation aluminum alloy 6082 is best.

• S. R. Durai Raju, M. Durai Balaji, N. Jaya Prakash and I. G. Jeevanandan et al. [6] by using vapour absorption system in Automobile there's a double cooling result. By combining each system, energy needed to engine cooling is totally obtaining reduced. Only providing a pump for aqua solution circulation and to condenser water circulation they are able to run air conditioning system with freed from price. The amount of components used may be reduced and therefore the load of car is reduced. It ends up in larger mechanics style. There's a scope of improvement in heat transfer of air cooled engine cylinder fin if mounted fin's form varied from typical one. The fin geometry and cross sectional space affects the warmth transfer co economical. In High speed vehicles thicker fins offer higher efficiency. Increased fin thickness resulted in swirls being created that helped in increasing the warmth transfer. Heat transfer constant may be augmented by increasing the encompassing fluid speed by forced convection. The thermal efficiency of the interior combustion engine is augmented remarkably by using small controller primarily based engine cooling system. Hot spot and corrosion on exhaust pipe and silencer may be controlled by exhaust temperature. Back pressure in exhaust pipe may be controlled by limiting exhaust temperature which might be improved the silencer and exhaust pipe efficiency. By dominant the exhaust gas temperature, converter era may be improved.

METHODOLOGY

STEPS OF WORKING METHOD

Below table gives the technical specifications of engine and fin geometry.

Table 4.1: *Engine Technical Specification (Hero Honda Passion 100 cc)*

Specifications	Dimensions
Displacement	97.50 cubic cm (5.95 cubic inches)
Engine type	Single cylinder, four-stroke
Power	7.37 HP (5.4 kW)) @ 8000 RPM
Torque	7.95 Nm (0.8 kgf-m or 5.9 ft.lbs) @ 5000 RPM
Compression	9.0:1
Bore x stroke	50.0 x 49.5 mm (2.0 x 1.9 inches)
Fuel system	Carburettor
Fuel control	OHC
Ignition	Digital CDI
Cooling system	Air
Driveline	4 speed constant mesh
Transmission type, final drive	Chain
Clutch	Multiplate, wet

Table 4.2: *Engine Fin Geometry (Cast Iron)*

Material/Properties	**Rectangular**		**Circular**	
Thermal Conductivity(K) (w/mK)	53.3	53.3	53.3	53.3
Heat Transfer Coefficient (h) (w/m^2K)	30	30	30	30
Thickness (t) (mm)	3	2.5	3	2.5
Length (L) (mm)	100	100	85	85
Cross Sectional Area (A) (mm^2)	600	500	1012.47	843.73
Perimeter (P) (mm)	0.406	0.405	688.93	93 679.98
Specific Heat (Cp)(J/KgK)	490	490	490	490
Density (Kg/mm^3)	0.00000711	0.00000711	0.00000711	0.00000711

Table 4.3: *Fin Material Composition*

Material	**Grade**	**C**	**Si**	**Mn**	**P**	**S**
%wt	**HT150**	3.2 - 3.5	1.9 - 2.3	0.5 - 0.8	0.2	0.12

GOVERNING EQUATIONS

Consider a volume element of a fin at location x having a length of x, cross-sectional area of Ac, and a perimeter of p, as shown in Fig. Under steady conditions, the energy balance on this volume element can be expressed as

Where

Qconvection = h(pΔx)(T -Ta)

$$\frac{d^2\theta}{dx^2} = m^2\theta \text{ . where. } m^2 = \frac{hp}{KA_c}$$

$$\theta(x) = C_1 e^{mx} + C_2 e^{-mx}$$

fin with finite length and tip un-insulated.

$$Q_{fin} = \sqrt{hpKAc}\,(T_S - T_a)\left(\frac{\tan h(ml) + \frac{h}{Km}}{1 + \frac{h}{Km}\tan h(ml)}\right)$$

$$\frac{\theta}{\theta_0} = \frac{T - Ta}{Ts - Ta} = \frac{\cos h\{m(l-x)\} + \frac{h}{Km}[\sin h\{m(l-x)\}]}{\cos h(ml) + \frac{h}{Km}[\sin h(ml)]}$$

Efficiency of fin (η_{fin}) = $\frac{\text{Actual heat transfer by the fin}}{\text{maximum heat that would be transferred if whole surface of the fin is maintained at the base temperature}}$.

Step 1: Collecting information and data related to cooling fins of IC engines.

Step 2: A fully parametric model of the Engine block with fin is created in Pro-e software.

Step 3: Model obtained in Step 2 is analyzed using ANSYS 14. (APDL), to obtain the heat rate , thermal gradient and nodal temperatures.

Step 4: Manual calculations are done.

Step 5: Finally, we compare the results obtained from ANSYS and manual calculations for different material, shapes and thickness.

STEPS OF ANSYS ANALYSIS

The different analysis steps involved in ANSYS are mentioned below.

1. Preprocessor

The model setup is basically done in preprocessor. The different steps in pre-processing are

- Build the model
- Define materials
- Generation of element mesh

2. Building the Model

To re-create mathematically the behavior of an actual engineering system is the ultimate purpose of a finite element analysis. The analysis must be an exact mathematical

 Creating a solid model within ANSYS.

 Using direct generation.

 Importing model created in a computer-aided design (CAD) system.

3. Define Materials

A material is usually defined by its material constants, in which each clement assigned with suitable material constants to obtain exact results.

4. Generate Element Mesh

The discrctization of the problem is solved by means of nodal points. The nodes are allied to form finite elements by which material volume are outlined collectively. The element types have to be determined based on the problems and the assumptions made. The different types of elements used are beam, truss, plate, shells and solid elements. The element mesh is formed in numerous ways in ANSYS. The familiar way is to create mechanically, through more or less controlled. The user can create a mesh which is able to generate a result with a sufficient degree of accuracy.

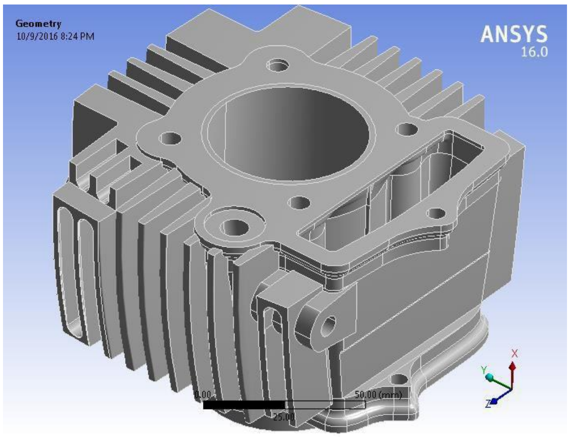
5. Solution Processor

The problem is solved here by gathering all the specified information regarding the problem. In this phase of analysis the computer takes over and solves the instantaneous equation which is generated by finite element method. The results of solution are nodal degree of freedom values, which outline the primary solution derived values that shapes the element. The steps involved in this process are

6. Apply Loads

Loads are applied on nodes or elements. The load may also be edited in ANSYS by the pre-processor.

Obtain Solution



The results of the problem can be obtained only when the problem is defined properly.

Figure 4.3: *CAD geometry of Actual cylinder block*

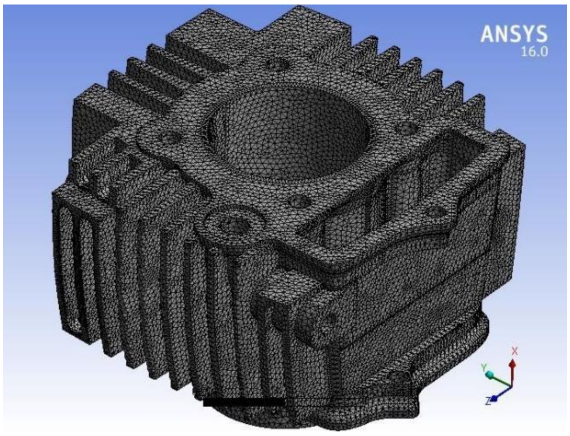


Figure 4.4: *Meshing: Total No. of Nodes: 611869 & Total No. elements: 351526*

8 Meshing

Meshing is a critical operation in finite element analysis. In this operation the CAD geometry is divided into large numbers of small pieces. The small pieces are called mesh. The analysis accuracy and duration depends on the mesh size and orientations. With the increase in mesh size, the finite element analysis speed increase but the accuracy decreases (Figure 4.4).

After completing the CAD geometry of cylinder block is imported in ANSYS workbench for further thermal analysis and the next step is meshing. The mesh created in this work is shown in figure No. The total Node is generated 611869 & Total No. of Elements is 351526, it is clear from the mesh geometry the node numbers and element numbers are almost six in digit which show that the mesh is very fine because the result accuracy depends on the mesh quality.

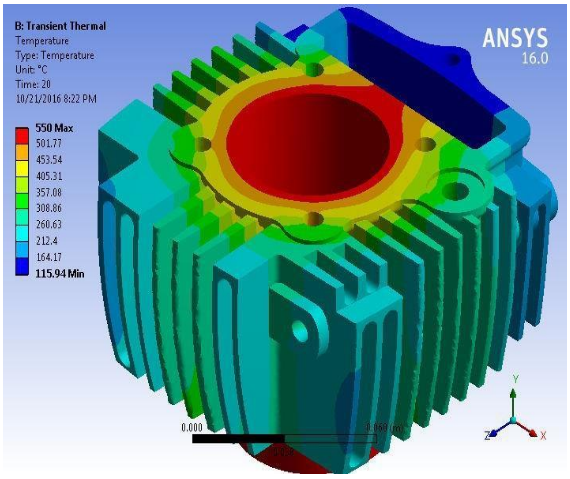


Figure 4.5: *Temperature distribution over cylinder block at ambient Temperature 25 OC*

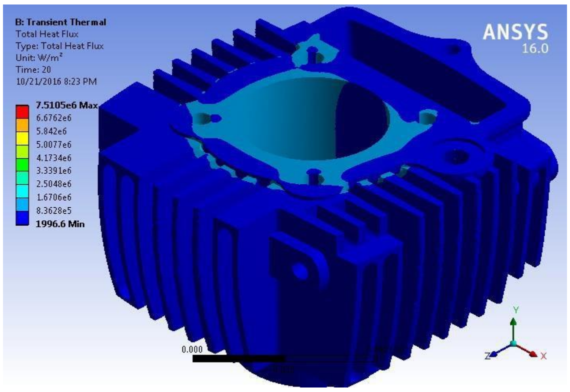


Figure 4.6: *Total Heat flux*

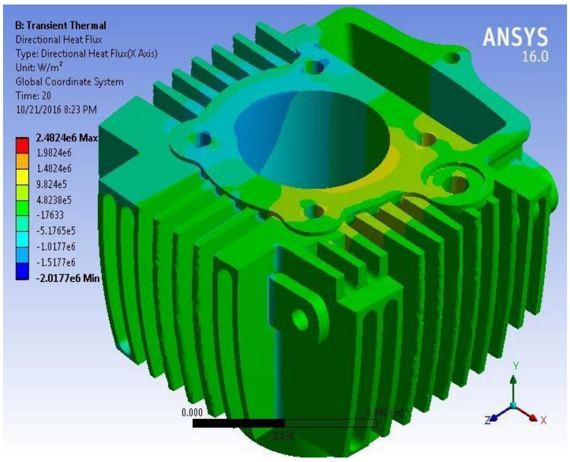


Figure 4.7: *Directional Heat flux*

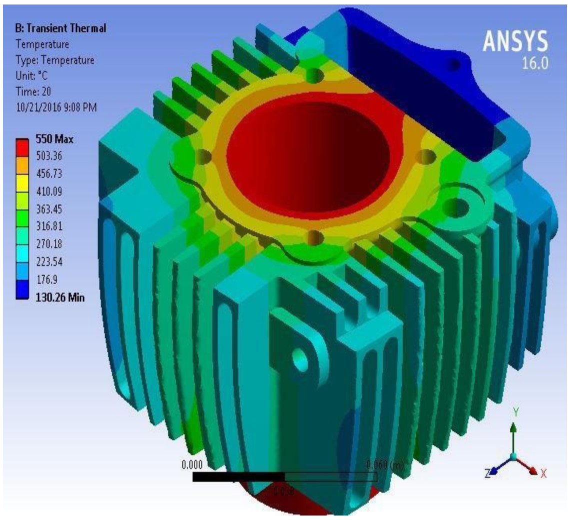


Figure 4.8: *Temperature distribution over cylinder block at ambient Temperature 45oC*

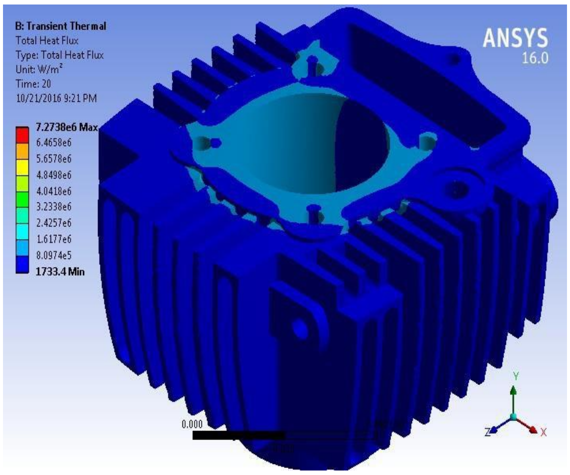


Figure 4.9: *Total Heat Flux*

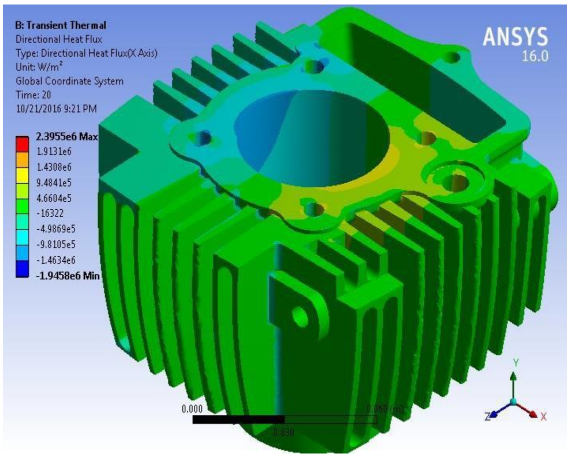


Figure 4.10: *Directional Heat Flux*

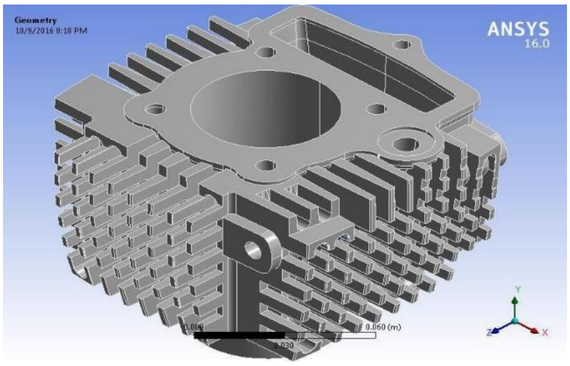


Figure 4.11: *CAD geometry of proposed design-1*

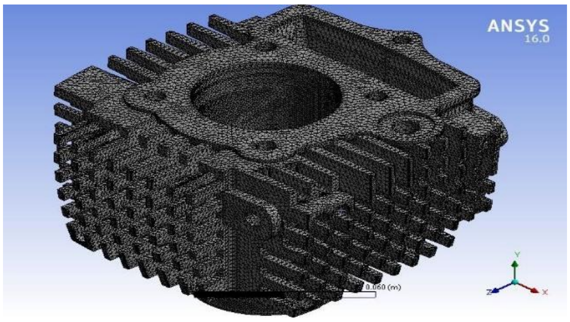


Figure 4.12: *Meshing, Total No. of Nodes: 807991 & Total no. of elements: 457469*

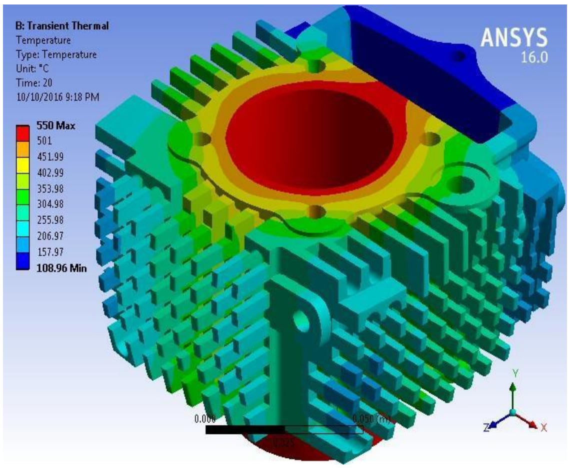


Figure 4.13: *Temperature distribution over the cylinder block of proposed design-1 during transient thermal analysis*

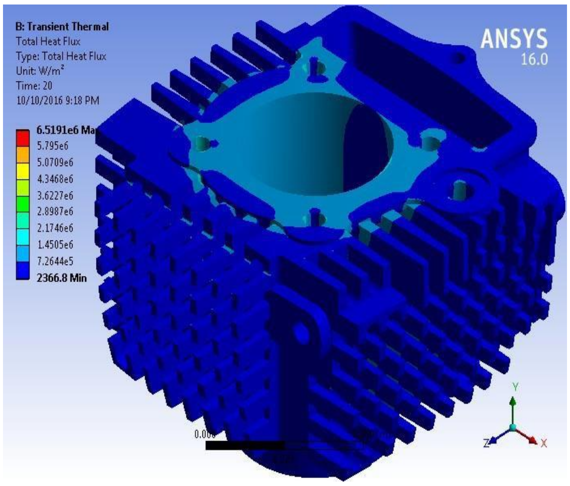


Figure 4.14: *total heat flux of proposed design-1 during transient thermal analysis*

RESULT AND DISCUSSION

The static and transient thermal analysis ware conducted using ANSYS workbench based on finite volume methodology the effects of different important geometrical parameters on the steady state and transient natural convective heat transfer rate from both actual and proposed design of cylinder block.

ASSUMPTIONS

The following assumptions are made to perform thermal analysis of cylinder block.

• Symmetric flow and identical heat transfer throughout the heat sink

• Isothermal boundary condition is applied for the base and fins.

• Air entrance from the side is Negligible on the heat sink means the fresh air inflow and outflow from the open sides of the outmost fins wall is small compared to the air flow entering from the bottom of the fins array

Thermal Conductivity: it is the degree to which a specified material conducts electricity, calculated as the ratio of the current density in the material to the electric field which causes the flow of current. The rate at which heat passes through a specified material, expressed as the amount of heat that flows per unit time through a unit area with a temperature gradient of one degree per unit distance.

Table 5.1: *Mechanical and thermal property cast iron*

Chemical composition: C=2.7-4%, Mn=0.8%, Si=1.8-3%, S=0.07% max, P=0.2% max

Thermal conductivity	83	W/(m*K)
Electric resistivity	$1.1x10^{-7}$	Ohm x m
Density	7200	Kg/m^3
Tensile strength	276	MPa
Compressive Strength	570 to 1290	MPa
Young's Modulus	82 to 140	GPa
Elongation at Break	0.51 %	-
Fatigue Strength (Endurance Limit)	69 to 170	MPa
Brinell Hardness	160 to 300	BHN

Table: 5.2 *Temperature distributions on actual cylinder block at 25 degree Celsius*

Temperature distribution at 25 °C		
Time sec	**Minimum Temperature °C**	**Maximum Temperature °C**
0.2	25	482.65
0.32494	25	459.26
0.40199	25	448.4
0.47904	25	440.18
0.70038	25	423.65
1.0078	25.2	408.39
1.4242	36.018	388.93
1.8406	47.447	370.49
2.3377	61.126	355.93
2.9613	74.513	337.73
3.7215	90.277	315.74
4.5927	110.27	296.89
5.5368	132.09	278.04
6.5491	153.24	259.89
7.6798	148.2	242
9.0517	141.84	247.48
10.925	133.76	299.25
12.925	126.58	354.51
14.925	121.19	409.78
16.925	117.72	465.04
18.925	116.2	520.3
20	115.94	550

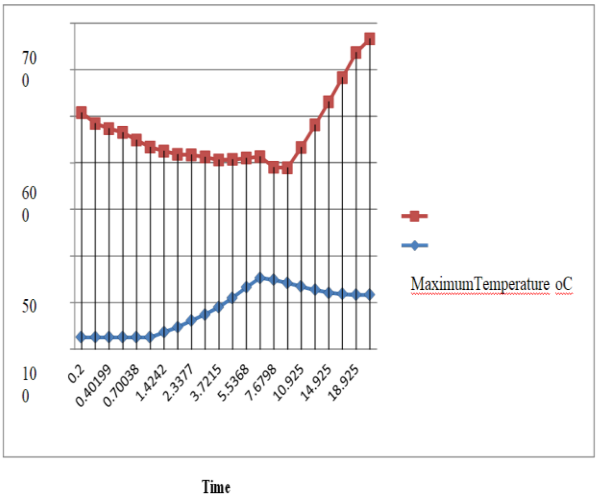


Figure 5.1: *Temperature distribution over cylinder block at ambient Temperature 25 oC*

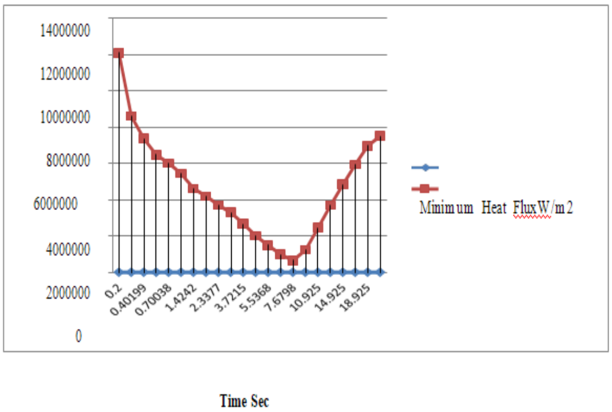


Figure 5.2: *Total Heat flux of actual cylinder block at ambient Temperature 25 Co*

Table: 5.3 Total Heat flux of actual cylinder block at ambient Temperature 25 C

Total Heat Flux of actual cylinder block at 25 ^{o}C		
Time sec	**Minimum Heat Flux W/m^2**	**Maximum Heat Flux W/m^2**
0.2	1509.7	12100000
0.32494	90.441	8600000
0.40199	23.118	7380000
0.47904	4.9186	6480000
0.70038	0.88356	6020000
1.0078	1.1003	5440000
1.4242	291.71	4610000
1.8406	7.0504	4200000
2.3377	138.59	3700000
2.9613	176	3290000
3.7215	98.025	2680000
4.5927	27.679	2000000
5.5368	30.732	1490000
6.5491	245.61	977000
7.6798	370.23	653000
9.0517	1779.9	1230000
10.925	2015.5	2450000
12.925	765.48	3680000
14.925	1301.3	4840000
16.925	1469.4	5940000
18.925	1737.1	6970000
20	1996.6	7510000

Directional Heat Flux

Time sec	Minimum Heat Flux W/m^2	Maximum Heat Flux W/m^2
0.2	-11900000	12000000
0.32494	-6800000	6880000
0.40199	-5660000	5720000
0.47904	-4980000	5040000
0.70038	-4150000	4150000
1.0078	-3620000	3790000
1.4242	-3040000	3170000
1.8406	-2920000	2600000
2.3377	-2760000	2060000

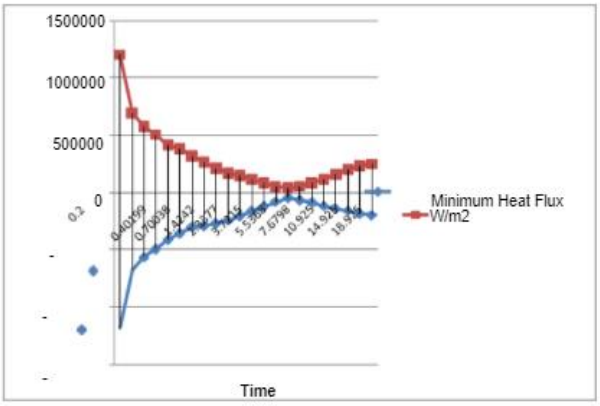


Figure 5.3: *Directional Heat flux of actual cylinder block at ambient Temperature*

25 oC

Table 5.5: *Temperature distribution over cylinder block at ambient Temperature 45oC*

Temperature distribution at 45 degree Celsius

Time sec	Minimum Temperature ^{0}C	Maximum Temperature ^{0}C
0.2	45	484.01
0.32489	45	460.79
0.40184	45	449.91
0.4788	45	441.42
0.69967	45	425.13
1.006	45.149	410.26
1.4206	55.503	391.88
1.8352	66.449	372.67
2.3253	79.422	358.97
2.9374	92.098	342.07
3.682	106.84	320.68
4.5366	125.67	303.1
5.4651	146.2	285.42
6.4627	161.76	268.48
7.5773	157.65	251.72
8.9282	152.31	255.72
10.769	145.39	304.64
12.769	139.1	357.8
14.769	134.41	410.95
16.769	131.46	464.11
18.769	130.31	517.27
20	130.26	550

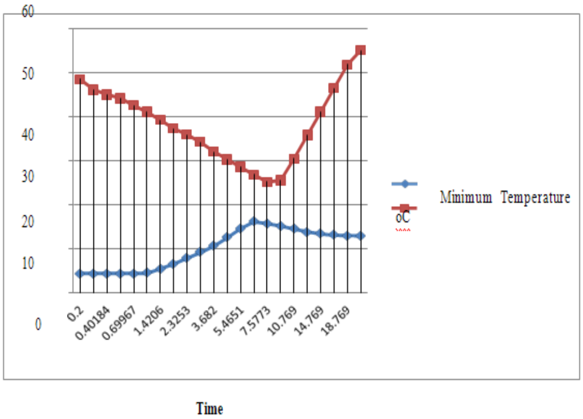


Figure 5.4: *Temperature distribution over cylinder block at ambient Temperature 45 oC*

Table 5.6: *Total Heat flux of actual cylinder block at ambient Temperature 45 oC*

Total Heat flux of actual cylinder block at ambient Temperature 45 ^{0}C

Time sec	Minimum Heat Flux W/m^2	Maximum Heat Flux W/m^2
0.2	2051.8	11600000
0.32489	85.462	8270000
0.40184	22.357	7080000
0.4788	4.7473	6210000
0.69967	0.85136	5750000
1.006	0.49712	5200000
1.4206	447.18	4380000
1.8352	50.053	3990000
2.3253	245.95	3500000
2.9374	85.71	2980000
3.682	65.618	2420000
4.5366	37.968	1910000
5.4651	13.349	1420000
6.4627	594.68	940000
7.5773	616	611000
8.9282	1039.3	1230000
10.769	470.46	2370000
12.769	1078	3540000
14.769	1773.8	4650000
16.769	804.62	5700000
18.769	2224.7	6680000
20	1733.4	7270000

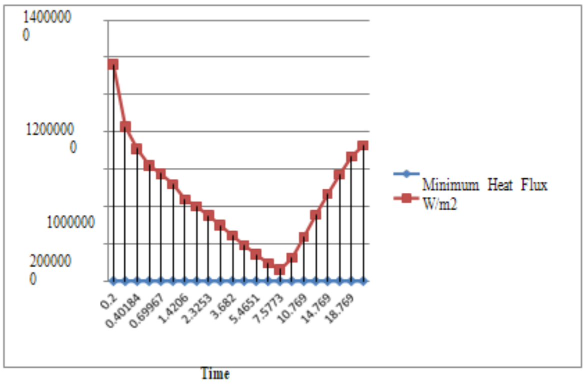


Figure 5.5: *Total Heat flux of actual cylinder block at ambient Temperature 45 oC*

CONCLUSION

Mathematical and analytical studies were performed in order to optimize geometrical parameters for natural convective heat transfer from Actual cylinder block and proposed design of cylinder block for geometrical optimization. The transient thermal analysis was performed on two different ambient temperatures; the first one is on 25 oC & another one is on 45 oC. The result of transient thermal analysis of cylinder block for proposed design-2 at 25 oC ambient temperature indicates the temperature distribution of actual cylinder block the maximum temperature is 550 oC and minimum temperature is 107.55 oC. Total heat flux generated for proposed design-2 cylinder block during transient thermal analysis, the maximum heat flux generated is 6.4025x106 W/m2 and minimum heat flux generated is 1016.2 W/m2. and at 45 oC ambient temperature indicates the temperature distribution of actual cylinder block the maximum temperature is 550 oC and minimum temperature is 120.71 oC. Total heat flux generated for proposed design-2 cylinder block during transient thermal analysis, the maximum heat flux generated is 6.2318x106 W/m2 and minimum heat flux generated is 958.6 W/m2.

To summarize the proposed design -2 of cylinder block has better performance and heat dissipation from the heating zone in the IC engine that is why the present work more concentrate on it and also proposed new design for it .Since the maximum temperature developed on all types of cylinder block design but the lower temperature is much below in proposed design-2 is attended.

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