THERMAL ANALYSIS OF MODIFIED COMBUSTION CHAMBER OF SPARK IGNITION ENGINE

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Abstract— Efficiency of an internal combustion engine can be increased by increasing the heat energy generation inside the combustion chamber without effecting the performance of lubricating oil and lessening the strength of the piston. The main aim of this paper is to determine temperature distribution in a four-stroke, single-cylinder, water cooled, variable compression ratio (3-9), variable speed (2200-3000 rpm) spark ignition engine with brake power of 2.2 kW at a speed of 3000 rpm with copper coated combustion chamber (CCE) [copper-(thickness, 300 µ) was coated on piston crown, inner side of liner and cylinder head] and compared the engine, with conventional combustion chamber (CE) with neat gasoline operation. Copper coated power piston, copp.

Keywords: Copper Coating, Piston, Liner, Solid Works, Ansys Workbench, Thermal Analysis.

INTRODUCTION

With advent of urbanization, energy consumption is increasing drastically, out of which gasoline energy utilization is foremost as transportation development is fast. Though alcohols are important substitute for gasoline to overcome the fossil fuel crisis, it plays the major contribution for the exhaust pollutants in SI engine due to incomplete combustion of fuel [1]

Engine modification with copper coating on crown of the piston and inner side of cylinder head improves the engine performance as the copper is a good conductor of heat, stabilizes flame, improves pre–flame reactions and turbulence [2-5]. Temperatures inside the combustion chamber are very high and the heat generated is transferred to different components of power piston ,liner and cylinder head such that the need for the study of temperature distribution across the components is a must, especially to provide proper lubrication between liner and power piston and cooling to the walls of combustion temperature [6-10]. Finite Element Analysis is applied in such situations and thereby temperature distribution across the components is determined by using ANSYS programme which employs finite element-based software

1. MATERIALS AND METHODS

1.1 Making of copper coated combustion chamber

In the copper coated engine, top surface of the power piston, top surface of auxiliary piston an inside of liner are coated with copper using Twin wire spray gun. For 100µ thickness, nickel-cobalt-chromium bond coating was sprayed. On this coating, for another 300µ thickness, an alloy of copper (89.5%), aluminum (9.5%) and iron (1%) was coated with a MEC (Trade name of the company) flame spray gun.

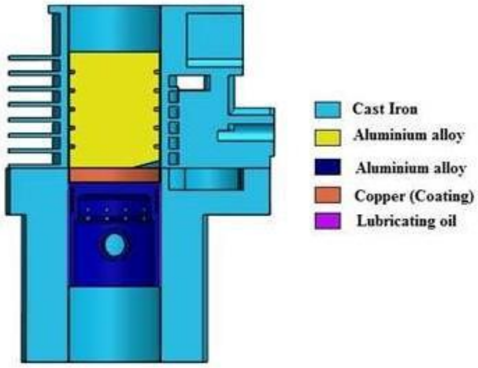
The bond strength of the coating was so high that it does not wear off even after operating it for 50hrs continuously.
The specifications of the engine are given below

ENGINE SPECIFICATIONS

1 Type: Four-Stroke, Single Cylinder, Variable

2 Make: Greaves Limited

3 Rated Power:2.2 KW at 3000rpm



4 Bore and stroke:70mm x 66.7mm

5 Speed:2200rpm-3000rpm

6 Compression Ratio: 3:1 to 9:1

7 Spark Plug: Make: MICOBOSCH

8 Spark Plug Gap:0.6mm

9 Type of Ignition: Battery

10 Specific fuel consumption:500 gm/h KW

11 Lubricating Oil: SAE-40

12 Dynamometer: Eddy Current Dynamometer loading Rheostat

13 Temperature and Speed: By Digital Indicators

14 Starting: Auto Start by DC Motor

15 Cylinder Pressure: By Sensor, range :5000PSI

16 Exhaust Gas Calorimeter: IND-LAB Make

17 Torque arm distance:200mm

18 Orifice Diameter:20mm

19 Recommended Spark Ignition Timing: 25

2.2. Measurement of Temperature distribution of engine components

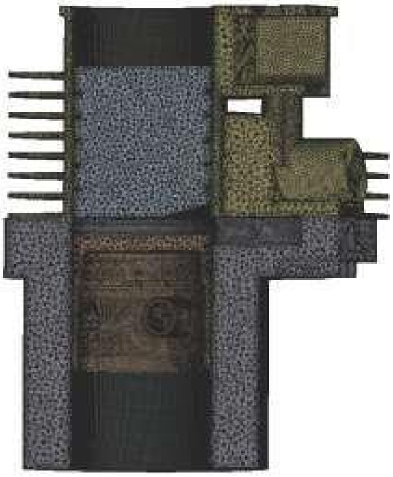
In the present scenario, steady state thermal analysis is done on the assembly of four stroke variable compression spark ignition engine to calculate temperature distribution, heat fluxes, temperature gradients and amount of heat lost or gained in engine components for different versions of the engine. Steady state thermal analysis is done in two main steps. First Geometric Modelling is done then Finite Element analysis is done.

2.2.1. Solid Model Creation: In Geometric Modelling, 3-D geometry of power piston, auxiliary piston, liner and cylinder head are created. The models are generated using SOLID WORKS 16. The components are assembled by giving constraints to obtain the final assembly. The assembly is saved as. IGS file. The file is imported to ANSYS workbench15.

Figure 1 shows the Configuration of the assembly with cu coating piston, liner and cylinder head and showing different materials in various zones
Figure 1 Configuration of the assembly witcu coating piston, liner and cylinder head showing different materials in various zones

2.2.1. Meshing the model: In finite element modelling, mesh was generated with tet10 element type using ANSYS WORKBENCH 15. Since the

geometry is complex, free style of meshing is employed. Fine mesh size is considered at small and critical components, while coarse mesh is considered for the remaining components.
Figure-2 Mesh employed in the thermal analysis for the assembly piston, liner and cylinder head with cu coating.



2.2.3 Boundary Conditions Application and Thermal Analysis Solution: The boundary conditions for the present problem are obtained from [11]

The top surface of the power piston is applied with a convective heat transfer (hc) of 250 w/m2 k and a bulk temperature (T) of 920 0 C and on the water jacket side of the liner, hc= 1800 w/m2 k and T=60 0 C and on the cylinder head fins of hc =120 w/m2 k, T = 60 0 C.

Steady state thermal analysis was solved after application of boundary conditions

3. RESULTS AND DISCUSSION

3.1 Thermal Analysis Results

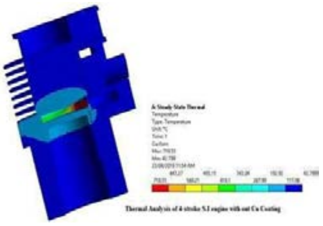


Figure 3 Isotherms of thermal analysis for the assembly of piston, liner and cylinder head of CE

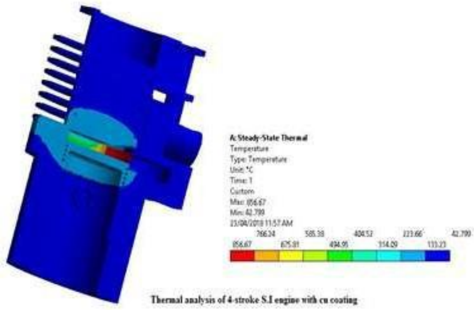
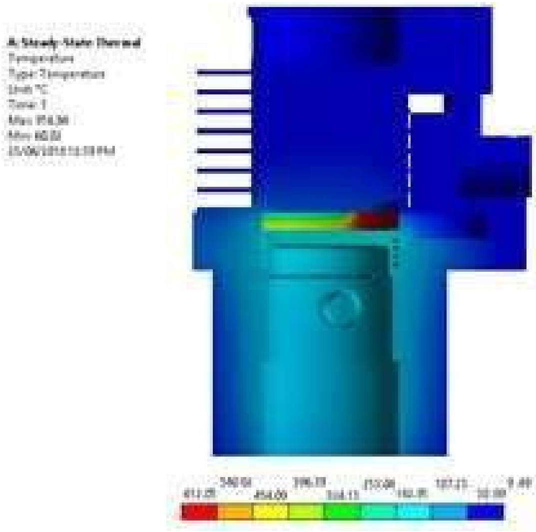


Figure 4 Isotherms of thermal analysis for the assembly of piston, liner and cylinder head of CCE



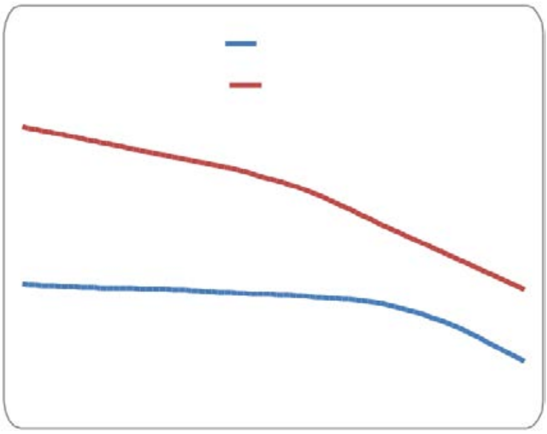
Prediction of the Temperature along the Piston

Radius for the Base Engine and Catalytic Coated

Engine

The fluctuation in the crown temperature of the piston predicted by FEM analysis with radius of the piston for CE and CCE was shown in Figure-5

Figure 5 Variation of the predicted crown temperature with radius of the piston for CE and CCE.



From the Figure 5 it was noticed that, as the radius of piston increases, crown temperature of the piston decreases marginally for both CE and CCE. The temperature decreases at the outer periphery of the piston, as it is cooled by means of lubricating oil and also with the presence of fins. The temperature of the piston of CE is

1810C while it is 2250C for the piston of CCE at the crown surface. At the outer periphery of the piston, the temperature decreases to1600C for CE and 1800C for CCE. The temperature drop for the piston of CCE from the crown to the outer periphery was less as the piston is coated with copper, which has high thermal conductivity and hence thermal resistance was less.

Figure 6 Heat flux in the assembly of piston, liner and cylinder head of CE

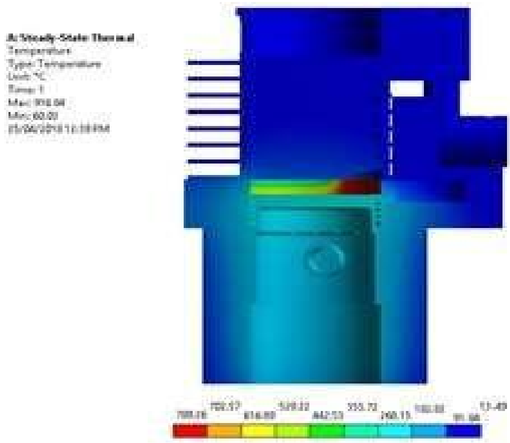


Figure 7 Heat flux in the assembly of piston, liner and cylinder head of CCE

Prediction of the Heat Flux along the Radius of the Piston in Base Engine and Catalytic Coated Engine

The variation of the percentage (%) increase in the heat flux in the piston of CCE over that of CE with its radius was shown in the Figure-8.

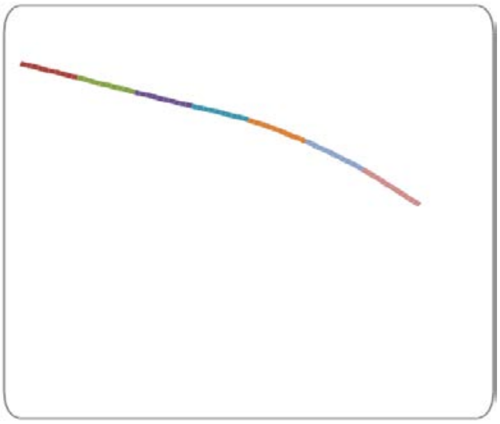


Figure 8 Variation of the % increase in the heat flux with radius of piston in CCE over CE.

As the radius of the piston increase, a marginal decrease in the heat flux(from19.6 % to 17.6 %) was noticed in the Figure-8. Since copper coating was done on the piston crown, maximum heat flux was concentrated at the centre of the piston crown. However, at the outer radius of the piston, heat flux was marginally lower, as the outer periphery of the piston is subjected to cooling by means of lubricating oil and fins.

The temperature at the inner side of the liner and cylinder head determined by FEM analysis were compared with the results obtained by experimentation, in order to ascertain the deviation of FEM results from experimental results.

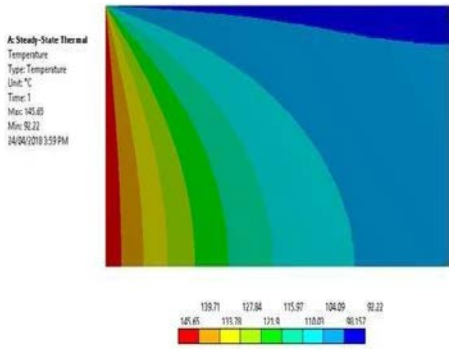


Figure-9,10 shows the isotherms of the lubricating oil between the piston and inner surface of liner of CE and CCE respectively

Figure 9 Isotherms from the finite element analysis in the lubricating oil between piston and inner surface of liner for CE

Figure 10 Isotherms from the finite element analysis in the lubricating oil between piston and inner surface of liner for CCE

From the Figures-9,10 the temperatures of the lubricating oil varied from 920C to 1450C for CE, while it varied between 1180C to 1680C for CCE respectively and found that temperatures are at safe limits for which lube oil does not deteriorate. The temperature limit for which lube oil does not deteriorate is 1800C [12].

4. CONCLUSIONS

- Temperature at the top surface of the copper coated piston was 2250C which is higher than 1810C for the conventional engine.
- Heat flux is increased by17-19% along the radius of piston for the copper coated engine

compared to conventional engine.

• Copper coating on the piston will not deteriorate the lubricating oil temperature as the lube oil temperature was in the safe limits between 1180C to 1680C,while it varied between 920C to 1450C for conventional engine.

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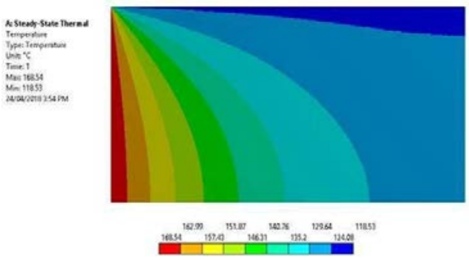

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