THERMAL ANALYSIS OF CERAMIC COATED PISTON CROWN IN DIESEL ENGINE USINGFINITE ELEMENT ANALYSIS METHOD

R.Sabariselvan[1]
[1]PG Scholar, Department of Mechanical Engineering, Muthayammal College of Engineering, Rasipuram, Tamilnadu.
E-Mail: rsabariselvan@gmail.com

V.Yogesh[2]
[2]Asst Prof, Department of Mechanical Engineering, Muthayammal College of Engineering, Rasipuram, Tamilnadu.
E-Mail: yogesh.msg@gmail.com

N.Natarajan[3]
[3]Head of Department, Department of Mechanical Engineering, Muthayammal College of Engineering, Rasipuram, Tamilnadu.

S.Shalini[4]
[4]PG Scholar, Department of Mechanical Engineering, Muthayammal College of Engineering, Rasipuram, Tamilnadu.
E-Mail: shalinipushpaaero@gmail.com

*Abstract:***In a conventional internal combustion engine the small portion of the total energy produced is converted to useful work. More than half of this energy is expelled from the system through friction losses, cooling the engine components, exhaust, etc. The sum of these losses is termed as energy loss for the engine. The most effective way of increasing the percentage of useful work is to reduce the energy loss. One way of reducing the energy loss or increasing the efficiency of the engine is by using Thermal Barrier Coatings (TBC) on the various elements of the combustion chamber like valves, piston, cylinder surfaces, and rings. Ceramic materials are most commonly used as thermal barrier coating materials. To enhance the thermal, mechanical, and corrosion strengths of automotive parts, ceramic materials are applied, either as whole part or as coatings. Making the whole part from ceramics has many drawbacks, like brittleness, manufacturing difficulty etc. Instead of this, coating the metallic parts of the combustion chamber with ceramic gives the design flexibility. Coating of these elements by a ceramic with low thermal conductivity keeps the heat in the chamber and hence increases the temperature. The higher temperature in the chamber increases the efficiency of the engine, but requires higher temperature components. Ceramics materials have high temperature resistance and offer an excellent coating surface to reduce the amount of degradation and to extend the life. The temperature distribution in piston is crucial parameter influence the thermal stresses and deformations. In the present work the temperature distribution of piston with Zirconium coatingor without coatingis carried out by using finite element method. The 3-D model of the piston is generated in the Solidworks and the analysis is carried out in the commercial software ANSYS.**

I.INTRODUCTION

The increasing trends and demands in the automotive world, there is always tug and tie between the designer and customer. To cope with the existing competition in the modern times there is always need for great improvement in compactability of the engine models. In this chapter the brief introduction about Internal Combustion engine (IC engine) is presented. The various components, type and recent advancements in IC engine are also presented in this chapter. Recently the performance of IC engines is enhanced by using various thermal barrier coatings. The importance of various coatings in IC engines is also presented.

A. General

In case of Internal Combustion Engines, most of the heat generated during combustion process is absorbed by piston. This is direct heat loss to the piston may reduce Indicated Power and in turn the performance of Internal Combustion Engine. Engine coating with a ceramic thermal barrier can be applied to improve reliability and durability of engine performance and efficiency in diesel engines. In a conventional diesel engine, about 30% of the total energy is rejected to the coolant and it was reported that the engine coating may be a good solution. Main advantages of the engine coating concept were such as improved fuel economy, reduced hydrocarbon, smoke and carbon monoxide emissions, reduced noise due to lower rate of pressure rise and high energy in the exhaust gases. Thermal barrier coatings are generally applied on the cylinder head, piston and valves by plasma spray method. Coating these parts with ceramic also limits the negative effects of wear, friction, heating, corrosion and oxidation. It was also reported in a theoretical diesel cycle analysis that more the heat transfer decreases, the less energy will be lost, thus increasing the work output and the thermal efficiency. In another study, with engine coating an increase in engine power and decrease in specific fuel consumption, as well as significant reduction in exhaust gas emissions and smoke density have been addressed in comparison to the uncoated engine. Using the coated piston, the required temperature in the combustion chamber will be maintained. This will reduce the heat loss to the piston. This reduction in the heat loss will be used to burn the unburn gases there by reducing the polluted exhaust gases.

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II.METHODOLOGY

A. Modelingof Piston

Solidworks software is the leading product development solution for any manufacturing industry. It is a solid modeling computer aided design and computer aided engineering computer program. It is unique software developed for the manufacturing industry to meet the competing demands of engineering productivity, faster time to market, and improved product quality. By using this we are going to model piston crown.Our model of piston is to be modeled for analyzing its behavior while the engine is in running condition. The designed model of piston in Solidworks software as shown in Fig.1

Fig.1. Modeled piston in Solidworks

B.Ansys

Pressure ANSYS finite element analysis software enables engineers to perform the following tasks. Built computer models or transfer CAD models of structures, products or systems. Apply operating loads or other design performance conditions. Study physical responses, such as stress levels, temperature distributions, electromagnetic fields. Optimize a design early in the development process to reduce production costs. Do prototype testing in environments where it otherwise would be undesirable or impossible (for example, biomedical applications).

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear static analysis to a complex, nonlinear transient dynamic analysis for different engineering disciplines. ANSYS program is a general-purpose program meaning that we can use it for almost any type of Finite Element analysis virtually in any industry. General purpose also refers to the fact that the program can be suited in all disciplines of engineering- Mechanical, Electrical, Thermal, Electromagnetic, Electronic, Fluid, Bio-medical, this is also used as an educational tool in universities and other academic institutions. ANSYS is the finite element analysis software enables engineers to perform the following tasks:

- Build computer models or transfer CAD models of structures, products, components, or systems.
- Apply operating loads or other design performance conditions.

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III.FINITE ELEMENT ANALYSIS

A. Piston model Import and Mesh

The single cylinder four stroke diesel engine piston model using Solidworks discussed in the second chapter is used for thermal analysis. In this work the designed model of piston is saved in IGS format to import the design for analyzing process. In this work 0.01 is selected for meshing. Before meshing in geometry process we have to add the material for the piston. Here the model of piston head, the coating layer and the meshed model with coating surfaced piston as shown in Fig.2, Fig.3 and Fig.4.

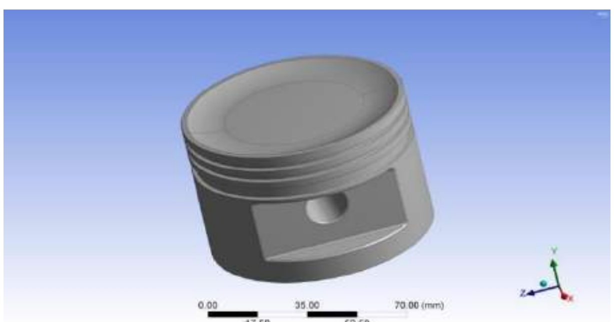

Fig.2. Uncoated Piston Head

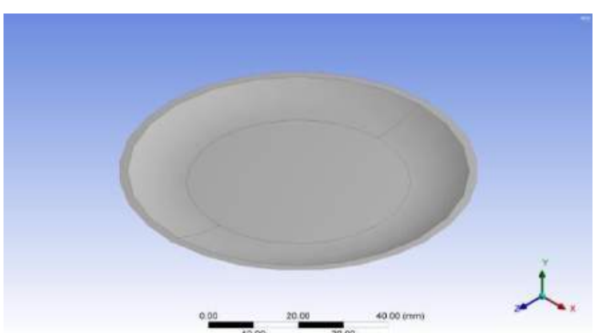

Fig.3. Coating Layer

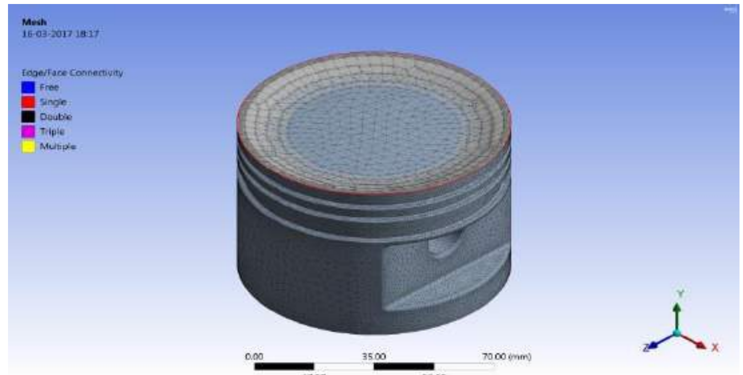

Fig.4. Meshed Piston Model with Coated layer

B. Steady State Thermal Analysis

Type of Analysis – Steady state thermal analysis

Temperature applied for Boundary Condition – 823k (550^0C)

Select the faces that the temperature is to be acted then apply the temperature. In this work not only the temperature process take place convection process also may take place. Same the faces that the convection process are also select to apply. In convection process the temperature dependent on Stangnant water – simpfi case.

Some of the additional heat energy in the cylinder can be converted into useful work, increasing power and efficiency. Reducing heat transfer also increases exhaust gas temperatures, providing greater potential for energy recovery with a turbocharger or possibly a thermoelectric generator. Additional benefits include protection of metal combustion chamber components from thermal stresses and reduced cooling requirements. A simpler cooling system would reduce the weight and cost of the engine while improving reliability.

The temperature distributions on conventional and Zirconium coated piston with Al alloy are shown in the figure. The maximum temperature value is determined as 550°C at the combustion chamber of conventional piston. The maximum temperature value of ceramic coating piston is determined as 605.8°C at the combustion chamber of coated piston .The combustion chamber has relatively larger heat transfer area compared to the other areas. Since the combustion chamber surface has been coated circumferentially with relatively very low conduction coefficient material, the heat transfer was reduced considerably to it. The surface temperature of the piston with Al alloy is found to improve approximately 9% - 10% via ceramic coating. The analyzed outputs are as shown in Fig.5 (a) , (b)& Fig.6 (a), (b).

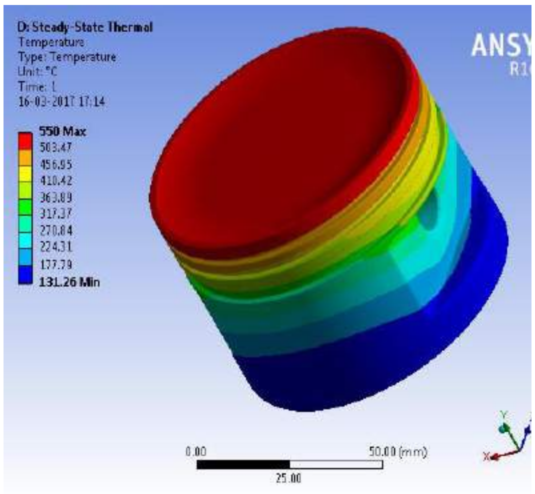

Fig.5. (a) Temperature distribution for uncoated piston

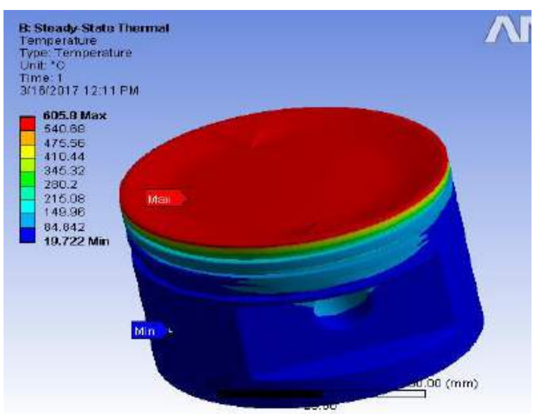

Fig.5. (b) Temperature distribution for coated piston

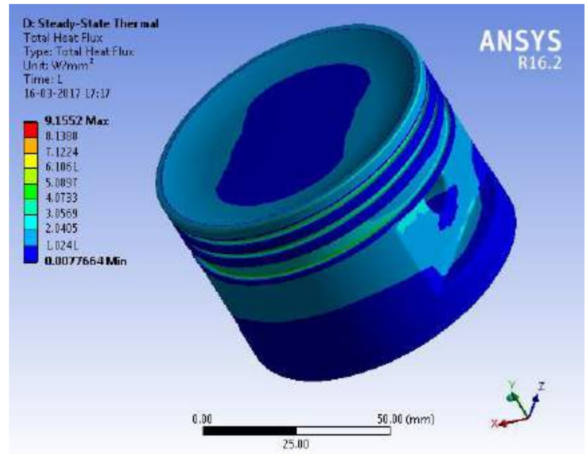

Fig.6. (a) Total Heat Flux For uncoated piston

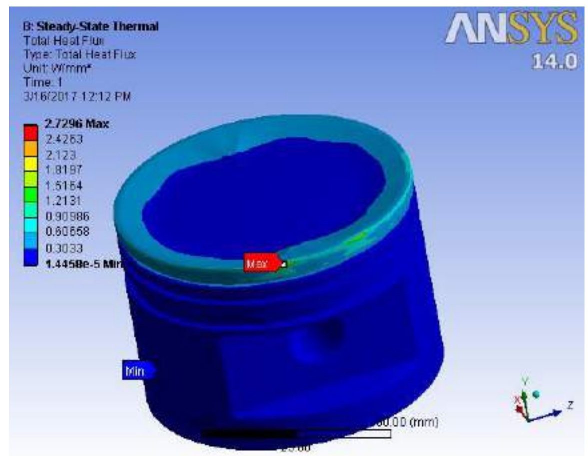

Fig.6. (b) Total Heat Flux For coated piston

IV. RESULTS AND DISCUSSIONS

The finite element results show that Zirconium coated piston is showing maximum surface temperature than Aluminum alloy piston for selected boundary conditions and coatings. It is due to lower thermal conductivity of Zirconium material than Aluminum alloy material. It is also observed from the results the surface temperature in uncoated piston is less than coated piston. The coatings act as thermal barrier on the surface of piston which resulting in lesser heat loss to the piston and maintaining higher temperature on the top surface of the piston. From the selected coating types and compositions the functional graded coatings are giving better performance compared with other coatings like single layer, composite and multilayer coatings. The performance characteristics of Zirconium coated piston diesel engine was investigated and compared with standard engine is displayed in figures (7&8).

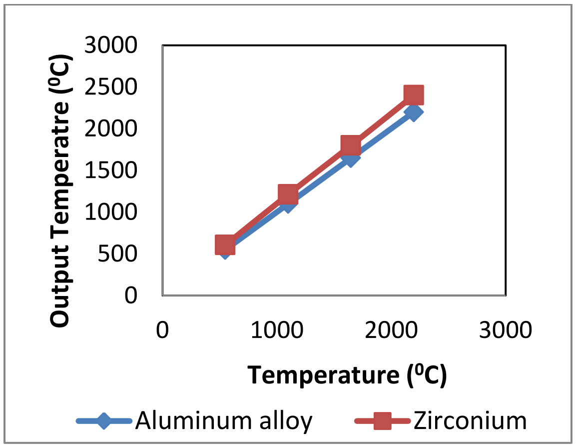

Fig.7. Chart of Temperature Difference of Uncoated & Coated Piston

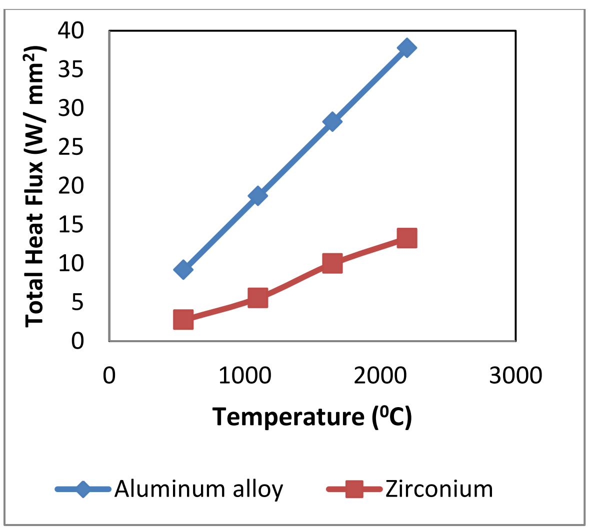

Fig.8. Chart of Total Heat Fluxof Uncoated&Coated piston

V. CONCLUSION

From the FEA results, the maximum temperature value of the coated piston was shown at the piston's combustion chamber. Therefore, this area must be coated intensively. The maximum surface temperature of the coated piston with material which has low thermal conductivity has improved approximately by 9% to 10%. Because of reduced heat losses, efficiency will improve.

VI. FUTURE SCOPE

In this work simulation is carried out for two types of ceramic coating materials and two types of piston materials. This work can be extended to study for various coating materials and for different compositions. The simulation results can also be validated with experimental results by conducting experiments with coated pistons.

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