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# Thermal Analysis of Coated Piston

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**ABSTRACT:** In this paper, dry and heat analysis examines standard pistons made with alloys for C26000, Al7068 and Ti10V-2Fe-3Al. The piston is one of the most important parts of the engine, intended to transfer power from the piston to the crankshaft via the connecting rod. The material used to make the piston must be lightweight, low cost, structural and physical, able to withstand high pressure and temperature conditions during the combustion process. In this project, we plan to build the piston model using SolidWorks modeling software first and then draw the mesh geometry using ANSYS software. For the analysis process of piston input conditions, most literature survey is exemplified. The high pressure of the combustion gas acts as a machine load and creates considerable pressure in the critical piston area and this causes large pressure in many areas of the piston. A detailed structural analysis is performed for different loading conditions such as maximum gas pressure loading, frictionless support and equivalent stress and elastic strain. In thermal analysis heat flow is the distribution of heat using the temperature level on the surface of the piston. We can determine the appropriate material by looking at all these analytical results..

**KEYWORDS:** C26000, Al7068, Ti-10V-2Fe-3Al, Analysis, Heat Distribution, Equivalent Stress, Equivalent Elastic Strain, Heat Flow, Deformation.

## I. INTRODUCTION

Traditionally, pistons are constructed from cast iron, which is characterized by its high specific weight and excellent wear resistance. Due to their substantial weight, cast iron pistons exhibit significant inertia forces. However, they are increasingly being replaced by pistons made from aluminum and its alloys, which are considerably lighter and demonstrate enhanced strength when combined with silicon. As research advances, various new material coatings have emerged, with ceramic coatings gaining popularity in the manufacturing sector. This type of coating improves engine performance parameters and thermal barrier coatings (TBC) protect piston components from the high temperatures generated during combustion, which can lead to engine part failures. Therefore, it is essential to evaluate the effectiveness of TBC in terms of temperature management. Thermal analyses have been conducted on both uncoated and ceramic-coated pistons. To optimize heat utilization and minimize heat transfer rates, the combustion chamber of an Internal Combustion (IC) engine must be properly insulated. Insulation within the cylinder can lead to extremely high temperatures, which conventional materials often cannot withstand. Consequently, the implementation of ceramic coatings is necessary, as they serve as thermal barriers that reduce heat transfer and endure elevated temperatures on the piston surface. The longevity of components, particularly the connecting rod, piston, and other internal cylinder parts, is compromised by the high temperatures present in internal combustion engines.

## II. LITERATURE SURVEY

### 1. B.A.Devan, G.Ravindra Reddy

International Journal of Emerging Trends in Engineering Research (IJETER), Vol. 3 No.6

In this study, Work is carried out to find out the thermal distribution on different Piston Materials used. In IC engine Piston is one of the most important and complex part, so it is important to maintain Piston in good condition in order to maintain the proper functioning of the engine. Piston mainly fails due to thermal Conditions. So as to search out proper thermal distribution different Piston Materials are considered.



**2. KANCHARLA RAJA SEKHAR, G. VIJAY PRAKASH**

International Journal of Research, Vol. 5 No.4

A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. Piston that transfer the combustive gases power to the connecting rod. To improve the efficiency of the engine there is a need to study about the piston. Pistons that are usually made up with alloy steels that show the grate resistant against thermal loads and structural loads. In the project we design a piston by using solid works 2016 design software and we did the structural load analysis and thermal analysis by applying various materials such as composites on piston in ansys workbench software.

**3. K Ramesh Babu, G Guru Mahesh and G Harinath Gowd**

Vol. 3, No. 1, January 2014 IJMERR.

The isotherms of cooper coated 4 stroke variable compression ratio petrol engines with pure gasoline operation and compared with conventional engine. The variation of Isotherms and heat flux with respect to radius, height of piston, liner, cylinder head and thermal analysis is also attempted in this paper. Copper coated engine showed higher temperature at salient points when compared with conventional engine at salient points like, on the top of the piston and liner. Temperatures were determined below SIT of the fuel. Deterioration of lube oil was not observed as temperatures were lower than the required combustion chamber wall temperature and this was found out so as to substitute in the equations of combustion model. First thermal analysis was done and analyzed the temperature distribution over the convectional engine and copper coated convectional engine. In the second stage structural analysis was carried out using the thermal loads obtained in the first stage. Three different types of materials were taken for analysis.

**4. S. Srikanth Reddy, Dr. B. Sudheer Prem Kumar**

International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 12, December 2013

In this study, firstly, thermal analyses are investigated on a conventional (uncoated) diesel piston, made of aluminium silicon alloy for design 1 and design 2 parameters. Secondly, thermal analyses are performed on piston, coated with Zirconium material by means of using a commercial code, namely ANSYS. The effects of coating on the thermal behaviours of the pistons are investigated. The finite element analysis is performed by using computer aided design software. The main objective is to investigate and analyze the thermal stress distribution of piston at the real engine condition during combustion process. This thesis describes the mesh optimization by using finite element analysis technique to predict the higher stress and critical region on the component. In this work, the main emphasis is placed on the study of thermal behaviour of functionally graded coatings obtained by means of using a commercial code, ANSYS on aluminium and zirconium coated aluminium piston surfaces. The analysis is carried out to reduce the stress concentration on the upper end of the piston i.e. (piston head/crown and piston skirt and sleeve). With using computer aided design NX/Catia software the structural model of a piston will be developed. Furthermore, the finite element analysis is done using Computer Aided Simulation software ANSYS.

**5. Soumen Pal, A Deore, A Choudhary, V Madhwani**

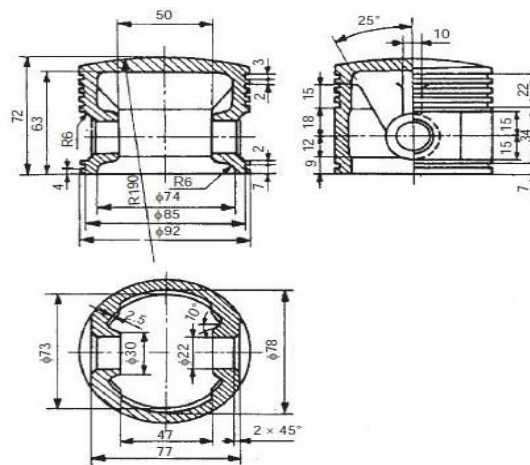
Analysis and experimental investigation of ceramic powder coating on aluminium piston

Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines. The diesel engine generally offers better fuel economy than its counterpart petrol engine. Even the diesel engine rejects about two thirds of the heat energy of the fuel, one-third to the coolant, and one third to the exhaust, leaving only about one-third as useful power output. Theoretically if the heat rejected could be reduced, then the thermal efficiency would be improved, at least up to the limit set by the second law of thermodynamics. Low Heat Rejection engines aim to do this by reducing the heat lost to the coolant. Thermal Barrier Coatings (TBCs) in diesel engines lead to advantages including higher power density, fuel efficiency, and multifuel capacity due to higher combustion chamber temperature. Using TBC can increase engine power by 8%, decrease the specific fuel consumption by 15-20% and increase the exhaust gas temperature by 200K. Although several systems have been used as TBC for different purposes, yttria stabilized zirconia with 7-8 wt.%yttria has received the most attention. Several factors playing important role in TBC life include thermal conductivity, thermo chemical stability at the service temperature, high thermo mechanical stability to the maximum service temperature and thermal expansion coefficient (TEC). This work mainly concentrates on the behaviour of three TBC powders under the same diesel engine conditions. This work finds out the best powder among yttria, alumina and zirconia to be used as a piston coating material i.e., the

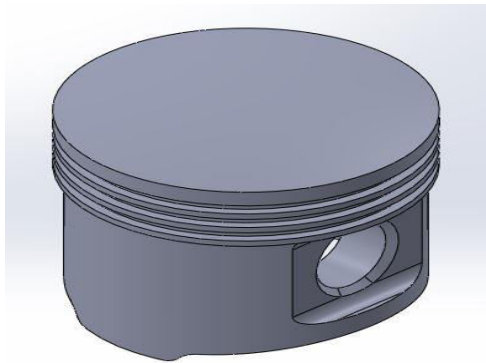
one resulting in lowest heat flux and low side skirt and bottom temperature has been chosen for the coating purpose. This work then analyses the coated sample for its surface properties such as hardness, roughness, corrosion resistance and microstructural study. This work aims at making it easier for the manufacturers choose the coating material for engine coating purposes and surface properties for operating them in their service period.

### III. METHODOLOGY

## 2D LAYOUT OF PISTON WITH DIMENSIONS



## PROCEDURE OF 3D MODELLING

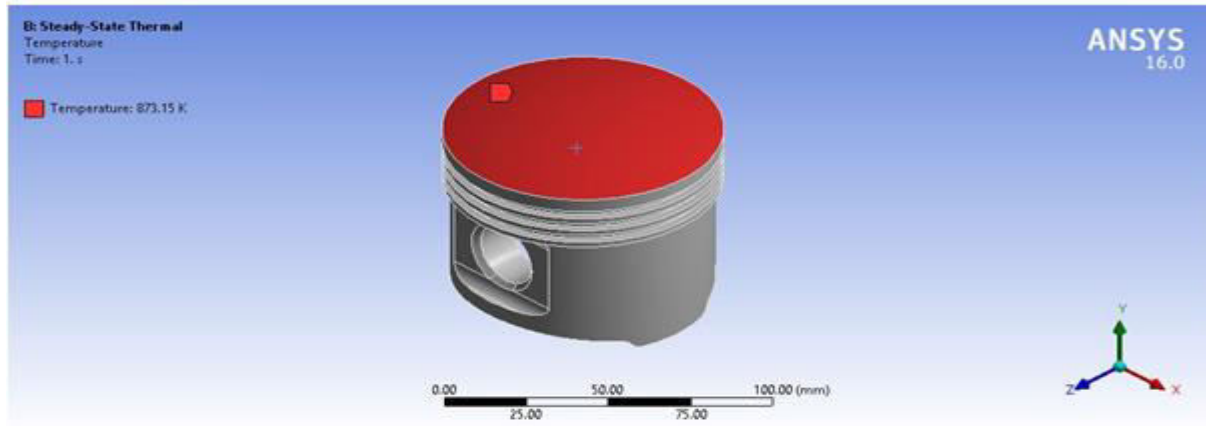


#### IV. THERMAL ANALYSIS

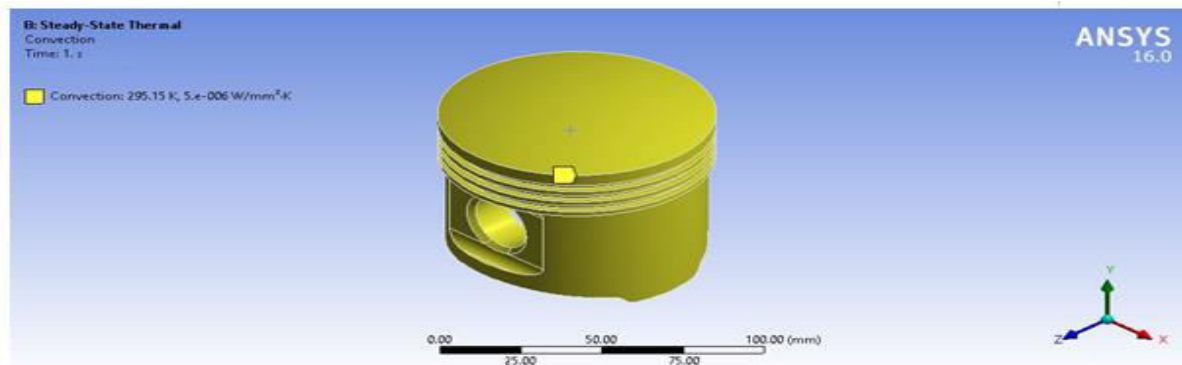
Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. Several methods are commonly used these are distinguished from one another by the property which is measured.

It is usual to control the temperature in a predetermined way either by a continuous increase or decrease in temperature at a constant rate (linear heating/cooling) or by carrying out a series of determinations at different temperatures (stepwise isothermal measurements). More advanced temperature profiles have been developed which use an oscillating (usually sine or square wave) heating rate (Modulated Temperature Thermal Analysis) or modify the heating rate in response to changes in the system's properties (Sample Controlled Thermal Analysis).

## THERMAL ANALYSIS PROCEDURE



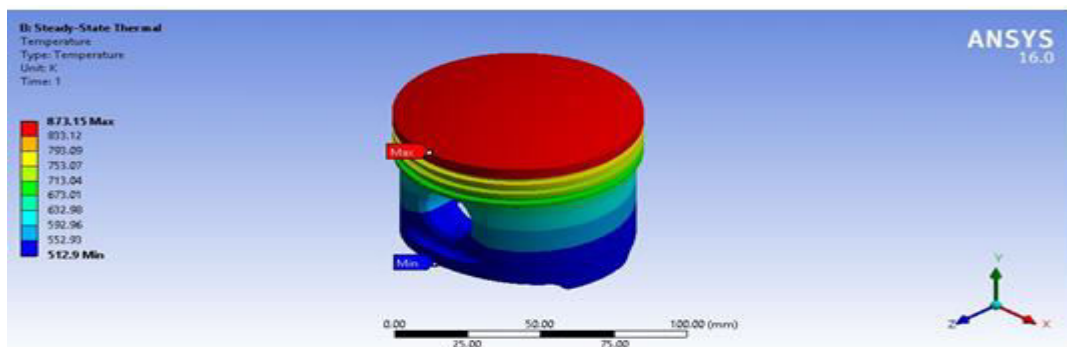
Temperature obtained during ignition is given at the top face of piston



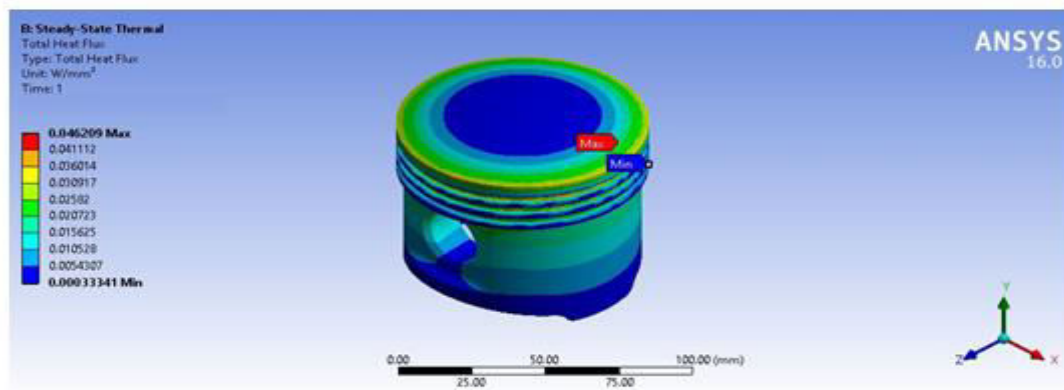
Convection is given at the remaining faces of piston to study the heat transfer characteristics

## V. RESULTS OF THERMAL ANALYSIS

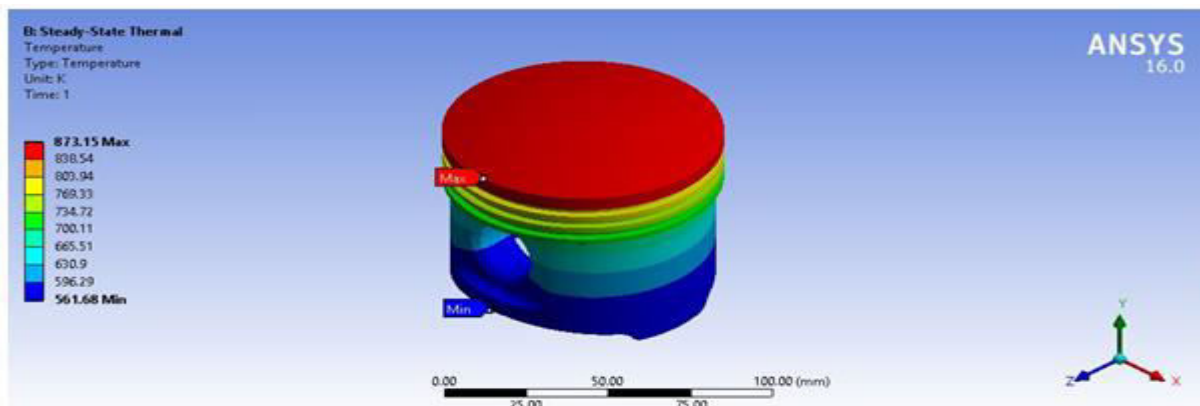
### 5. 1 ZIRCONIA



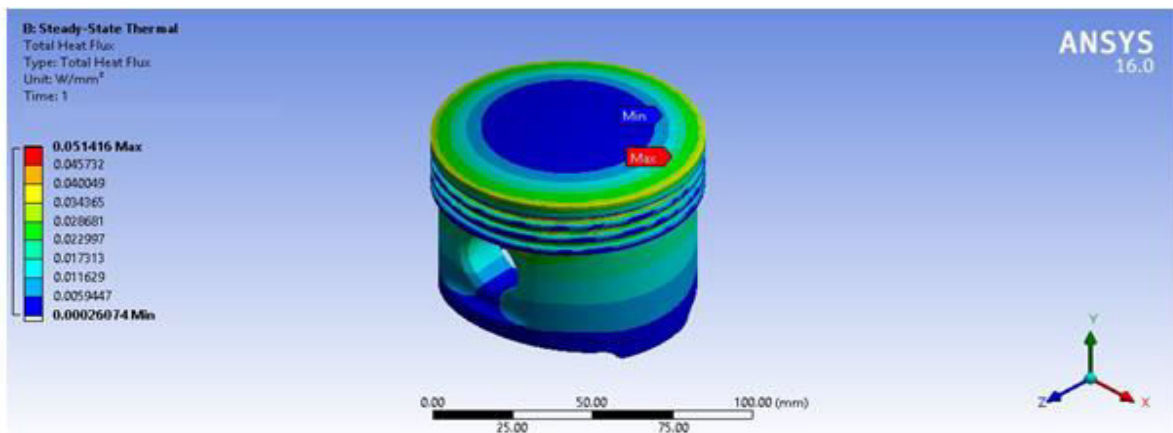
### TEMPERATURE DISTRIBUTION



### TOTAL HEAT FLUX 5.2 CHROMIUM NITRIDE



### TEMPERATURE DISTRIBUTION



### TOTAL HEAT FLUX

**VI. CONCLUSION**

Due to the time-consuming and costly nature of physical experimentation for testing purposes, Computational Fluid Dynamics (CFD) offers a more efficient and cost-effective alternative for conducting tests on models and analyzing results with minimal investment of time and resources. Consequently, after evaluating the outcomes using CFD Ansys Fluent, satisfactory and practical results have been achieved. This study employed CFD analysis through FLUENT to investigate the fluid flow and heat transfer characteristics of a solar tunnel dryer at varying solar temperatures. The combined effects of turbulence and fluid reattachment were identified as key factors contributing to the enhancement of the heat transfer rate. The results and discussions clearly indicate that an increase in solar radiation temperature leads to a gradual rise in system temperature, thereby heating the air within the system, which facilitates the drying process of stored items. Additionally, it was observed that the heat source does not disrupt the airflow paths within the chamber, maintaining velocity and pressure distributions within acceptable limits. Undoubtedly, a primary objective of the CFD analysis of the solar tunnel dryer is to improve the design process related to heat transfer and fluid flow.

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