THERMAL ANALYSIS OF COATED PISTON WITH DIFFERENT MATERIALS

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ABSTRACT

Piston is made of aluminum alloys is a fundamental phase in inside combustion engine. When the combustion of gasoline take vicinity insides the engine cylinder, excessive strain and excessive temperature will be developed as the engine will function at excessive load and at excessive speed. As a end result of this excessive thermal and excessive structural stresses in the piston is produced inner the engine cylinder and if these stresses exceeds the designed values, the failure of piston take place. To keep away from the failure of the piston thermal and structural depth must be decreased to protected allowable limits. In this work an try is made to limit the thermal and structural stress depth by means of covered the piston with ceramic material. The ceramic coatings are used as thermal barrier coatings owing their low conductivity and their tremendously excessive coefficient of thermal expansion. The structural and thermal analyses are carried out on the piston covered with zirconium, chromium nitride, titanium nitride, chromium oxide and aluminum oxide fabric the usage of the ANSYS software. The outcomes of coating on the thermal behaviors of the piston are investigated. The foremost goal is to inspect and analyze the structural and thermal stress distribution of the piston at the actual engine circumstance at some point of combustion process. The evaluation is carried out to decrease the stress attention on the top quit of the piston .i.e. piston head/crown and piston skirt and sleeve the usage of ANSYS software. The end result got is in contrast to pick the higher fabric for piston manufacturing.

Index: Heat flux, stress, pressure, engine, heat transfer, temperature field of piston, coatings.

I. INTRODUCTION

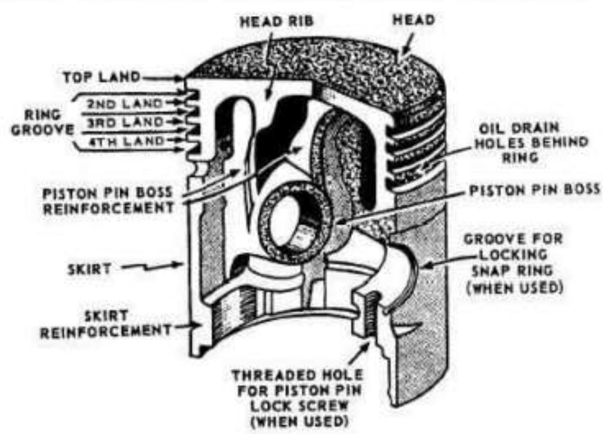
Normally, piston made of solid iron material, having excessive particular weight and precise resistance to wear. Piston, made of forged iron, possess excessive inertia forces due to the fact of excessive particular weight. They are changed with the aid of the piston made up of Aluminum and its alloys. They are very mild in weight and possess excessive energy when blended with silicon. As the lookup progresses, countless new fabric coatings are available. Ceramic coating is additionally turning into famous in the manufacturing industry. This coating enhances the overall performance of the engine parameters. TBC prevents the piston components from the excessive temperature producing from the combustion. The excessive temperature is accountable for the failure of the engine parts. Thus, there is are a requirement to locate how superb this TBC is in time period of temperature. Thermal evaluation on the piston is achieved for uncoating and ceramic coating.

The combustion chamber of Internal Combustion (IC) engine ought to be insulated for the high-quality utilization of warmness in order to preserve a low fee of warmth transfer. Temperatures upward jostle to very excessive values due to the fact of insulation in the cylinder. Commonly used traditional materials are unable to undergo very excessive temperatures in IC engines. Hence, there is a requirement to use ceramic coatings, which acts as a thermal barrier, which helps to minimize warmth switch and stand up to excessive temperatures on the floor of the piston. The existence of components, mainly connecting rod, piston and different inner components of the cylinder are affected due to excessive temperatures in the inner combustion engine.

Introduction to piston

The piston is cylindrical in form and is succesful of taking stress electricity produced via the gases burnt interior the cylinder to energy the crankshaft thru connecting rod in a non-stop manner. The piston additionally performs compression of gasses interior the cylinder alongside with the exhaust of gasses after the entire combustion process.

All the activities, stated above occur concurrently one after the other. It is a reciprocating member which runs the shaft of the engine via transferring energy.



II. LITERATURE REVIEW

2.1 OVERVIEW OF LITERATURE REVIEW

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 HarinathGowd**

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. SudheerPrem 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.

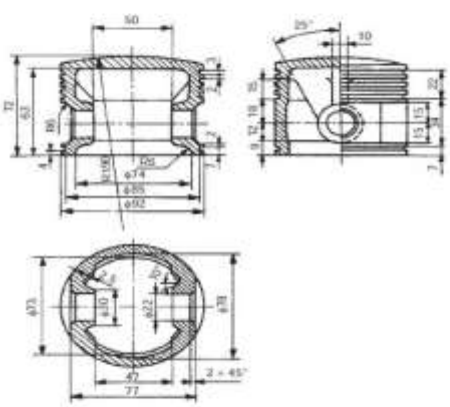
III. DESIGN AND ANALYSIS

SOILD WORKS

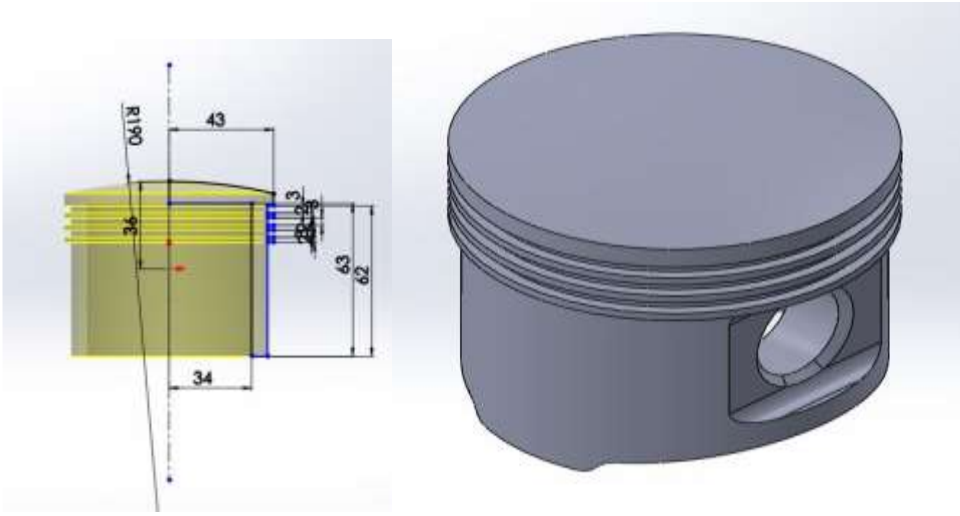
SolidWorks (stylized as SOLIDWORKS), is a stable modelling computer-aided diagram (CAD) and computer-aided engineering (CAE) software program application that runs on Microsoft Windows. The SolidWorks is produced by using the DASSAULT SYSTÈMES— a subsidiary of Dassault Systems, S. A. primarily based in Velizy, France— due to the fact 1997.

SolidWorks is presently used by means of over two million engineers and designers at greater than 165,000 corporations worldwide. In 2011–12, the fiscal income for SolidWorks was once suggested $483 million.

2D LAYOUT OF PISTON WITH DIMENSIONS



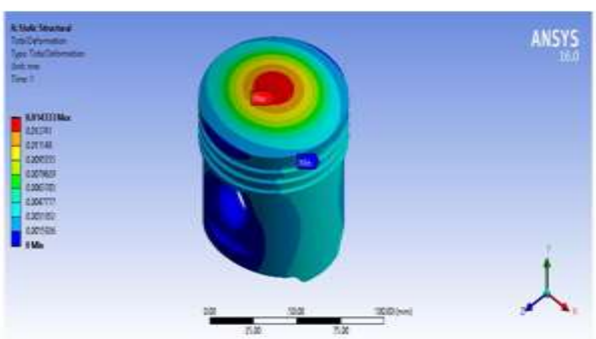
PROCEDURE OF 3D MODELLING

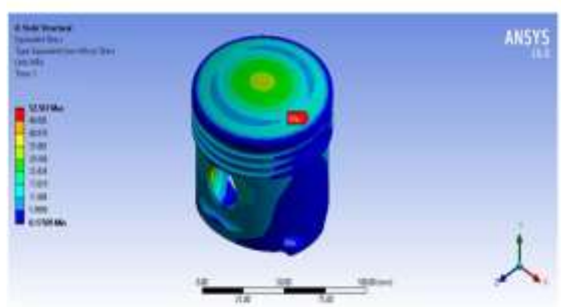


3D model of piston created using SOLIDworks

RESULTS OF ZIRCONIA

Structural **Total deformation**





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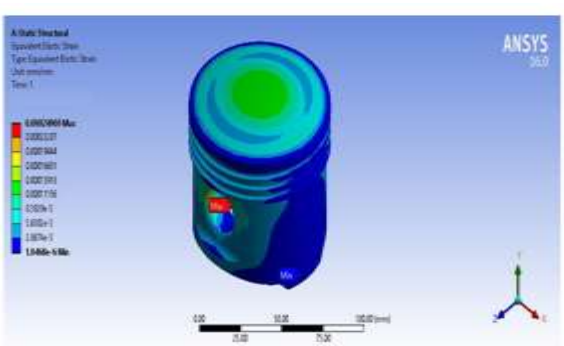
Stress distribution



CHROMIUM NITRIDE

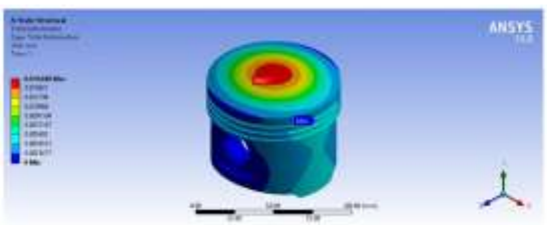
Chromium Nitride is an extremely hard, inert, thin film coating that is applied primarily to precision metal parts. Chrome Nitride (CrN) offers greater temperature resistance than TiN and is an ideal choice in high temperature environments. CrN also performs well in corrosive environments and in sliding wear applications.

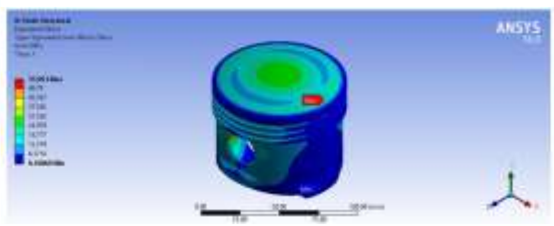
PROPERTIES OF CHROMIUM NITIRDE

SL. NO	PROPERTIES	VALUE
1	DENSITY	5.9G/CM^3
2	YOUNG'S MODULUS	200GPA
3	POISSON RATIO	0.2
4	THERMAL CONDUCTIVITY	4 W/MK

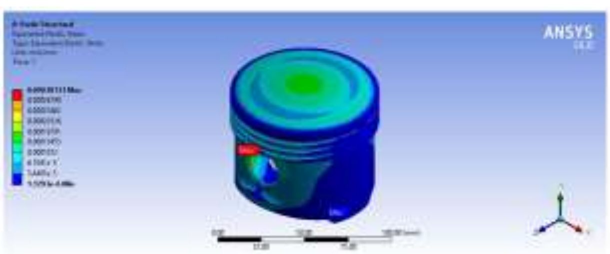
RESULTS OF CHROMIUM NITIRDE

Structural **Total deformation**





Stress distribution



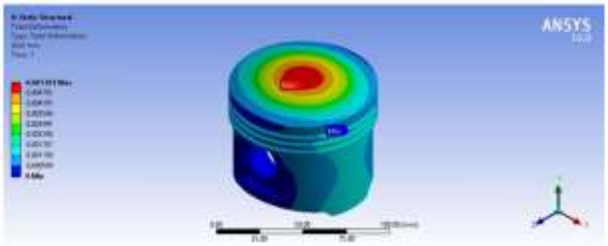
Strain distribution

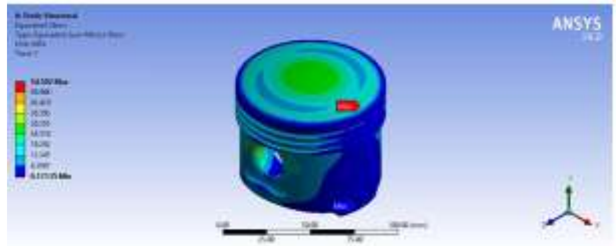
TITANIUM NITIRDE

Titanium Nitride is an extremely hard, inert, thin film coating that is applied primarily to precision metal parts. Titanium Nitride (TiN) is the most common PVD hard coating in use today. TiN has an ideal combination of hardness, toughness, adhesion and inertness.

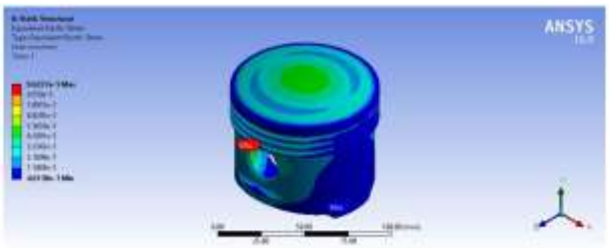
RESULTS OF TITANIUM NITIRDE

Structural **Total deformation**





Stress distribution



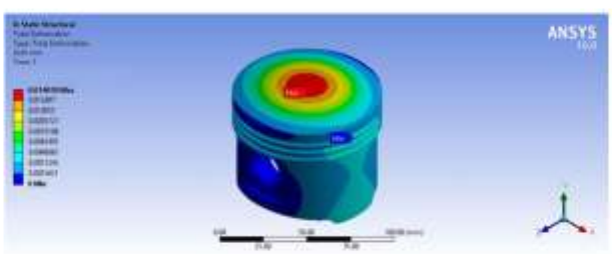
Strain distribution

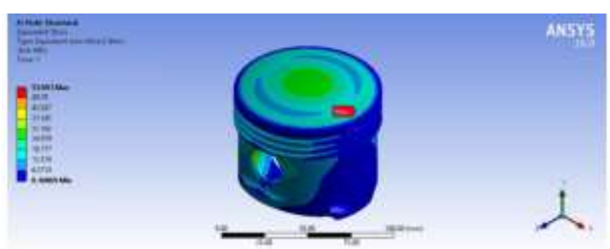
CHROMIUM OXIDE

Chromium oxide powder is used as a coating material this process is carried out with the help of Plasma Spray Process. It was designed to produce dense, hard, wear resistant coatings. The coatings also have excellent self-mating and anti-galling properties. This material is recommended for resistance to wear by abrasive grains, hard surfaces, particle erosion and cavitation, all at temperatures below 540℃ (1,000℉). These coatings are insoluble in acids, alkalis and alcohol. When properly sealed, they are recommended for use in corrosive chemical environments in temperatures up to 177-205℃ (350-400℉). Additionally, these coatings can also be useful in the textile industry on any machine element which comes into contact with fibers and threads, where a relatively coarse, brush finished, hard, wear and corrosion resistant ceramic coating is required.

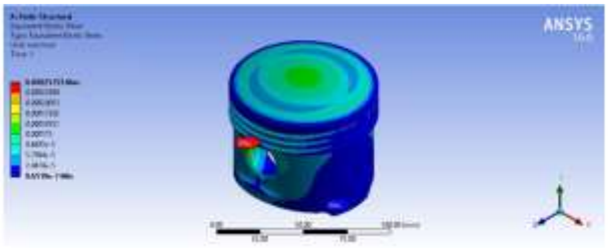
RESULTS OF CHROMIUM OXIDE

Structural **Total deformation**





Stress distribution



Strain distribution

ALUMINIUM OXIDE

An improved process for the formation of an aluminum oxide protective coating has been developed. Barriers created with this new, patented alpha-Al_2O_3 oxide coating process have wide applications for making many useful alloys, super alloys, and metallic compounds. Alpha-Al_2O_3 applied by conventional processes inherently cracks and spalls from the substrate surface. The major weakness of conventional aluminum oxide coatings is their susceptibility to cracking and spalling. The overall process of mixed-oxide formation on an alloy indirectly causes spalling during oxidation of the alloy in air or oxygen. Voids are formed which become segregation sites for sulfur. Accumulation of sulfur in such voids causes separation of the oxide from the alloy. The process is solved by the use of a process medium that allows only single alpha-Al_2O_3 oxide to form, preventing the formation of voids and eliminating segregation of sulfur to the interface region. This makes possible the creation of several different alloys and super alloys that all have their surfaces protected by a single oxide, alpha Al_2O_3.

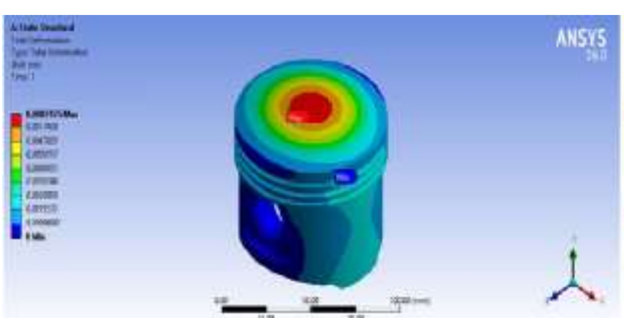
PROPERTIES OF ALUMINIUM OXIDE

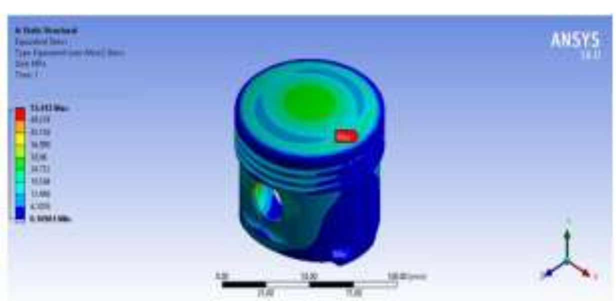
SL. NO	PROPERTIES	VALUE
1	DENSITY	3.89G/CM^3
2	YOUNG'S MODULUS	375GPA
3	POISSON RATIO	0.22
4	THERMAL CONDUCTIVITY	35W/MK

RESULTS OF ALUMINIUM OXIDE

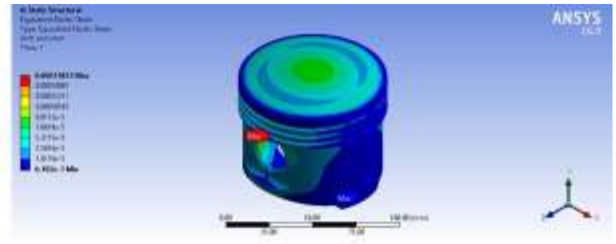
Structural

Total deformation





Stress distribution



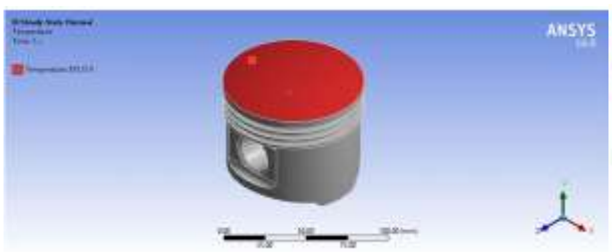
Strain distribution

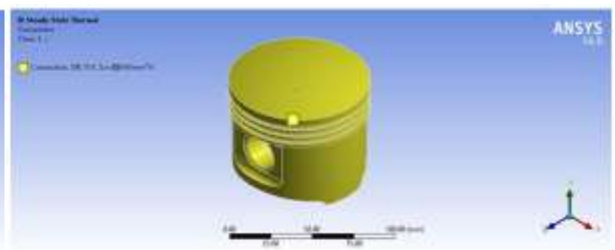
THERMAL ANALYSIS

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



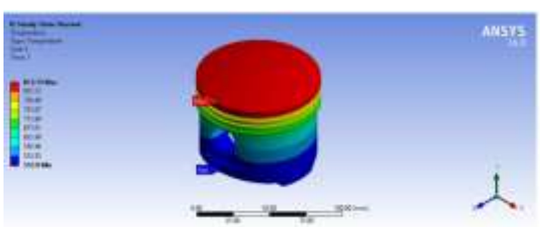


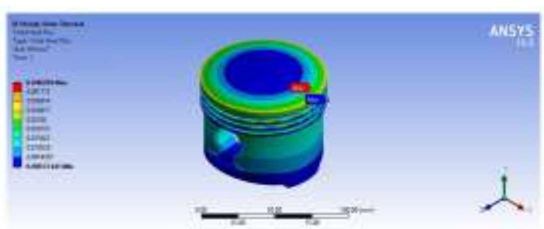
Temperature obtained during ignition is given at the top face of piston

RESULTS OF THERMAL ANALYSIS

ZIRCONIA

TEMPERATURE DISTRIBUTION

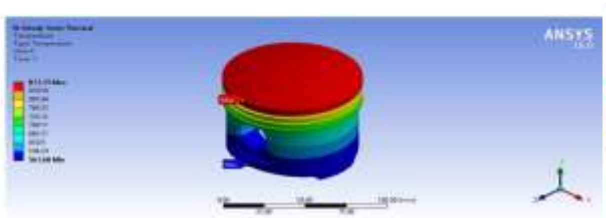


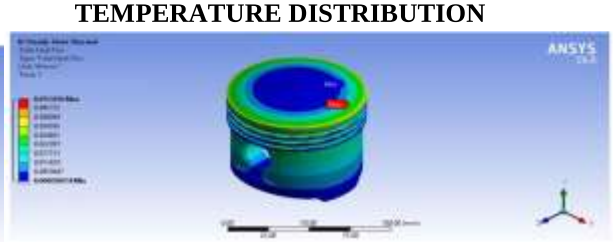


TOTAL HEAT FLUX

CHROMIUM NITRIDE

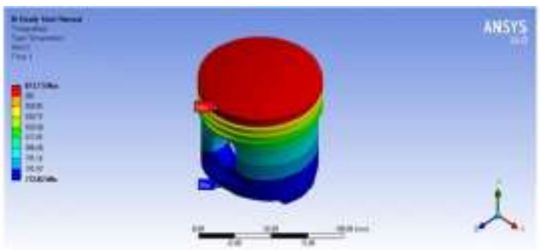
TEMPERATURE DISTRIBUTION

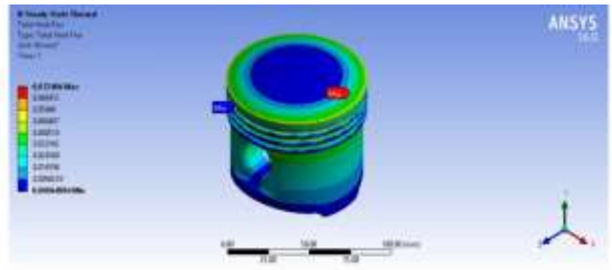




TOTAL HEAT FLUX

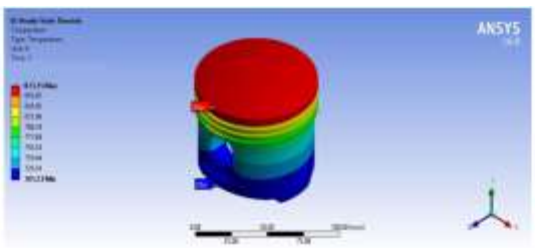
TITANIUM NITRIDE **TEMPERATURE DISTRIBUTION**

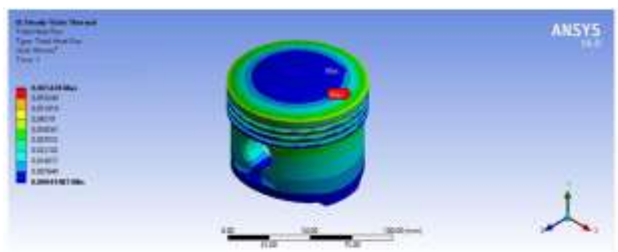




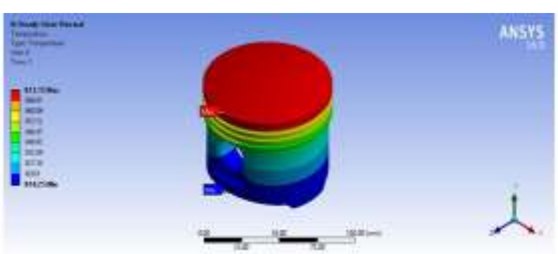
TOTAL HEAT FLUX

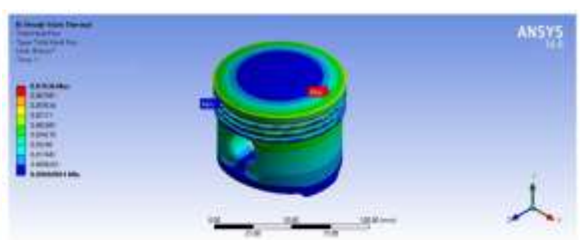
CHROMIUM OXIDE **TEMPERATURE DISTRIBUTION**





TOTAL HEAT FLUX
ALUMINIUM OXIDE **TEMPERATURE DISTRIBUTION**





TOTAL HEAT FLUX
TABULATED RESULTS OF STRUCTURAL ANALYSIS

COATING MATERIAL	TOTAL DEFORMATION (MM)		STRESS (MPA)		STRAIN (MM/MM)		MASS (KG)
	MIN	MAX	MIN	MAX	MIN	MAX	
ZIRCONIA	0	0.014	0.175	52.5	1.04E-6	2.49E-4	0.79

CHRO MIUM NITRIDE	**0**	**0. 016**	**0 .168**	**5 5.9**	**1.12 E-6**	**3E -4**	**0 .78**
TITAN IUM NITRIDE	**0**	**0. 005**	**0 .171**	**5 4.5**	**4.01 E-7**	**9. 62E-5**	**0 .69**
CHRO MIUM OXIDE	**0**	**0. 014**	**0 .168**	**5 5.9**	**9.65 E-7**	**2. 57E-4**	**0 .69**
ALUM INIUM OXIDE	**0**	**0. 008**	**0 .169**	**5 5.4**	**6.19 E-7**	**1. 58E-4**	**0 .51**

TABULATED RESULTS OF THERMAL ANALYSIS

COATING MATERIAL	**TEMPERATURE (K)**		**TOTAL HEAT FLUX (W/MM^2)**	
	MIN	**MAX**	**MIN**	**MAX**
ZIRCONIA	**512.9**	**873.15**	**3.3E-4**	**0.046**
CHROMIUM NITRIDE	**561.6**	**873.15**	**2.6E-4**	**0.051**
TITANIUM NITRIDE	**772.8**	**873.15**	**6.4E-4**	**0.072**
CHROMIUM OXIDE	**701.2**	**873.15**	**4.1E-4**	**0.065**
ALUMINIUM OXIDE	**814.2**	**873.15**	**6.0E-4**	**0.076**

IV. CONCLUSION

The end result confirmed that covered piston with ceramic cloth has higher overall performance in stress and deformation in assessment with the specific coating substances namelyzirconia, chromium nitride, titanium nitride, chromium oxide and aluminum oxide below the joint motion of the thermal and mechanical loads. The preliminary thermo-mechanical FE evaluation used to be introduced in the thesis. Its most important motive was once to examine behavior of the piston made of distinctive kind of substances beneath thermal load. The new composite cloth was once mainly viewed due to low hysteresis of the coefficient of thermal growth for heating and cooling. The got effects suggests that the new composite piston has round 2.5 instances decrease radial displacements than the proper one. Therefore, a dimensional balance of the piston is strongly improved. The radial issue of the stress is additionally a good deal decrease for the new composite piston as well. Combined CAD and ANSYS, get the effects of stress and deformation and temperature when the piston beneath the mechanical loads, thermal masses and meeting the mechanical and thermal load. And get the discussion as below:

The temperature is greater at the combustion chamber facet of the deviation from the centre of the piston. Highest temperature seems in the throat of the exhaust port of the combustion chamber adjoining side, the temperature reached 350°C. The temperature of the piston ring location is extraordinarily vital for the reliability of the engine, if the temperature of the ring region is too high, it will make the lubrication oil to be deterioration even carbonization. It reasons the piston ring bonded, loss of exercise to make the piston fast wear, deformation.

The stress beneath the mechanical action, the most stress cost of the piston is 390 Mpa, and the most stress of different components beneath 100Mpa. For the tensile energy of the piston, it's having an ample energy margin.

When beneath the meeting of mechanical and thermal loads, the cost of the biggest displacement is 0.016 mm, inflicting at the middle of the piston top. The stress of the pinnacle of the piston is often brought on through the temperature load and the deformation of the piston is triggered by using the thermal expansion.

From the above mentioned effects it is clear that zirconia coating offers a comfy consequences and it is extraordinarily advocated as a coating cloth for improvising each mechanical and thermal residences of piston..

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