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Computational Thermal Analysis of Fused Calcia Zirconia Ceramic Coating Over Piston Head

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Abstract: *This project is aimed at improving the performance of diesel engine. Diesel engines burn fuel oils, which require less refining and are cheaper than higher-grade fuels such as petrol. During the combustion process, the stored chemical energy in the fuel is converted to the thermal, or heat, energy. The pressure in each cylinder is about 230 psi and creates engine power of about 55 BHP. During combustion, the top surface of the piston faces the maximum temperature. Due to conduction, this heat is transferred throughout the piston. As heat is generated continuously in the piston surface, conduction takes place rapidly allowing more heat to be conducted to the piston. Due to this, some amount of heat which is to be combusted is lost to the pist on. Also the piston tends to get expanded due to the high temperature of heat which is transferred to piston. In this study, a coating is done on the top surface of the piston to reduce the heat which is being transferred throughout the piston. Functionally graded materials which have a low thermal conductivity is been applied as coating to the top surface of the piston. Nano coating technology is obtained for the coating process. Thermal analysis is done on both the uncoated and coated piston and the stress results are compared. The thermal stresses obtained are compared with the numerically obtained values. The thermal stress of coated piston is found less than the uncoated piston which results in reduced heat transfer in the piston.*

Keywords: *piston crown, thermal barrier coating*

I. Introduction

Functionally graded materials are of widespread interest because of their superior properties such as corrosion, erosion and oxidation resistance, high hardness, chemical and thermal stability at cryogenic and high temperatures. These properties make them useful for many applications, including Thermal Barrier Coating (TBC) on metallic substrates used at high temperatures in the fields of aircraft and aerospace, especially for thermal protection of components in gas turbines and diesel engines.

Thermal barrier coatings have been successfully applied to the internal combustion engine, in particular the combustion chamber in order to simulate adiabatic changes. The objectives are not only for reduced in-cylinder heat rejection and thermal fatigue protection of underlying metallic surfaces, but also for possible reduction of engine emissions and brake specific fuel consumption. The application of TBC reduces the heat loss to the engine cooling-jacket through the surface exposed to the heat transfer such as the cylinder head, liner, piston crown and piston rings.

The insulation of the combustion chamber with ceramic coating affects the combustion process and, hence, the performance and exhaust emissions characteristics of the engines improve. On the other hand, the desire of increasing the thermal efficiency or reduce fuel consumption of engines lead to the adoption of higher compression ratios, in particular for diesel engines, and reduced in-cylinder heat rejection. Both of these factors cause increased mechanical and thermal stresses of materials used in combustion chamber.

However oxidation and thermal mismatch are identified as two major factors influencing the life of the coating system. The coatings are permeable to the atmospheric gases and liquids resulting in the oxidation of the bond coat and spalling of the coating. The functionally graded coatings were used to reduce the mismatch effect. Therefore the thermal expansion and interfacial stresses are an alternative approach to conventional thermal barrier coatings.

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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 200K. Although several systems have been used as TBC for different purposes, fused calcia stablised zirconia with 7-8 wt. % while calcia has received the most attention. Several important factors playing important roles in TBC lifetimes including thermal conductivity, thermal, chemical stability at the service temperature, high thermo mechanical stability to the maximum service temperature and at last but not least the thermal expansion coefficient (TEC).

The diesel engine with its combustion chamber walls insulated by ceramics is referred to as Low Heat-Rejection (LHR) engine. The LHR engine has been conceived basically to improve fuel economy by eliminating the conventional cooling system and converting part of the increased exhaust energy into shaft work using the turbocharged system. A large number of studies on performance, structure and durability of the LHR engine have been carried out since Kamo and Bryzik presented a new concept of the LHR engine 041 combined with the turbo compound system. Although promising the results of the investigations have been somewhat mixed. Most have concluded that insulation reduces heat transfer, improves thermal efficiency, and increases energy availability in the exhaust. However contrary to the above expectations some experimental studies have indicated almost no improvement in thermal efficiency and claim that exhaust emissions deteriorated as compared to those of the conventional water-cooled engines. Plasma spray is the most common method of depositing TBCs for diesel applications. It creates a splat structure with 10-20 % volume fraction of voids and cracks. High porosity of this structure makes it an ideal choice for TBC. Widespread application has been limited by insufficient lifetimes and the cost.

TBCs for diesel engines have generally been accepted to improve engine thermal efficiency and reduce emissions as well as specific fuel consumption because of their ability to provide thermal insulation to the engine components. The generally known principle that increased operation temperatures in energy conversion systems lead to an increase in efficiency, fuel savings and reduced emissions as particles, carbon monoxides (CO), hydrocarbons (HC) and limited reductions of NOx emissions have, over many decades, promoted R&D activities in the field of TBCs development.

II. Design And Modelling Procedure In Ansys

Engine Displacement:

Cylinder bore diameter = 101.68mm
Stroke length = 88.46mm
Number of cylinders = 8
Engine displacement = bore X bore X 0.7854 X number of cylinders
Engine displacement = 101.68 X 101.68 X 88.46 X 8
Engine displacement = 5746440.23 mm^3

Stroke Length:

Stroke Length = engine displacement / (bore X bore X 0.7854 X number of cylinders)
Engine Displacement = 5749031.43 mm^3
Cylinder bore diameter = 101.68 mm
Number of cylinders = 8
Stroke Length = engine displacement / (bore X bore X 0.7854 X number of cylinders)
Stroke Length = 349.8486 / (4.000 X 4.000 X 0.7854 X 8)
Stroke Length = 88.46 mm

***Cylinder Bore Diameter*:**

Cylinder bore diameter = square root of [engine displacement/(stroke X 0.7854 X number of cylinders)]
Engine Displacement = 350 mm^3
Stroke Length = 88.46 mm^3
Number of cylinders = 8
Cylinder bore diameter = square root of [engine displacement / (stroke X 0.7854 X number of cylinders)]
Cylinder bore diameter = √[349.8486 / (3.480 X 0.7854 X 8)]
Cylinder bore diameter = 101.68 mm

Example

NASCAR® has a 5880437.86 mm^3 maximum engine size rule. If we use a 3.480" crank, what is biggest bore allowed?
Engine Displacement = 5880437.86 mm^3
Stroke Length = 88.462
Cylinder bore diameter = square root of [engine displacement/(stroke X 0.7854 X number of cylinders)]
Cylinder bore diameter = √[5880437.86 / (88.462 X 0.7854 X 8)]
Cylinder bore diameter = 102.85 mm
Formula For Milling Pistons

(For 4032 material only)
Piston dome cc's to gram conversion: 1cc (volume) = 2.8 grams (weight)
This is a good way to remove excess dome without having to re-cc piston: Mill a small amount and re-weight piston until total reduction is reached.

Example:
A piston has 12.5cc effective dome volume. The desired effective dome volume is 10.5cc.
To remove 2.0cc, cut 5.6 grams (2 X 2.8) from the piston dome.
Compression Ratio is given as….
Compression ratio = (swept volume + total chamber volume) / total chamber volume
It is important that we understand two terms and their relationship to compression ratio: Swept Volume and Total Chamber Volume. Swept Volume is the area the piston travels through bottom dead center to top dead center. Total Chamber Volume is all the area above the piston at top dead center. This would include the area above the piston in the cylinder block, the area of the compressed head gasket, the combustion chamber, the valve pocket, and the dome of the piston.
The compression ratio is the relationship of the swept volume to the total chamber volume. in cubic centimeters.

Cylinder head cc = 72180mm^3
Piston = flat top with two valve pockets that measure a total of 101.68 mm
Head gasket = 101.68 mm round and 0.966 mm thick when compressed
Deck clearance = The piston at top dead center is 0.2542 mm below the surface of the deck
Gasket cc = bore X bore X compressed thickness X 12.8704
Gasket cc = 4.000 X 4.000 X 0.038 X 12.8704 = 9987.30 mm^3
Deck clearance volume = bore X bore X deck clearance X 12.8704
Deck clearance volume = 4.000 X 4.000 X 0.010 12.8704
Deck clearance volume = 2.059 x10^3 mm
Total chamber volume = 86070 mm^3

Now we are finally ready to calculate the compression ratio.
Swept volume = 716620 mm^3
Total chamber volume = 86070 mm^3
Compression ratio = (716.16 + 86.07) / 86.07
Compression ratio = 9.33:1

Total Combustion Chamber Volume For a Specific Compression Ratio
Cylinder head chamber volume = swept volume / (desired compression ratio - 1)
Swept volume = 716620 mm^3
Desired compression ratio = 11:1
Cylinder head chamber volume = 716.62 / (11:1 - 1)
Cylinder head chamber volume = 71660 mm^3

III. Cylinder Head Deck Machining To Reduce Total Chamber Volume

Cylinder head deck material removal = (current chamber volume - desired chamber volume) X deck material per cc By experience, we have learned that a small block Chevy cylinder head will need 0.006" deck removed for each cc we want to reduce. An open chamber big block will take 0.005" per cc. These numbers will put us in the ballpark. Always check by "cc-ing" the cylinder head chamber volume for accuracy.
Current chamber volume = 86.07 cc
Current chamber volume = 71.66 cc
Deck material removal per cc = 0.1525 mm/cc
Deck material to remove = (current chamber volume - desired chamber volume) X deck material per cc
Deck material to remove = (86.07 - 71.66) X 0.1523 mm
Deck material to remove = 2.18612 mm

To create an area in a place, which is away from the global origin then the working plane has to offset to that plane by selecting a key point on that plane. To create an area in a plane, which is not parallel to the X-Y plane, there is an option to align working plane with required plane.

For attaching two adjacent entities properly glue operation is used. In that line, areas and volumes can be attached to the nearby entities. This glue operation is very useful one while creating volumes by selected areas and creating areas by selected lines. The user can alter the tolerance limit of the glue operation. The model was fully created using different ANSYS commands like points, lines, areas, volumes, etc.

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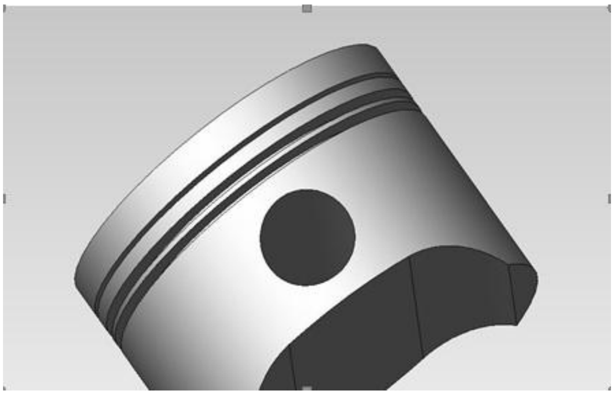
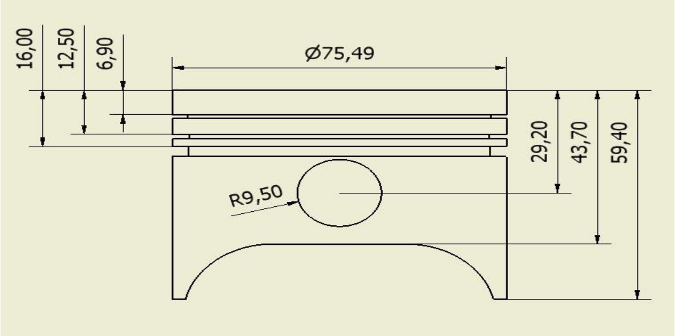
It is important to calculate the piston temperature distribution in order to control the thermal stresses and deformations within acceptable levels. The temperature distribution enables us to optimize the thermal aspects of the piston design at lower cost, before the first prototype is constructed. As much as 60% of the total engine mechanical power lost is generated by piston ring assembly. The piston skirt surface slides on the cylinder bore. A lubricant film fills the clearance between the surfaces. The small values of the clearance increase the frictional losses and the high values increase the secondary motion of the piston. Most of the Internal Combustion (IC) engine pistons are made of an aluminum alloy which has a thermal expansion coefficient,80% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behavior is extremely crucial in designing more efficient engine.

Steps involved in modeling of piston

1. Points have been created first with the graphical plot.
2. Lines are created on the consecutive Key points
3. Area is created by using lines
4. Solid model is created as shown in fig, extrude about axis command is used for creating model



Piston 3D Model



Piston 2D Model

IV. Meshing

The collection of nodes and elements form the finite element mesh. Each element is of simple shape for which the finite element program has information to write the governing equations in the form of stiffness matrix. The unknowns at each element are the stress and displacement at the node points, which are the points at which the elements are connected. The finite element program will assemble the stiffness matrix for the entire model. This stiffness matrix is solved for the unknown displacements, stress given the known forces and boundary conditions. From the displacements at the nodes, the stress in each element can be calculated.

Steps Involves For Meshing

The steps followed to mesh the modeled cross section of the piston are explained briefly as follows

Piton	No of elements
Without coating	175230
With coating	178740

Meshed element numbers

Element type

Before meshing model, element attributes should be specified based on the material, analysis and so on the required results. The following are the elements used in this analysis.

Element type for base material – SOLID 86

This element is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is now available in two forms: Structural Solid and Layered Solid. The element is well suited to modeling irregular meshes (such as those produced by various CAD/CAM systems).

This element is used for modeling and meshing of basic piston material.

Element type for coating material – SHELL 93

Shell 93 is particularly well suited to model curved shells. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The deformation shapes are quadratic in both in-plane directions. The element has plasticity, stress stiffening, large deflection, and large strain capabilities

This element is used for coating layer. After defining element type material properties should be defined. Material properties used for aluminum is defined in table

Material properties	Values
Young’s modulus	70 x 10^9 N\mm2
Poisson’s ratio	0.31 (no unit)
Coeff of thermal expansion	23x10^{-6} /K
Coeff of thermal conductivity	234 W/mK

Material Properties of Aluminium After defining material properties mesh attribute should be defined.

Element length is given as 2 for the meshing, and free mesh is used for meshing the volume. Meshed model is shown in fig Material properties of fused calcia stablised zirconia is shown in table

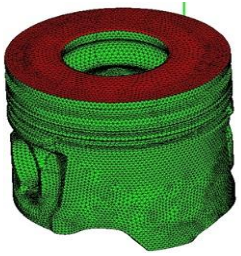
Material properties	Values
Young’s modulus	205 X 10^9 N\mm2
Poisson’s ratio	0.35 (no unit)
Coeff of thermal expansion	10 X 10^{-6}K
Coeff of thermal conductivity	2 W/mK

Material Properties of fused calcia stablised zirconia

V. Steps Involved For Creating Coating

1. Define element type 1 for coating i.e. shells 93
2. Define element 2 for solid piston i.e. solid 186
3. Define material properties for coating as material model no 1 and define base material as material model no 2
4. Set element as 1 and material model 1 in element attributes.
5. Create area in upper side of piston.
6. Now mesh upper layer.
7. Change element attributes, changes material model as 2 and element as solid 186.
8. Now mesh the solid.

Meshed model with coating is showing in figure



Meshed Model of Piston with Coating

Analysis

Analysis is the process of breaking a complex topic or substance into smaller parts to gain a better understanding of it.

Thermal Analysis

The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution is performed via ANSYS which calculates nodal temperatures, and then uses the nodal temperatures to obtain the other thermal quantities.

Only the ANSYS Multi physics, ANSYS Mechanical, ANSYS Professional, and ANSYS FLOTRAN programs support thermal analyses. The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation.

Convection

The convection is specified as a surface load on conducting solid elements or shell elements. The convection film coefficient and the bulk fluid temperature at a surface; ANSYS then calculates the appropriate heat transfer across that surface. If the film coefficient depends upon temperature, a table of temperatures is specified along with the corresponding values of film coefficient at each temperature.

For use in finite element models with conducting bar elements (which do not allow a convection surface load), or in cases where the bulk fluid temperature is not known in advance, ANSYS offers a convection element named LINK34. In addition, you can use the FLOTRAN CFD elements to simulate details of the convection process, such as fluid velocities, local values of film coefficient and heat flux, and temperature distributions in both fluid and solid regions.

Radiation

ANSYS can solve radiation problems, which are nonlinear, in four ways:

- By using the radiation link element, LINK31
- By using surface effect elements with the radiation option
- By generating a radiation matrix in AUX12 and using it as a super element in a thermal analysis.
- By using the Radiosity Solver method.

Results And Discussion

In this work, the uncoated piston and coated piston are been tested by analysis, numericaland methods. The results of the software and numerical methods are compared and correlated

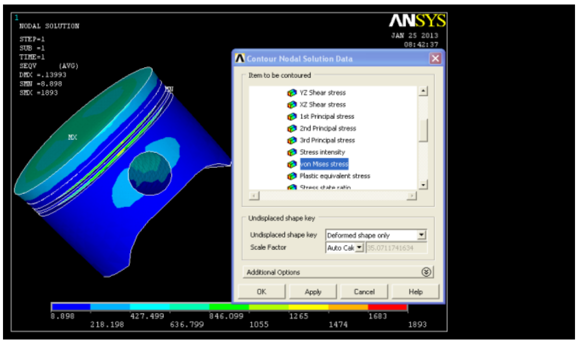
Analysis Method

The coated and uncoated piston models are analyzed in ANSYS and the thermal stresses developed in the surfaces are obtained. The maximum stress developed in both the pistons are obtained and compared

VI. Thermal Stress Developed On Uncoated Aluminium Piston Model

The uncoated Aluminium piston model is been analyzed in ANSYS to find the thermal stresses developed in the surfaces. To obtained the thermal stresses of the surfaces a thermal load should be applied at the surfaces of the piston. In combustion chamber, combustion takes place at the top surface of the piston and produces maximum heat on and above the surface of the piston. Thus a temperature load of 673K is applied at the top surface of the piston. While applying the thermal load on the top surface, the piston surfaces are symmetrically constrained. Now the thermally loaded piston model is analyzed to obtain the thermal stresses.

The stresses developed in the piston surfaces are obtained in the result as shown



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Scale Factor: Auto Calc 35.0711741634

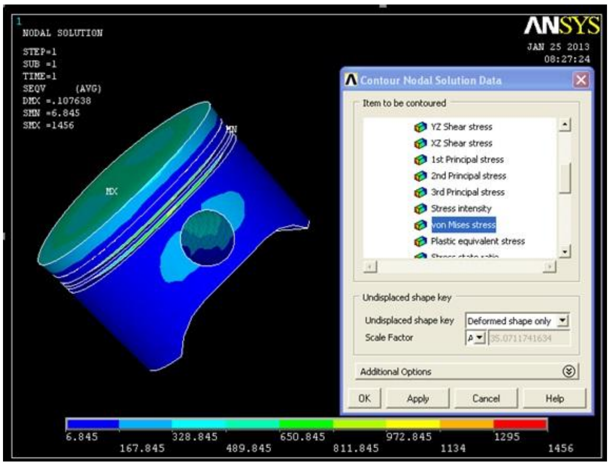
Thermal Stress Developed On Uncoated Piston

Maximum stress developed on uncoated Aluminium piston = $1.898 \times 10^9 N/m^2$.

Thermal stress developed on fused calcia stablised zirconia coated aluminium piston model

A layer is formed at the top surface using the shell command in ANSYS and the material properties of the coating material is inputted for that shell layer. Thus this forms the coating surface of the piston. Now the thermal load is applied on the top surface of the coated layer to obtain the thermal stresses.

The thermal stresses developed is shown and the maximum stresses is pointed out



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Maximum Thermal Stress Developed On fused calcia stablised zirconia Coated Al Piston

Maximum thermal stress developed on fused calcia stablised zirconia coated Al piston = $1.456 X 10^9 N/m^2$

Results from analysis

The coated and uncoated pistons are analyzed in ANSYS and the thermal stresses are obtained. Comparing between the coated and uncoated stress results, the maximum thermal stress is low in coated piston, resulting in less transfer of heat to the piston. As only less amount of heat is lost, combustion process should be increased.

Numerical Method

The maximum thermal stresses of both uncoated and coated pistons are calculated numerically.

Numerical calculation for uncoated aluminum piston

Maximum Stress developed due to thermal influence,

σmax = $\alpha \Delta TE$

Where

$\alpha = 23 X 10^{-6}$ (Thermal expansion coefficient /K).

$\Delta T = 932K$ (Temperature difference(K).

$E = 70 x 10^5 N/mm^2$ (Young's modulus).

$\sigma max = 23 X 10^{-6} X(932) X(70 X 10^9)$

Maximum Stress developed on uncoated Al piston, σmax (uncoated)= $1.51 \ x10^9 N/m^2$

σmax(uncoated) = $1.51. \ x10^9 N/m^2$

Numerical calculation fused calcia stablised zirconia coated aluminium piston model

Maximum Stress developed due to thermal influence on coated object,

Where,

Ef = Young's modulus of coating (Pas).

Es = Young's modulus of base (Pas).

αs = Thermal expansion coefficient of base (/K).

αf = Thermal expansion coefficient of coating (/K)

h = Coating thickness (m).

H = Base thickness (m).

Td = Maximum temperature (K).

Tr = Room temperature (K).

$$\sigma max = \frac{205 \ X \ 109 \int_{300}^{673} (23 \ X \ 10-6) - (10 \ X \ 10-6) dT}{1 + 4(205 \ X \ 109/70 \ X \ 109)\ (4X10-3/5)}$$

Therefore, σmax (coated piston) = $1.06 x 10^9 N/m2$

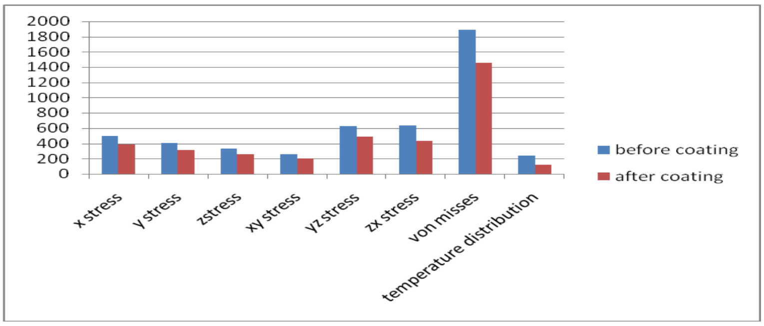
Maximum Stress developed on coated Al piston,

σmax (coated) = $1.06 x 10^9. \ N/m^2$

The following graph shows the variation of thermal stress in various components of piston for before and after coating which also indicates the thermal stress is considerably reduced after coating by stabilized yittria zirconia material.

Stress	Before coating(N/mm^2)	After coating(N/mm^2)
x stress	501	385.976
y stress	404.788	311.375
zstress	335.612	258.163
xy stress	262.157	201.659
yz stress	629.191	483.993
zx stress	635.41	435.419
von misses	1893	1456
Temperature distribution	242^{0}C	120^{0}C

Stress Components &Temperature Before And After Coating

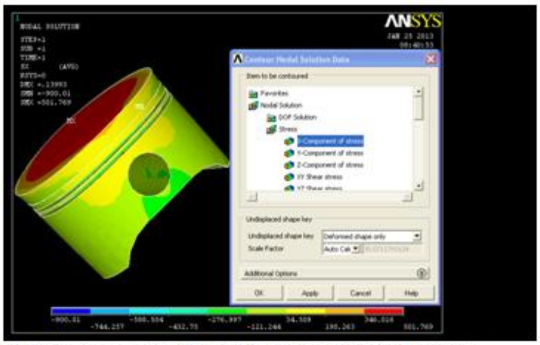


Graph Of Stresse Componenets Before And After Coating Of Piston

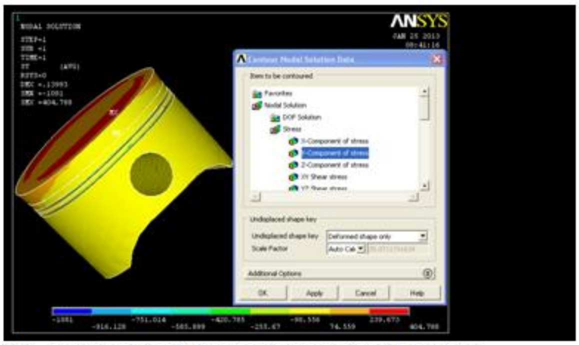
VII. Vii Results From Numerical Calculation

From the numerical calculations of both coated and uncoated piston models, the maximum thermal stress is low for fused calcia stablised zirconia coated piston as compared to the uncoated Aluminium piston.

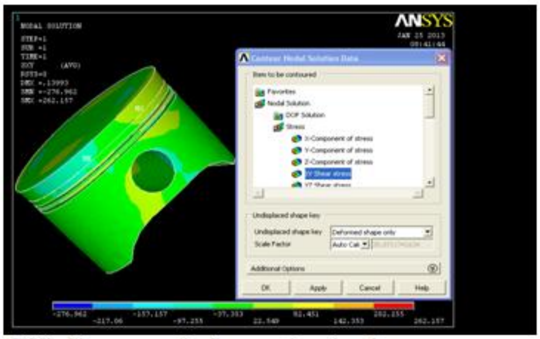
Piston Image Before Coating Of Thermal Barrier



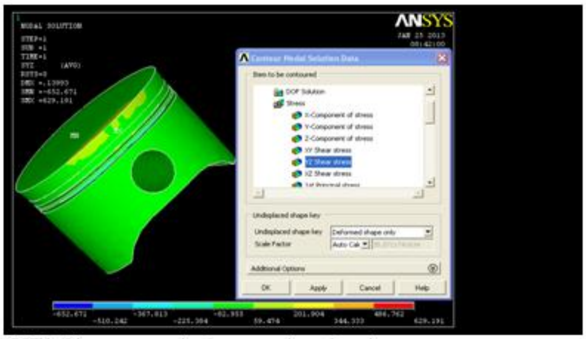
'X'- Component of stress before coating the piston.



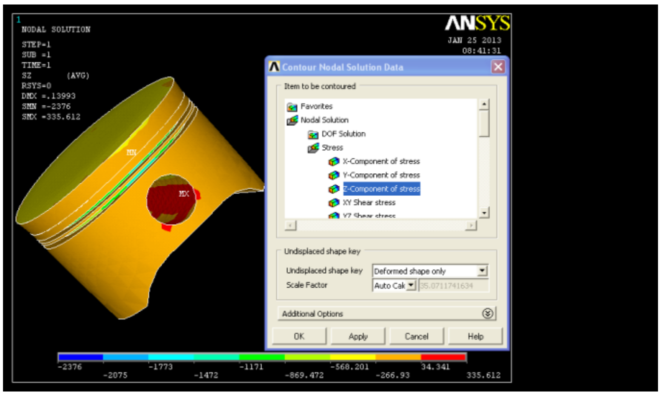
'Y'- component of stress before coating the piston



'XY'- Shear stress before coating the piston



'YZ'- Shear stress before coating the piston



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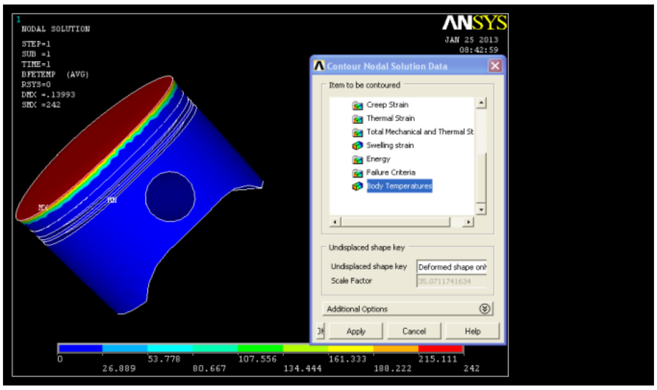
'Z'- component of stress before coating the piston



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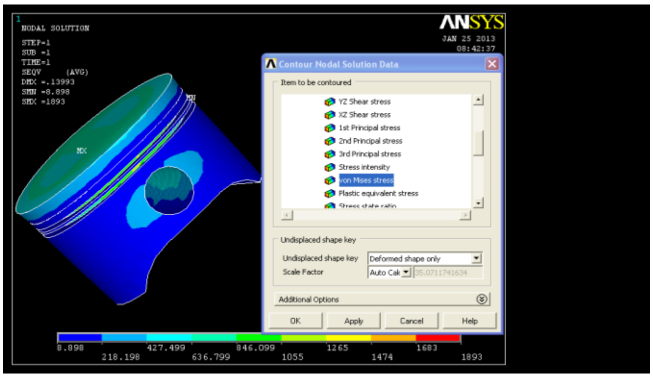
Body Temperature before coating the piston



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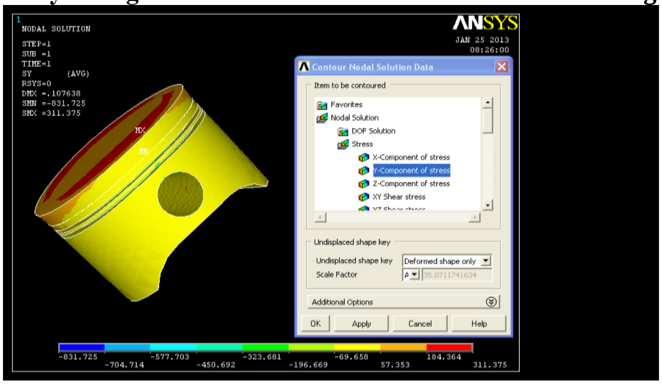
Von mises stress before coating the piston

Ansys Images Of Piston 'After' Thermal Barrier Coating



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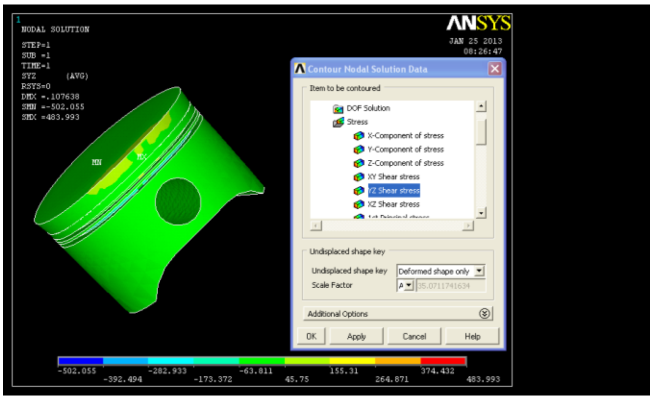
'Y'- component of stress After coating the piston



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Item to be contoured: YZ Shear stress

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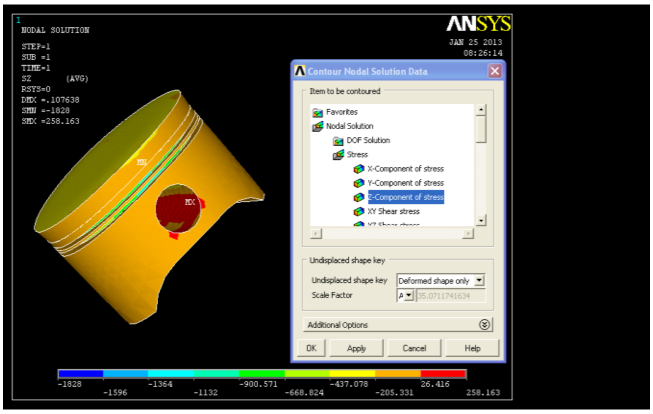
‘YZ’- Shear stress After coating the piston



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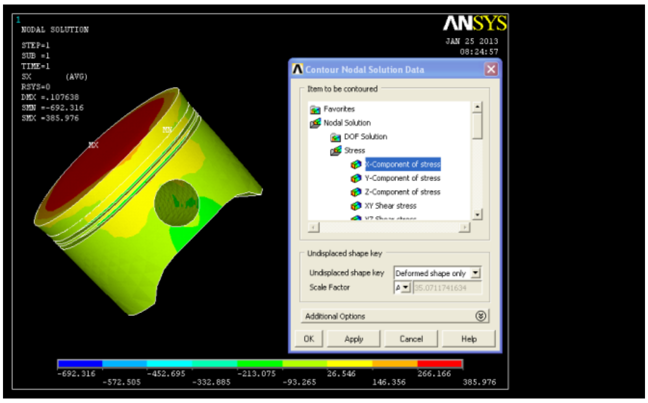
SZ        (AVG)
RSYS=0
DMX =.107638
SMN =-1828
SMX =258.163
```

Item to be contoured: Z-Component of stress

Undisplaced shape key: Deformed shape only

Scale Factor: 35.0711741634

‘Z’- Component of stress After coating the piston



```
NODAL SOLUTION

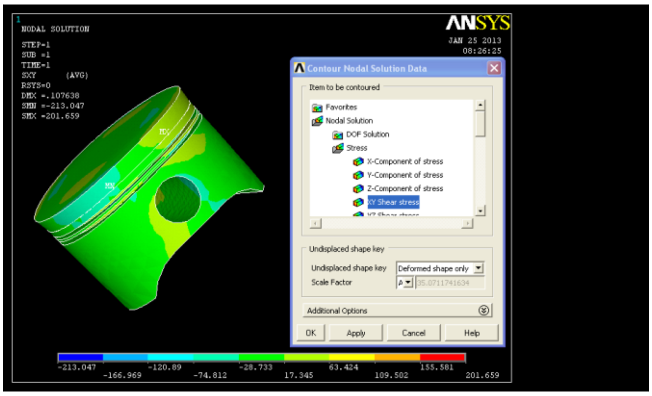
STEP=1
SUB =1
TIME=1
SX        (AVG)
RSYS=0
DMX =.107638
SMN =-692.316
SMX =385.976
```

Item to be contoured: X-Component of stress

Undisplaced shape key: Deformed shape only

Scale Factor: 35.0711741634

‘X’- Component of stress After coating the piston



```
NODAL SOLUTION

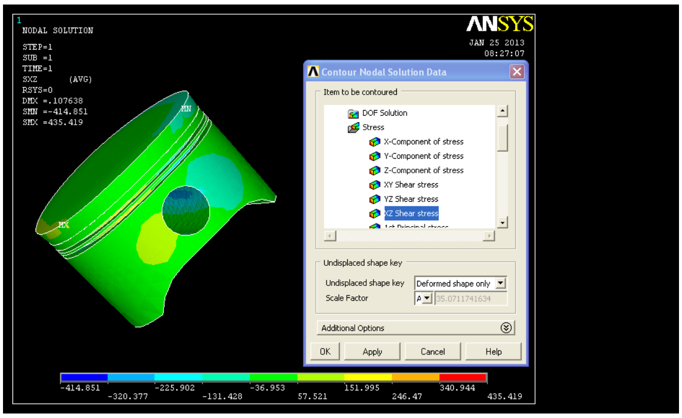
STEP=1
SUB =1
TIME=1
SXY       (AVG)
RSYS=0
DMX =.107638
SMN =-213.047
SMX =201.659
```

Item to be contoured: XY Shear stress

Undisplaced shape key: Deformed shape only

Scale Factor: 35.0711741634

‘XY’- Shear stress After coating the piston



```
1
NODAL SOLUTION

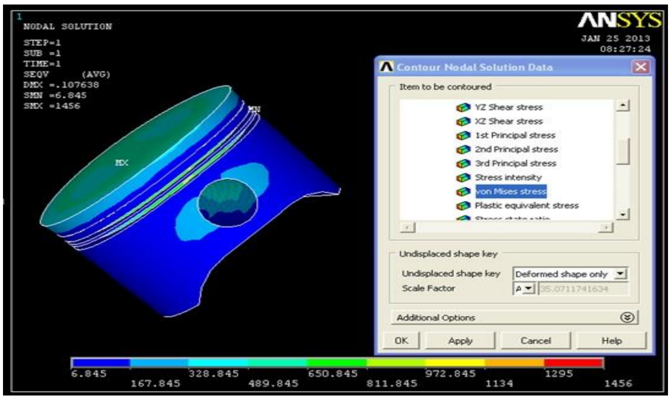
STEP=1
SUB =1
TIME=1
SXZ        (AVG)
RSYS=0
DMX =.107638
SMN =-414.851
SMX =435.419
```

```
JAN 25 2013
08:27:07
```

Undisplaced shape key: Deformed shape only

Scale Factor: 35.0711741634

‘XZ’- Shear stress After coating the piston



```
1
NODAL SOLUTION

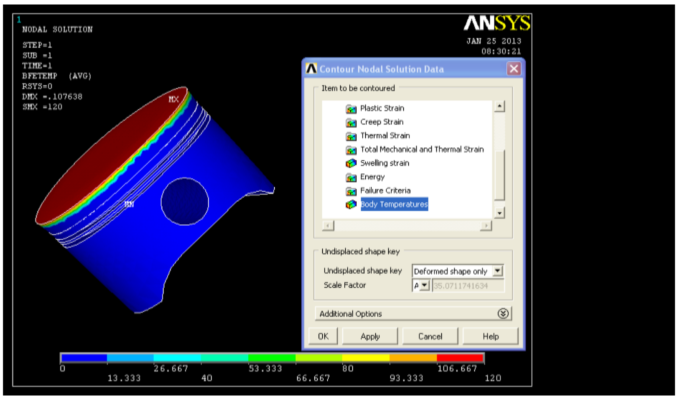
STEP=1
SUB =1
TIME=1
SEQV       (AVG)
DMX =.107638
SMN =6.845
SMX =1456
```

```
JAN 25 2013
08:27:24
```

Undisplaced shape key: Deformed shape only

Scale Factor: 35.0711741634

‘Von mises stress after coating the piston



```
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
BFETEMP  (AVG)
RSYS=0
DMX =.107638
SMX =120
```

```
JAN 25 2013
08:30:21
```

Undisplaced shape key: Deformed shape only

Scale Factor: 35.0711741634

‘Body Temperature After coating the piston

VIII. Conclusion

A finite element model of the piston without and with coating layer is created in ANSYS and analyzed in the influence of thermal load on the top surface of the piston. The thermal stresses of both coated and uncoated pistons are obtained and compared. The maximum thermal stress of fused calcia stablised zirconia is low as compared to the maximum thermal stress obtained by the uncoated aluminum piston. As the thermal stresses are reduced, the heat transfer in the piston is also reduced resulting in increased combustion which should result with the increase in engine power.

The results obtained from software method are verified with numerically calculated thermal stress values of uncoated and coated piston surfaces. The thermal stress of fused calcia stablised zirconia coated piston is less compared to uncoated aluminum piston.

Piston skirt may appear deformation at work, which usually causes crack on the upper end of piston head. Due to the deformation, the greatest stress concentration is caused on the upper end of piston, the situation becomes more serious when the stiffness of the piston is not enough, and the crack generally appeared at the point A which may gradually extend and even cause splitting along the piston vertical. The stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration, the piston crown should have been coated to reduce the deformation & stress

1. The optimal mathematical model which includes deformation of piston crown and quality of piston and piston skirt.
2. The FEA is carried out for standard piston model used in diesel engine and the result of analysis indicate that the maximum stress has changed from $1.893X10^9$ N/mm^2 to $1.456 X 10^9$ N/mm^2

References

[1]. A.I.Pandey a literature review on the performance analysis of 4 stroke diesel engines with ceramic coating material international journal of advance engineering and research development.2(2015) 2348-4470

[2]. K. Sridhar, R. Reji Kumar, M. Narasimha Thermal barrier analysis in Diesel International Journal of Modern Engineering Research.3(2013) 1435-1441

[3]. Lavanya.S , L.Nafeez Ahmed fea and experimental investigation on the thermal properties of the ceramic coating on aluminium piston International Journal of Innovative Research in Science, Engineering and Technology.4(2015) 2319 – 8753

[4]. Kuldeep Singh, Dr. O.P. Jakhar The Behavior of temperature on insulated(mgzro3) diesel engine piston with ansys International Journal of Emerging Technology and Advanced Engineering.4(2014) 2250-2459

[5]. Vinoth M. A, Aru n L , R Vinay Kumar Uppinal Development and assessment of piston by using al-si hybrid metal matrix composites reinforced with sic and cenosphere particulates International Journal of Engineering Research & Technology.3(2014) 2278-0181

[6]. P. Carvalheira1, and P. Gonçalves Fea of two engine pistons made of aluminium cast alloy a390 and ductile iron 65-45-12 under service conditions Product Engineering & Development in Design(2006)

[7]. S. Srikanth Reddy1, Dr. B. Sudheer Prem Kumar Thermal analysis and optimization of I. C. engine piston using finite element method International Journal of Innovative Research in Science, Engineering and Technology.2(2013)2319-8753

[8]. Kenny Vernieuwe , Petra Lommens , José C. Martins , Freya Van Den Broeck , Isabel Van Driessche and Klaartje De Buysser Aqueous ZRO2 and YSZ colloidal systems through microwave assisted hydrothermal ynthesis. Materials.(2013) 1996-1944