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MODELLING AND COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF CERAMIC LAYER PISTON

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ABSTRACT: A piston is a disc which reciprocates within a cylinder. It is either moved by the fluid or it moves the fluid which enters the cylinder. The main function of the piston of an IC engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod. The piston must also disperse a large amount of heat from the combustion chamber to the cylinder walls. Cast iron, Aluminium Alloy and Cast Steel etc. are the common materials used for piston of an Internal Combustion Engine. In this project here we were taken steel is an existing material and aluminium 5 series materials. The aim of our project is to design a piston for a two wheeler using theoretical calculations, designing with Creo software. The material used is Aluminium 2014&5019 and steel (existing material) are used to determine the good material for manufacture of the piston here we analyse the two materials with the help of fem. In order to get better results here we are adding 0.25mm ceramic (Si3N4& ZrB2) layer for both material and analysed with same boundary conditions. And calculating results like deformation, stress, safety factor. And total temperature and heat flux also.

The main objective piston is investigate and analysed the thermal stress distribution of piston at the real engine condition during combustion process, in this process we applied temperature and convection as boundary conditions and we determining total temperature on the body, total heat flux values. Cfd analysis results also calculating for both ceramic and existing piston, finally conclude the results of each piston and discussing how the piston behaves in each boundary condition (static,thermal,cfd) , by knowing 3 different conditions results with suitable tables and graphs project can be concluded each piston limitations and advantages &disadvantages

Tools were used:
Cad tool: solid works
Cae tool: Ansys Workbench.

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1. Introduction

Piston

A piston is a part of reciprocating engines, reciprocating pumps, gas blowers, water powered chambers and pneumatic chambers, among other comparable components. It is the moving segment that is contained by a chamber and is made gas-tight by cylinder rings. In a engine, its purpose is to move power from extending gas in the chamber to the driving rod by means of a cylinder bar or potentially associating bar. In a pump, the capacity is turned around and power is moved from the driving rod to the cylinder to pack or shooting the liquid in the chamber. In certain engines, the piston likewise goes about as a valve by covering and revealing ports in the cylinder.

Ceramic

"Ceramic originates from the Greek word κεραμικός (keramikos), "of earthenware" or "for stoneware", from κέραμος (keramos), "potter's mud, tile, earthenware". The most punctual known notice of the root "ceram-" is the Mycenaean Greek ke-ra-me-we, "laborers of earthenware production", written in Linear B syllabic content. "Ceramic" might be utilized as a descriptive word to portray a material, item or cycle, or it might be utilized as a thing, either particular, or, all the more regularly, as the plural thing "pottery".

Si3N4

Silicon nitride is a synthetic compound of the components silicon and nitrogen. Si3N4 is the most thermodynamically stable of the silicon nitrides. Consequently, Si3N4 is the most economically significant of the silicon nitrides when alluding to the expression "silicon nitride". It is a white, high-softening point strong that is moderately synthetically latent, being assaulted by weaken HF and hot H2SO4. It is exceptionally hard (8.5 on the mohs scale). It has a high warm security

Applications

Generally, the fundamental issue with utilizations of silicon nitride has not been specialized execution, yet cost. As the expense has descended, the quantity of creation applications is quickening

Zirconium di-boride

Zirconium di-boride (ZrB2) is an exceptionally covalent obstinate fired material with a hexagonal precious stone structure. ZrB2 is a ultra high temperature earthenware (UHTC) with a softening purpose of 3246 °C. This alongside its generally low thickness of ~6.09 g/cm3 (estimated thickness might be higher because of hafnium pollutants) and great high temperature quality makes it a contender for high temperature aviation applications, for example, hypersonic flight or rocket drive frameworks. It is an abnormal fired, having moderately high warm and electrical conductivities, properties it imparts to isostructural titanium di-boride and hafnium di-boride.

Applications

a) Useful in atomic applications as a result of the presence of Boron-10.

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b) Also utilized as an aviation stubborn, in slicing devices and to ensure thermocouple tubes.

c) Other applications incorporate utilization of its generally high conductivity, particularly for a clay.

Aim of the project

The main aim of the thesis is to design optimize the 100cc piston by utilizing cad/cae tools, in this process solid works were used to modeling piston and then analyzing with Ansys workbench, here al-2014&5019 material were chosen, both of these materials are having high yield limit values compare to existing piston materials like steel or cast iron, and also it has 3 time less density compare to steel and cast iron, so that by using these materials weight of the object will reduces and strength will increases,

As of now these both materials are good at their mechanical properties, but when compare thermal properties these materials are not up to the level, to increase the thermal efficiency of the piston, ceramic coatings (si3n4 & zrb2) were applied and then calculated results like temperature and heat flux values.

Finally each piston with ceramic and without ceramic under goes with 3 different boundary conditions (static, thermal, fluent) and then calculating results like deformation, stress, strain, safety factor, total temperature distribution, heat flux,. By knowing all these results thesis can conclude with optimum material with suitable ceramic layer, and their advantages and disadvantages, with suitable graphs and tables.

Literature review

[1] Muhammet Cerit, Mehmet Coban "Temperature and warm pressure examinations of an artistic covered aluminum compound cylinder utilized in a diesel motor" International Journal of Thermal Sciences , Volume 77, March 2014 The objective of this paper is to decide both temperature and warm pressure appropriations in a plasma - splashed magnesia balanced out zirconia covering on an aluminum cylinder crown to improve the exhibition of a diesel motor. Impacts of the covering thickness on temperature and warm pressure dispersions are examined, incorporating correlations with results from an uncoated cylinder by methods for the limited component technique. Temperature and warm pressure examinations are performed for different covering thicknesses from 0.2 to 1.6 mm barring the bond coat layer. Temperature at the covered surface is fundamentally higher than that of the uncoated cylinder. It is seen that the covering surface temperature increments with covering thickness by diminishing rate. Increment in the most extreme temperature as indicated by the uncoated cylinder is 64.3% for 1.0 mm thick covering. The higher burning chamber temperature gave by methods for covering brings about the better warm productivity of the motor

[2] Helmisyah Ahmad Jalaludin , Shahrir Abdullah, Mariyam Jameelah Ghazali, Bulan Abdullah, Nik Rosli Abdullah "Trial Study of Ceramic Coated Piston Crown for Compressed Natural Gas Direct Injection Engines" INTERNATIONAL TRIBOLOGY CONFERENCE MALAYS IA 2013 Volume 68, 2013 In this paper it is seen that the YPSZ(Yttria Partially Stabilized

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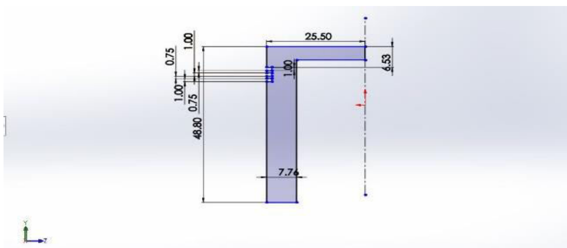
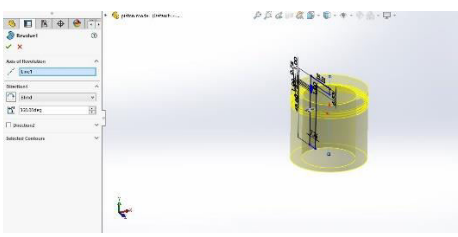
Zirconia)/NiCrAl covered CNGDI cylinder crown encountered the least warmth motions than the uncoated cylinder crowns and the covered CamPro cylinder crown, giving additional insurance during burning activity.

Solid works step by step process

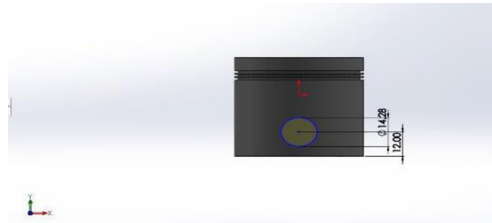
Piston dimensions



Here piston cross section were created by using line option with mentioned dimensions in the above image, and to create this piston here need to select center axis first, and then create a sketcher without exceeding other side, if the sketcher exceeds center line then revolve option wont workout, after following these rules now exit 2d sketcher window, and then select revolve option

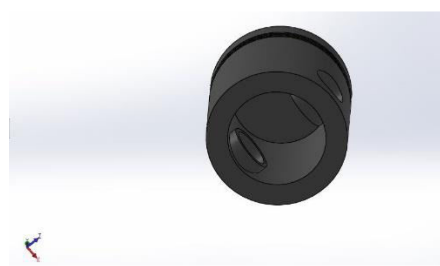


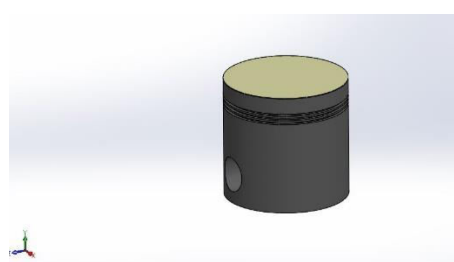
After exit 2d sketcher window then click revolve option and this option is used when circular object has to be created, and here piston is a circular object, after selecting revolve option and then then click ok to create piston,



After completing piston then need to create hole to place connecting rod pin, to do this select center plane and then create a circle with 14.28mm diameter and then place this circle with a distance of 12mm from bottom of the piston, after creating this circle, then select extrude cut option and then cut the object throughout the body

The above image shows the cutting of gudgeoned pin for both ends, to create this both end cut here up to next option were used.





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Piston assembly with ceramic layer

Material selection

Al-2014

Al-2014 density: 2800 kg/m^3

Al-2014 young's modulus: 7.3e10 Pa

Al-2014 poison ratio: 0.29

Al-2014 yield strength: 4.8e8 Pa

Al-5019

Al-5019 density: 2700 kg/m^3

Al-5019 young's modulus: 6.8e10 Pa

Al-5019 poison ratio: 0.33

Al-5019 yield strength: 3e8 Pa

Si3n4

Si3n4 ceramic density: 3250 kg/m^3

Si3n4 ceramic young's modulus: 2.97e11 Pa

Si3n4 ceramic poison ratio: 0.28

Si3n4 ceramic yield strength: 5.25e8 Pa

Zrb2

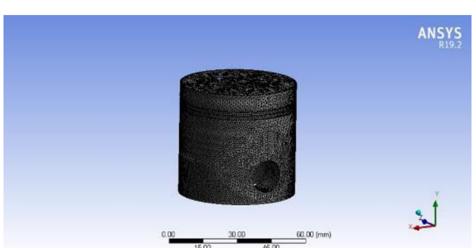
Zrb2 ceramic density: 6085 kg/m^3

Zrb2 ceramic young's modulus: 5.2121e11 Pa

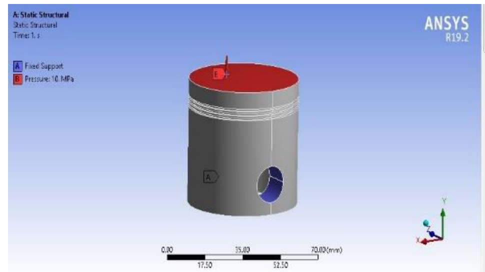
Zrb2 ceramic poison ratio: 0.13603

Zrb2 ceramic yield strength: 6.95e8 Pa

Meshing



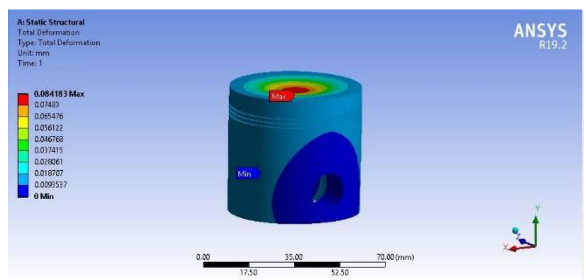
Boundary conditions



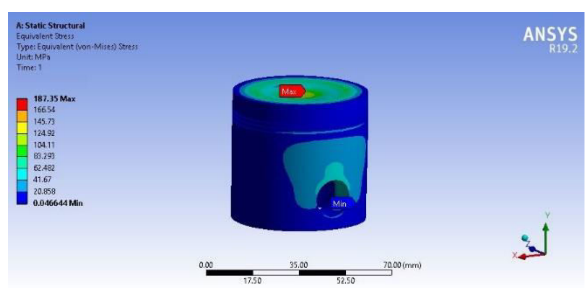
Select boundary conditions and apply fixed support at holes and then→apply pressure 10Mpa

Static analysis

Al-5019 Deformation



Stress



Safety factor

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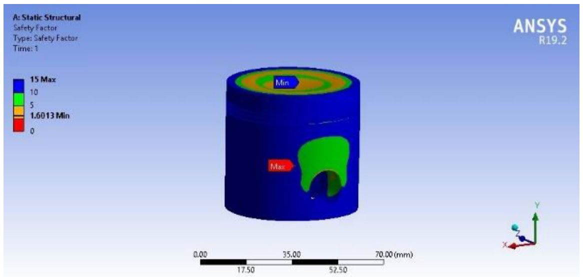


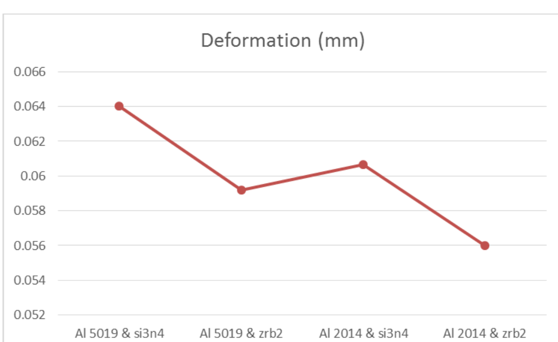
Table

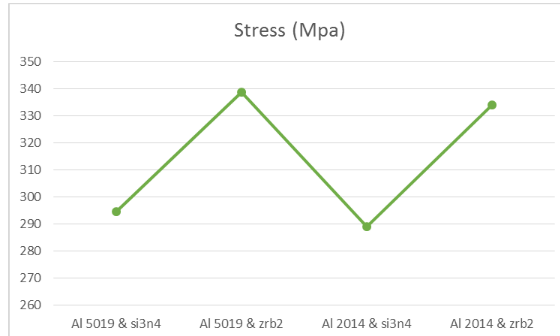
	Deformation (mm)	Stress (Mpa)	Strain	Safety f
Al-5019	0.084183	187.35	0.0030091	1.60
Al -2014	0.079564	195.55	0.0029286	2.45

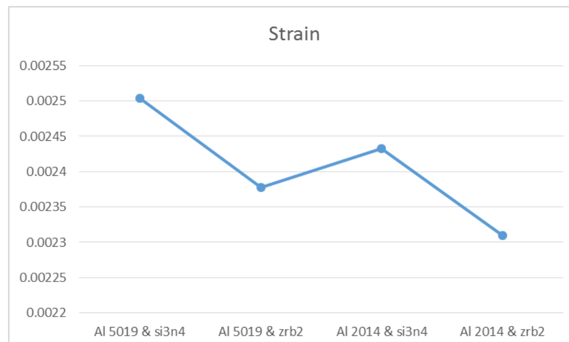
Static analysis results with ceramic coating

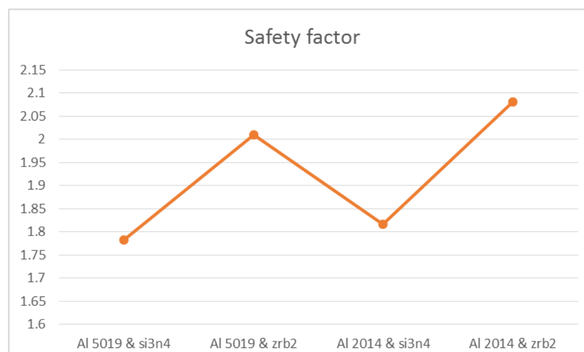
	Deformation (mm)	Stress (Mpa)	Strain	Safety factor
Al 5019 & si3n4	0.064017	294.46	0.0025034	1.7829
Al 5019 & zrb2	0.059192	338.72	0.0023781	2.0101
Al 2014 & si3n4	0.060657	289.13	0.0024327	1.8158
Al 2014 & zrb2	0.056009	333.93	0.0023094	2.0813

Graphs

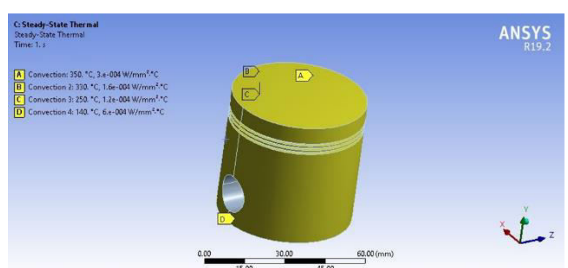








Thermal analysis process



Tables

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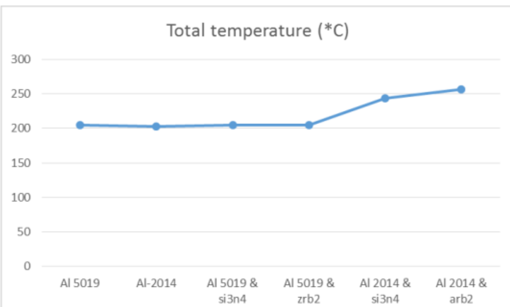
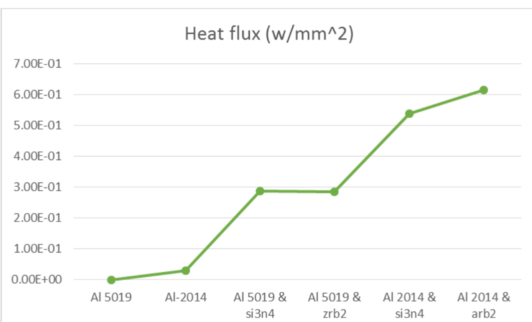
	Total temperature (*C)	Heat flux (w/mm^2)
Al 5019	204.97	0.28798
Al-2014	202.87	0.29131
Al 5019 & si3n4	205.04	0.28627
Al 5019 & zrb2	204.94	0.28585
Al 2014 & si3n4	243.92	0.53859
Al 2014 & arb2	256.42	0.61411

Graphs





Fluent analysis process

Tables

	Pressure (Mpa)	Velocity (m/s)	Heat transfer coefficient (w/m^2-k) (kg/m^3)	Total temperature (*C)
Al 2014 & si3n4	6.052	4.217e-2	2.39	258.01
Al 2014 & zrb2	6.055	4.217e-2	2.398338	265.02

CONCLUSION

In this paper piston modeling were developed by using solid works software and analyzing it by using Ansys workbench with 2 different (al-2014& al 5019) materials, after analyzing these piston materials individually by applying static and thermal boundary conditions, these both piston materials can withstand up to 10Mpa of pressure on it when it is used in combustion chamber, among these 2 materials al-2014 materials has highest (2.4546 safety factor value), it means this material more stronger than al 5019 (1.6013 safety factor) in static boundary conditions, after completing static analysis , thermal boundary condition were applied and calculated temperature and heat flux values for each material, in this case also al 2014 has got better thermal results than al 5019,

To improve the performance of the piston, here 2 ceramic layers were chosen (si3n4 & zrb2) and assembled on each piston, both these ceramics are good at their mechanical and thermal properties and this is the main reason behind choosing these two , and these ceramics having high yield limit values than al-2014&5019 materials, from static analysis results, zrb2 is having above 2 safety factor for both al-2014& 5019 material, when comes to thermal analysis this zrb2 ceramic with al 2014 materials is having high amount of temperature (256.42*c) at TDC compare to other ceramics and materials, it means nearly 50*c more temperature is observed this ceramic at TDC and this extra amount of energy can convert into mechanical energy by transmitting through crank shaft, so that energy wastage has been reduces and more mechanical energy will be generated by using al2014 material with zrb2 ceramic layer.

By using fluent module also here calculated total temperature distribution and pressure and heat transfer coefficient values

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for both ceramic models, in Ansys fluent both air and fuel mixed together and calculated piston temperature at TDC, from fluent analysis results al2014 with zrb2 ceramic piston has got approximately 262*c of temperature at TDC, and this value is near to thermal analysis results. At this time the maximum pressure generated on piston is nearly 6Mpa where both pistons can withstand up to 10Mpa, so that from fluent analysis results it is easy to convey that, these ceramics can increases the performance of the object in both static and dynamic conditions, finally thesis concluded with al2014 material with zrb2 ceramic layer is optimum among all.

Advantages of zrb2 ceramic layers pistons

- Thermal efficiency will increases
- Exhaust wastage will reduces
- It has high melting point range, so that durability of the object will increases

Disadvantages of zrb2 ceramic layers pistons

- Thermal stress are more compare to normal piston, but these stress values all are under yield limit only so that no damage will occur on piston
- Compare to normal piston the cost will be high, by considering performance and fuel consumption it can consider as one time investment with lifelong benefits

References

[1] Muhammet Cerit, Mehmet Coban "Temperature and thermal stress analyses of a ceramic-coated aluminum alloy piston used in a diesel engine" International Journal of Thermal Sciences , Volume 77, March 2014

[2] Helmisyah Ahmad Jalaludin , Shahrir Abdullah, Mariyam Jameelah Ghazali, Bulan Abdullah, Nik Rosli Abdullah "Experimental Study of Ceramic Coated Piston Crown for Compressed Natural Gas Direct Injection Engines" INTERNATIONAL TRIBOLOGY CONFERENCE MALAYSIA 2013 Volume 68, 2013

[3] Muhammet Cerit "Thermo mechanical analysis of a partially ceramic coated piston used in an SI engine" Surface and Coatings Technology Volume 205, Issue 11, 25 February 2011

[4] O.P. Singh , Yogesh Umbarkar, T. Sreenivasulu, E. Vetrivendan, M. Kannan, Y.R. Babu "Piston seizure investigation: Experiments, modeling and future challenges" Engineering Failure Analysis Volume 28, March 2013

[5] M. Cerit, V. Ayhan, A. Parlak, H. Yasar "Thermal analysis of a partially ceramic coated piston: Effect on cold start HC emission in a spark ignition engine" Applied Thermal Engineering Volume 31, Issues 2–3, February 2011 [6] Ekrem Buyukkaya, Muhammet Cerit "Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method" Surface and Coatings Technology Volume 202, Issue 2, 25 November 2007

6. Ravinder Reddy P., Ramamurthy G., "Computer Aided Analysis of Thermally Air Gap Insulated Pistons made of Composites", National Conference on Machines and Mechanisms (NACOMM-95), pp. 177-180, Jan 20-21, 1995, CMERI, Durgapur.

7. K. Bala Showry, A.V.S. Raju, P. Ravinder Reddy, "Multi-Dimensional Modeling of Direct Injection Diesel Engine

and Effects of Split Injection", International Journal of Scientific and Research Publications, Volume 2, Issue 1, pp. 1-8,January 2012

8. Pradeep Halder, Edla Franklin, Dr. P. Ravinder Reddy, "Combustion and Mixing Analysis of a Scramjet Combustor Using CFD", International Journal for Scientific Research & Development (IJSRD),Vol. 2, Issue 09,pp.27-33