THERMAL ANALYSIS COATED DIESEL ENGINE PISTON FOR VARIOUS COATING ANSYS THICKNESS

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Abstract:

The objective of this project is to investigate the temperature distribution effects of thermal barrier coated diesel engine piston as a function of various coating thickness. Mullite coatings are used to improve high temperature components in diesel engines to reduce heat transfer between the piston crown and the cylinder head. Using PROE wildfire technology, the piston is modeling. Using commercial code namely ANSYS 13.0 version, the thermal analysis is performed on the piston for different coating thickness. The temperature distribution of the piston various parts are measured for both conventional and coated pistons based on the Experimental results the optimum coating thickness is determined. The optimum coating thickness performance and emission results are compared with conventional and coated pistons.

Key words: *mullite,ANSYS 13 version,Pro-E,Nox,Convective heat transfer coefficient*

INTRODUCTION

Direct injection Diesel engines are major role in medium and heavy duty applications. Because of superior features such as lower fuel consumption, high engine power output and lower emissions compared to gasoline engines. The piston's job is to absorb the released energy after the high temperature ignites the air fuel mixture. This can be achieved by piston rings that also help prevent oil from reaching the combustion chamber below the piston. The concept of cooled components like diesel engine piston and hot working fluid valves with ceramic thermal barrier coating is very effective. A practical system, however, has only been identified in the past few years. The findings published indicate that mullite in cylinder coatings can reduce the carbonaceous fraction of diesel particulates without raising No or other controlled emissions. Reductions in total PM emissions may be achieved by combining mullite coatings with diesel oxygen catalysts.

LITERATURE SURVEY

Preparing Your Paper Surface engineering essentially involves the improvement of the surface properties of the parent material by some enhancements done on the surface of the same. A common method of achieving the above is by treating the surface with specialized physical of chemical process. Another and later means by coating the surface with the materials or combination of materials which produced enhanced properties.

The temperature distribution allows us to optimize the thermal aspects of the piston design at lower c ost before the construction of the first prototype.Piston ring assembly generates as much as 60 percent of the total engine mechanical power lost [1].

The small clearance values increase the loss of friction and the high values increase the piston's seco ndary motion.Most internal combustion (IC) engine pistons are made of an aluminum alloy with a thermal e xpansion coefficient, 80 percent higher than the cast iron cylinder bore.This results in some differences betw een running and the clearances of the design.Analyzing the thermal behavior of the piston is therefore extre mely important in designing more efficient engines. From different perspectives, piston thermal analysis is i mportant.Next, the maximum temperature of any piston point shall not exceed 66% of the alloy's melting po int temperature [2].

The current engine piston alloy's maximum temperature is about 640 K. Distribution of temperature r esults in thermal deformation and thermal stress.The thermal deformation of the piston plays an important ro le in the development of the piston skirts, which can reduce friction and piston slap.In this design it is necess ary to consider both thermal and mechanical stresses indicating the importance of piston thermal analysis.

Moreover, their model has been applied to realistic issues and has given a good agreement with avail able experimental data.JenkinetalmodifiedAn current quasidimensional engine cycle model to accurately pre dict nearBurned and unburned fuel wall temperature.

METHODOLOGY

The objective of this project is to investigate the temperature distriburtion effects of thermal barrier coated diesel engine piston as a function of coating thickness. To achieve this work, the following methodology has been followed.-Geometric modeling of piston using Pro-E wildfire software -Estimation of temperature distribution and thermal stresses

Piston thermal boundary conditions are the governing equation for heat transfer analysis.

1. The thermal boundary of the circle and skirt;
2. Thermal boundary state on the underside;
3. Thermal boundary condition of the piston pin

CALCULATIONS OF HEAT TRANSFER COEFFICIENTS:

1.Combustion Chamber Side Thermal Boundary Condition

$$h_g = 226.8\ P^{0.8}\ T^{-0.4}(Vp+1.4)0.8 \qquad (1)$$

2.Heat Transfer Coefficient Between Piston Crown And Liner

$$Nu = hxD_h/k \quad = 8.235 \qquad (2)$$

3. Heat Transfer CoefficintInThe Rings

$$h_{eff} = 1/(R_{tot} x A_{eff}) \qquad (3)$$

4.Piston Crown Underside heat transfer coefficient

$$h = 900x\ (N/4600)^{0.35} \qquad (4)$$

5.Heat Trnasfer Piston Skirt Underside coefficient $h = 240x(N/4600)^{0.35}$(5)

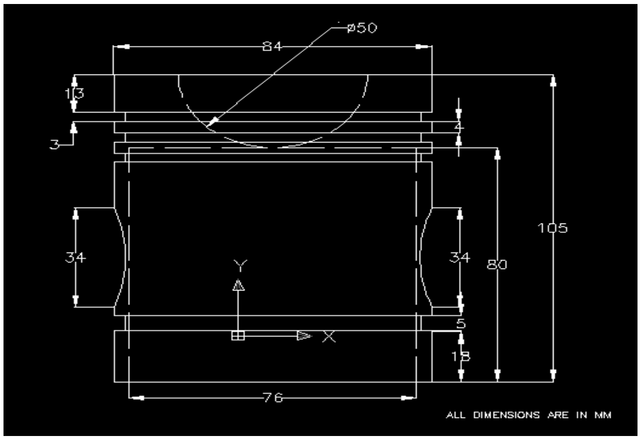
I. The Boundary Conditions of the Piston

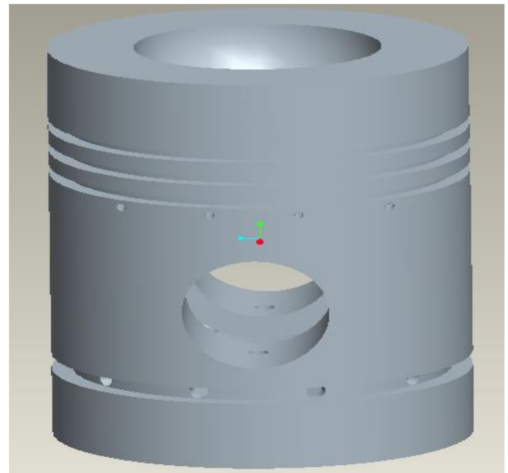
Region	Temperature (^{0}C)	Heat transfer coefficient W/m^{2}k
Combustion chamber	656	356.36
Rings	160	9046.56
Crown underside	100	608
Skirt underside	100	162.35
Skirt outside	85	60

TEXVEL ENGINE SPECIFICATIONS

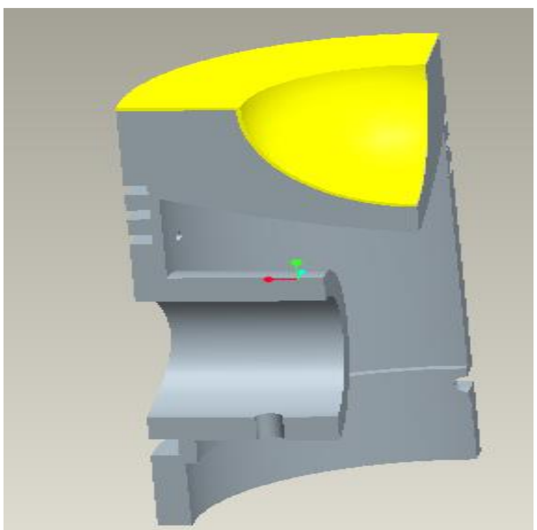
Type	Single cylinder four stroke diesel engine
Bore in mm	85
Stroke in mm	110
Speed in rpm	1500
Connecting rod length in mm	235
Compression ratio	18:1
Brake Horse power	6.5
Loading	Rope brake
Lubrication system	Forced type
Injection timing	19.58^0 BTDC

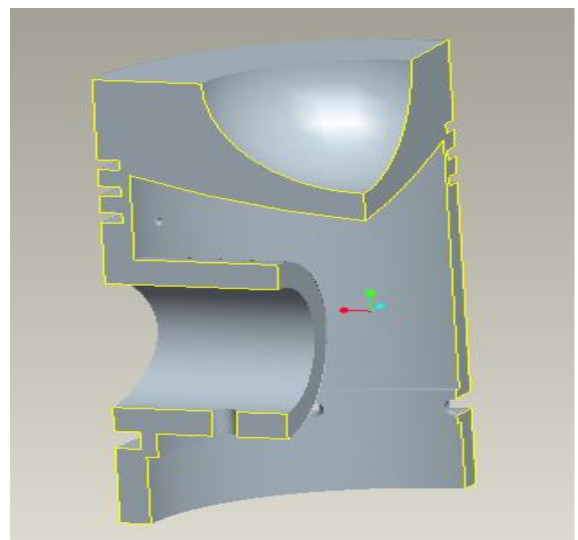
GEOMETRIC MODELING





GEOMETRIC MODELING BY PRO-





Conventional piston cut section

Estimation of Thermal Stresses

The temperature distribution along the conventional and coated piston are predicted in ANSYS software package. The various methods involved in Finite Element Analysis are as follows

i)Selection of the type of element

ii)Defining material properties

iii) Meshing the model

iv) Applying the loads

v) the results using post - processor

i) Selection of the type of element:

The shapes, sizes, number and configurations of the elements haveTobe carefully chosen without increasing the computational effort needed for the solution. Mostly the choice of the element is dependent on the geometry of the object. The three types of elements are used in this analysis, each for thermal individually. SOLID90 element is used for piston, SOLID 70 Element is used for ceramic coating material and SLOID 98 element is used for Bond coat (NiCrAl).

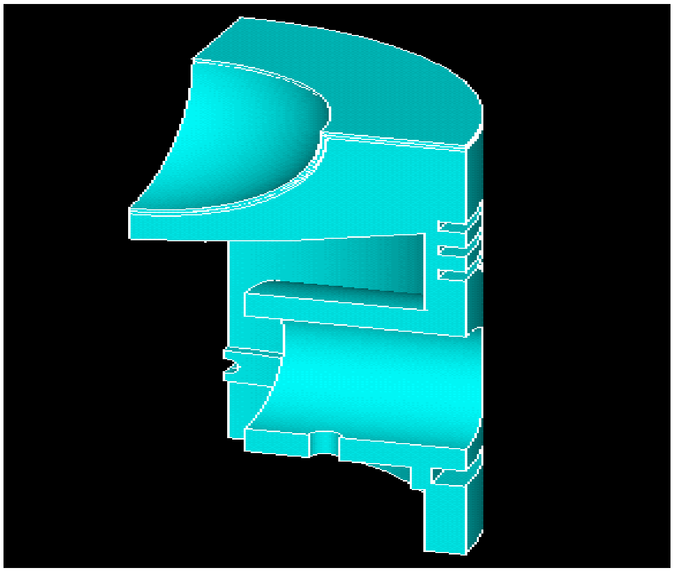


Figure 3 : IGES file of the piston

Material	Thermal conductivity W/m^{0}C	Specific heat J/kg^{0}C	Poisson's ratio	Young's modulus GPa	Thermal expansion coefficient 10^{-6} 1/^{0}C	Density kg/m^3
AlSi	155	960	0.3	90	21	2700
NiCrAl	16.1	764	0.27	86	12	7870
Mullite ($3Al_2O_3.2SiO_2$)	3.5	230	0.25	30	5.3	3030

c) Meshing the model:

The given model is discritized into elements and nodes. A fine mesh is done so that applying the loads a fine output can be obtained. The mesh concentration is more on the bent tube area so that the stress concentration can be viewed accurately. The various parameters are:

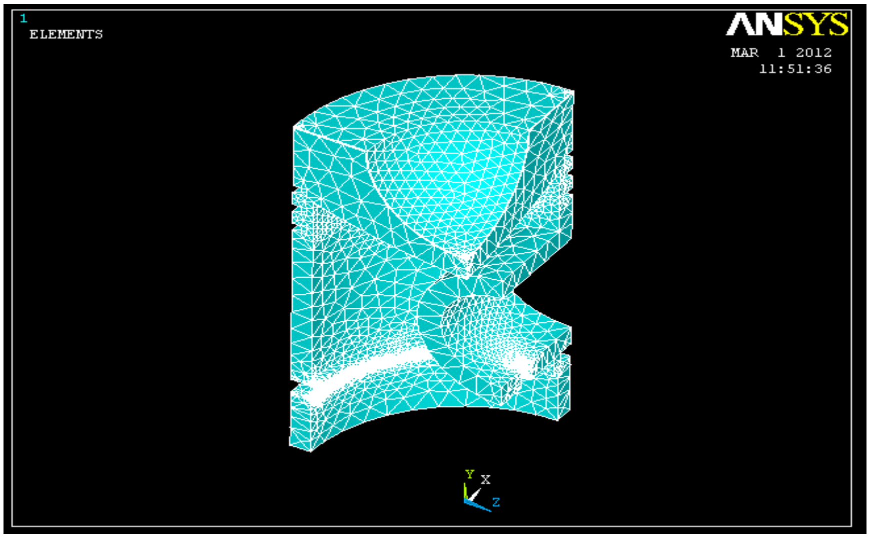


Figure 4 Meshing the model

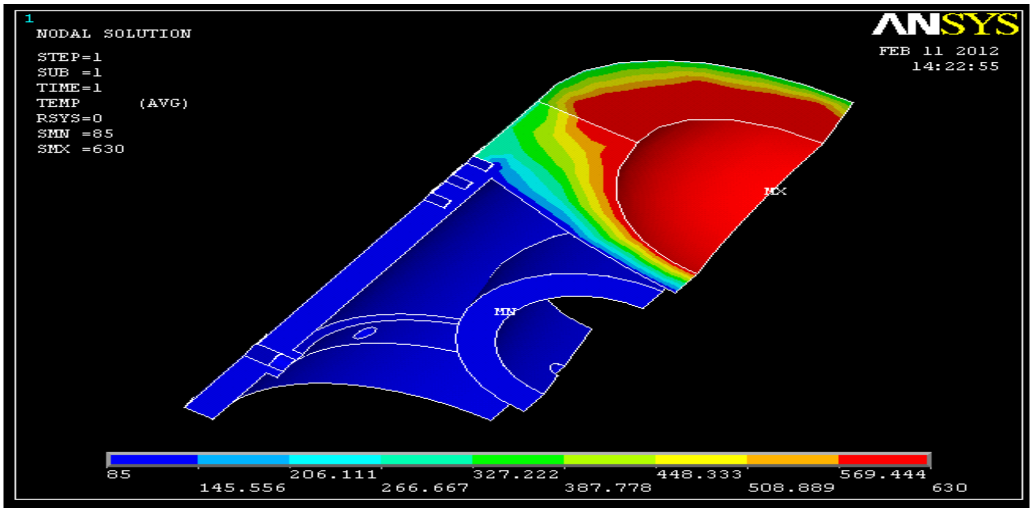
d) Applying the loads:

Once the mesh is generated the thermal loads are applied to the piston. The loads are temperature and the Convection heat transfer coefficients. They are calculated and tabulated in the chapter. The loads are applied separately the loads the model is solved using solver option.

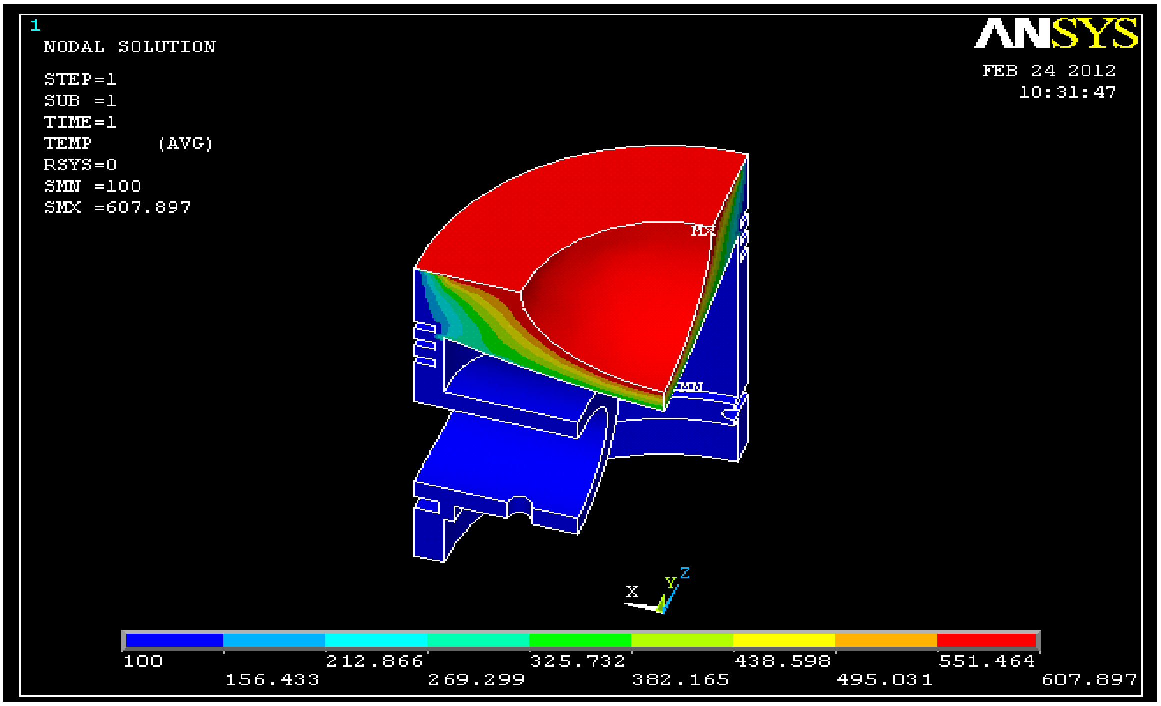
e) Viewing the results using post-processor:

The temperature distribution along the piston is predicted using nodal solution.

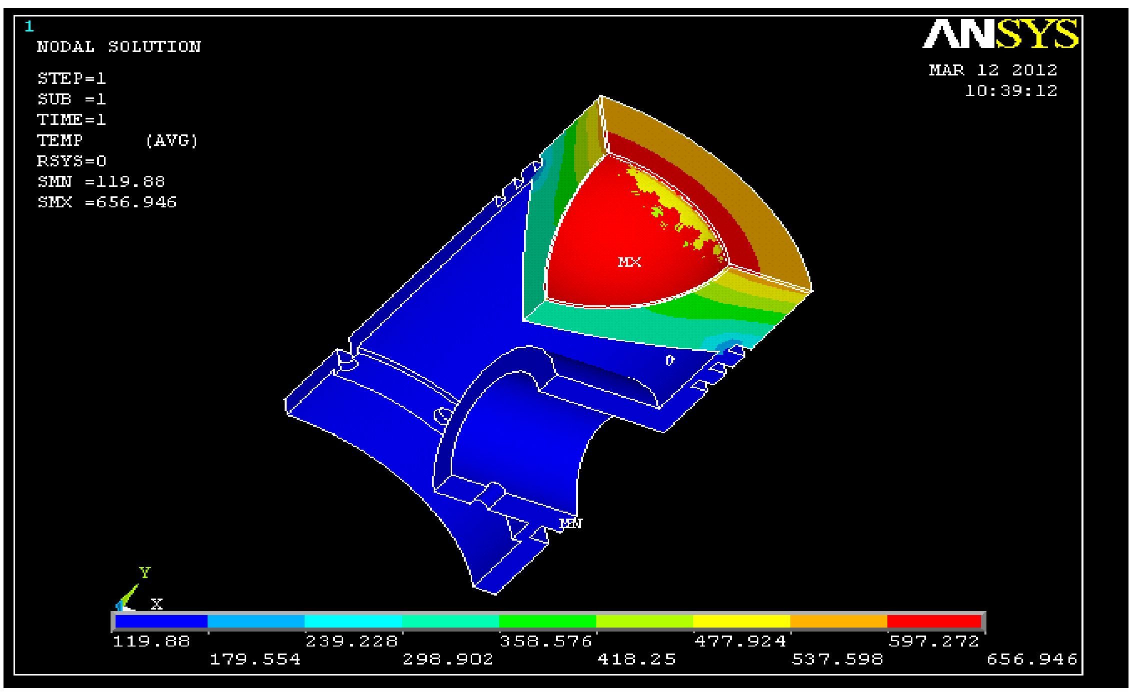
TEMPERATURE DISTRIBUTION FOR CONVENTIONAL PISTON



TEMPERATURE DISTRIBUTION FOR (0.55MM MULLITE +0.10MM NICRAL)



TEMPERATURE DISTRIBUTION FOR COATED PISTON



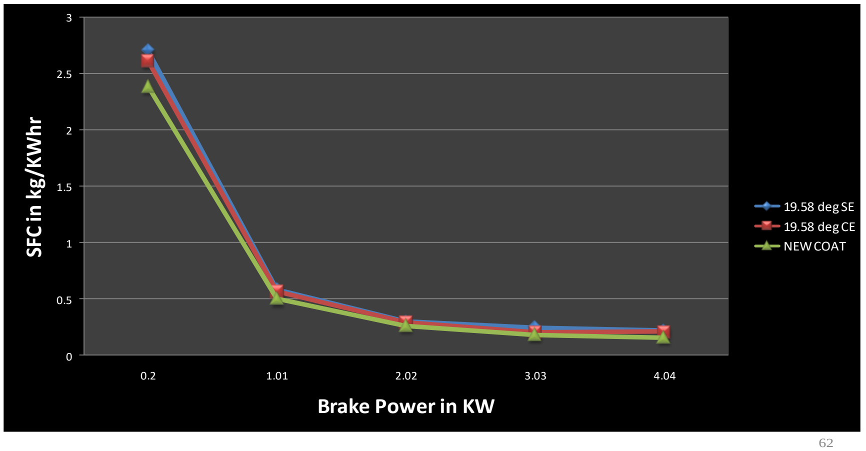
PERFORMANCE TABULATION FOR STANDARD 19.58 DEG INJECTION TIMING

LOAD	TIME	B.P	TFC	SFC	BTE	IMEP	ITE
Kg	s	KW	Kg/hr	Kg/KW hr	%	bar	%
1	138	0.2	0.55	2.706866	3.068	2.63	30.31
5	128	1.01	0.59	0.583668	14.23	3.69	39.46
10	127	2.02	0.59	0.294132	28.23	5.01	53.22
15	102	3.03	0.74	0.244149	34.01	6.34	54.04
20	86	4.04	0.88	0.217179	38.24	7.67	55.09

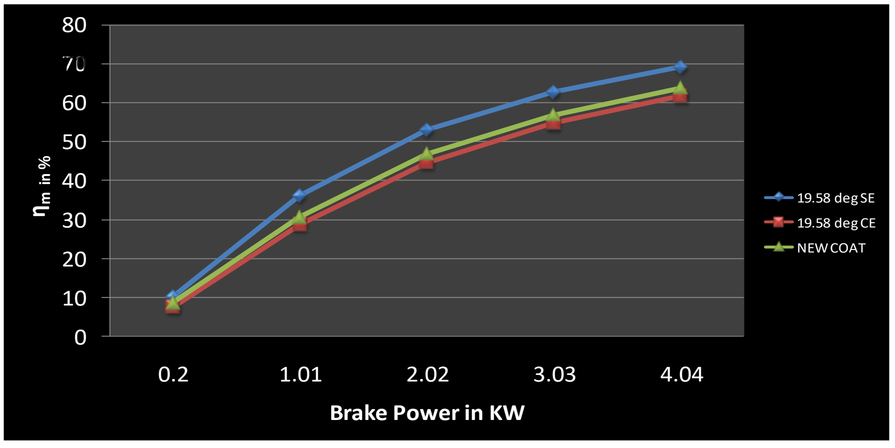
PERFORMANCE TABULATION FOR 0.55MM MULLITE COATED ENGINE 19.58 DEG INJECTION TIMING

LOAD	TIME	B.P	TFC	SFC	BTE	IMEP	ITE
Kg	s	KW	Kg/hr	Kg/KW hr	%	bar	%
1	138	0.2	0.55	2.706866	3.068	2.63	30.31
5	128	1.01	0.59	0.583668	14.23	3.69	39.46
10	127	2.02	0.59	0.294132	28.23	5.01	53.22
15	102	3.03	0.74	0.244149	34.01	6.34	54.04
20	86	4.04	0.88	0.217179	38.24	7.67	55.09

GRAPHS



BP VS SFC



BP VS MECHANICAL EFFICIENCY

CONCLUSION

The thermal analysis has been performed on the conventional, coated and optimum thickness of the pistons. The Use of the ANSYS software package to predict temperature distributions. The results of the analysis reveal that, the combustion chamber temperature of the conventional piston is 630degree Celsius. The combustion chamber temperature values are increased from 650.579 degree Celsius to 668.786 at some intervels for 0.05mm to 0.50mm coating thickness. This is due to the very small layer of the coating thickness.The temperature of the combustion chamber in 0.55mm mullite coated piston is decreased to 607 degree Celsius. The temperature contours are also evenly distributed in 0.55mm coated piston. Then the combustion chamber temperature values are gradually increased for other coating thickness greater than 0.55mm.

From the above analysis, it is concluded that 0.55mm coating thickness is the optimum coating thickness for diesel engine applications. The temperature and the stress values are reduced then the cooling load is also diminished for 0.55mm coating thickness.Thermal efficiency of the optimum thickness coated piston is 8% increase compared to the conventional and coated pistons and Specific fuel consumption is 4.5% decreased compared to the coated engine.

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