International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 2, March-April-2021, ISSN (Online): 2395-566X

Optimize Piston Durability by Coating Layer of Tungsten Carbide

Student of M.Tech. Nitesh Kumar, Gouraw Beohar(HOD), Assistant Professor Anshul Jain
Department of Mechanical
Shri Ram Institute of Technology, MP, India

***Abstract*- This coating enhance piston durability on layer of 0.20 to 0.25µm which explore that after all testing on Coated piston minimum coating thickness which has been coated will be 0.20 µm whereas maximum thickness of coating which has been coated on piston will be 0.25 µm . There are various result which shows that these layer are efficient during long run .These layer also having less absorption capacity of heat results in maximum heat energy transform into work due to this exhaust will be less. The most expensive way to reduce fuel consumption is to develop more efficient fire engines. Today, about 40-45% of gasoline is converted into useful energy, while the remaining thermal energy is converted into heat. One of the possible solutions of decreasing heat losses from the engine is by insulation of piston coated with Tungsten carbide; all possible measures of improvements are in the scope of interest. Therefore this master thesis was carried out. The theoretical study was focused on about appropriate materials, industrial applications and the state of the art research in the area of coating. Sample prototypes and material samples were coated using a thickness of 0.5 µm to 0.25 µm and coated with Tungsten Carbide powder coating. Heat flux, Shear stress, Elastic strain, and total deformation are measured for each coating. The integrated pistons have been tested in a single cylinder engine, to ensure the strength of the thermal barrier. Due to the negative impact on piston the combustion process and the overall efficiency of piston, were obtain .A trend showing a decrease in heat loss with an increase in the coating of the layer was observed. During both load and thermal cycling tests of different thickness of Tungsten Carbide powder coating such as 0.05 µm, 0.1 µm, 0.15 µm, 0.20 µm, 0.25 µm, and 0.3µm. The temperature and stress field of piston are resolved using ANSYS (Version 18) software. The optimum result obtained to acquire minimum heat loss during combustion and obtained no deformation during high heat in general 150 cc Aluminum alloy piston, the best result obtained on coating piston with 0.25 µm with Tungsten Carbide powder coating.**

***Keywords*- Piston, Tungsten Carbide, Temperature, Temperature Probe, Heat Flux, Stress, Strain, ANSYS version (18).**

I.INTRODUCTION

The most cost effective way to reduce the oil consumption is to develop more efficient combustion engines. Today, about 40-45% of fuel energy is converted into a useful work, while remaining fuel energy in form of heat losses is transferred to environment. One of the possible solutions of decreasing heat losses from the engine is by insulation of piston coated with Tungsten carbide; all possible measures of improvements are in the scope of interest. Therefore this master thesis was carried out.

The theoretical study was focused on about appropriate materials, industrial applications and the state of the art research in the area of coating. For the experimental studies, three selected materials have been selected that are documented in the engine and turbine industries. Piston prototypes and samples for material study were coated using five thicknesses 0.5 µm to 0.25 µm and a coating of Tungsten Carbide powder coating. Heat capacity, apparent heat distribution and low durability are measured for each garment. Stability under high temperature variations is tested on a machine specifically designed for hot cycling. The integrated pistons have been tested in a single cylinder research engine, to ensure the strength of the insulation. Due to the negative impact of partitioning the fire process and the overall efficiency of the engine, it was difficult to obtain results.

A trend showing a decrease in heat loss with an increase in the stiffness of the firm was observed. During both engine and thermal cycling tests of different thickness of Tungsten Carbide powder coating from 0.05 µm, 0.1 µm, 0.15 µm, 0.20 µm, 0.25 µm, 0. 3µm. The best result obtained to acquire minimum heat loss during combustion and obtained no deformation during high heat in general 150 cc pistons, the best result obtained when we coated piston with 0.25 µm with Tungsten Carbide powder coating. Reduction of Greenhouse Gases (GHG) emission is one of highest importance in all industrial sectors around the world in order to prevent the unwanted climate changes. According to International Energy Agency (IEA), without preventing actions the energy related CO2

© 2021 IJSRET

emission will be more than double by 2050 and increased oil demand will create more concerns about supplies. Among all countries a number of international and national procedures and commitments were already implemented in the last years. In the transportation sector however, due to its rapid growth the general release of GHG has recently increased. On the IEA's technical roadmap it is stated that today more than 55% of the fuel consumption of the vehicles and three quarters of them are used on the roads. If nothing is done about this, total fuel consumption in the sector will double by 2050.

Nevertheless, by further development, improvements and commercialization of available technologies, the achievement of 30% to 50% reduction of fuel consumption per kilometer from new light and heavy duty vehicles is possible before 2030; and from all light and heavy duty vehicles by 2050. The most cost effective way to reduce the oil consumption is to develop more efficient combustion engines.

II. STRUCTURE AND OVERVIEW TUNGSTEN CARBIDE

In order to increase efficiency of the piston, the coating of Tungsten Carbide is to be done. Tungsten Carbide has various properties describe below which is required for enhancing efficiency of normal piston. In this we are coating a normal piston with Tungsten Carbide and find the result of piston and comparing the result of coated piston with uncoated one.

The method which I had used will be to coat a thin layer Tungsten Carbide of 0.25um on the outside of piston and boundary condition which I have given to it that the atmospheric temperature will be 22degree Celsius and temperature of combustion chamber increases from 500 degree Celsius to 4000 degree Celsius.

III. ANALYSIS OF THE MODEL

Here Stress analysis of the 150cc piston model has been performed to obtain the value and parameters at which the piston coating of Tungsten carbide of different thickness would be damaged.

Damages may have different origins: thermal stresses; wear mechanisms; temperature degradation, etc. For this analysis parameters like Pressure, Temperature, Thermal Stress have been used and to discuss the effects of these parameters on the piston coated model are as follows:

1. Pressure:
When firing a gasoline mixture, pressure is applied to the fire head on the piston's head, forcing the piston to face the crankshaft. Due to the pressure on the piston head, there are two critical areas: piston pin holes and areas made in the piston head. This causes a significant impact on the piston head leading to damage and deformation of the piston head. This effect of pressure and heat due to the analysis of temperature rise was made for a separate cover of Tungsten Carbide.

2. Thermal Stress:
Heat pressure is difficult to imitate because there are, in the piston, two types of thermal pressure. Heat pressures due to direct vertical distribution of temperatures and high piston temperatures above and below and below. There is a consistent and normal gradient of heat in the head of the part. It is evident that the highest point of the piston has high temperatures. Thermal deformities below operating temperature are blocked by the surrounding material. This results in greater pressure pressures on the piston's entire rotation head which often exceeds the harvesting force of the object. After a series of high pressure pressures and when the piston acquires a cold affect it increases the residual pressure on the piston head. This cyclic suppresses the origin of the cracks scattered throughout the cycle.

By carrying the heat pressure Tungsten Carbide was performed and analysis was performed on the ANSYS software.

2.1 Analyzing the Model in ANSYS: After designing the model in CATIA, the CAT FILE has been converted to IGES format. This format makes the design compatible with ANSYS software. After importing the build into ANSYS, the analysis process begins. Various measures designed for appropriate model analysis.

2.2 Applying Material to the Model: As here we are considering that the model material for which the model is made is Al Alloy bound with Tungsten Carbide, which is why we added this item to the model designed built in CATIA. By doing this the model will have the same Alloy characteristics, such as Density, Poisson Ratio, Young Modulus, Thermal Conductivity, direct heat.

2.3 Meshing the Model: Mathematically, the structure to be analyzed is divided into a machine for limited objects with a simple structure. With in each object, the migration variation is thought to be determined by simple polynomial structure functions as well as irregular removal. Statistics of problems and pressures are made according to the unknown migration of nodals. From this, the equilibrium figures are grouped in a matrix that can be easily sorted.

I am doing analysis with the help of ANSYS in the model of static analysis basically I had taken a piston of 150 cc general IC engine and tested under the peak pressure generated during combustion. This piston has been performed its work under high pressure and under high

© 2021 IJSRET

combustion temperature in a closed chamber since an uncoated piston will be deformed quiet easier than a coated piston.

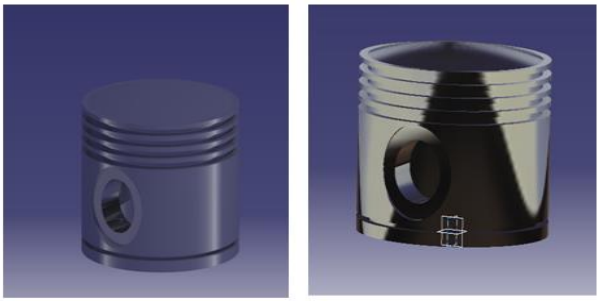

Fig 1. Work under high pressure and under high combustion temperature.

In this analysis I am coating this 150cc piston with Tungsten Carbide which is having high density and heat absorbing capacity due to which I basically perform the minimum heat loss and to obtain the output by the heat which has been generated during combustion.

It also means that this Tungsten Carbide Coated piston will perform well during high temperature and high pressure during combustion, the Tungsten Carbide coated piston durability increase in comparison with general piston. The service life and durability of the coated piston will increase half more than general piston and this coated piston will be economical and more durable than uncoated piston.

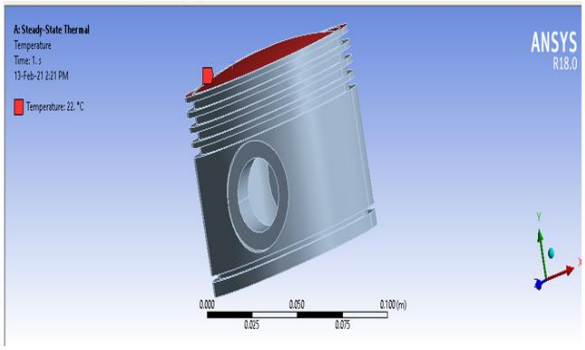

Fig 2. the coated piston will increase half more than general piston and this coated piston.

This Figure shows the pressure acting on the top of the piston acting downwards during burning of fuel.The above picture indicate that combustion acting on the top of piston which is made up of aluminum and coated with Tungsten Carbide on the outer surface of piston which means piston is protected with Tungsten Carbide during high heat which means piston can absorb much amount of heat without get deformed.

To prove that coated piston will be more efficient than uncoated piston. There is some analysis which is required to prove this theory that coated piston is more efficient than uncoated piston.The first thing is to complete the mesh in ANSYS the meshing is done in static structure completed mesh picture is given below-

3. Mechanical Load and Support:

The main pressure applied to the piston is the gas pressure is considered to be 6.5 Mpa and is applied over the piston head. The piston is provided with non-grounding bases as shown in Fig in two places. Strict structural analysis was performed on the piston at Ansys.

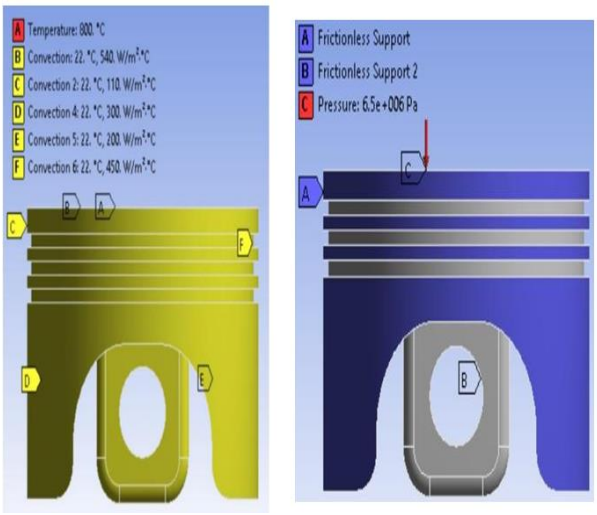

Fig 3. Taken from G.V.N. Kaushik.

4. Finite Element Analysis of Piston:

The Finite element analysis method is used to perform the analysis on the piston when facing hot and mechanical loads. To perform a complete piston analysis the Ansys Work bench analysis software is used. Direct static analysis occurs in this experiment, where small changes in objects remain within a precise position with minimal flexibility and pressure.

Table 1. Minimum and Maximum Deformation of Piston Due to Thermal Loads.

Material	Min Deformation	Max Deformation
42CrMo	$7.4418e^{-6}$m	0.00052935m
Al-Mg-Si	$2.1809e^{-6}$m	0.13799m
Al-Si	$2.147e^{-6}$m	0.0013114m
Al-Si-C-12	$9.0436e^{-7}$m	0.00057229m
Tungsten Carbide Coated	$10.0436e^{-7}$m	0.000103829m

© 2021 IJSRET

Table 2. Minimum and Maximum Heat Flux of Piston Due to Thermal Loads.

Material	Min Heat Flux	Max Heat Flux
42CrMo	3804.6 W/m^2	2.0709e^5 W/m^2
Al-Mg-Si	11095 W/m^2	5.3234e^5 W/m^2
Al-Si	11411 W/m^2	5.29e^5 W/m^2
Al-Si-C-12	12071 W/m^2	4.9623e^5 W/m^2
Tungsten Carbide Coated	142.67 W/m^2	2.9116e^6 W/m^2

Table 3. Minimum and Maximum Temperature of Piston Due to Thermal Loads.

Material	Min Temperature	Max Temperature
42CrMo	62.448 ^{0}C	800 ^{0}C
Al-Mg-Si	328.91^{0}C	800 ^{0}C
Al-Si	325.43 ^{0}C	800 ^{0}C
Al-Si-C-12	291.81 ^{0}C	800 ^{0}C
Tungsten Carbide Coated	239.41^{0}C	1000^{0}C

IV. RESULT AND SIMULATION

1. Steady State Thermal:

The test result will be performed at different temperatures and this effect is compared to a standard piston, the strength of a standard piston is in Aluminum only and the strength of the coated piston will be increased with the help of Tungsten Carbide cover. The various results obtained during the analysis will be provided with a table graph with tables and all ANSYS report obtained during the analysis.

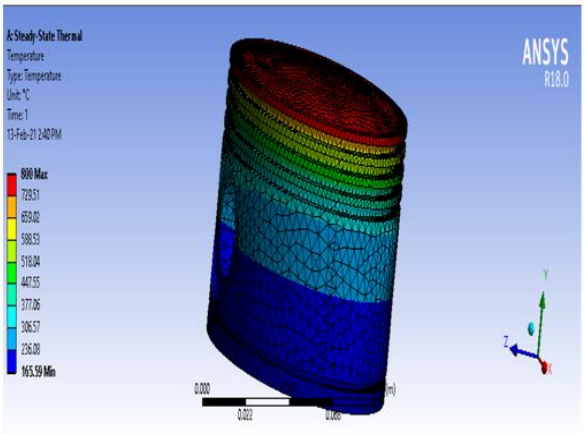

Fig 4. Figure shows temperature analysis.

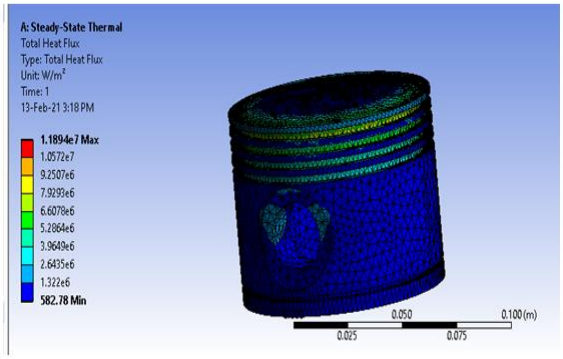

Fig 5. ANSYS report obtained during the analysis.

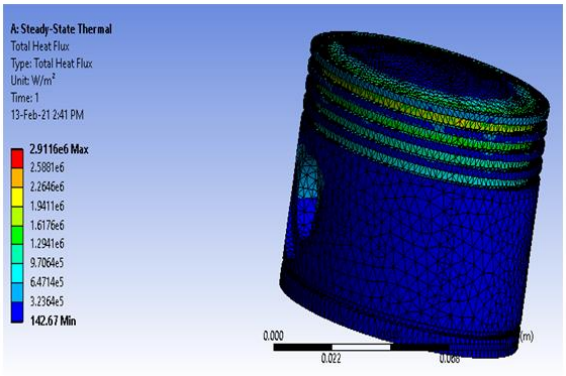

Fig 6. Figure shows steady state analysis.

Table 4. Tungsten carbide Coating and Maximum Shear Elastic Strain.

Coating Thickness	Maximum Shear Elastic Strain (N/m^2 or Pascal)
0.05um	5.2780
0.10um	5.2794
0.15um	5.2778
0.20um	5.2677
0.25um	5.2665
0.30um	5.2785

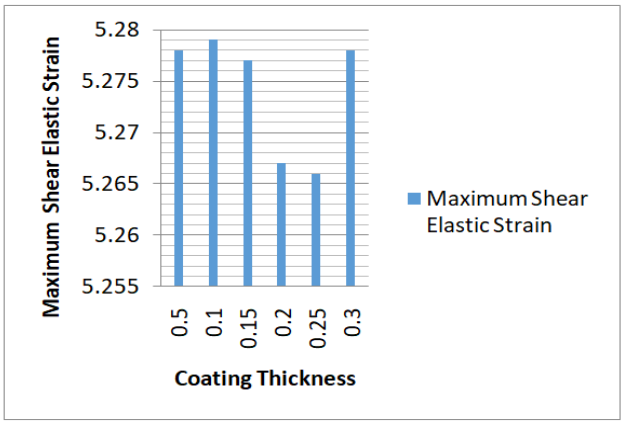

Fig 7. Graph between Tungsten carbide Coating and Maximum Shear Elastic Strain.

© 2021 IJSRET

Comment: The failure of materials is most accurately governed by the distortion energy criterion. Which means that shear strain value should be minimum to sustain object at high temperature and high pressure during load. In this graph the deformation due to distortion will be less for coating layer 0.25um.

Table 5. Different Coating layers of different Thickness.

Coating thickness (um)	0.05	0.10	0.15	0.20	0.25	0.30
Diameter of Piston	56.055	56.060	56.065	56.070	56.075	56.080
Temperature	100 - 800	100 - 800	100 - 800	100 - 800	100 - 800	100 – 800
Layer Tearing at temperature	960	970	980	997	1000	800
Heat Flux	4.46	4.42	4.04	4.03	3.96	2.97
Young's Modulus	6×10^5Mpa	6×10^5Mpa	6×10^5Mpa	6×10^5Mpa	6×10^5Mpa	6×10^5Mpa
Thermal Conductivity	88 W/m^{0}c	88 W/m^{0}c	88 W/m^{0}c	88 W/m^{0}c	88 W/m^{0}c	88 W/m^{0}c
Specific Heat	292 J/kg^{0}c	292 J/kg^{0}c	292 J/kg^{0}c	292 J/kg^{0}c	292 J/kg^{0}c	292 J/kg^{0}c
Thermal expansion	7.1	7.1	7.1	7.1	7.1	7.1

The above Table shows different layers of thickness varies with parameters and result obtained at various layer of thickness in which top curves shows that heat absorption is maximum and it can be notable absorb maximum heat since layer of piston forms a crack by which durability of piston decreases at Coating Of 0.3um.The heat absorption is in form of crystal due to which it is not able to stay during maximum load. This coating layer gets deformed at temperature of 800 Degree Celsius.

In case of 0.25um coating of Tungsten Carbide heat absorption is in a boundary condition and it does not deform as previously layer deformed earlier. This coating layer can bear temperature of 800 degree Celsius and it get deformed at 1000 Degree Celsius. It bear temperature of 1000 degree Celsius because in previous piston of thickness 0.3um there is a heat accumulation is excessive because heat is absorbed in form of Crystals and more heat causes breaking at 3.0um thickness but in thickness of 0.25um coating it is not more thick not more thin it is quietly appropriate for heat absorbing and heat transfer to other particles of coating. Hence it can be concluded that 0.25um thickness is suitable for piston for heat transfer, heat absorption, wear, tear and for cracking phenomenon. This is best and suitable for coating in Piston.

For coating thickness of 0.20um results are as same as coating of 0.25um but there is a slight difference in heat flux and tearing temperature. In other can be state that it can also be liable to a great extent but thickness of 0.25um coating is required and needed for piston analysis. So it can also be liable but not too much. The coating limit which I have found that minimum thickness of Tungsten Carbide coating will be 0.20um is liable and maximum limit of thickness will be 0.25um. In case of increasing thickness of Tungsten carbide heat absorption in form of Crystal is found whereas on decreasing layer of thickness below 0.20um heating phenomenon will increase on surface of piston.

In coating of thickness 0.15um there is deformation in coating. Coating is heated due to heat supply and continuity in heat supply results in breaking of piston coating. So further decreasing coating layer of different thickness is not liable and appropriate for piston analysis. With all of above thickness of coating there is only two coating layers of Tungsten Carbide thickness 0.20um (minimum) and 0.25um (maximum) is absolute and desired for temperature 150 Degree Celsius (minimum) to 800 Degree Celsius (maximum) in 150 cc engine.

V. CONCLUSION AND FUTURE SCOPE

1. Conclusion:

Tungsten carbide-bound piston was durable and could receive high temperatures without paralysis and could be operated for a long time since the piston strength would be increased by more than 35%.

A field of heat pressure caused by unequal distribution of temperatures was found in this study. To simulate the pressure field, a fixed temperature field was calculated. In the thermal analysis, the absolute limit of the piston is obtained by adjusting the piston pin, which corresponds to the actual position of the piston. After all the previously performed operations, the simulation effects of thermal pressure are well obtained. This concept attempts to prioritize the thermal conductivity method, which is used to mimic a field of thermal pressure caused by uneven heat distribution when operating a piston.

© 2021 IJSRET

The main conclusion that can be drawn from this work is that although thermal pressure is not the major cause of a large piece of piston damage, it remains a problem for engine pistons and its solution remains the goal of piston manufacturers.

It is clear that the heat pressure was higher than the mechanical pressure and therefore it can be concluded that the piston will fail due to the thermal load rather than the mechanical load and therefore during efficient construction, this can be considered to ensure that the themal loads are reduced. It can also be considered that the both thermal and mechanical dimensions have a direct impact on the combination of mechanical combustion pressure and therefore during design each load controlled independently. It can be concluded that the piston can safely withstand the pressures caused by its operation.

The pressures experienced by the teaching census and FEA were found to be almost same. And it will remain a challenge for long time, because efforts to reduce fuel consumption and increase energy will push the weight limit, which means thinner walls and higher pressure.

Satisfying all the requirements regarding the efficient use of pistons, especially mechanical heating at high temperatures which results in thermal fatigue, There are many ideas available that can be used to improve its performance, such as design, materials, processing technologies, etc.

2. Future Scope:

Further research can also do in future in which the coating layer can be changed or it can be also done in the internal combustion chamber to increase durability.Tungsten coating can be most useful so that it can also be done in the walls of the cylinder to use maximum amount of heat and to utilize it as a work.

During practical use of this piston when working durability of the engine will be increases from the normal piston and at an average the durability will be increased more than 30% from the normal one.This coated piston can be used in all vehicles to increase durability during long run of the engine and it will be liable to all IC Engine to be work at a high combustion.

As Tungsten is available in huge amount and its cost is negotiable in market so cost price will be in a limit and it can widely used in automobile for various mechanism tools. On coating with 0.25 um of Tungsten Carbide the piston diameter will remain same so it doesn't increase so most of vehicle will use this piston than the durability of engine will be increased from general one.

REFERENCE

[1] Diesel Net Technology Guide. Copyright © 1997-2014 ECO point Inc. Available at: http://www. diese lnet.com/tg.php#basics.
[2] Auto evolution. © 2008-2014 SoftNews NET. http://www.autoevolution.com/news/two-stroke-vs-four-stroke-motorcycle-engines-19664.html.
[3] 2-Stroke Engine Applications & Lubrication. Beset Synthetic Oil. http://bestsyntheticoil.com/amsoil-synthetic-motor-oil-filter-info/synthetic-petroleum-motor-oil- info/2-stroke-engine-applications-lubrication/. Consulted on June 27th, 2014.
[4] R. Stone. Introduction to Internal Combustion Engines. Palgrave Macmillan. 4th Edition. (2012)
[5] Automotive Handbook. BOSCH Invented for live. Ed. Wiley. 8th Edition. (2011)
[6] C. Chartier. Spray Processes in Optical Diesel Engines. Doctoral thesis. Lund University (2012)
[7] O.I. Smith. Fundamentals of Soot Formation in Flames with Application to Diesel Engine Particulate Emissions. Prog Energy Combust Sci, 7(1981), pp. 275-291
[8] J. Dec. A Conceptual Model of DI Diesel Combustion Based on Laser-Sheet Imaging. SAE Technical Paper 970873, 1997. Doi: 10.4271/970873.
[9] All emission standards. Available at: https://www. dieselnet.com/standards/eu/hd.php.
[10] Combustion. Academic Press, San Diego (1996).
[11] Tree, D.R., Svensson, K.I., Soot processes in compression ignition engines, Progress in energy and Science 33 (2007) pp. 272-309.
[12] H. Dembinski. In-cylinder Flow Characterisation of Heavy Duty Diesel Engines Using Combustion Image Velocimetry. Doctoral thesis in Machine Design. The Royal Institute of Technology (2014).

© 2021 IJSRET