Thermal Analysis of single cylinder 4-Stroke SI Engine Fuel With Petrol (Gasoline) And Ethanol Blend.

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ABSTRACT:-

As the population of the world increases, consumption of the energy also increases tremendously. With the current consumption rate it has been quoted that there will be great shortage of petroleum products in upcoming decades, it may not be wrong. For this reason people are looking for alternative fuels. Sharp hike in petroleum prices and increase in environmental pollution jointly have necessitated exploring some renewable indigenous alternatives to conventional petroleum fuels. Also, depletion of fossil fuels, vehicular population, increasing industrialization, extra burden on home economy, growing energy demand, explosion of population, environmental pollution, emission norms, etc emphasize on the need for alternative fuels. The possible options we have are renewable energies solar power, Compressed Natural Gas (CNG), alcohols, hydrogen, bio alcohol such as methanol, ethanol, butanol, batteries and fuel cells, propane, non-fossil methanol, non-fossil natural gas, emulsified fuels, biofuels mostly from non-edible seed oils, biodiesels i.e. trans-esterified form of seed based oils and other biomass sources. Ethanol produced from biomass has high octane number and good antiknock characteristic, less ozone depletion potential and global warming potential than the pure gasoline, therefore it can be used as a blended fuel with gasoline fuel in the S.I. engine. In this work, thermal analysis of single cylinder 4- stroke spark ignition engine is carried out with fuel petrol and ethanol blends and facts supporting use of ethanol and petrol blends have been discussed. As the present government norms permits to use 10% of ethanol addition with the petrol, the current work focuses on the calculations & simulations for the same.

Keywords: - SI engine, ethanol, thermal analysis

I. INTRODUCTION

World's energy consumption has increased continuously since decades except for a brief period like the oil crisis in 1970's in which the growth slowed down. Energy consumption is not expected to decrease in this century, because the world population is increasing continuously and the economies of developing countries are expanding rapidly. In contrast, the source and supply of primary energy sources like coal, oil and natural gas seem to decrease to a critical point. The petroleum fuels, one of the major sources of energy, are currently the dominant global source of CO_2 emissions, greenhouse gases and global warming. Therefore many nations have signed the UN agreement to prevent a dangerous imbalance in the climate system. Petrol engines contributing the major share in private vehicles on road do not have much high thermal efficiency due to small compression ratio constraints in SI engine for petrol. Also the emissions of the petrol and kerosene engine include high percentage of HC and CO contents as the engine grows older leading to ozone formation on round level. With the stringent emission standard and limited petroleum reserve, alternative fuels for diesel engine have been used. As a renewable and oxygen containing bio-fuel, ethanol is a prospective fuel for vehicle, which can be blended with diesel or be injected into cylinder directly. Studies on the use of ethanol in diesel engines have been continuing since 1970s. In a country like India having a huge agricultural potential, vegetable oil proves a promising alternate for petroleum (diesel) fuel. Today, India has 17% of the world's population, and just 0.8% of the world's known fossil fuel and natural gas resources. India's annual requirement of oil is 120 million metric tons. India produces only about 25% of its total requirement. The import cost today of oil and natural gas is over Rs. 2, 00,000 cores. We have nearly 60 million hectares of wasteland, of which 30 million hectares are available for energy plantations like Jatropha, Karanja. Each acre will produce about 2 tonnes of biodiesel at about Rs. 20 per liter. India being predominantly an agricultural country requires major attention for the fulfilment of energy demands of a farmer. Irrigation is the bottleneck of Indian agriculture, it has to be developed on a large scale, but at the same time Diesel fuel consumption for these sectors must be kept at a minimum level because of the price of Diesel oil and its scarcity due to fast depletion. Finding an alternative fuel for petroleum diesel fuel is critically important for our nation's economy and security. The complete substitution of oil imports by indigenous alternatives for the transportation and agricultural sectors is the biggest and toughest challenge for India.

II. LITERATURE REVIEW:

Wei Y., Wang K., Wang W., Liu S., Yang Y. [1] experimentally investigated ethanol (C_2H_5OH) emission characteristics on spark ignition engine when it ran on 10%, 20%, and 85% blends. The main results can be summarized as follows. The alcohol emission is the residual fuel alcohol, their emission rates all decrease exponentially with the increasing exhaust temperature. The alcohol fraction in fuel blends only improved the minimum value of emission rates; it had little impact on the maximum value. Regardless of the alcohol fraction in fuel blends, the emission rate of C_2H_5OH was higher; it was no more than 35%. The emission rate of non alcohol HC was one grade higher than the alcohol emission rate; it firstly decreased and then began to keep nearly constant at middle and high engine load. The existence of as high as 20% alcohols in fuel blends did not change the HC emission rate. The minimum HC emission rate was about 50% for ethanol/gasoline blends. The HC emission of alcohol/gasoline fuelled engine was no more than 25% for ethanol. Preetham J. [2] experimentally tested compression ratio of SI engine varied from 3.6 to 7.4. The tests were conducted using four fuels namely Petrol, Kerosene, 5% Ethanol blend, 10% Ethanol blend for compression ratios varying from 4.0 to 6.0. From the experiments conducted, it is observed that the maximum brake thermal efficiency of the engine is found to be abnormally low (around 11%). For Petrol, the compression ratio of 4.8 is found to be optimum from the point of view of emissions and efficiency. For Kerosene also, the optimum compression ratio is found to be 4.8. For Gasohol also, the optimum compression ratio is found to be 4.8. Kumar J., Ansari N. A., Verma V., Kumar S. [5] in their review paper presented a review on exhaust gas analysis and parametric study of ethanol blended gasoline fuel in spark ignition engine. From the results, it can be concluded that Ethanol blends are quite successful in replacing pure Gasoline in Spark Ignition Engine. Results clearly show that there is a decrease in exhaust emissions, increase in Brake Thermal Efficiency. So 10% ethanol blended Gasoline is the best choice for use in the existing Spark Ignition Engines without any modification to reduce exhaust and increase Efficiency. A little consideration has to be taken on material used as maximum pressure inside cylinder is increased by blending. A balance has to be made between Specific Fuel Consumption and Efficiency to take care of users using blend as more fuel will be consumed due to blending of Ethanol with gasoline.

Sarkar A., Chowdhuri A.K., Bhowal A.J., Mandal B.J. [7] in their review paper presented a review on the performance and emission characteristics of SI engine running on different ethanol-gasoline blends. The performance characteristics are improved but only to some extent with the use of ethanol or blends of ethanol and gasoline. The power, torque increases at a certain percentages of ethanol in the blends and BSFC increases with the increment of the percentage of ethanol in the blend. Also octane number and volumetric efficiency increases with the increase in percentage of ethanol in the blends. Misron N., Rizuan S., Vaithilingam A., Mailah N.F. ,Tsuyoshi H. , Hiroaki Y., Yoshihito S. [12] studied performance improvement of a portable electric generator using an optimized bio-fuel ratio in a single cylinder two-stroke engine. An evaluation of the effects of bio-fuel-gasoline blends on the generator performance of single cylinder two stroke engines is performed and reported. As the fuel consumption is improved, the electrical power output performance is increased. In this research the engine performance is investigated by measuring the output power generated by an electric generator that is coupled to the engine. With the load resistance of 15 Ω and with a blending ratio of 10% ethanol–90% gasoline the performance of the engine is increased up to 6% more than by using 100% gasoline alone as fuel. For a blending ratio of 20% butanol-80% gasoline, the engine performance is increased by 8% more than when using 100% gasoline as fuel. In conclusion, the engine performance increases compared to using 100% gasoline as fuel for a typical load condition with certain bio-fuel and gasoline blends, especially when high load torque is required.

Project Objectives:

- To carry out experimentation on variable compression ratio engine for petrol & ethanol blends
- To carry out thermal analysis numerically for petrol engine & ethanol blend
- To carry out thermal analysis simulation using ANSYS software for temperature distribution & thermal stress computation.

III. EXPERIMENTAL SET-UP & PROCEDURE :

In this experiment, we conduct an experiment on MK-25 HSP Single Cylinder Four Stroke S.I Engine using pure petrol (gasoline) and the Blends of Ethanol E10 with Gasoline. we have tested on the above engine. On the basis of Volumetric analysis we have mixed separate volumes of Ethanol as well as Petrol in given proportion. In this study the blend were prepared on volume basis. Ethanol is blended with gasoline in concentration of 10% and this blend is known as E10. The purity of ethanol and gasoline is 99.9%.

Sr. No.	Particulars	Data
1	Engine Make And model	Cottan Greaves Mk-25 HSP Engine
2	Engine Type	Single Cylinder Four Stroke Petrol Engine
3	Cubic Capacity	256 cc
4	Bore	70 mm
5	Stroke	66.7 mm
6	RPM (Engine Speed)	3000

TABLE 1: TEST ENGINE SPECIFICATION

Fig. no.1: Experimental Set-up Of MK -25 HSP Engine

A single cylinder four stroke spark ignition engine was used in this experiment. Test Were carried out at constant speed and different load conditions and different compression ratios varries from 4.5 to 6.5. The specification of the engine were given in table no 1. The Test were performed for pure petrol and ethanol blend at different load conditions with allow to stabilize the rated speed i.e2800 or 3000 rpm. The brake power and brake specific fuel consumption were measured.

Performance test calculations formulae:

1. Brake Power:

BP = 2πNT/ 60000 KW,

Where, N= speed of the engine in rpm; T= Torque in N-m

2.Brake Specific Fuel Consumption:

BSFC = m_{fc} / BP kg/KW hr,

Where, m_{fc} = Mass of fuel consumption from the indicator

3.Brake Thermal Efficiency:

$\eta_{b=}$ **BP ×3600 ×100/ (m_{fc} × C_V),**

Where, C_V= calorific value

IV. RESULTS AND DISCUSSION:

The experimentation carried out on engine for pure petrol and ethanol blend, The observation values are taken which is mentioned previous chapter. The various observations are plotted for comparative analysis.The effect of ethanol addition to unleaded gasoline on spark ignition engine performance at various engine load investigation:

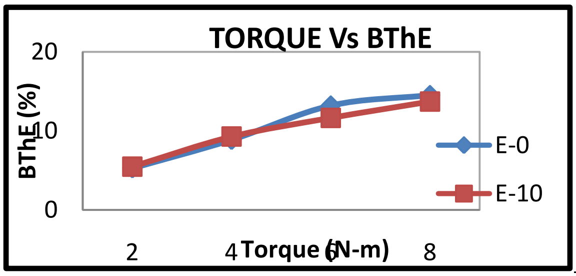


Fig. 4.1T vs BthE, CR 4.5, natural Ignition.

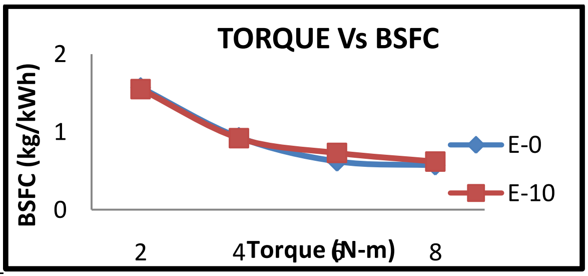
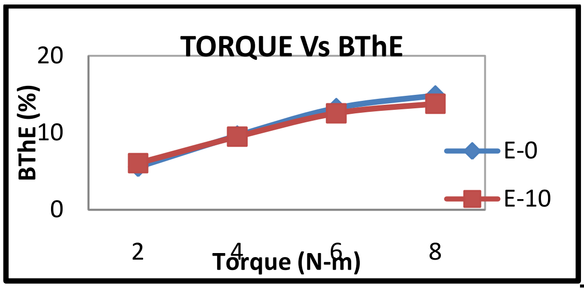


Fig.4.4 T Vs BSFC, CR 4.5, Natural Ignition.



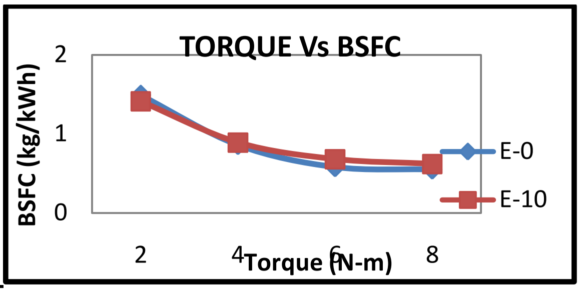
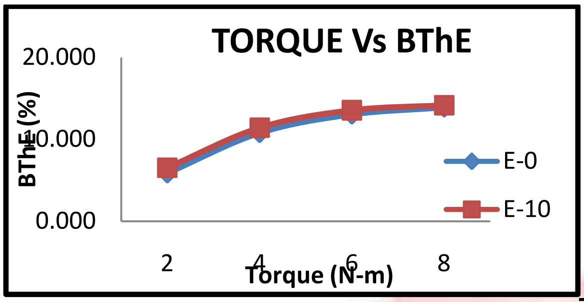


Fig. 4.2 T vs BthE, CR 5.5, natural Ignition

Fig.4.5 T Vs BSFC, CR 5.5, Natural Ignition.



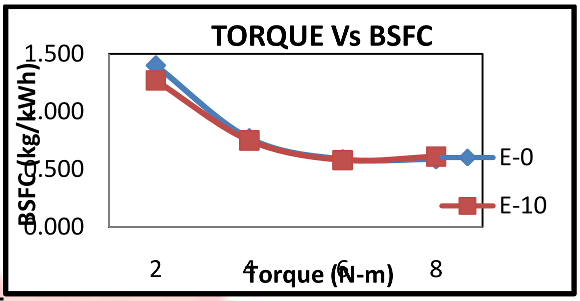


Fig. 4.3T vs BthE, CR 6.5, natural Ignition

Fig.4.6 T Vs BSFC, CR 6.5, Nat Ignition.

Effect On Brake Thermal Efficiency:

Figure 4.1 to 4.3 represents the effect of ethanol blend with gasoline on brake thermal efficiency for the compression ratio 4.5 to 6.5 at different load conditions. It shows the same trend that thermal efficiency increases as load increases for petrol (E0) and ethanol blend (E10) with gasoline. For compression ratio 4.5 and 5.5 at low load condition thermal efficiency of E10 is more as compared to E0. And at higher load, thermal efficiency of E10 is less as compared to E0. For compression ratio 6.5 Thermal efficiency at low load and at high load of E10 is more as compared to E0.

Effect On Brake specific fuel consumption:

Figure 4.3 to 4.6 represent the effect of ethanol blend with gasoline on brake specific fuel consumption for the compression ratio 4.5 to 6.5 at different load condition. It shows the trend that the brake specific fuel consumption decreases as load increases for petrol (E0) and ethanol blend with gasoline (E10).Figure 4.4 and 4.5 shows that brake specific fuel consumption of ethanol blend (E10) is less at low load condition and higher at high load condition as compared to petrol (E0). Figure 4.6 shows that brake specific fuel consumption of ethanol blend (E10) is nearly same as petrol (E0) at higher at high load condition for compression ratio 6.5. Figure 4.3 to 4.6 for compression ratio 6.5 the brake thermal efficiency is more and brake specific fuel consumption is nearly same, this is due to the inherent oxygen contents of ethanol is the chief contributor to increases power output and thermal efficiency with ethanol gasoline blend.

Higher latent heat of vaporization of ethanol of 207 kcal/kg as compared to 70-100 kcal/kg of gasoline, also due to the higher latent heat of vaporisation the combustion temperature for the blended ethanol fuel decreases and the amount of thermal load on the engine. Therefore for the engine designed to run on gasoline, marginal thermal efficiency improvement can be achieved.

ANSYS Simulations:

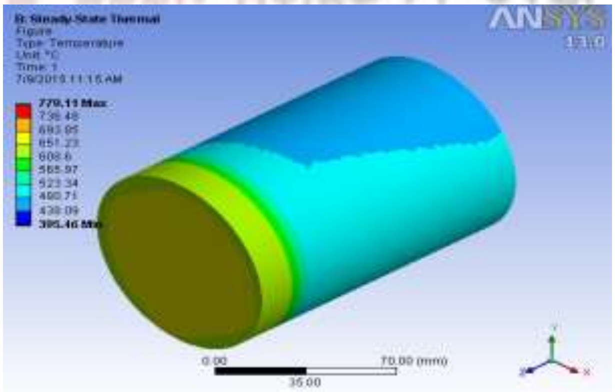
ANSYS is a finite element analysis (FEA) software package. It uses a pre-processor software engine to create geometry. Then it uses a solution routine to apply loads to the meshed geometry. Finally it outputs desired results in post-processing. FEA is used throughout almost all engineering design including mechanical systems and civil engineering structures. In most structural analysis applications it is necessary to compute displacements and stresses at various points of interest. The finite element method is a very valuable tool for studying the behaviour of structures. In the finite element method, the finite element model is created by dividing the structure in to a number of finite elements. Each element is interconnected by nodes. The selection of elements for modelling the structure depends upon the behaviour and geometry of the structure being analyzed. The modeling pattern, which is generally called mesh for the finite element method, is a very important part of the modeling process. The results obtained from the analysis depend upon the selection of the finite elements and the mesh size. Although the finite element model does not behave exactly like the actual structure, it is possible to obtain sufficiently accurate results for most practical applications.

The goal of meshing in ANSYS is to provide robust, easy to use meshing tools that will simplify the mesh generation process. These tools have the benefit of being highly automated along with having a moderate to high degree of user control.

Temperature Distribution in Engine Parts:

Cylinder:
Material Grey Cast Iron
Combustion temperature: 1190^{0}C
Thickness of Cylinder: 10 mm, I.D. = 70 mm,
Length: 137 mm (including top thickness)

Fig 4.7: Temperature Distribution on Outer wall:



Piston:

Material: Aluminum Alloys

Thickness at the Top = 4 mm

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Thickness in Top Portion of Piston: 9.5 mm (portion inline with rings)

Skirt Thickness: 3.5 mm

Piston Rings: Grey Cast Iron (Nos. 3)

Axial Thickness = 2.5 mm

Radial Thickness = 2.5 mm

O.D. = 70 mm

Figure 4.8: Temperature distribution in Piston

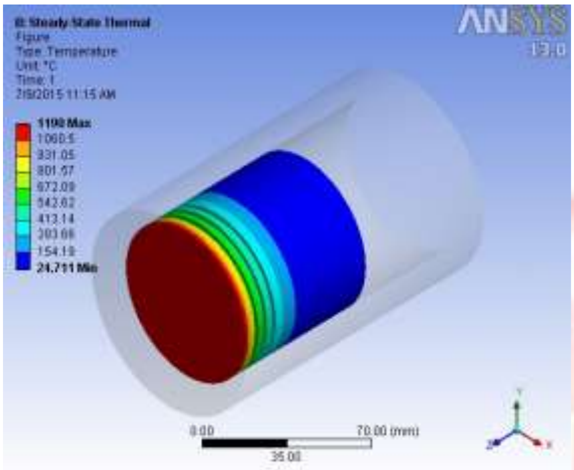
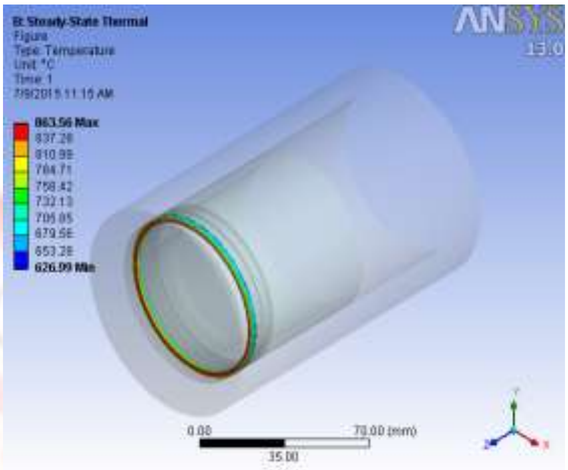


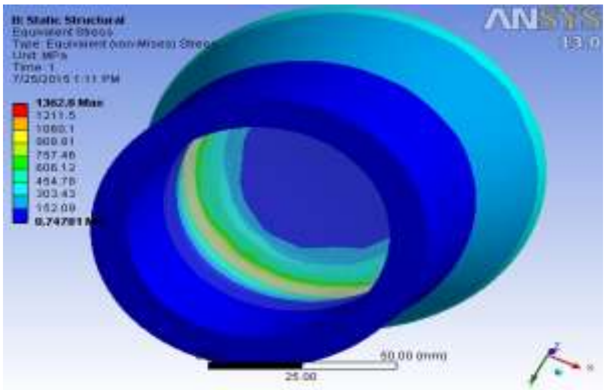
Fig 4.9: Temperature distribution in Piston Ring



Thermal Stress Distribution in Engine Parts:

Cylinder:

Figure 4.10 Thermal stresses on cylinder body:



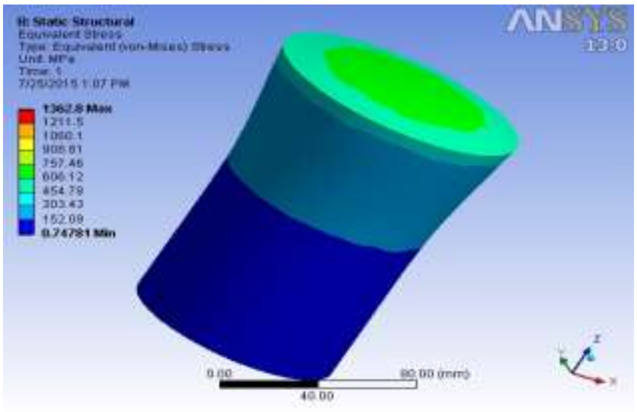


Figure 4.11 Thermal stresses on piston:

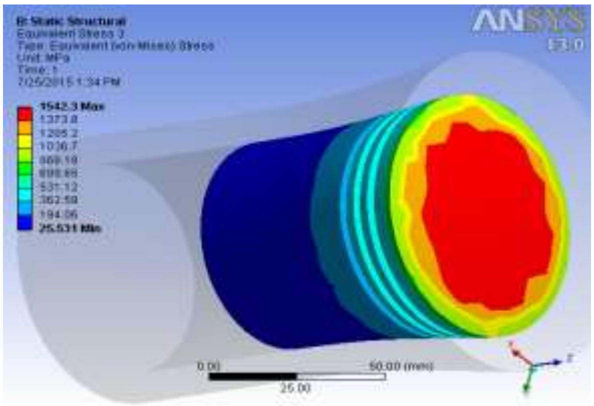
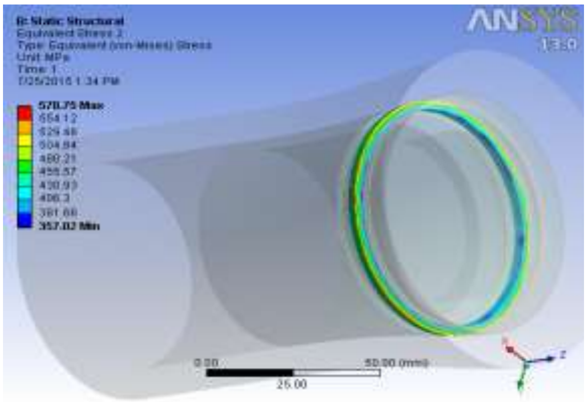


Figure 4.12 Thermal stresses on piston Ring



ANSYS Simulation Results For E10 blend:

	Maximum temperature (^{o}C)	Maximum Thermal stress (MPa)
Cylinder outer surface	779	757
Cylinder Inner surface	1190	1362
Piston	1190	1542
Piston ring	863	579

V. CONCLUSION

In the present work E10 is tested & its thermal analysis is carried out by using ANSYS software. It can be seen from the testing results that the various performance parameters are having better values than the pure petrol case. From the experimental results as concusses as follows.

- For different compression ratio (C.R) from 4.5 to 6.5, percentage increase or decrease in thermal efficiency of E10 blend is found in the range of +11.74% to -7. 14%. and percentage increase or decrease in brake specific fuel consumption is found in the range of + 17.24% to -9.29%.
- For compression ratio 4.5 and 5.5 at low load condition (25% - 50% of the rated load) the thermal efficiency increases and at higher load thermal efficiency decreases while for compression ratio 6.5 thermal efficiency increases at high load conditions.
- For compression ratio 4.5 and 5.5 at low load condition (25% - 50% of the rated load) the brake specific fuel consumption is more and at higher load brake specific fuel is low. For compression ratio 6.5 brake specific fuel consumption is nearly same at high load conditions.

- As the present government norms permits to use 10% of ethanol addition with the petrol From the analysis of ANSYS simulation of E10 blend maximum thermal stresses developed on piston and piston ring is 1542 Mpa and 579 Mpa respectively; stresses developed in cylinder inner surface is 1362 Mpa. at the internal temperature is 1190 deg. Cent. As internal temperature of cylinder and piston using pure petrol and ethanol blend (E10) is nearly equal so that internal stresses and temperature distribution is same in both cases so no need to change engine modification.

- The maximum temperature constraint at the piston ring is satisfied, as the temperature there is well below its limits. The thermal stresses for the given temperature are on the higher side, but as in actual practice cooling arrangement is provided for the engine, these stresses will be well within their limits. It can be expected that, with the increment in the ethanol content the temperature & the corresponding stresses may further gets reduced & the overall modified engine cost can be reduced significantly.

VI. FUTURE SCOPE

- ♣ The various blends like E20, E30 & even up to pure ethanol can be tested & their effect on the engine configuration can be studied.
- ♣ The CFD analysis of the actual combustion process can be done to study the flow behaviour of ethanol & to increase the efficiency of an engine.
- ♣ Cost analysis for the newly configured ethanol blend engines.

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