Analysis of Combustion Characteristics with Catalytic Coated Cylinder Head in Two Stroke Spark Ignition Engine using Gasoline-Methyl Alcohol Blend

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***Abstract*—** Experiments were conducted to analyze the combustion characteristics of two stroke single cylinder, spark ignition (SI) engine, using gasoline blended with methyl alcohol (80% gasoline, 20% methyl alcohol, by volume) having catalytic coated engine [CCE, copper-(thickness, 300 microns) sprayed on the inner surface of cylinder head] and compared with conventional SI engine (CE) operating on pure gasoline. Combustion characteristics [peak pressure (PP), time of occurrence of peak pressure (TOPP), maximum rate of pressure rise (MRPR), maximum heat release (MHR) and temperature of burned gases at exhaust port opening (EPO)] were determined at full load operation of the engine by special P-Ө software package. Catalytic coated combustion chamber with methyl alcohol blended gasoline increased the PP, decreased the TOPP, increased the MRPR, increased the MHR and decreased the temperature of burned gases at EPO when compared with pure gasoline operated CE.

Keywords- *catalytic coated cylinder head, methyl alcohol blend, PP, TOPP, MRPR, MHR, EPO*

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I. INTRODUCTION

The paper is divided into i) Introduction, ii) Materials and Methods, iii) Results and Discussions, iv) Conclusions, Research Findings, Future scope of work followed by References.

The increase of fuel consumption and fossil fuel depletion necessitates the search for alternate and renewable fuels. The main objective of any engine designer is that the engine should give maximum thermal efficiency with minimum pollution levels. To achieve this, different alternate and renewable fuels have been used in SI engines by many researchers. As alcohols have got properties similar to those of base fuel (gasoline), they are the better alternate fuels for SI engines. Engine designs are modified to improve the thermal efficiency and to minimize the pollutants. But when small quantities of ethyl alcohol/methyl alcohol are blended with the base fuel, no major engine design modification is required.

As the fossil fuels are fastly depleting and their prices in the international market are increasing, there is a huge economic burden on Indian government. The pollution levels are increasing with the use of fossil fuels, necessitating the search for alternate fuels. Alcohol is a potential and renewable fuel for SI engine, because its properties are compatible to those of gasoline fuels. No major engine design modification is needed, if small quantities of alcohols are blended with gasoline. The change in fuel composition like blending of petrol with methanol is one of the methods adopted to improve the combustion characteristics of the engine.

When a high thermal conductivity material like copper was coated on the inner surface of cylinder head and on the top surface of piston crown [1], the fuel economy and combustion reactions were improved. Copper was selected as catalyst and was coated by plasma spraying technique on the top surface of piston crown and on the inner surface of combustion chamber walls [2] to study the variation of combustion parameters on a two-stroke catalytically activated SI engine and compared with base engine. Shortened combustion duration and acceleration of pre-flame reactions [2], [3] were observed as a result of copper coating.

The present paper evaluated the combustion characteristics of copper coated combustion chamber, which includes determining combustion characteristics [4] [peak pressure (PP), time of occurrence of peak pressure (TOPP), maximum rate of pressure rise (MRPR), maximum heat release (MHR) and temperature of burned gases at exhaust port opening (EPO)] at full load operation, with alcohol blended gasoline (gasoline-80%, methanol- 20% by volume) and compared with CE with pure gasoline operation. CCE with methyl alcohol blend increased PP, MRPR, MHR and decreased TOPP and temperature of exhaust gases at EPO.

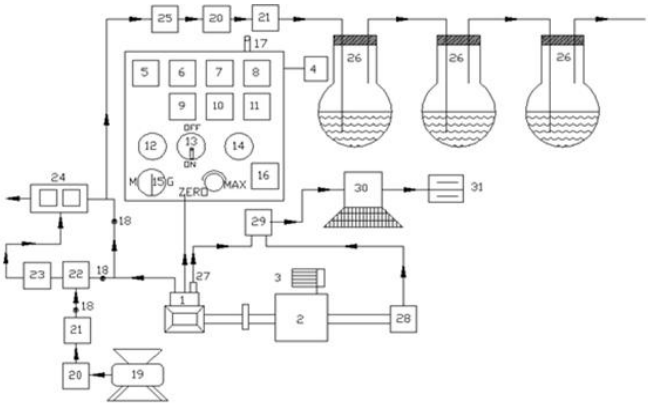
II. MATERIALS AND METHODS

This section deals with fabrication of copper coated engine (CCE, inner surface of the cylinder head being coated with copper), description of experimental set up and the measurement of combustion characteristics.

In CCE, an alloy of copper (89.5%), aluminium (9.5%) and iron (1%) was coated on the inner surface of cylinder head [5] for a thickness of 300 microns over a bond coating of nickel-cobalt-chromium which was sprayed for a thickness of 100 microns. The coating was sprayed by a flame spray gun.

Plate-1 shows the photographic view of copper coated cylinder head.

Plate-1 Photographic view of copper coated piston



1.Engine,2.Electrical swinging field dynamometer, 3. Loading arrangement, 4.Fuel tank, 5.Torque indicator/controller sensor, 6. Fuel rate indicator sensor, 7. Hot wire gas flow indicator, 8. Multi- channel temperature indicator, 9. Speed indicator, 10. Air flow indicator, 11. Exhaust gas temperature indicator, 12. Mains ON 13. Engine ON/OFF switch, 14. Mains OFF, 15. Motor and Generator option switch,16. Heater controller, 17. Speed indicator, 18. Directional valve, 19. Air compressor, 20. Rotometer, 21. Heater, 22. Air chamber, 23. Catalytic chamber, 24. CO/HC analyzer, 25. Filter, 26. Round bottom flasks containing DNPH solution, 27. Piezoelectric pressure transducer, 28. TDC encoder, 29. Consol, 30. Pentium personal computer, 31. Printer.

Figure-1 Schematic diagram of the experimental set up

Fig. 1 shows the schematic diagram of the experimental set up employed to measure the combustion characteristics.

Dhandapani et al. [2, 3] conducted experiments on copper coated SI engine with gasoline as fuel and life test was carried out for 50 hours. During these 50 hours, wear and tear was not reported from the engine.

An air-cooled single-cylinder 2.2 kW BP two-stroke SI engine with a rated speed of 3000 rpm was provided with an electrical swinging field dynamometer for the measurement of brake power (BP). Combustion characteristics [6] of the engine are very important when the engine is run with alternative fuel.

PP is an important parameter by means of which the engine efficiency can be determined. TOPP is another important parameter by means of which the pressure can be calculated with respect to TDC. Nearer the value of TOPP, better the performance is. MRPR denotes the knocking condition of the engine and hence it is necessary to determine these combustion characteristics of the engine, if any new alternative fuel is to be tested. It is important to determine the temperature of burned gases at EPO of the engine experimentally, as it is useful to assess the performance of the engine. Lower the value, better the performance of the engine is.

The cylinder head of the engine was provided with a piezoelectric pressure transducer to measure the pressure in the combustion chamber. The extended shaft of the dynamometer was provided with a TDC encoder to measure the crank angle. The piezoelectric pressure transducer and TDC encoder were connected to a consol, which in turn was connected to a personal computer. Pressure-crank angle diagram and Heat release-crank angle diagram were obtained on the screen of the personal computer. From the signals of P-Ɵ software, the combustion characteristics such as peak pressure (PP), time of occurrence of peak pressure (TOPP), maximum rate of pressure rise (MRPR), maximum heat release (MHR) and temperature of burned gases at EPO, were evaluated [7] at full load operation of the engine.

III. RESULTS AND DISCUSSION

A. Combustion Characteristics

TABLE I. DATA OF EXPERIMENTAL VALUES OF PP

Peak Pressure (PP), bar	**CE**		**CCE**	
	Pure gasoline	***Methanol blended gasoline***	***Pure gasoline***	***Methanol blended gasoline***
Magnitude	8.1	9.5	8.9	10.5
% deviation over CE with pure gasoline	---	+ 17.3%	+ 9.7%	+ 29.6%

The data of experimental values of peak pressure (PP) obtained from the special software package at full load operation of CE and CCE using experimental fuels {magnitude and the % deviation over the base condition (CE with pure gasoline)} was presented in the TABLE-I.

From the Table-1, PP was observed to be more with catalytically activated engine using methyl alcohol blend. The ratio of moles of products to the reactants for the base fuel and methyl alcohol blend was shown in (1) and (2).

$$1.058\ C_8H_{18} + 12.5O_2 + 47\ N_2 \rightarrow 8\ CO_2 + 9\ H_2O + 47\ N_2$$
(60.5 moles) (64.0 moles) (1)

$$1.061\ CH_3OH + 1.5\ O_2 + 5.65\ N_2 \rightarrow CO_2 + 2H_2O + 5.65\ N_2$$
(8.15 moles) (8.65 moles) (2)

The peak pressure depends on the number of moles of products per mole of the reactant. Methyl alcohol gave comparatively higher moles of products per mole of air at

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chemically correct mixture ratio neglecting the dissociation. This showed that peak pressure increased with methyl alcohol preparation in comparison with the base fuel.

The data of experimental values of time of occurrence of peak pressure (TOPP) obtained from the special software package at full load operation of CE and CCE using experimental fuels {magnitude and the % deviation over the base condition (CE with pure gasoline)} was presented in the TABLE-II.

From the TABLE-II, it was noticed that, TOPP was found to be minimum with CCE using methyl alcohol blend. Addition of methyl alcohol aids the process of combustion, decreased the energy flow in to the crevices, reduction in the temperature of cylinder, decrease of the ignition delay, increase in the speed of propagation of flame front and decreased the combustion duration. Hence, its TOPP is nearer to TDC. That means more energy is utilized to actual work rather than wasting the energy.

TABLE II. DATA OF EXPERIMENTAL VALUES OF TOPP

Time of Occurrence of Peak Pressure (TOPP), ^{0}a TDC	**CE**		**CCE**	
	Pure gasoline	***Methanol blended gasoline***	***Pure gasoline***	***Methanol blended gasoline***
Magnitude	31	29	30	28
% deviation over CE with pure gasoline	---	- 6.4%	- 3.2%	- 9.6%

TABLE III. DATA OF EXPERIMENTAL VALUES OF MRPR

Maximum Rate of Pressure Rise (MRPR), bar/deg	**CE**		**CCE**	
	Pure gasoline	***Methanol blended gasoline***	***Pure gasoline***	***Methanol blended gasoline***
Magnitude	2.8	3	2.9	3.1
% deviation over CE with pure gasoline	---	+ 7.1%	+ 3.5%	+ 10.7%

The data of experimental values of maximum rate of pressure rise (MRPR) obtained from the special software package at full load operation of CE and CCE using experimental fuels {magnitude and the % deviation over the base condition (CE with pure gasoline)} was presented in the TABLE-III.

It was clear from the TABLE-III that, MRPR followed similar trends [8] as that of PP. MRPR was found to be within the limits and it can be said that the engine is not in knocking condition.

It was important to determine the heat release [9] of the engine as it was useful to calculate the energy supplied by the engine which is the product of fuel burning rate and calorific value of the fuel. Higher the heat release, better the performance of the engine is.

The data of experimental values of maximum heat release (MHR) obtained from the special software package at full load operation of CE and CCE using experimental fuels {magnitude and the % deviation over the base condition (CE with pure gasoline)} was presented in the TABLE-IV.

TABLE IV. DATA OF EXPERIMENTAL VALUES OF MHR

Maximum Heat Release (MHR), joules	**CE**		**CCE**	
	Pure gasoline	***Methanol blended gasoline***	***Pure gasoline***	***Methanol blended gasoline***
Magnitude	1196	1237	1219	1255
% deviation over CE with pure gasoline	---	+ 3.4%	+ 1.9%	+ 4.9%

From the TABLE-IV, MHR was found to be more with methyl alcohol blend in catalytically activated engine when compared with the base engine. The increase in MHR (calculated from the diagram of MHR provided by the software package) indicates that the combustion in catalytically activated engine with methyl alcohol blend was enhanced in comparison with the base engine because of the combustion of lower stoichiometric air-fuel ratio, which confirmed that combustion was improved with catalytic coated engine with methyl alcohol blend.

To assess the performance of the engine, the temperature of burned gases at EPO is important to determine. Lower the value, better the performance of the engine is.

The data of experimental values of temperature of burned gases [10] at EPO (T_{EPO}) obtained from the special software package at full load operation of CE and CCE using experimental fuels {magnitude and the % deviation over the base condition (CE with pure gasoline)} was presented in the TABLE-V.

TABLE V. DATA OF EXPERIMENTAL VALUES OF TEMPERATURE (K) OF BURNED GASES AT EPO

Temperature (K) of Burned Gases at EPO, (T_{EPO})	**CE**		**CCE**	
	Pure gasoline	***Methanol blended gasoline***	***Pure gasoline***	***Methanol blended gasoline***
Magnitude	771	624	682	596
% deviation over CE with pure gasoline	---	- 19%	- 11.5%	- 22.7%

It was understood from the TABLE-V that, CCE with methyl alcohol blend gave lower value of temperature obtained at EPO in comparison with the base engine with experimental fuels, which again confirms that CCE with methyl alcohol blend was found to be more suitable in achieving higher efficiency over the base engine.

IV. CONCLUSIONS

1. Methanol blended gasoline in the catalytic coated engine increases PP by 29.6%, decreases TOPP by 9.6%, increases MRPR by 10.7% and increases MHR by 4.9% over conventional engine with pure gasoline operation.
2. The temperature of burned gases at EPO was decreased by 175 K with methyl alcohol blend in the catalytic coated engine in comparison with the pure gasoline operated conventional engine.

A. Research Findings and Future Scope of Work

Evaluation of combustion characteristics with copper coating on the inner surface of cylinder head was systematically investigated. Copper coating can also be done in addition on the top surface of piston crown to improve the combustion characteristics further.

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