

INVESTIGATIONS ON TWO STROKE SPARK IGNITION ENGINE WITH COPPER COATED COMBUSTION CHAMBER WITH ALCOHOL BLENDED GASOLINE

S. NARASIMHA KUMA¹, M. V. S. MURALI KRISHNA² & P. V. K MURTHY³

^{1,2}Department of Mechanical Engineering, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad,
Andhra Pradesh, India

³Jaya Prakash Narayan Educational Society Group of Institutions, Mahabubnagar, Andhra Pradesh, India

ABSTRACT

Experiments were conducted on single cylinder, two-stroke, spark ignition (SI) engine with copper coated combustion chamber with alcohol blended (80% gasoline blended with 10% ethanol and 10% methanol). Performance parameters and combustion parameters were determined at full load operation of the engine with alcohol blended gasoline. These parameters were compared with conventional engine operated with pure gasoline. Performance parameters and combustion characteristics improved with alcohol blended gasoline operation on copper coated combustion chamber in comparison with conventional engine operated with pure gasoline.

Nomenclature

ρ_a	=	Density of air, kg/m ³
ρ_d	=	Density of fuel, gm/cc
η_d	=	Efficiency of dynamometer, 0.85
a	=	Area of the orifice flow meter in square metre, $\frac{\pi \times d^2}{4}$
BP	=	Brake power of the engine, kW
C_d	=	Coefficient of discharge, 0.65
D	=	Bore of the cylinder, 57 mm
D	=	Diameter of the orifice flow meter, 20 mm
I	=	Ammeter reading, ampere,
h	=	Difference of water level in U-tube water manometer in cm of water column.
IT	=	Injection timing, degree bTDC
k	=	Number of cylinders, 01
L	=	Stroke of the engine, 57 mm
m_a	=	Mass of air inducted in engine, kg/h
m_f	=	Mass of fuel in kg/h,

n	=	Power cycles per minute, N,
N	=	Speed of the engine, 3000 rpm
P_a	=	Atmosphere pressure in mm of mercury,
R	=	Gas constant for air, 287 J/kg-K
t	=	Time taken for collecting 10 cc of fuel, second
T_a	=	Room temperature, degree centigrade
T_i	=	Inlet temperature of water, degree centigrade
T_o	=	Outlet temperature of water, degree centigrade
V	=	Voltmeter reading, Volts
V_s	=	Stroke volume, m^3

KEYWORDS: Alternative Fuels for Gasoline, Change of Fuel Composition, Change of Engine Design, Combustion Parameters, Performance Parameters

INTRODUCTION

Due to fast depletion of fossil fuels, ever increase of fuel prices in International Market, the increase of pollution levels with fossil fuels the search for alternative fuels has become prominence.

Ethanol and methanol are important substitutes for gasoline, which can be used as fuels for spark ignition engines, since their properties are similar to gasoline. Further advantage with these fuels, they have octane number, more than 100, which determine the combustion quality in internal combustion engines. Blending of methanol and ethanol in small quantities with gasoline, engine modification is not required.

Change of fuel composition is one of the techniques to improve the performance of conventional spark ignition engine [1-4]. Thermal efficiency improved, pollution levels decreased and combustion characteristics improved with change of fuel composition with different blends of ethanol and methanol in conventional spark ignition engine [1]. Experiments were conducted on compression ratio conventional spark ignition engine with gasoline fuel blended with ethanol [2-4]. It was reported from their investigations that power increased, carbon monoxide levels decreased by 30% and combustion characteristics improved with blended gasoline.

Copper coating on engine components is an old art. Copper is a good conductor of heat. It increases pre-flame reactions and improves combustion stabilization. Experiments were conducted on two-stroke spark ignition engine with pure gasoline operation with copper coating of thickness 0.3 mm on crown of the piston [5]. It was revealed from their investigations that copper coated engine improved brake specific fuel consumption at full load by 3.5%. Investigations were carried out on two-stroke copper coated engine with gasohol operation (20% ethanol blended with 80% gasoline by volume) and reported that gasohol operation improved peak thermal efficiency by 4% over conventional engine with gasoline operation. [6].

Studies were made on variable compression ratio, four-stroke copper coated engine with gasohol operation [7]. It was known from their investigations that thermal efficiency increased and combustion characteristics improved with

increasing compression ratio and change of fuel composition from pure gasoline to gasohol. Experiments were conducted on two-stroke copper coated spark ignition engine with different fuels like methanol blended gasoline and gasohol. Results were compared with pure gasoline operation on conventional engine [8]. It was known from their investigations gasohol operation increased thermal efficiency and combustion characteristics, while methanol blended gasoline operation reduced pollution levels with copper coated engine.

Experiments were conducted with blend of 10% methanol, 10% ethanol with gasoline on four-stroke, variable compression ratio, variable speed, spark ignition engine [9-10]. Performance parameters and combustion characteristics were evaluated with this blend. In comparison with conventional engine with gasoline operation, peak thermal efficiency increased by 8%, at full load operation-exhaust gas temperature decreased by 5%, volumetric efficiency comparable, peak pressure increased by 10% and maximum heat release rate increased by 2% with copper coated combustion chamber.

Two stroke engine offers many advantages over four-stroke engine on the aspects of mechanical efficiency, size of the engine, simple in operation etc.,. However, it faces criticism in the issue of thermal efficiency as there is loss of fuel in cycle. Hence it is worthwhile to study the performance and combustion characteristics of the copper coated two-stroke engine with alcohol blended gasoline.

This paper evaluated the performance parameters and combustion characteristics with alcohol blended gasoline (ethanol- 10%, methanol- 10% by volume and gasoline-80%,) at full load operation and compared with pure gasoline operation on conventional engine.

METHODOLOGY

The piston crown and inner surface of cylinder head of spark ignition engine were coated with copper by flame spray gun. The surface of the components to be coated were cleaned and subjected to sand blasting. A bond coating of nickel- cobalt- chromium of thickness 0.1 mm was sprayed over which alloy of iron (1%), aluminium (9.5%) and copper of thickness 0.3 mm was coated with flame spray gun.

Figure 1 shows schematic diagram of experimental set-up used for investigations. A two-stroke, single-cylinder, air-cooled spark ignition engine was coupled to an eddy current dynamometer for measuring its brake power. The conventional engine had an aluminum alloy piston with a bore and stroke of 57 mm each. The rated output of the engine was 2.2 kW at a speed of 3000 rpm. Compression ratio of engine was 7.5:1. The recommended spark ignition timing was 25°aTDC (after top dead centre). Fuel consumption, speed, air flow rate, exhaust gas temperature were measured with electronic sensors.

Combustion characteristics were determined at full load operation of the engine with Piezo electric transducer, TDC encoder, console and special P-θ software package. Combustion characteristics like peak pressure (PP), time of occurrence of peak pressure (TOPP), maximum rate of pressure rise (MRPR) and maximum heat release. The instrumentation accuracy was 1%.

Performance parameters of brake thermal efficiency, brake specific energy consumption, exhaust gas temperature and volumetric efficiency were determined as full load operation of the engine. Experiments were carried out with copper coated combustion chamber with gasoline blended with alcohol [gasoline-80%, methanol-10% and ethanol-10% by volume]. Comparative studies were made with pure gasoline operation on conventional engine.

Definitions of Used Values

$$m_f = \left(\frac{10}{t}\right) \times (\rho_d) \times \left(\frac{3600}{1000}\right)$$

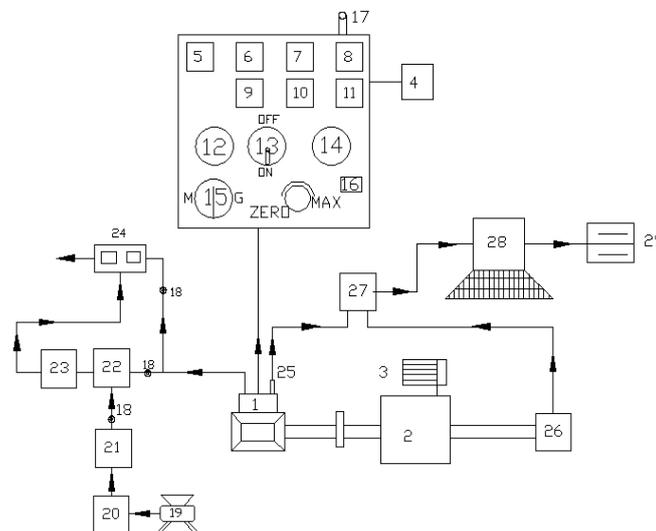
$$BP = \frac{V \times I}{1000 \times \eta_d}$$

BTE

$$BSEC = m_a = C_d \times a \times \sqrt{2 \times 10 \times g \times h \times \rho_a} \times 3600$$

$$\eta_v = \left(\frac{m_a}{60}\right) \times \left(\frac{1}{\rho_a}\right) \times \left(\frac{1}{N}\right) \times \frac{1}{V_s}$$

$$\rho_a = \left(\frac{P_a}{750}\right) \times 10^5 \times \frac{1}{R \times T_a}$$



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/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. Piezoelectric Transducer, 26. TDC Encoder, 27. Consol, 28. Pentium Personal Computer, 29. Printer

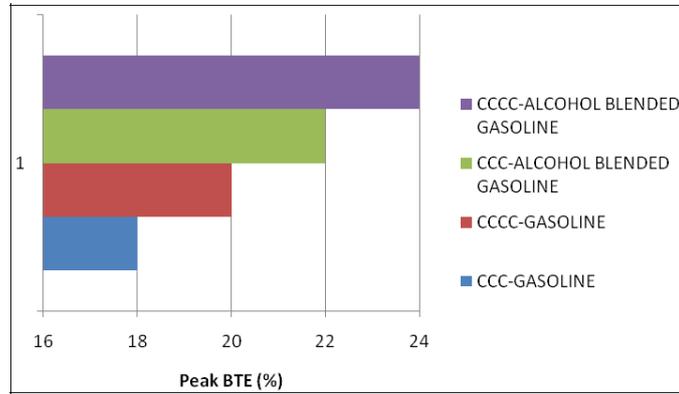
Figure 1: Schematic Diagram of Experimental Set up

RESULTS AND DISCUSSIONS

Performance Parameters

Figure 2 presents the bar charts showing the variation of peak brake thermal efficiency in different configurations of the combustion chamber with test fuels of pure gasoline and alcohol blended gasoline at a compression ratio of 7.5:1 and speed of 3000 rpm. Peak thermal efficiency with alcohol bended gasoline was higher in comparison with pure gasoline operation on both versions of the combustion chamber such as conventional combustion chamber and copper coated

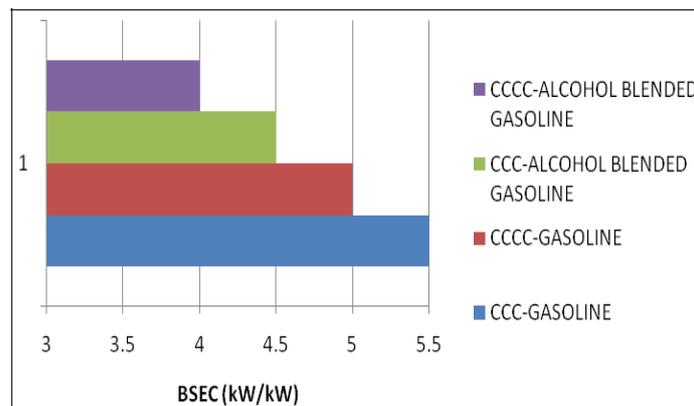
combustion chamber. This was due to reduction of dissociation losses, specific heat losses and theoretical air-fuel ratios. This was also because of improved octane rating of the fuel. Engine with copper coated combustion chamber showed improved thermal efficiency in comparison with conventional engine at full load operation with both test fuels. This was because of increased catalytic activity with prevalent temperatures at full load operation, with which combustion improved as pre-flame reactions increased and there was stabilization of combustion.



CCC- Conventional Combustion Chamber, CCCC-Copper Coated Combustion Chamber. Peak BTE- Peak Brake Thermal Efficiency

Figure 2: Bar Charts Showing the Variation of Peak Brake Thermal Efficiency in Different Versions of the Combustion Chamber with Test Fuels at a Speed of 3000 rpm and Compression Ratio of 7.5:1

From Figure 3, it is understood that alcohol blended gasoline lowered brake specific energy consumption at full load operation when compared with pure gasoline operation on both versions of the combustion chamber. This was due to reduction of various losses with reduction of temperatures as alcohol (both ethanol and methanol) have high latent heat of evaporation. With test fuels, copper coated combustion chamber showed lower brake specific energy consumption at full load when compared with conventional combustion chamber with test fuels. This was due to efficient energy utilization by copper coated combustion chamber with increase of pre-flame reactions and combustion stabilization.

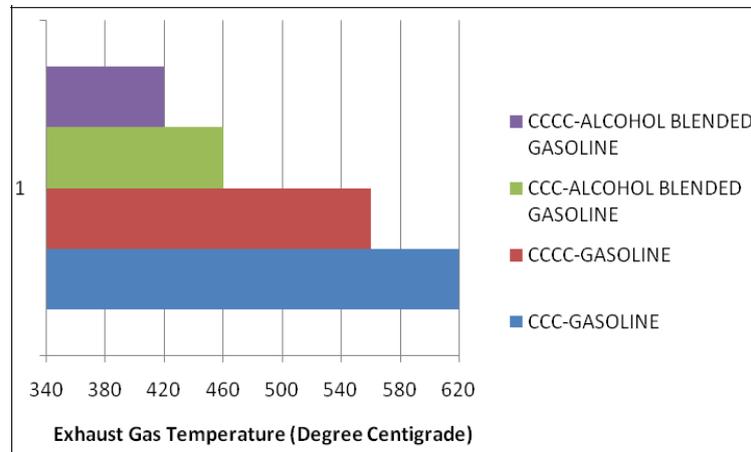


CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber., BSEC-Brake specific energy consumption

Figure 3: Bar charts Showing the Variation of Brake Specific Energy Consumption (BSEC) at Full Load Operation with Different Versions of the Combustion Chamber with Test Fuels at a Speed of 3000 rpm and Compression Ratio of 7.5:1

Figure 4 presents the bar charts showing the variation of exhaust gas temperature at full load operation in different versions of the combustion chamber at a compression ratio of 7.5:1 and speed of 3000 rpm. Alcohol blended gasoline showed lower value of exhaust gas temperature at full load in comparison with pure gasoline operation on both versions of

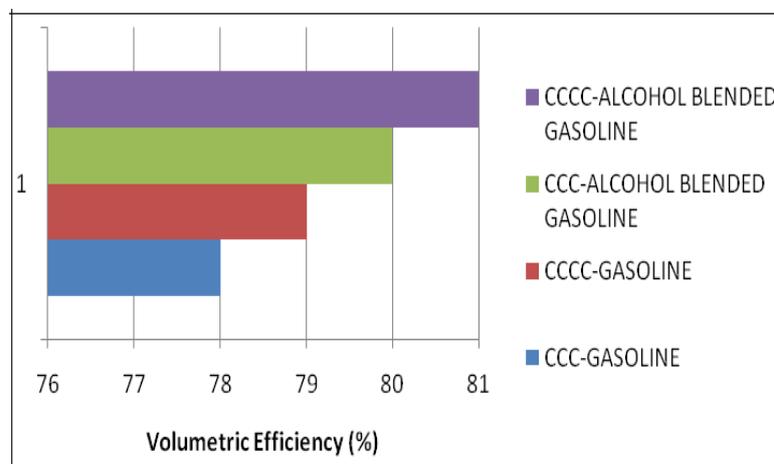
the combustion chamber. This was due to high latent heat of evaporation of alcohol (ethanol and methanol) which absorbed gas temperatures. This was also because of lower calorific value of the gasoline blended with alcohol which released lower heat release rates. Copper coated combustion chamber registered lower value of exhaust gas temperature when compared to conventional chamber for both test fuels, which confirmed that efficient combustion with the copper coated combustion chamber when compared with conventional combustion chamber.



CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber.

Figure 4: Bar Charts Showing the Variation of Exhaust Gas Temperature at Full Load Operation in Different Versions of the Combustion Chamber with Test Fuels at a Speed of 3000 rpm and Compression Ratio of 7.5:1

From Figure 5, it is evident that alcohol bended gasoline operation at full load showed marginal increase of volumetric efficiency in comparison with pure gasoline operation on both versions of the combustion chamber. This was decrease of increase of air density due to reduction of temperature of air as alcohol has high latent heat of evaporation. Copper coated combustion chamber showed marginally higher volumetric efficiency at full load operation when compared with conventional combustion chamber with test fuels. Copper is a good conductor of heat and hence it absorbs higher amount of alcohol leading to decrease of gas temperatures with which density of air increases and hence volumetric efficiency increases. Reduction of combustion wall temperatures also contributes to increase volumetric efficiency.



CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber.

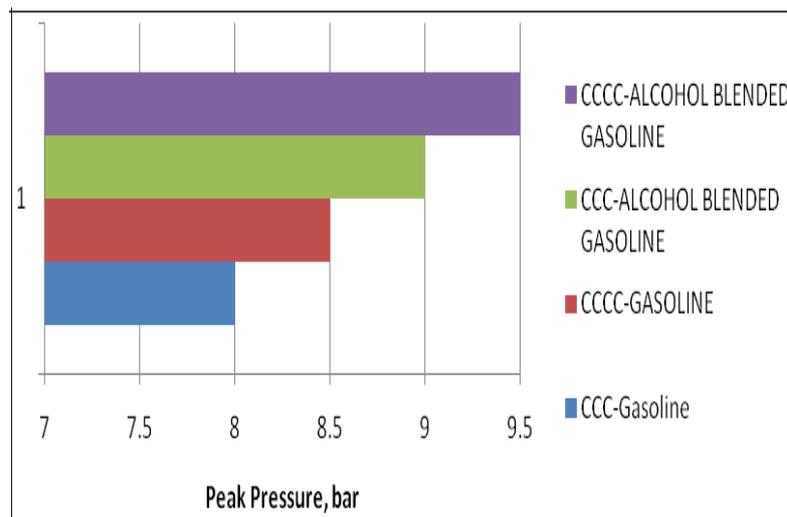
Figure 5: Bar charts Showing the Variation of Volumetric Efficiency at Full Load Operation in Different Versions of the Combustion Chamber with Test Fuels at a Speed of 3000 rpm and Compression Ratio of 7.5:1

Combustion Characteristics

From Figure 6(a), it is understood that peak pressures were found to be higher with alcohol blended gasoline in comparison with pure gasoline in both versions of the combustion chamber. This was due to more number of moles of product per mole of reactant. Copper coated combustion chamber showed marginally higher peak pressure in comparison with conventional combustion chamber with test fuels. This was due to improved combustion with catalytic activity which resulted higher peak pressures.

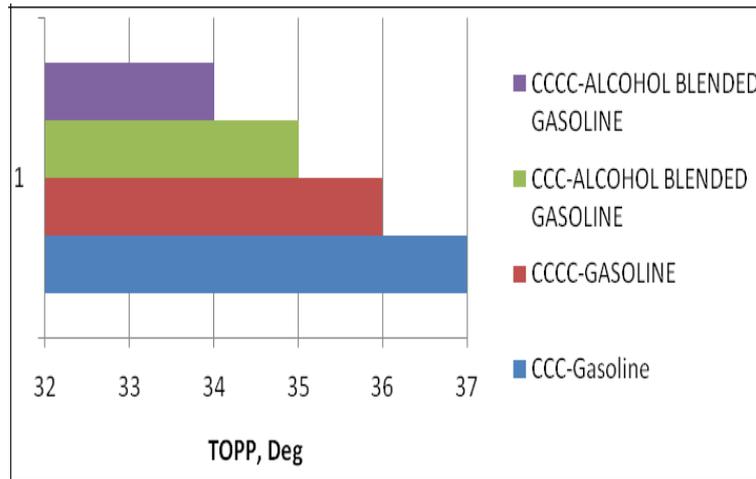
From Figure 6(b), it is noticed that alcohol blended gasoline operation showed lower time of occurrence (TOPP) in comparison with pure gasoline operation on both versions of the combustion chamber. This was due to improved combustion with improved octane rating of the fuel. Copper coated combustion chamber produced lower TOPP when compared with conventional combustion chamber with both test fuels, This was conventional combustion chamber exhibited higher temperatures of combustion chamber walls leading to continuation of combustion, giving peak pressures away from TDC. However, this phenomenon is nullified with copper coated combustion chamber because of reduced temperature of combustion chamber walls thus bringing the peak pressures closure to TDC.

The trends followed by maximum rate of pressure rise was similar to those of peak pressure in both versions of the combustion chambers with both test fuels as indicated by Figure 6(c). The increase in maximum heat release as shown in Figure 6(d) confirms that combustion improved with alcohol blended gasoline in comparison with pure gasoline operation with both versions of the combustion chamber. Heat release further improved with copper coated combustion chamber when compared with conventional combustion chamber with test fuels. This was due improved combustion with catalytic activity.



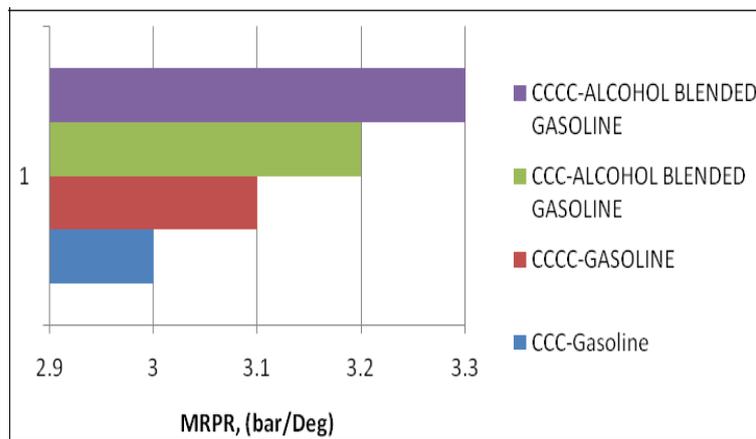
CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber

Figure 6: (a) Variation of Peak Pressure



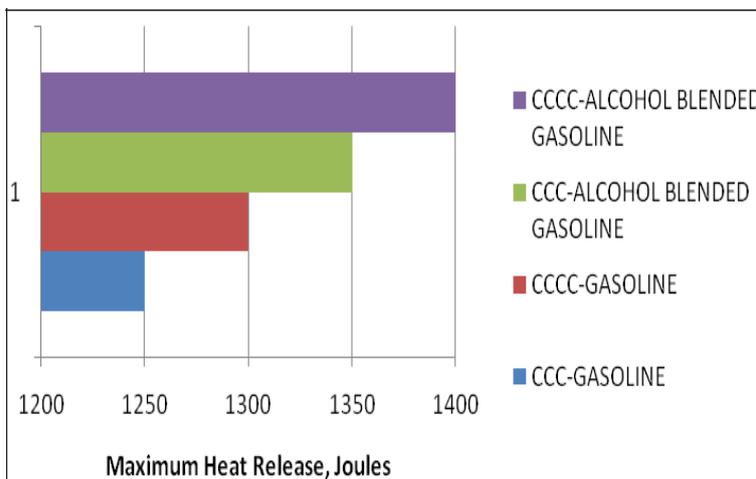
CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber

Figure 6: (b) Variation of Time of Occurrence of Peak Pressure (TOPP)



CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber

Figure 6: (c) Variation of Maximum Rate of Pressure Rise (MRPR)



CCC-Conventional combustion chamber, CCCC-Copper coated combustion chamber

Figure 6: (d) Variation of Maximum Heat Release

Figure 6: Bar Charts Showing the Variation of Combustion Parameters at Full Load Operation in Different Versions of the Combustion Chamber with Test Fuels at a Speed of 3000 rpm and Compression Ratio of 7.5:1

SUMMARY

In comparison with conventional combustion chamber, with copper coated combustion chamber,

- Peak brake thermal efficiency increased by 11% with gasoline operation, while increasing by 9% with alcohol blended gasoline operation.
- Exhaust gas temperature at full load operation decreased by 10%, with gasoline operation, while decreasing 9% with alcohol blended gasoline operation.
- Volumetric efficiencies were comparable with gasoline operation as well as alcohol blended gasoline operation.
- Peak pressure increased by 6% with gasoline operation, while increasing by 5% with alcohol blended gasoline.
- Both maximum rate of pressure rise and time of occurrence of peak pressure were comparable
- Maximum heat release rate increased by 3% with gasoline operation and alcohol blended gasoline.

Research Findings

Experiments were carried out to evaluate performance parameters and combustion characteristics with different configurations of the combustion chamber such as conventional combustion chamber and copper coated combustion chamber with pure gasoline and alcohol (10% ethanol and 10% methanol) blended gasoline.

Future Scope of Work

The above investigations can be carried out with varied spark plug timing.

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REFERENCES

1. Farayedhi, A. A., Dawood, A. M. and Gandhidasan, P., "Experimental investigation of spark ignition engine performance using oxygenated fuel", *ASME Journal of Engineering for Gas Turbines and Power*, Volume- 126, 178-191, 2004.
2. Ceviz, M.A. and Yuksel, F., "Effects of ethanol-unleaded gasoline blends on cyclic variability and emissions in a spark ignition engine", *Applied Thermal Engineering*, Volume- 25, 917-925, 2005
3. Bahattin Celik, M., "Experimental determination of suitable ethanol-gasoline blend rate at high compression ratio for gasoline engine", *Applied Thermal Engineering*, Volume-28, 396-404, 2008
4. Al-Baghdadi., "Measurement and prediction study of the effect of ethanol blending on the performance and pollutants emission of a four-stroke spark ignition engine", *Proceedings of the Institution of Mechanical Engineers*, Volume- 222, Number- 5, 859-873, 2008

5. Nedunchezian N & Dhandapani S, Experimental investigation of cyclic variation of combustion parameters in a catalytically activated two-stroke SI engine combustion chamber, *Engg Today*, 2 (2000) 11-18.
6. Narasimha Kumar, S., Murali Krishna, M.V.S. Murthy, P.V.K. Reddy, D.N. and Kishor, K. (2011). "Performance of copper coated two stroke spark ignition engine with gasohol with catalytic converter with different catalysts". *International Journal of Applied Engineering Research*, Dindigul, 2(1), 205-218.
7. M.V.S. Murali Krishna, K. Kishor, P. V. K. Murthy, A.V.S.S.K.S. Gupta and S. Narasimha Kumar, "Performance evaluation of copper coated four stroke spark ignition engine with gasohol with catalytic converter", *International Journal of Engineering Studies*", Volume-2, Number-4, 2010, pp: 465-473.
8. Murali Krishna, M.V.S., Kishor, K., Murthy, P.V.K Gupta, A.V.S.S.K.S., and Narasimha Kumar, S.," Comparative studies on performance evaluation of a two stroke copper coated spark ignition engine with alcohols with catalytic converter," *International Journal of Renewable and Sustainable Energy Reviews*. 16, 6333-6339. 2012.
9. Kishor, K., Murali Krishna, M.V.S. and Murthy, P.V.K., "Comparative studies on performance parameters and exhaust emissions from four stroke copper coated spark ignition engine with alcohol blended gasoline", *International Journal of Innovative Research in Science, Engineering and Technology*, 2(12), 343-7352, 2013.
10. Kishor, K., Murali Krishna, M.V.S. and Murthy, P.V.K. "Studies on performance and combustion characteristics of copper coated four stroke spark ignition engine with alcohol blended gasoline", *International Journal of Engineering Research and Applications*, 3(6), 1437-1444, 2013.