Journal of Scientific & Industrial Research
Vol. 67, July 2008, pp. 543-548

Performance of copper coated spark ignition engine with methanol-blended gasoline with catalytic converter

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Received 27 August 2007; revised 28 April 2008; accepted 30 April 2008

This paper reports performance evaluation of four-stroke, single cylinder spark ignition (SI) engine with methanol blended gasoline (20% methanol, 80% gasoline, by vol) having copper coated engine [copper (thickness, 300 ¼) coated on piston crown and inner side of cylinder head] provided with catalytic converter with sponge iron as catalyst and compared with conventional SI engine with gasoline operation. Brake thermal efficiency increased with methanol blended gasoline with both engine types. Copper-coated engine showed improved performance than conventional engine with both test fuels. Catalytic converter with air injection significantly reduced pollutants with both test fuels on both engine types.

Keywords: Air injection, Catalytic coating, Catalytic converter, Pollutants, SI engine

Introduction

Gasoline blended with methanol (20%, by vol) improved engine performance and decreased pollution levels when compared to pure gasoline on conventional engine[1-3]. Carbon monoxide (CO) and unburnt hydrocarbons (UHC), major exhaust pollutants formed due to incomplete combustion of fuel, cause many human health disorders[4-9]. Such pollutants also cause detrimental effects[10] on animal and plant life, besides environmental disorders. Engine modification[11,12] with copper coating on piston crown and inner side of cylinder head improves engine performance as copper is better conductor of heat and good combustion is achieved with copper coating. Catalytic converter is effective[13-15] in reduction of pollutants in SI engine.

This study evaluated performance of copper-coated engine (CCE) using 20% methanol blended with gasoline and compared with conventional engine (CE) using pure gasoline.

Materials and Methods

A four- stroke, single-cylinder, water-cooled, SI engine (brake power 2.2 kW, rated speed 3000 rpm) is coupled to an eddy current dynamometer for measuring brake power (Fig. 1). Compression ratio of engine is varied (3-9) with change of clearance volume by adjustment of cylinder head, threaded to cylinder of the engine. Engine speeds are varied (2400-3000 rpm). Exhaust gas temperature (EGT) is measured with iron-constantan thermocouples. Fuel consumption of engine is measured with burette method, while air consumption is measured with air-box method. In catalytic coated engine, piston crown and inner surface of cylinder head are coated with copper by plasma spraying. A bond coating of NiCoCr alloy is applied (thickness, 100 μ) using a 80 kW METCO plasma spray gun. Over bond coating, copper (89.5%), aluminium (9.5%) and iron (1.0%) are coated (thickness 300 μ). The coating has very high bond strength and does not wear off even after 50 h of operation[12]. Performance parameters [brake thermal efficiency (BTE), EGT and volumetric efficiency (VE)] are evaluated at different magnitudes of brake mean effective pressure (BMEP) of the engine. CO and UHC emissions in engine exhaust are measured with Netel Chromatograph analyzer.

A catalytic converter[15] (Fig. 2) is fitted to exhaust pipe of engine. Provision is also made to inject a definite quantity of air into catalytic converter. Air quantity drawn from compressor and injected into converter is kept constant so that backpressure does not increase. Experiments are carried out on CE and CCE with different test fuels [pure gasoline and gasoline blended with methanol (20% by vol)] under different

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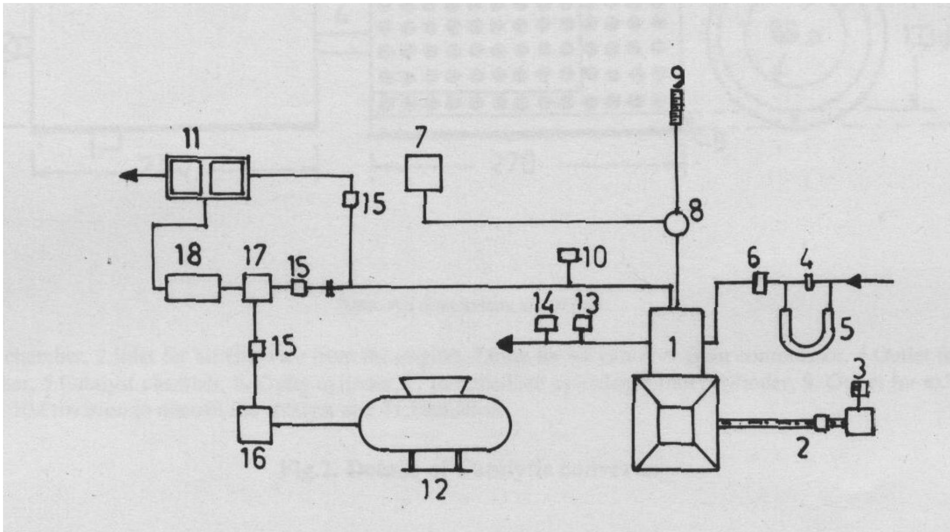
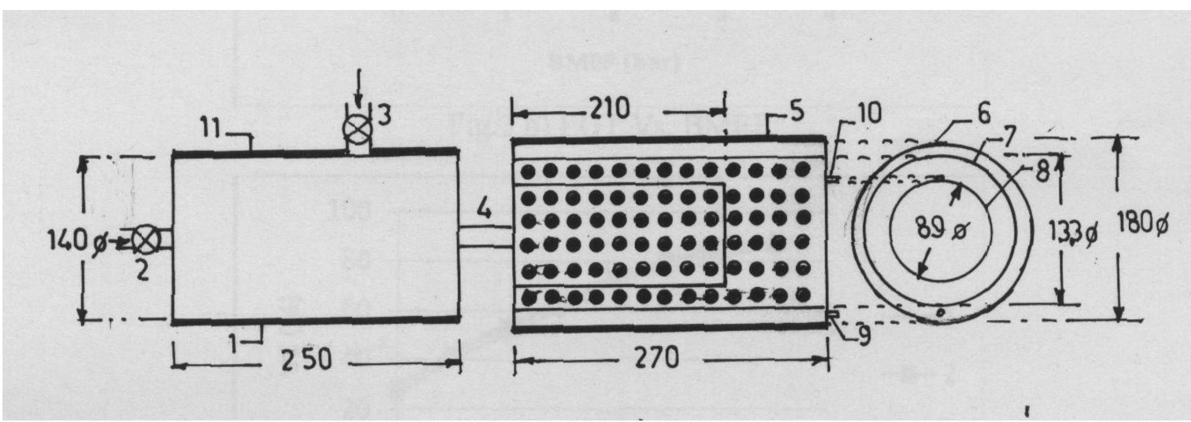


1.Engine, 2.Eddy current dynamo meter, 3. Loading arrangement, 4.Orifice meter, 5.U-tube water manometer, 6.Air box, 7.Fuel tank, 8, Three-way valve, 9.Burette, 10. Exhaust gas temperature indicator, 11. CO analyzer, 12. Air compressor, 13.Outlet jacket water temperature indicator, 14. Outlet-jacket water flow meter.15. Directional valve, 16Rotometer, 17 Air chamber and 18.Catalyst chamber

Fig. 1 — Experimental set up



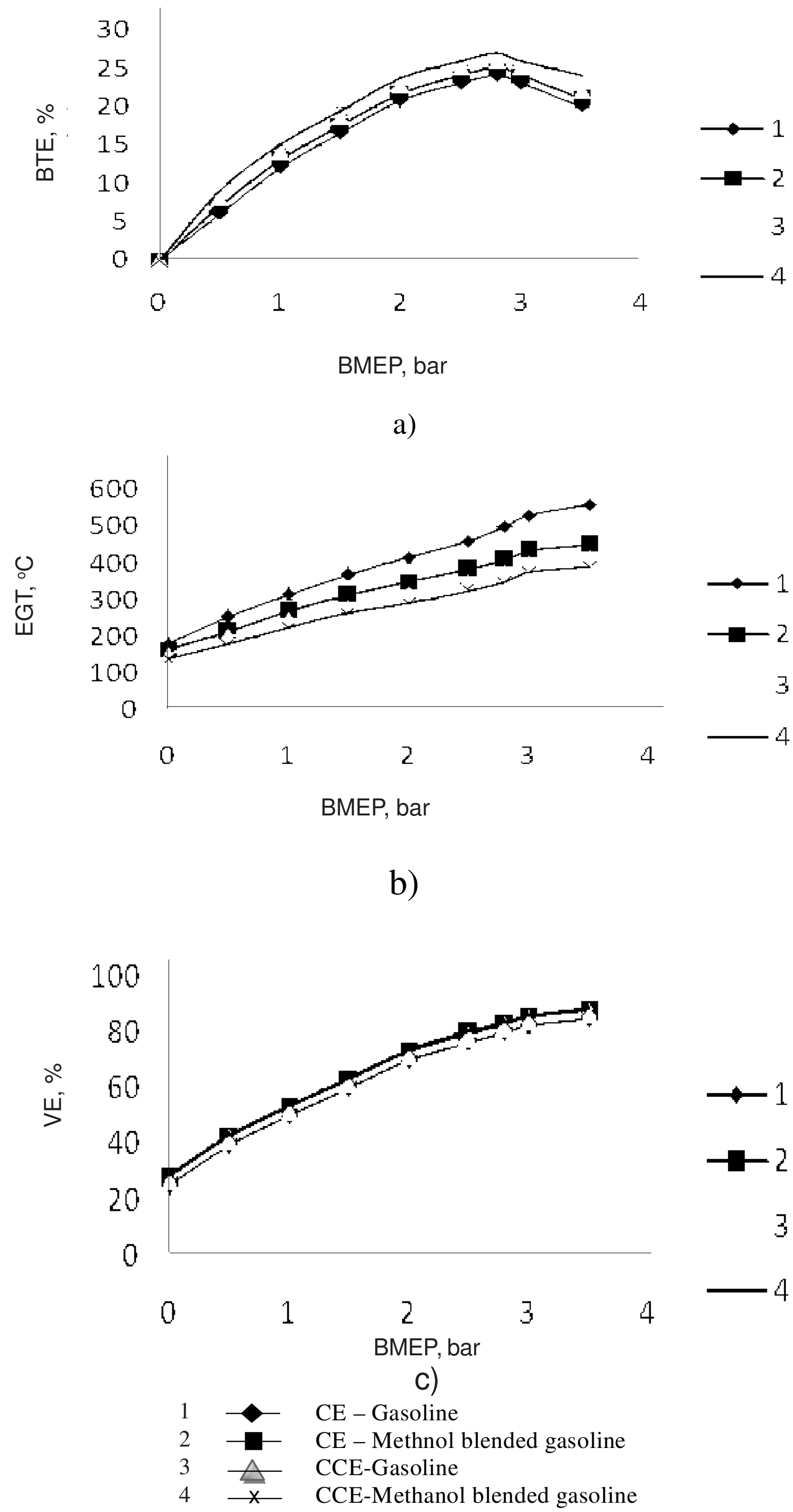
1.Air chamber, 2.Inlet for air chamber from the engine, 3.Inlet for air chamber from compressor, 4.Outlet for air chamber, 5.Catalyst chamber, 6. Outer cylinder, 7. Intermediate cylinder, 8.Inner cylinder, 9. Outlet for exhaust

Fig. 2 — Details of catalytic converter

operating conditions of catalytic converter: set-A, without catalytic converter and without air injection; set-B, with catalytic converter and without air injection; and set-C, with catalytic converter and with air injection.

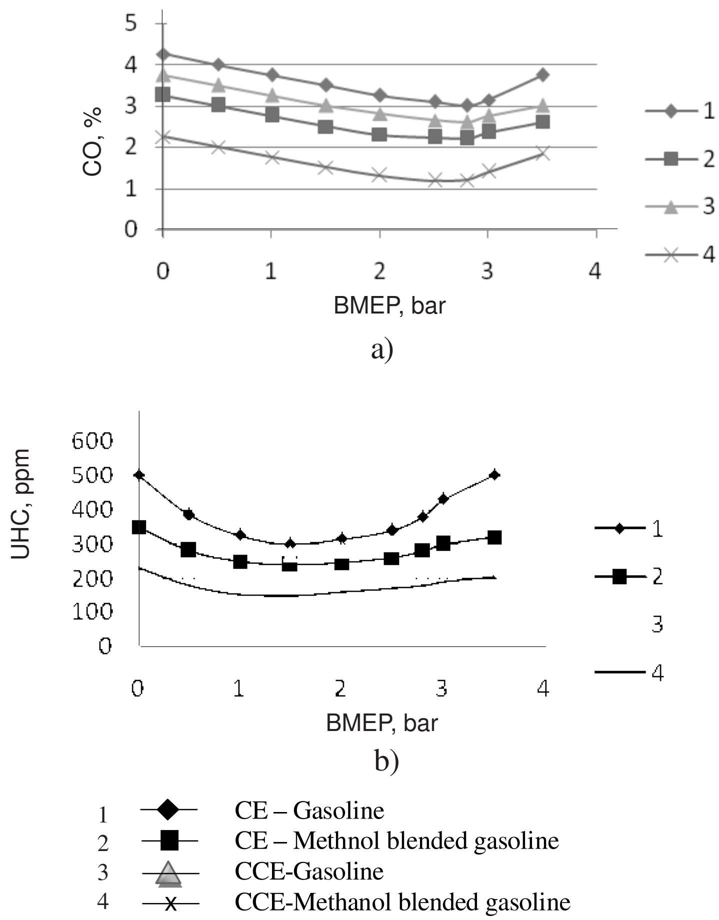
Results and Discussion

Variation of BTE with BMEP in different versions of the engine with pure gasoline and methanol blended gasoline at a compression ratio of 9:1 and speed of 3000 rpm indicated that BTE increased with an increase of BMEP (Fig. 3a). Higher BTE is observed with methanol-blended gasoline over pure gasoline at all loads due to lower Stoichiometric air requirement of methanol-blended gasoline over pure gasoline operation. CCE showed higher thermal efficiency when compared to CE with both test fuels at loads, particularly at near full load operation. This is due to efficient combustion with catalytic activity, which is more pronounced at peak load, as catalytic activity increases with prevailing high temperatures at peak load. Peak BTE increased with



CE, conventional engine; CCE, Copper coated engine ; BTE, brake thermal efficiency;
EGT-exhaust gas temperature ; VE, volumetric efficiency ; BMEP, brake mean effective pressure

Fig. 3 — Variation of BMEP in CE and CCE with pure gasoline and methanol blended gasoline at compression of 9:1 and a speed of 3000 rpm with: a) BTE ; b) EGT; and c)VE



CE, conventional engine; CCE, Copper coated engine; BMEP, brake mean effective pressure; CO-Carbon monoxide; UHC-Un-burnt hydro carbons;

Fig.4 — Variation of BMEP in CE and CCE with pure gasoline and methanol blended gasoline at ompression of 9:1 and a speed of 3000 rpm with a) CO; b) UHC.

increase of compression ratio with CE and CCE at different test fuels, due to increase in expansion work with increase of compression ratio. Peak BTE drastically decreased at lower compression ratios. Thermal efficiency marginally increased with increase of engine speed, due to increase of turbulence of combustion, though friction power increased with an increase of speed. EGT increased with increase of BMEP (Fig. 3b). EGT is lower with methanol-blended gasoline when compared to pure gasoline at all loads in CE and CCE, because, with methanol-blended gasoline, work transfer from piston to gases in cylinder at the end of compression stroke is too large, leading to reduction in the magnitude of EGT. This is also due to high latent heat of evaporation of methanol. CCE registered lower EGT when compared to CE for both test fuels, which confirm efficient combustion with CCE than CE. EGT decreased with increase of speed and compression ratio for CE and CCE with different test fuels. EGT is lower at higher compression ratio because increased expansion causes the gas to do more work on piston and less heat is rejected at the end of the stroke. Magnitude of EGT decreases marginally with increase of speed with different test fuels. Magnitude of EGT is high at lower compression ratios confirming that efficiency decreased with decrease of compression ratios.

VE (Fig. 3c) increased with increase of BMEP. CCE showed higher VE at all loads in comparison with CE with different test fuels, due to reduction of residual charge and deposits in the combustion chamber of CCE when compared to CE, which shows the same trend as reported earlier[12]. CCE with methanol blended gasoline showed VE higher (8%) than that of CE at peak load operation of the engine with gasoline as fuel. VE increased with methanol-blended gasoline when compared to pure gasoline operation with CE and CCE at all loads, due to increase of mass and density of air with reduction of temperature of air due to high latent heat of evaporation of methanol. VE marginally increased with increase of engine speed with different test fuels with different versions of the engine, as volume of charge sucked into cylinder is directly proportional to engine speed. VE marginally increased with increase of compression ratio of CE and CCE with different test fuels due to improvement in combustion with increase of compression ratio and reduction of deposits. However, VE decreased at lower speeds and lower compression ratios. Methanol blended gasoline decreased CO emissions at all loads when compared to pure gasoline operation on CCE and CE, as fuel-cracking reactions[1] are eliminated with methanol (Fig. 4a). Alcohol combustion produces more water vapor than free carbon atoms as methanol has lower C/H ratio of 0.25 against 0.44 of gasoline. Methanol has oxygen in its structure and hence its blends have lower stoichiometric air requirements compared to gasoline. Therefore, more oxygen that is available for combustion with the blends of methanol and gasoline, leads to reduction of CO emissions. Methanol dissociates in the combustion chamber of engine forming hydrogen, which helps fuel-air mixture to burn quickly and thus increases combustion velocity, which brings about complete combustion of carbon present in the fuel to CO_2 and also CO to CO_2 thus makes leaner mixture more combustible, causing reduction of CO emissions. CCE reduces CO emissions in comparison with CE.

Copper or its alloys acts as catalyst in combustion chamber, whereby facilitates effective combustion of fuel leading to formation of CO_2 instead of CO. UHC emissions followed same trend as CO emissions in CCE and CE with both test fuels, due to increase of flame speed with catalytic activity and reduction of quenching effect with CCE (Fig. 4b). Catalytic converter reduced pollutants considerably with CE and CCE and air injection into catalytic converter further reduced pollutants. In presence of catalyst, pollutants get further oxidised to give less harmful emissions like CO_2. As compression ratio decreases, pollutants decrease marginally with both engine types, due to EGT with decrease of compression ratio[16] leading to increase of oxidation in exhaust-manifold causing a reduction of pollutants. CCE reduced more pollutants than CE at all speeds and compression ratios.

Conclusions

Thermal efficiency increased (4%) relatively with methanol blended gasoline in comparison with pure gasoline operation with conventional and copper-coated engine, while copper coated engine increased thermal efficiency by 8% relatively when compared with conventional engine with pure gasoline and methanol blended gasoline respectively at a compression ratio of 9:1 and speed of 3000 rpm of the engine. Thermal efficiency increased with increase of compression ratio and speed with both configurations of the engine with both test fuels. CO and UHC in exhaust decreased by 53% and 60% respectively in conventional engine with methanol blended gasoline when compared to pure gasoline operation. CO and UHC emissions decreased with decrease of compression ratio and increase of speed with test fuels and with different configurations of the engine. These pollutants decreased by 20% with catalytic coated engine when compared to conventional engine with both test fuels. Set-B operation decreased CO and UHC emissions by 40%, while Set-C operation decreased these emissions by 60% with test fuels when compared to Set-A operation.

Acknowledgements

Authors thank authorities of Chaitanya Bharathi Institute of Technology, Hyderabad for facilities provided.

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