Experimental Investigation of Cyclic Variation of Combustion Parameters in Catalytically Activated and Magnetically Energised Two-stroke SI Engine

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Abstract

The two stroke spark ignition engine is the major contributor of the total vehicular pollution in a country like India. It is therefore an area that requires great attention to reduce fuel consumption and hence pollution. The use of strong magnetic charge from the magnet put into the fuel line gives a complete and clean burn so that power is increased with reduced operating expenses. The magnetic flux on the fuel line dramatically reduces harmful exhaust emissions while increasing mileage, thereby saving money and improving engine performance. It increases combustion efficiency and provides higher-octane performance. The experimental results show that the magnetic flux on fuel reduces the carbon monoxide emission up to 13% for base engine, 23% in copper coated (inside the cylinder head) engine and 29% in zirconia coated (inside the cylinder head) engine.

Introduction

Transport is the prime source of mobility in urban society. It not only provides a fast, convenient and economical mode of carrier to meet multifarious activities of citizens but also caters to the need of transportation of goods of commercial and industrial importance. However, it vitiates the environment in the process by emanating obnoxious and toxic pollutants in the surrounding atmosphere and thereby creates serious health hazards to biotic community.

Automobiles have been castigated as polluters of the environment. Pollution due to automobile emissions is of great concern more, particularly in metropolitan cities. It creates a potential threat to the existence of healthy life [1-2]. Thus, safeguarding quality of air from degradation due to transportation is important. For complete combustion, air to fuel ratio is computed as 14.5. This ratio is a stoichiometric ratio [3]. But in spark ignited engines, complete combustion does not take place and pollutants are produced even at stoichiometric values of A/F ratio. This is because the spark induce reaction is not fully propagated inside the piston chamber.

This paper presents an eco-friendly system to reduce harmful emissions while increasing engine performance. The fuel is energized by keeping high gauss magnet on fuel line [4-5]. It easily installs in minutes by strapping to the fuel line next to the carburetor, diesel pump or injector rail.

Working Principles

Mono pole technology

The most important factors in the monopole technology are the magnetic field intensity and the collimation of the magnetic lines of flux [6-7]. It is these two aspects that render the monopole technology different from any ordinary permanent magnets.The intensity of the magnetic field is far superior to that generated by regular permanent magnets and the collimation of the magnetic fields (Fig. 1) renders the magnetic lines of flux exactly parallel to each other at extremely high densities (to the order of millions of lines of flux per sq. cm.). These devices are external online installations without cutting or modifying the fuel pipes and the magnetic energy generated through the monopole technology is rendered concentric and exactly perpendicular to the flow of the fuel.

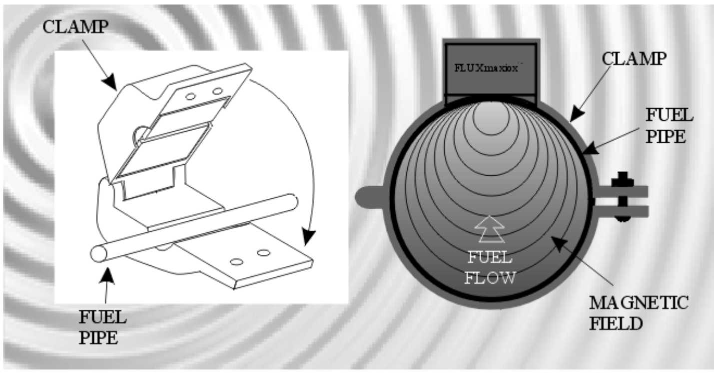


Fig. 1 Magnetic field on fuel line

Ortho-para orientation

The hydrogen atom has one positive charge (proton) and one negative charge (electron), i.e. it possesses a dipole moment. It can be either diamagnetic or paramagnetic (weaker or stronger response to the magnetic flux) depending on the relative orientation of its nucleus spins. Hence, it occurs in two distinct isomeric varieties (forms) - para and ortho, characterized by the different opposite nucleus spins [8]. In para H2 molecule, which occupies the even rotation levels (quantum number), the spin state of one atom relative to another is in the opposite direction rendering it diamagnetic. In the ortho molecule, which occupies the odd rotational levels, the spins are parallel with the same orientation for the two atoms, and therefore is paramagnetic and a catalyst for many reactions (Fig. 2).

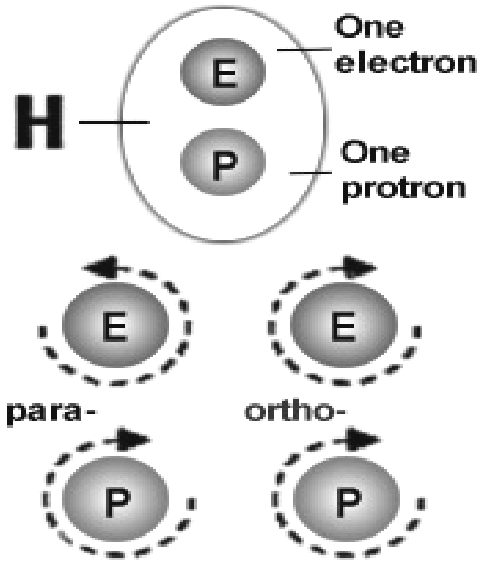


Fig. 2 Atomic orientation

This spin orientation has a pronounced effect on physical properties (specific heat, vapour pressure), as well as behavior of the gas molecule. The coincident spins render ortho-hydrogen exceedingly unstable and more reactive than its para-hydrogen counterpart. To secure conversion of para to ortho state, it is necessary to change the energy of interaction between the spin states of the H2 molecule.

De-cluster of fuel

Hydrocarbons have basically a "cage like" structure. That is why during the combustion process oxidizing of their inner carbon atoms is hindered. Furthermore they bind into larger groups of pseudo-compounds. Such groups form clusters (associations). The access of oxygen in the right quantity to the interior of the groups of molecules is hindered and it is this shortage of oxygen to the cluster that hinders the full combustion [9]. In order to combust fuel, proper quantity of oxygen from air is necessary for it to oxidize the combustible agents.

The exhaust should theoretically contain carbon dioxide, water vapor and nitrogen from air, which does not participate in the combustion. Practically the exhaust gases contain CO, H2, HC, NOx and O2. In reality, complete combustion of fuel is never achieved and the incompletely oxidized carbon is evident in the form of HC, CO or is deposited on the internal combustion chamber walls as black carbon residue. The incomplete combustion process causes all this.

Hydrocarbon fuel molecules treated with the magnetic energy of the mono pole technology tend to de-cluster, creating smaller particles more readily penetrated by oxygen, thus leading to better combustion[10]. They become normalized & independent, distanced from each other, having bigger surface available for binding (attraction) with more oxygen (better oxidation). In accordance with van der Waals' discovery of a weak-clustering force, there is a very strong binding of hydrocarbons with oxygen in such magnetized fuel, which ensures optimal burning of the mixture in the engine chamber

Experimental System

The experiment was carried out on a single cylinder air-cooled two-stroke SI engine whose specifications are given in Table 1. Provisions were fabricated and installed in the engine setup to vary ignition timing and fuel quantity. These two arrangements help the engine to run on maximum best torque (MBT) operation mode in each load of its operations.

Table 1 Engine specifications

Engine Make	Bajaj 150 CC
Cylinder Bore	57.5 mm
Stroke	58 mm
Displacement	150 cc
Power	4.5 kW @5500 rpm
Con Rod Length	110 mm
Compression Ratio	7.4:1
Carburetor	Jetex, Down draft
Lubrication	Petroil

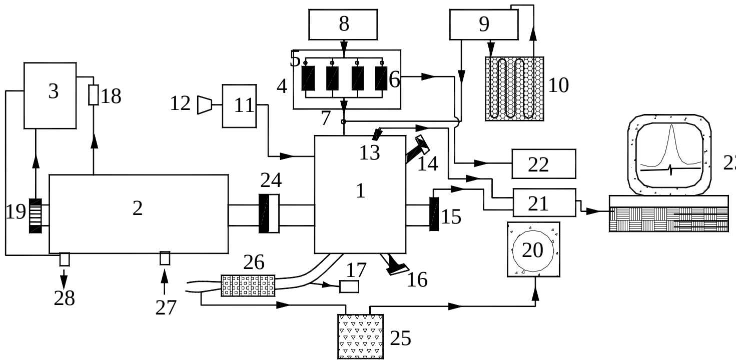
The engine was loaded by an eddy current dynamometer and the engine was run at a constant speed of 3000 rpm and the load was varied and various parameters were measured.

Fuel flow measurements were carried out using an automatic flow control device and digital stopwatch. Airflow was measured with orifice flow meter. Engine and exhaust temperatures were measured by chrome-alumal thermocouples. An infrared gas analyzer measured exhaust emissions. The schematic diagram of experimental set-up is shown in Figs. 3 and 4.

The cylinder pressure was measured using a Kistler model piezoelectric pressure transducer flush mounted in the cylinder head of the engine. The output of the transducer was fed to a Kistler model charge amplifier, which possesses a high degree of noise rejection with ground level current attenuation [10]. For each set of reading, pressure data were recorded using a high speed AVL data acquisition system timed by an optical encoder mounted on the engine crankshaft and after collection, each sample was transferred to a hard disk on a personal computer system for storage and further analysis. A sample size of 500 cycles was selected for further analysis [11].

1) Exhaust gas analyzer 2) Fuel line change 3) Amplifier 4) AVL data acquisition system 5) Eddy current dynamometer 6) Fuel line assembly fit 7) Fuel metering unit 8) Fuel recirculation unit

Fig. 3 Photographic view of experimental setup

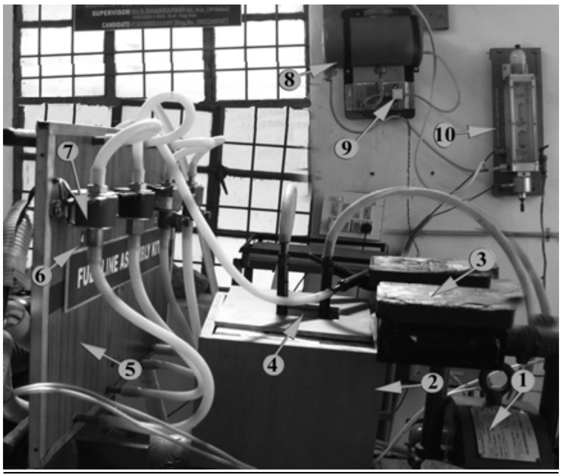


1) Engine 2) Eddy current dynamometer 3) Dynamometer control panel 4) Fuel line assembly kit 5) Solenoid valve 6) High gauss magnet 7) Solenoid valve 8) Primary fuel tank 9) Fuel recirculation tank 10) Radiator core 11) Air box 12) Orifice meter 13) Piezo-electric pressure pickup 14) Variable area jet-screw 15) Crank angle encoder 16) MBT timing gear 17) Exhaust gas temperature sensor 18) Load sensor 19) RPM counter 20) Exhaust gas analyzer 21) Charge amplifier 22) Fuel line changer 23) Avl-data acquisition system 24) Coupling 25) Moisture separator 26) Muffler 27) Cooling water in 28) cooling water out

Fig. 4 Schematic view of experimental setup

Fuel line changer with solenoid valves helps to change the fuel line to pass fuel in to variety of energized bank. This magnetic source magnetizes the fuel coming through the fuel line and prepares it for better combustion as shown in the Fig. 5.

In addition, the carbon in the fuel is also eliminated. As a result, the petrol crossing the device is polarized (that is, the molecules of the fuel are aligned along a particular direction). This improves the combustion characteristic of the fuel and reduces the amount of noxious gases in the exhaust.



1) Eddy current dynamometer 2) Monopole fuel energizer 3) 4500 gauss bar magnet 4) Radiator core inside 5) Fuel line assembly kit 6) Fuel line indicator (led) 7) Solenoid valve 8) Fuel recirculation tank 9) Electronic fuel pump 10) Electronic fuel consumption meter

Fig. 5 Fuel energizer and fuel line assembly kit

Materials Used

Neodymium-Iron-Boron based magnets [12] having 3000 Gauss is used for initial testing purpose. Rare earth based magnets having 4500 and 9000 gauss have also been used for testing (Fig. 6).

1) 9000 gauss magnet 2) 4500 gauss magnet 3) Radiator core 4) 3000 gauss magnet

Fig. 6 Photographic view of different gauss magnets

The higher gauss magnets need to be shielded to safeguard the encoder, data acquisition system and dynamometer. A commercially available radiator core was used as base to keep magnets on both sides and allow fuel to re circulate around the magnets to get energized fuel.

Methodology

Engine was operated on constant speed mode and the following cases were considered to acquire results.

Fuel line 1: Base engine with absence of magnet
Fuel line 2: Base engine with magnet of 3000 gauss
Fuel line 3: Base engine with magnet of 4500 gauss
Fuel line 4: Base engine with magnet of 9000 gauss

The above fuel lines were selected on each load with the help of fuel line changer . Engine was allowed to run on lean limit with the help of fabricated adjustable fuel jet. MBT have also been maintained with the help of ignition timing changer to validate the experimental data with base engine performance data (Fig. 7).

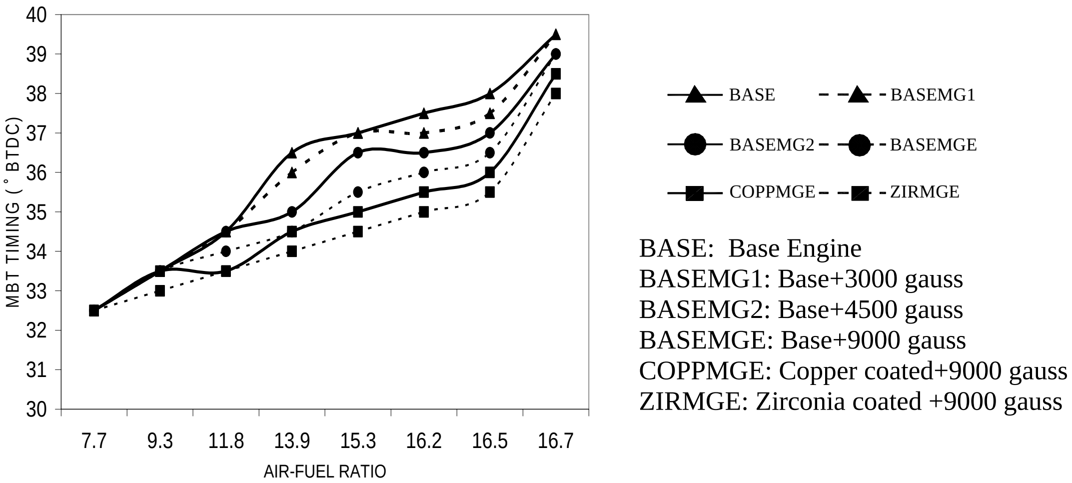
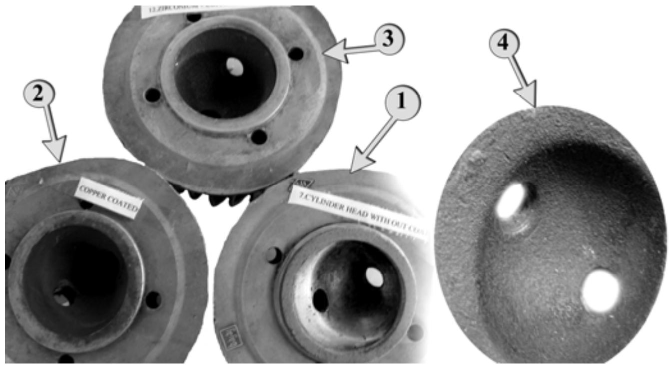


Fig. 7 Optimizied MBT for different engine setups

The inner surface of the cylinder head was coated (Fig. 8) with copper chromate and zirconia by thermal evaporation technique in a vacuum coating unit [13-14]. The above experimental procedure has been repeated for this changes and data were acquired.



1) Base engine cylinder head 2) Copper coated cylinder head
3) Zirconia Coated cylinder head 4) Zirconia Coating-Close View

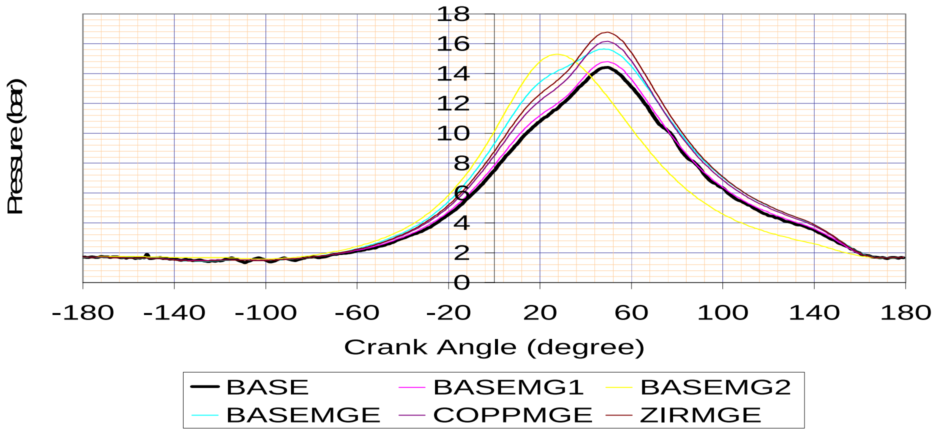
Fig. 8 Coated heads

The air and fuel are subject to the lines of forces from permanent magnets mounted on the air and fuel inlet lines. The magnet is oriented so that its South Pole is located adjacent the fuel line and its North Pole is located spaced apart from the fuel line.

Results and Discussion

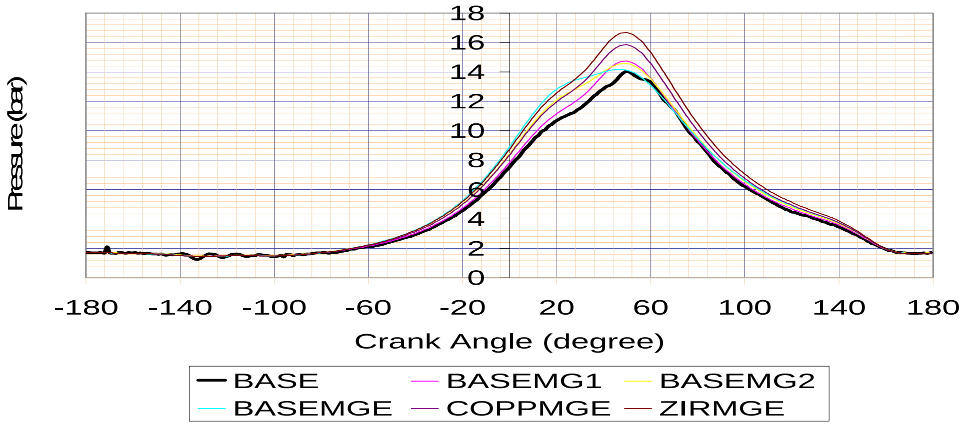
Engine performance

For the same amount of air fuel mixture, which is supplied to the engines, the base engine gives a lesser brake power and brake thermal efficiency compared to the Energized fuelled engine [15-16]. The same trend is maintained between base engine and catalytic coated engine with and without energized fuel. This is due to the incomplete combustion of the charge due to mixture limit inside the combustion chamber at a given compression ratio (Figs. 9-15). The actual volume of charge combusted is comparatively less than the volume of charge entering the chamber [17]. Hence the amount of fuel charge to give the mechanical power gets reduced and this reduces the brake thermal efficiency.



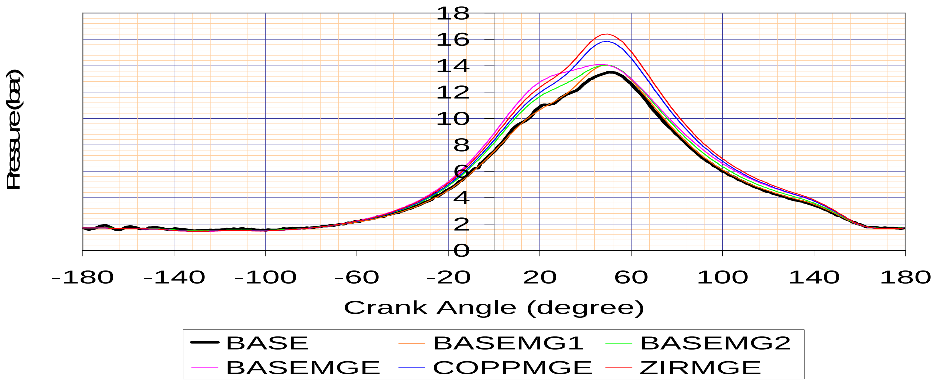
BASE	=17.2 Kg	BASEMG1	=17.7 Kg	BASEMG2	=17.8 Kg
BASEMGE	=18 Kg	COPPMGE	=19.8 Kg	ZIRMGE	=20.8 Kg

Fig. 9 Variation of pressure with crank angle at AFR=9.3



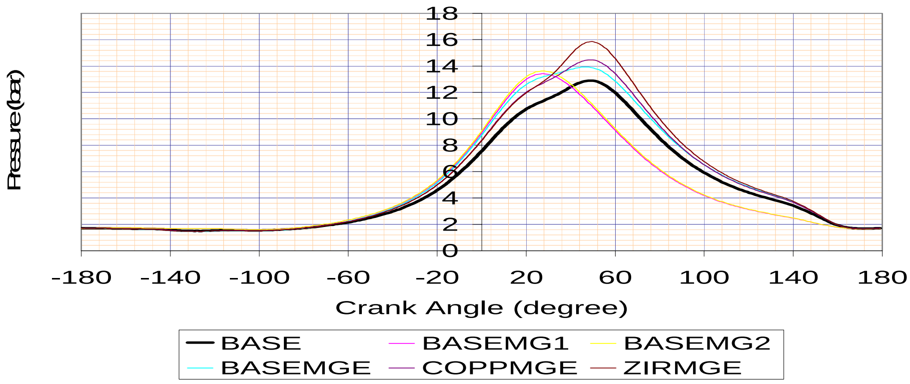
BASE	=16.5 Kg	BASEMG1	=16.9 Kg	BASEMG2	=17 Kg
BASEMGE	=17.4 Kg	COPPMGE	=18.8 Kg	ZIRMGE	=19.5 Kg

Fig. 10 Variation of pressure with crank angle at AFR=11.8



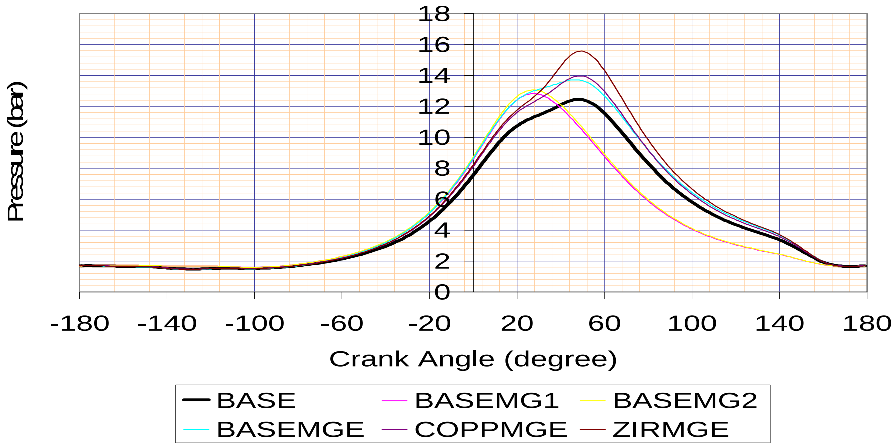
BASE	=15.2 Kg	BASEMG1	=15.7 Kg	BASEMG2	=15.8 Kg
BASEMGE	=16.1 Kg	COPPMGE	=17.7 Kg	ZIRMGE	=18.2 Kg

Fig. 11 Variation of pressure with crank angle at AFR=13.9



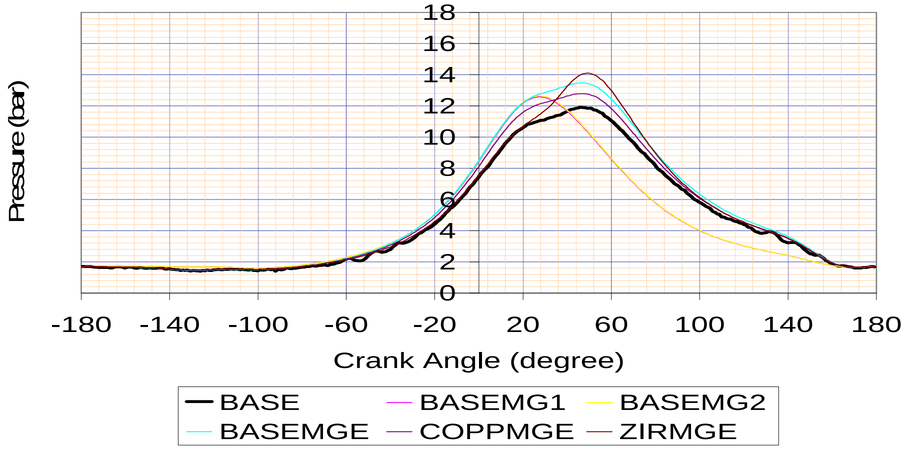
BASE	=14 Kg	BASEMG1	=14.4 Kg	BASEMG2	=14.5 Kg
BASEMGE	=15 Kg	COPPMGE	=16.7 Kg	ZIRMGE	=17.2 Kg

Fig. 12 Variation of pressure with crank angle at AFR=15.3



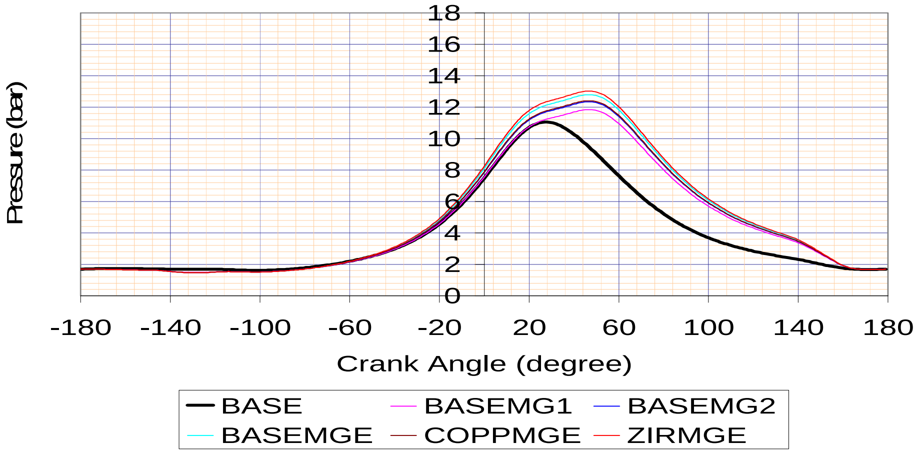
BASE	=12 Kg	BASEMG1	=12.5 Kg	BASEMG2	=12.6 Kg
BASEMGE	=12.9 Kg	COPPMGE	=14 Kg	ZIRMGE	=15.3 Kg

Fig. 13 Variation of pressure with crank angle at AFR=16.2



BASE	=10 Kg	BASEMG1	=10.4 Kg	BASEMG2	=10.5 Kg
BASEMGE	=10.8 Kg	COPPMGE	=12.1 Kg	ZIRMGE	=13.4 Kg

Fig. 14 Variation of pressure with crank angle at AFR=16.5



BASE	=9 Kg	BASEMG1	=9.1 Kg	BASEMG2	=9.1 Kg
BASEMGE	=9.2 Kg	COPPMGE	=9.3 Kg	ZIRMGE	=9.3 Kg

Fig. 15 Variation of pressure with crank angle at AFR=16.7

The fuel molecules start diffusing from the free stream into the boundary layer and this fuel concentration at various sub layers and at various crank angle position is found to be different [18]. It is found that the fuel level in the sub layer near the free stream shows a sudden increase near top dead centre TDC because it was found that the boundary layer thickness suddenly decreases near TDC due to the effect of high Reynolds number. Due to this the effective distance that the fuel molecule diffuses becomes lesser near the TDC and hence the fuel levels in the sub layers were higher. The variation in the fuel concentration in the sub layers near to the wall was less compared to the sub layers near the free stream. This shows that the diffusion rate of fuel is the main controlling factor in limiting the reaction rate. In the magnet with 9000 gauss fuel line the diffusion from the free stream to the layers is found to be more which proves the higher reaction rate. Due to the higher reaction rate the maximum mass of charge is combusted for a given actual charge. This leads to a higher mechanical power and hence a higher brake thermal efficiency.

Effect on cycle variation

There are many methods to analyses the combustion variation in SI engines. The widely used parameter is the peak pressure (P max), measured inside the cylinder during combustion.

As the combustion rate increases due to the energized fuel, the gas force developed by combustion of the charge inside the energized fuelled combustion is found to be more compared to that developed at the base combustion. This increased gas force leads to higher peak pressure for the same supply of air fuel mixture in the energized fuel engine. Also the cyclic variations of peak pressures are found to be controlled because the combustion rate depends on the diffusion rate of the fuel, which further varies with crank angle position. So the maximum pressure is developed more or less at a constant crank position in a cycle. So the peak pressure at different cycles is found to be improved.

Figs.16 and 17 show the scatter plots of Pmax and IMEP of individual cycles for both base and energized fuel engine at an optimal air-fuel ratio of 16.7:1. The Pmax is directly obtained from the measured cylinder pressure trace . The crank angle speed is measured by an optical crank angle encoder. The mean values of these parameters are also indicated in the figures.

The Pmax is a measure of rate of pressure rise due to combustion. If the combustion is faster, higher-pressure rise rate occurs and a higher Pmax results.The magnitude of variation depends on whether the combustion is faster or slower. A faster combustion will produce a higher Pmax[19]. Also the Pmax will tend to occur closer to TDC Whereas, a slower burning cycle will have lower Pmax and that will be away from TDC.

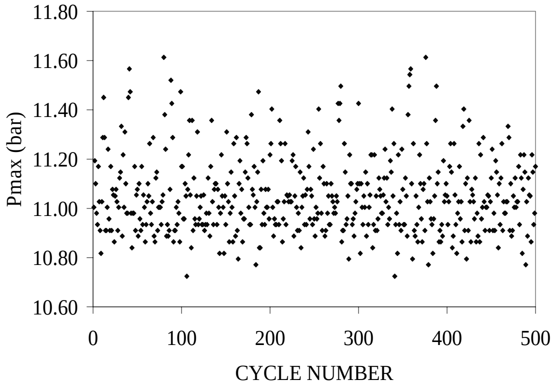
Air-fuel ratio (AFR) for BMEP (Fig. 18), BTE (Fig. 19), variation of exhaust energy (Fig. 20), CO (Fig. 21) was varied from the minimum to a maximum extent and graphs are drawn with various cylinder parameters against AFR. Improvement in thermal efficiency and reduction in exhaust emissions mainly depends magnetically energized. With increase of load on engine, combustion chamber temperature and air movement increases. Efficiency increases as the engine is made leaner to some extent and then it fails due to the lean misfire limit.

Fig. 22 presents the variation of peak cylinder pressure with air fuel ratio. Fig. 23 compares different level of magnetized fuel engine emission performance. The graph indicates improvement in brake thermal efficiency at higher A/F ratios to some extent. This variation is due to improvement in combustion as the hydrocarbon fuel molecules treated with the magnetic energy tend to de-cluster, creating smaller particles more readily penetrated by oxygen, thus leading to better combustion. They become normalized and independent, distanced from each other, having bigger surface available for binding (attraction) with more oxygen (better oxidation).

The IMEP is a measure of work output from the combustion products. A faster pressure rise and a quick combustion may result in higher work output. A higher trapped charge may also lead to increased work output. Hence, the IMEP fluctuations may be due to variation in combustion rate or variation in quantity of energy released [20].

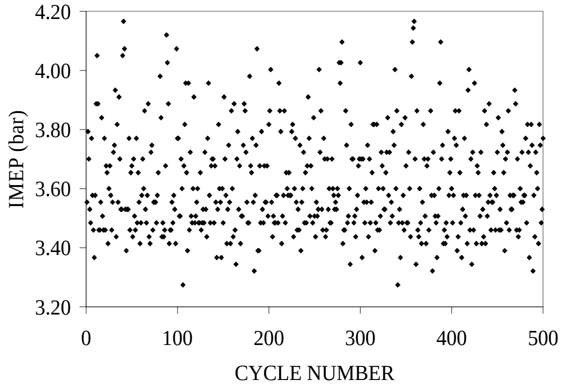
It is interesting to note that the variation in Pmax among these operating modes is higher at lean side in catalytic coated head engine. Similarly, the variation in IMEP is more in lean operation. The coefficient of variation (COV) of Pmax and IMEP are calculated from the cycles belonging to different modes are plotted. The COV of Pmax decreases from base engine to catalytic coated head engine whereas COV of IMEP is increased.

Mean =11.05 bar Stdev = 0.90 bar
COV =0.081



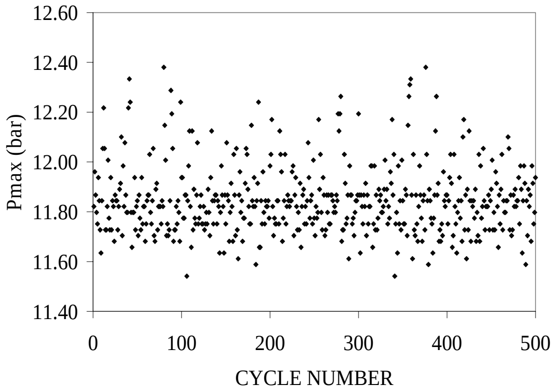
Base engine with absence of magnet

Mean = 3.61 bar Stdev= 0.15 bar
COV = 0.041



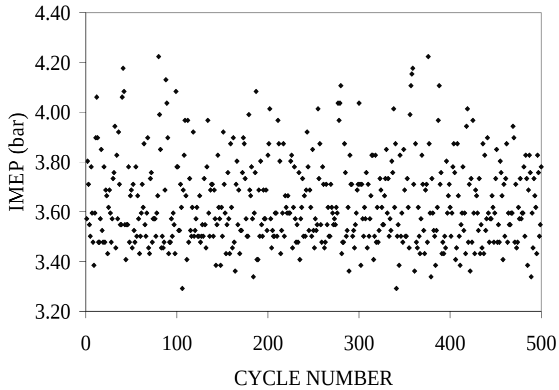
Base engine with absence of magnet

Mean =11.837 bar Stdev = 0.872 bar
COV = 0.074



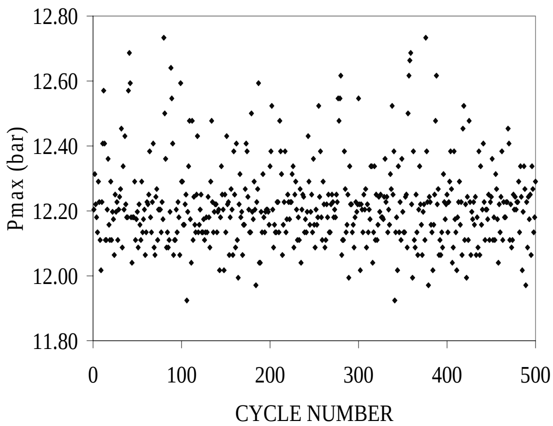
Base Engine with 3000 gauss magnet

Mean = 3.63 bar Stdev = 0.17 bar
COV = 0.047



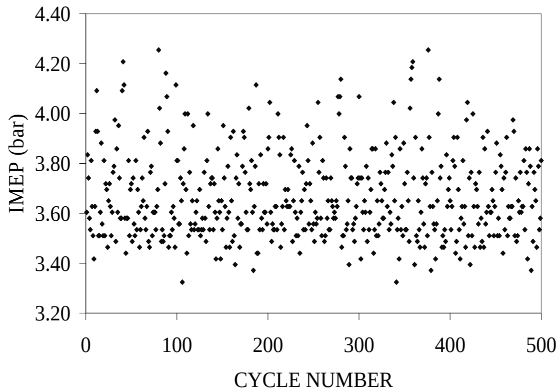
Base Engine with 3000 gauss magnet

Mean = 12.200 bar Stdev = 0.842 bar
COV = 0.069



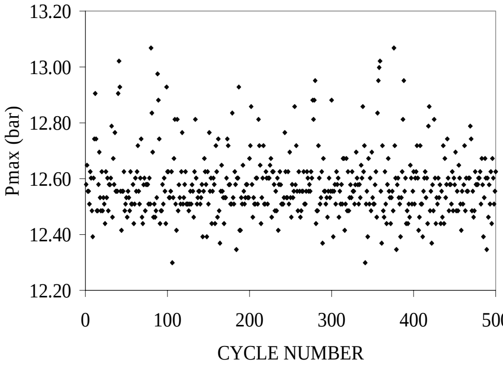
Base Engine with 4500 gauss magnet

Mean = 3.68 bar Stdev = 0.18 bar
COV = 0.049



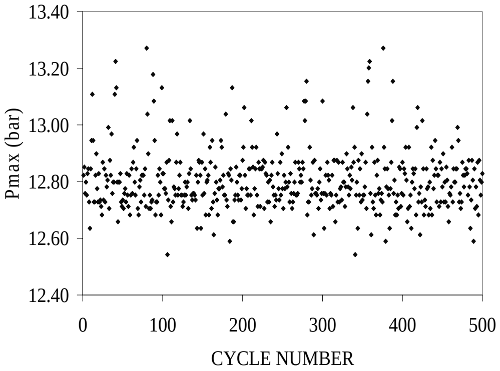
Base Engine with 4500 gauss magnet

Mean = 12.55 bar Stdev = 0.822 bar
COV = 0.065



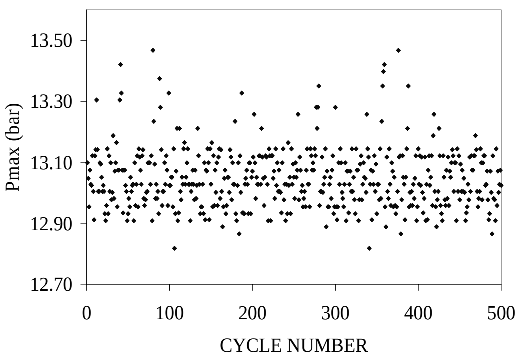
Base Engine with 9000 gauss magnet

Mean = 12.788 bar Stdev = 0.820 bar
COV = 0.064



Copper coated Engine with 9000 gauss magnet

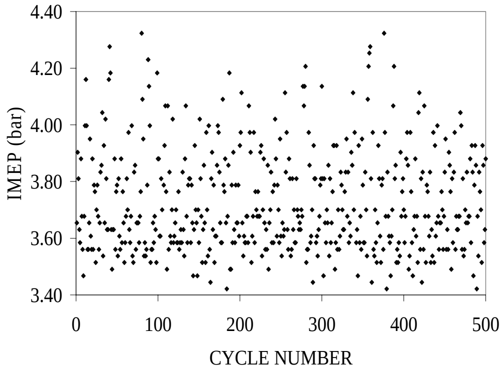
Mean = 13.014 bar Stdev = 0.791 bar
COV = 0.060



Zirconia coated Engine with 9000 gauss magnet

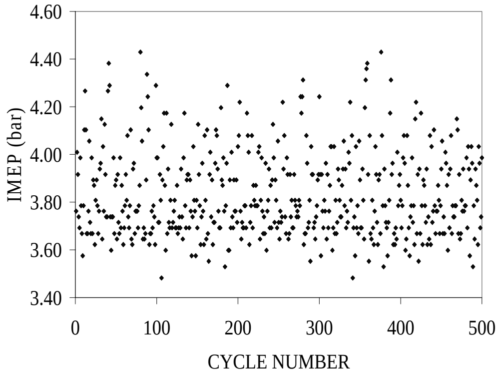
Fig. 16 Scatter plot of peak pressure for different phase of operations at 3000 rpm at an AFR of 16.7

Mean = 3.74 bar Stdev = 0.22 bar
COV = 0.059



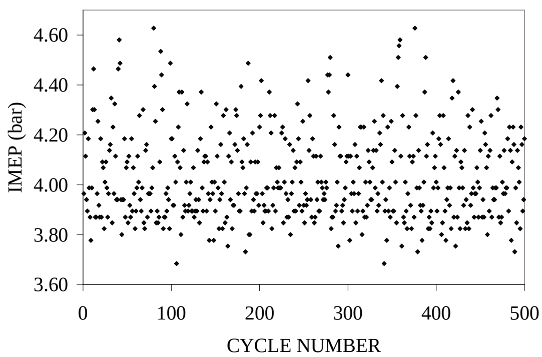
Base Engine with 9000 gauss magnet

Mean = 3.83 bar Stdev = 0.29 bar
COV = 0.075



Copper coated Engine with 9000 gauss magnet

Mean = 4.05 bar Stdev = 0.36 bar
COV = 0.089



Zirconia coated Engine with 9000 gauss magnet

Fig. 17 Scatter plot of IMEP for different phase of operations at 3000 rpm at an AFR of 16.7

Full Open Throttle
Speed = 3000 rpm
Compression Ratio = 7.4:1
MBT Timing

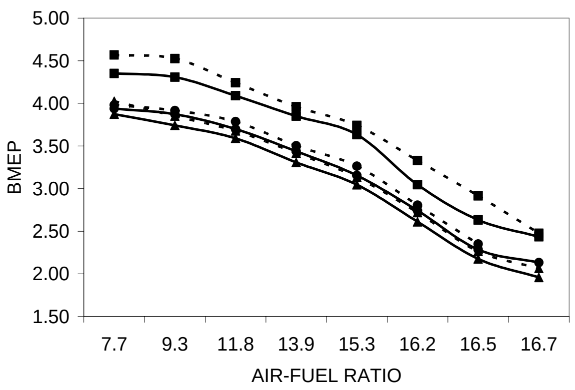


Fig. 18 Variation of brake mean effective pressure with air-fuel ratio

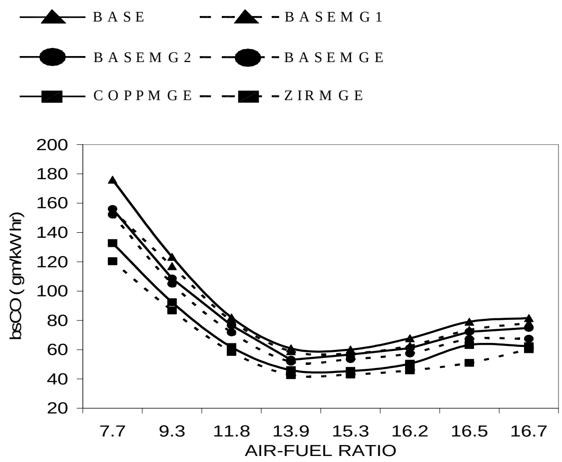


Fig. 21 Variation of brake specific CO emission with air-fuel ratio

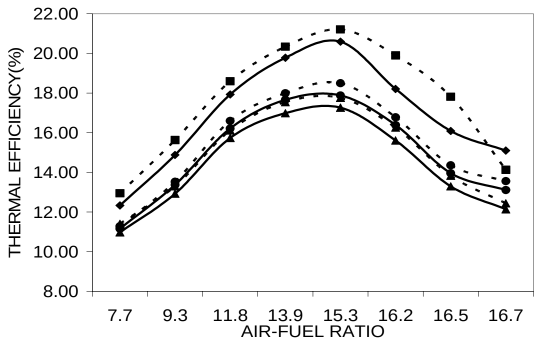


Fig. 19 Variation of brake thermal efficiency with air-fuel ratio

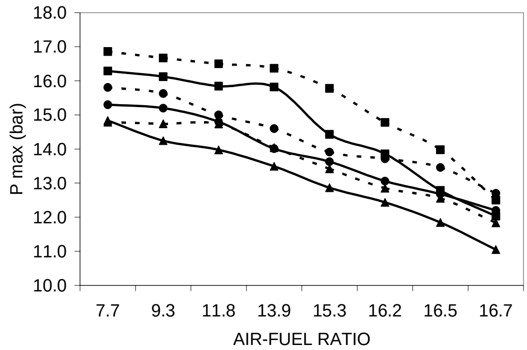


Fig. 22 Variation of peak cylinder pressure with air-fuel ratio

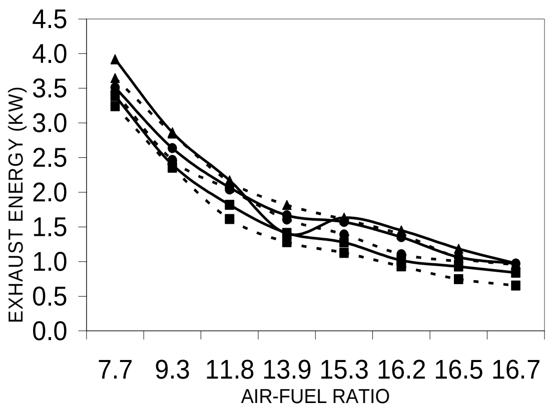


Fig. 20 Variation of exhaust energy with air-fuel ratio

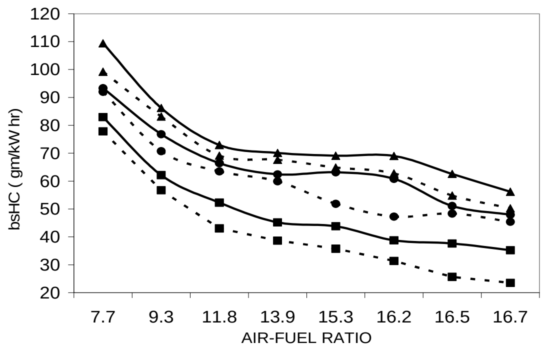


Fig. 23 Variation of brake specific HC emission with air-fuel ratio

Conclusion

There is significant increase in brake thermal efficiency and peak pressure whereas decrease in CO, HC and cyclic variation in case of copper and zirconia coated engines as compared to base engine. Table 2 presents the changes in different parameters with base, copper and zirconia coated engine with 9000 gauss magnetic flux.

Table 2 Changes in different parameters with base, copper and zirconia coated engine with 9000 gauss magnetic flux

S No	Parameters	Base engine %	Copper-coated engine, %	Zirconia-coated engine, %
1	Increase in brake thermal efficiency	3.2	6.6	11.2
2	Increase in peak pressure	13.5	15.72	17.78
3	Reduction in cyclic variation	8.6	8.8	12.1
4	Reduction in CO emission	13.3	23.5	29.5
5	Reduction in HC emission	22.1	37.3	44.2

The variation of peak pressures for continuous cycles of coated engine (9000 gauss) is less than that of the base engine. Among the various combinations at a leaner side (AFR=16.7), zirconia coated engine with 9000 gauss magnetic flux has higher IMEP (4.05 bar) and lower cyclic variation (0.791 bar).

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