Performance and emissions achievements by magnetic energizer with a single cylinder two stroke catalytic coated spark ignition engine

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This paper presents work conducted on a zirconia (catalyst) activated two-stroke spark ignited engine to investigate the effect of high gauss magnetic energy on cyclic variation of combustion parameters. A 9000 gauss magnet, made up of Neodymium-Iron-Boron, is fixed on fuel line before carburetor. The coating is carried out by thermal evaporation technique on the inside surface of combustion chamber walls and piston crown. In-cylinder pressures were recorded for 500 continuous cycles using a piezo electric pressure pickup and PC based data acquisition system. Magnetic flux activates preflame reaction and shortens combustion duration. Cyclic variation of combustion parameters due to magnetic energy were 25.1% less than the base engine and mean value of the peak pressures were found to have upper shift of 13.6%. Magnetically energized zirconia coated engine performed better than the base engine during running.

Keywords: Catalyst, Emission, Energizer, Spark ignition engine

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Introduction

Cyclic variation1-11 in combustion of spark ignition (SI) engine is influenced by both mixture strength and the turbulence in tile cylinder. Laminar flame speed at the spark plug region was found to be a major cause of cyclic variation in early flame development. Winsor & Patterson12 suggested that by improving mixture turbulence, cyclic variation of combustion can be minimized. Urushihara et al13 employed combination of swirl flow and tumble flow, generated by swirl control value. Whitelaw & Xu14 used an intake shroud to create tumble flow and increased swirl ratio. Dhandapani15 applied copper coating over piston crown and inside of cylinder head wall, and reported that the catalyst improves fuel economy and increases combustion stabilization. Results16 of a computer model for NiCoCr alloy coated combustion chamber showed a slight increase in peak pressures and the rate of heat release. But most of these studies were aimed to understand the problem of cyclic variation and the influence of either one or more number of parameters such as air/fuel ratio, turbulence inside the combustion chamber and distribution of air/fuel ratio.

This study presents variations of magnetic flux on combustion17,18 of normal lean combustion and catalytically activated lean combustion19-26 and various other in-cylinder activities using Zirconia as catalyst in a two stroke SI engine.

Magnetic Energizer –Working Principle

Mono Pole Technology

The most important factors in the monopole technology are the magnetic field intensity and the collimation of the lines of magnetic flux27,28. Intensity of magnetic field is far superior to that generated by...
regular permanent magnets and the collimation of magnetic fields (Fig. 1) renders the lines of magnetic flux exactly parallel to each other at extremely high densities (to the order of millions of lines of flux per cm$^2$). These devices are external online installations without cutting or modifying the fuel pipes.

**Ortho-Para Orientation**

In Para H$_2$ molecule, which occupies even rotation levels (quantum number), spin state of one atom relative to another is in the opposite direction rendering it diamagnetic. In ortho molecule, which occupies odd rotational levels, spins are parallel with the same orientation for the two atoms, and therefore is paramagnetic and a catalyst for many reactions (Fig. 2).

This spin orientation has a pronounced effect on physical properties (specific heat, vapour pressure), as well as behavior of the gas molecule$^{29,30}$. The coincident spins render $o$-H$_2$ exceedingly unstable and more reactive than its $p$-H$_2$ counterpart. To secure conversion of $p$ to $o$ state, it is necessary to change energy of interaction between spin states of H$_2$ molecule$^{31-33}$.

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**Materials and Methods**

In a single cylinder air-cooled two-stroke SI engine (Table 1) provisions were fabricated and installed in the engine setup to vary ignition timing and fuel quantity. To facilitate operating the engine under maximum best torque (MBT) timing mode, a timing gear was designed in such a way that for one complete rotation of hand wheel, the timing advance/retard is exactly measures one degree. By adjusting this hand wheel mechanically, spark timing could be varied at will, even at engine in operation. For a given quantity and quality of the mixture under a given load setting, the timing which gives the maximum speed, was taken as the MBT timing. Fuel quantity is varied by adjusting fabricated metering rod, inserted in carburetor jet. These two arrangements help the engine to run on MBT operation mode in each load of its operations.

An AVL Electrical Eddy Current dynamometer has been coupled to the engine. It has the facility to control speed and load externally by a computer and provision to record speed and torque fluctuations (Fig. 3). An automatic fuel flow meter with digital clock allows accurate fuel flow measurements. Commercially available petrol mixed with proper grade lubricant is used as fuel. A separate fuel tank is maintained beside the main fuel tank. Fuel is drawn from the bottom of the tank by an electronic fuel pump.
and discharged to the top of the tank. High gauss magnet is placed facing North Pole towards the radiator core surface, which is placed next to the fuel pump. This arrangement is properly shielded for safeguarding the data acquisition system. The pump is operated an hour earlier before commencement of the experiments so as to energize the fuel. This fuel recirculation tank can be accessed as one of the fuel resources in the fuel line changer. Fuel line assembly kit consists of four fuel lines with solenoid valves control and LED indicators to know the fuel line alive. This kit actually receives fuel either from main tank or from recirculation tank but one at a time. All solenoid valves are connected with fuel line changer, which is placed adjacent to the on line data acquisition system. Fuel line selection can be done in the fuel line changer itself. Manually adjustable solenoid valve is also fixed for one fuel line for emergency operation. CO and unburnt hydrocarbon emissions are measured by an AVL make (Digas 4000 Light) exhaust gas analyzer. Exhaust gases are allowed to pass through a water trap immersed in ice bath to separate the condensed water, so that only dry exhaust gas is allowed into the exhaust analyzer.

The cylinder pressure was measured using a Kistler model piezoelectric pressure transducer flush mounted in the cylinder head of the engine. The output of transducer was fed to a Kistler model charge amplifier, which possesses a high degree of noise rejection with ground level current attenuation. 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. 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 (Fig. 4).

Initially the non-magnetized fuel line has been selected in the fuel line changer and the engine is allowed to run 20 min for warming up before taking readings. The engine has been operated in constant speed mode of 3000 rpm, which represents the average cruising road speed of the vehicle. The exhaust gas analyzer is switched on quite early, so that it will be stabilized before the commencement of experiment. Ambient pressure, humidity and temperature are noted. The fuel flow is varied to supply rich and lean mixtures. Ignition timing is kept advanced to run the engine on MBT operation mode. The load on the engine is automatically controlled by the dynamometer while keeping the engine at constant speed.

After the engine is stabilized for a particular operating point, airflow, fuel flow, and exhaust gas temperature are recorded. The dynamometer readings such as load, speed are also noted. At each operating point, cylinder pressure traces of 500 cycles and their average are measured and stored in a computer hard disc.

Materials Used

Neodymium-Iron-Boron based magnets (3000 gauss) is used for initial testing purpose. Rare earth based magnets (4500 & 9000 gauss) have also been used for testing (Fig. 5). The higher gauss magnets need to be shielded to safeguard the encoder, data acquisition
A commercially available radiator core was used as base to keep magnets on both sides and allow fuel to recirculate around the magnets to get energized fuel.

**Methodology**

Engine was operated on constant speed mode and the following cases were considered: 1) Base engine without magnet; 2) Base engine with magnet of 3000 gauss; 3) Base engine with magnet of 4500 gauss; 4) Base engine with magnet of 9000 gauss; 5) Copper coated engine with magnet of 9000 gauss; and 6) Zirconia coated engine with magnet of 9000 gauss. Engine was allowed to run on lean limit with the help of fabricated metering rod. MBT have also been maintained with the help of timing gear wheel to validate experimental data (Figs 6 & 7) with base performance data. Inner surface of the cylinder head was coated with copper chromate and zirconia by thermal evaporation technique in a vacuum coating unit (Fig. 8). Above experimental procedure has been repeated and data were acquired. Air and fuel are subject to the lines of forces from permanent magnets mounted on the air and fuel inlet lines\(^{31,42}\). 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 (Fig. 4).

**Results and Discussion**

**Engine Performance**

For the same amount of air fuel mixture supplied to the engines, base engine gives a lesser brake power (BP) and brake thermal efficiency (BTE) compared to the energized fuel engine. 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 combustion chamber at a given compression ratio. Actual volume of charge combusted is comparatively less than the volume of charge entering the chamber. Hence, amount of fuel charge to give mechanical power gets reduced and this reduces BTE (Fig. 9a).

Fuel molecules start diffusing from free stream into boundary layer and this fuel concentration at various sub layers and at various crank angle position is found to be different. Fuel level in sub layer near the free stream shows a sudden increase near TDC because boundary layer thickness suddenly decreases near TDC due to the effect of high Reynolds number. Due to this, effective distance that the fuel molecule diffuses becomes lesser near TDC and hence the fuel levels in sub layers were higher. The variation in fuel concentration in sub layers near to the wall was less compared to the sub layers near free stream. This shows that diffusion rate of fuel is the main controlling factor in limiting the reaction rate. In the magnet (9000 gauss) fuel line, diffusion from the free stream to the layers is found to be more and hence maximum mass of charge is combusted for a given actual charge. This leads to a higher mechanical power and hence a higher BTE (Fig. 9a).
Fig. 9—Variation of air fuel ratio with: a) BTE; b) CO; c) HC; d) Brake specific fuel consumption (BSFC)

Fig. 10—Cyclic variation for base engine with: a) No magnet ($P_{\text{avg}}$ 13.395 bar); b) 3000 gauss magnet ($P_{\text{avg}}$ 13.420 bar); c) 4500 gauss magnet ($P_{\text{avg}}$ 14.011 bar); d) 9000 gauss magnet ($P_{\text{avg}}$ 14.022 bar)
Air-fuel ratio (AFR) for BTE (Fig. 9a), CO (Fig. 9b), HC (Fig. 9c) and BSFC (Fig. 9d) were 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.

Effect on Cycle Variation
The widely used parameter to analyze the combustion variation in SI engines is peak pressure ($P_{\text{max}}$), measured inside cylinder during combustion. As combustion rate increases due to energized fuel, gas force developed by combustion of the charge inside energized fuel combustion is found 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 (16.7:1) in energized fuel engine (Figs 10-12). Also, cyclic variations of peak pressures are controlled because combustion rate depends on diffusion rate of the fuel, which further varies with crank angle position. So maximum pressure is developed more or less at a constant crank position in a cycle. So the peak pressure at different cycles is improved.

Conclusions
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). The variation of peak pressures for continuous cycles of coated engine (9000 gauss) is less than that of the base engine.

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