CHAPTER 5

MAGNETICALLY ACTIVATED COMBUSTION

5.1 INTRODUCTION

The review on performance improvement and emission reduction of SI engines presented in Chapter 2 indicates that there are many methods available to incorporate the concept in spark ignition engines. They can be broadly classified based on the principles as: (a) Engine design and operating variables (b) Engine system design (c) Fuel system design (d) Exhaust treatment devices (e) Evaporative emission devices. All these methods except magnetic fuel conditioner which comes under the fuel system design, involve major modifications or additional gadgets involving high cost. A high gauss magnet is placed on fuel line before carburetor to activate the fuel to make better combustion (Marshall and Skitek 1996). The advantages of a two-stroke engine lie in its simplicity and low cost of production. This should not be lost in improving the performance of the engine. Hence, in the present work, the magnetically activated fuel on combustion is selected for base and catalytic coated engines.

Although the literatures indicate the potential application of magnetic fuel conditioner in different commercial brands, extensive studies are not conducted yet (Mcneely 1994). Hence, it is proposed to conduct a detailed study to explore the possibilities of magnetic fuel activation in base and catalytic coated engines for enhancing combustion.
In the present study, three different gauss values of magnets are selected and tested with base and catalytic coated engine. Neodymium-Iron-Boron magnets are used for this experimentation. Non-noble metal catalysts such as Copper and Zirconia are used as catalyst and they are coated inside the combustion chamber walls (Nedunchezhian et al 1993). Detailed experimental study is carried out to evaluate the effect of magnetic flux on performance and its influence on combustion.

5.2 AIM AND SCOPE OF THE PRESENT WORK

The present work aims at studying the performance of different gauss magnets in improving the thermal efficiency and reducing the exhaust emissions in a real engine situation. The high gauss magnets performances are evaluated under varied air-fuel ratios.

The objectives of the present work are:

- To supply fuel through high gauss permanent magnet to achieve better combustion in a two-stroke SI engine.
- To compare different gauss magnets and evaluate their performances.
- To compare the effect of magnetic activation on catalytic coated engine

5.3 METHODOLOGY

To fulfill the above objectives, experimental investigations are done. Detailed experimental works are carried out under varied air-fuel ratios to compare the performance of magnetically activated fuel on base engine and magnetically activated fuel on catalytic coated engine with base engine.
The experimental setup and the scheme of experimentation are described in Chapter 4. The following are the important steps involved in analyzing the above problem:

- Measuring the engine performance under variable air-fuel ratio in a dynamometer test bed.
- Measuring the cylinder pressures by using a PC based data acquisition system.

5.4 SELECTION OF MAGNETS

Neodymium-Iron-Boron based magnets of 3000 gauss, 4500 gauss and 9000 gauss are specially fabricated for the experimental purpose. These magnets can be installed without cutting or modifying the fuel pipes.

The intensity of the magnetic field generated by these magnets is far superior to that generated by regular permanent magnets. An analogy can be drawn to that of the laser. An ordinary beam of light radiates in all directions; however, the laser is an intense beam of light that will not waver from its line of direction. Similarly, whereas an ordinary magnet radiates magnetic lines of flux in all possible directions heading from one pole to the other, this fabricated special magnet generates a concentrated field of lines of flux that are available in concentric lines at the location of application (Fuller 1969).

5.5 SELECTION OF CATALYSTS

From the review of literature, it is found that many noble and non-noble metals can be used as catalysts for hydrocarbon oxidation (Thring 1980). The noble metal catalysts such as Platinum, Palladium etc. are well proved for their catalytic activity, but not used in practical systems due to their
cost. Rychter et al (1981) identified that some non-noble metals with comparable performance with noble metal catalysts in hydrocarbon oxidation are available. Their results show that the non-noble metal catalysts such as Copper, Nickel, etc., also showed catalytic activity. Hence, the catalysts such as Copper and Zirconia are selected for in-cylinder coating.

Although these catalysts are already studied by different researchers under certain conditions, detailed study involving the effect of magnetic flux on various catalysts are not carried out. Table 5.1 shows the list of different gauss magnets with different catalysts that are tested in the present work:

**Table 5.1  Code names for different gauss magnets with different catalysts**

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Catalysts</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Base (No Coating)</td>
<td>BASE</td>
</tr>
<tr>
<td>2.</td>
<td>Base with 3000 gauss magnet</td>
<td>BASEMG1</td>
</tr>
<tr>
<td>3.</td>
<td>Base with 4500 gauss magnet</td>
<td>BASEMG2</td>
</tr>
<tr>
<td>4.</td>
<td>Base with 9000 gauss magnet</td>
<td>BASEMGE</td>
</tr>
<tr>
<td>5.</td>
<td>Copper Coated Cylinder Head Engine with 9000 gauss magnet</td>
<td>COPPMGE</td>
</tr>
<tr>
<td>6.</td>
<td>Zirconia Coated Cylinder Head Engine with 9000 gauss magnet</td>
<td>ZIRMGE</td>
</tr>
</tbody>
</table>

The engine with different gauss values of magnet on fuel line on different catalytic coatings is designated as per the above mentioned code. The code names will be used as abbreviated form in the following sections.
5.6 RESULTS AND DISCUSSIONS

The engine is run at a constant speed of 3000 rpm and loaded by an eddy current dynamometer. Throttle opening is fixed and fuel flow is varied. After the engine is stabilized, ignition timing is adjusted so as to run the engine on lean operation and readings are recorded. This MBT is maintained throughout the engine operation. The results of engine performance are calculated from the readings taken for the following categories of engine operation:

1. Base Engine (No Coating)
2. Base Engine with 3000 gauss magnet on fuel line
3. Base Engine with 4500 gauss magnet on fuel line
4. Base Engine with 9000 gauss magnet on fuel line
5. Copper Coated Engine with 9000 gauss magnet on fuel line
6. Zirconia Coated Engine with 9000 gauss magnet on fuel line

The engine performance parameters are explained in the following sections.

5.6.1 Thermal Efficiency

Figure 5.1 indicates the MBT timing for different air-fuel ratios. Figure 5.2 shows the thermal efficiency plotted against the air-fuel ratio for base engine, magnetically activated fuel on base engine and magnetically activated fuel on catalytic coated engines.
Full Open Throttle; Speed = 3000 rpm; Compression Ratio = 7.4:1

Figure 5.1 Variation of MBT timing with air-fuel ratio

Figure 5.2 Variation of brake thermal efficiency with air-fuel ratio
From the figure, it can be observed that 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 magnetically activated fuel on engine. The same trend is maintained between base engine and catalytic coated engines with and without magnetic activation of 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.

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 magnetically activated 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.

In addition, the best operating range for the base engine lies between 12:1 and 14:1 air-fuel ratios, whereas for the high gauss magnetic activated engine it lies between 13:1 and 15:1 air-fuel ratios and magnetically
activated fuel on catalytic coated engines the best operating range is between 14:1 and 15.5:1.

This shift in best performance range towards the lean side is due to the magnetic activation on fuel for combustion and catalytic activation of charge. This trend is pronounced for all the magnetically activated fuel on base and catalytic engines. The thermal efficiency of the base engine drops suddenly just after the stoichiometric ratio indicating the reach of lean limit. For the magnetically activated fuel on base and catalytic engines the brake thermal efficiency drops gradually after the air-fuel ratio of 16:1. The increase of brake thermal efficiency in the BASEMGE engine is 3.2%, COPPMGE engine is 6.6% and ZIRMGE engine is 11.2% compared with base engine. The highest thermal efficiency of 21.2 % is noted in ZIRMGE engine.

The corresponding brake specific fuel consumption is plotted in Figure 5.3. The fuel consumption of the base engine is varying between 0.48 kg/kWh to 0.72 kg/kWh for the air-fuel ratio range of 8:1 to 14:1. Whereas, the fuel consumption of high gauss magnetically activated fuel on catalytic coated engines varies between 0.38 kg/kWh to 0.6 kg/kWh for the air-fuel ratio range of 8:1 to 15.3:1. The low BSFC range is shifted well into the lean side. Beyond a certain air-fuel ratio, BSFC suddenly increases, indicating the reach of lean limit.

At the lean limit, combustion becomes erratic and thermal efficiency drops. Among the different gauss values of magnet for base and catalytic coated engines, the best BSFC is achieved for ZIRMGE engine. However, compared to the base engine, all the magnetically activated fuel on base and catalytic coated engines show better performance.
Figure 5.3  Variation of brake specific fuel consumption with air-fuel ratio

5.6.2  Brake Mean Effective Pressure

The variation of brake mean effective pressure with air-fuel ratio at full throttle is illustrated in Figure 5.4. BMEP of the base, magnetically activated fuel on base and catalytic coated engines are compared in the figure. The base engine has a BMEP of 3.6 bar at 11:1 air-fuel ratio and then drops drastically there after. Similar trend is observed for the magnetically activated fuel on base and catalytic engines except that the peak BMEP occurring at leaner ratios. The ZIRMGE engine shows a higher BMEP of 4.5 bar at an air-fuel ratio of 15:1. Generally, the BMEP values of catalytic engines are comparable to the base engine and attain their maximum either at stoichiometric or slightly lean ratios, whereas the base engine has its peak BMEP at a rich mixture range.
Full Open Throttle; Speed = 3000 rpm; Compression Ratio = 7.4:1 MBT Timing

Figure 5.4 Variation of brake mean effective pressure with air-fuel ratio

5.6.3 Exhaust Emissions

The brake specific CO (bsCO) and HC (bsHC) emissions are shown in Figures 5.5 and 5.6. The carbon monoxide, which arises mainly due to the incomplete combustion, is a measure of combustion inefficiency. From the Figure 5.5, it can be observed that the bsCO emissions are higher for all the cases in rich range and lower in lean range.

However the bsCO emissions are higher in the lean range for the base engine compared to the magnetically activated fuel on base and catalytic engines. The same trend is observed for the bsHC emissions (Heywood 1989), which is illustrated in Figure 5.6. The base engine exhibits a rise in bsHC emissions just after the air-fuel ratio of 15:1, whereas the magnetically activated fuel on base and catalytic engines show a late rise. The reduction of
carbon monoxide emission in the BASEMGE engine is 13.3%, COPPMGE engine is 23.5% and ZIRMGE engine is 29.5% compared with base engine. Reduction of hydrocarbon emission in the BASEMGE engine is 22.1%, COPPMGE engine is 37.3% and ZIRMGE engine is 44.2% compared with base engine.

The data in the Figures 5.5 and 5.6 shows that the best range of operation with respect to CO and HC emissions for the base engine is between 12:1 and 15:1. The corresponding range for the magnetically activated fuel on catalytic coated engine is 15:1 to 16:1 air-fuel ratio. This clearly indicates that lean operation of magnetically activated fuel on base and catalytic coated engines favours lower emissions.

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

Figure 5.5  Variation of brake specific CO emission with air-fuel ratio
Full Open Throttle; Speed = 3000 rpm; Compression Ratio = 7.4:1 MBT Timing

Figure 5.6 Variation of brake specific HC emission with air-fuel ratio

5.6.4 Energy Carried out by Exhaust Emissions

The exhaust of a two stroke engine contains CO and HC, which carry significant amount of energy that is originally contained in the fuel, into the atmosphere (Blair 1996). This energy content $Q_{ex}$ is determined from the power output $W$, the specific HC emission rate, $bsHC$, the specific CO emission rate, $bsCO$, the calorific value of fuel, $C_{fHC}$ and the calorific value of CO, $C_{fCO}$. They are related by,

$$Q_{ex} = (W/3.6) \times (C_{fCO} \times bsCO + C_{fHC} \times bsHC)$$

(5.1)

The exhaust energy carried out by CO and HC emissions are shown in Figure 5.7 for the base, magnetically activated fuel on base and catalytic coated engines. The graph shows the energy ‘thrown away’ as waste in
exhaust gas. The exhaust gas heat energy is not included in the above calculations. It can be observed from the figure that a significant amount of energy is carried out by the exhaust emissions and this is highest in the rich range. Most of the energy carried out into the exhaust is due to CO emissions which are higher at the rich range. Operating the engine under lean mixtures will result in less energy waste due to exhaust emissions.

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

![Exhaust Energy vs Air-Fuel Ratio](image)

**Figure 5.7** Variation of exhaust energy with air-fuel ratio

5.6.4 Cylinder Pressures

From the average of measured cylinder pressures for 500 cycles, the peak pressure is calculated and compared for the magnetically activated fuel on base and catalytic coated engines.
The variation of $P_{\text{max}}$ for different air-fuel ratios is plotted for base, magnetically activated fuel on base and catalytic coated engines in Figure 5.8. $P_{\text{max}}$ is a measure of combustion rate and higher values of $P_{\text{max}}$ indicate a faster combustion rate. $P_{\text{max}}$ of base, magnetically activated and catalytic coated engines decrease with increase in air-fuel ratio. Magnetically activated fuel on base and catalytic coated engines has higher $P_{\text{max}}$ compared to the base engine for lean mixtures. This indicates that the combustion is faster for magnetically activated mode of engine operation. The increase of $P_{\text{max}}$ in the BASEMGE engine is 6.1%, COPPMGE engine is 9.7% and ZIRMGE engine is 13.6% compared with base engine.

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

![Figure 5.8 Variation of $P_{\text{max}}$ with air-fuel ratio](image-url)
5.7 SUMMARY

From the above discussions, the following points are noted.

- The increase of brake thermal efficiency in the BASEMGE engine is 3.2%, COPPMGE engine is 6.6% and ZIRMGE engine is 11.2% compared with base engine. The highest thermal efficiency of 21.2% is noted in ZIRMGE engine.

- The reduction of CO emission in the BASEMGE engine is 13.3%, COPPMGE engine is 23.5% and ZIRMGE engine is 29.5% compared with base engine. Reduction of HC emission in the BASEMGE engine is 22.1%, COPPMGE engine is 37.3% and ZIRMGE engine is 44.2% compared with base engine.

- The increase of $P_{\text{max}}$ in the BASEMGE engine is 6.1%, COPPMGE engine is 9.7% and ZIRMGE engine is 13.6% compared with base engine.

However, further details on heat release rates, magnetic and catalytic activation of charge are required to compare the magnetically activated fuel on base and catalytic engine performance. It was identified in the earlier studies (Ozdor et al 1994) that one of the important problems of lean mixture operation is cyclic variation. Hence, detailed analysis of heat release rates, magnetic and catalytic activation and cyclic variations are carried out to compare the magnetically activated fuel on base and catalytic coated engines with base engine.