Fig. 7.8 (b) Variation of Ignition delay with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.

Fig. 7.8 (c) Variation of combustion duration with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.
Chapter - 8

HIGH ENERGY IGNITION SYSTEM

8.1 INTRODUCTION

Several approaches have been used to modify conventional ignition systems for lean mixtures. The most common method is to use a long duration, high energy spark discharge through an extended reach spark plug with a wide gap. Recent development in electronics field have made it possible to economically design and manufacture new ignition systems to be used with two stroke SI engines for lean mixtures.

8.2 DEVELOPMENT OF HIGH ENERGY IGNITION SYSTEM

In the conventional ignition systems rise in voltage is a function of rate of current change and is determined by the inductance of the coil and the capacitance of the condenser connected. However it is relatively inefficient and exhibits "voltage droop" between the electrodes in the spark plug at the time of spark as rpm increases. This voltage drop off occurs due to the lower current build up.

In the Capacitor Discharge Ignition (CDI) the ignition energy is stored in the electrical field of a capacitor. The system does not rely on inductive kick for its primary voltage source, but rather uses a dc-dc converter. It does not exhibit the drop off in voltage at higher engine speeds. The ignition transformer transforms the primary voltage generated by the discharge of the capacitor to the required high voltage. The short burn time of the spark is the limitation of the CDI system and it makes difficult to ignite the air fuel mixture under certain driving conditions. This can be compensated by an increase of the spark plug gap, which is possible with the high available voltage in the order of 30 to 40 kv.
The circuit for a breakerless, high energy ignition system is shown in the block diagram Fig. No. 8A. A fixed signal at 60 degrees bTDC from an optical trigger pulse generator is used as the triggering signal for the ignition system. This signal is converted to Transistor-Transistor Logic (TTL) levels and was delayed by using digital mono stable multivibrator. The spark timing is varied by changing this delay and the width of the delayed trigger signal is varied by using another mono stable multivibrator which varies spark duration. An Opto-isolator and CDI-driver are introduced in order to isolate the TTL stage (low voltage section) from CDI unit (high voltage section). This will help to avoid any damage to the ignition circuit by high voltage spikes from the CDI unit and the resulting signal is used to trigger a high energy ignition system. The spark starting can be varied from 60 degrees bTDC to TDC and the spark duration can be changed from 1 deg. CA to 40 deg. CA. The schematic diagram of the timing diagram at various stages in the ignition circuit is explained in Fig. 8B.

### 8.3 Experimental Programme

Experiments are conducted with the breakerless High Energy Ignition System using normal spark plug, standard compression ratio (7.4) and fuel jet size of 0.84mm at speeds 2000 rpm and 3000 rpm. Further experiments are also conducted using a Platinum tipped electrode spark plug along with breakerless High Energy Ignition System. Finally experiment is also conducted at Compression ratio 9.0 and fuel jet size 0.80mm with breakerless High Energy Ignition System together with Platinum electrode spark plug.

### 8.4 Results and Discussion

The performance of the engine having High energy ignition system with and Platinum tipped electrode spark plug, at compression ratios of 7.4 and 9.0 is as follows.
8.4.1 Performance of High Energy Ignition System at Compression Ratio of 7.4

The performance of the engine having High energy ignition system is compared with performance of normal engine at the compression ratio of 7.4 and the details are discussed below.

8.4.1.1 Brake Thermal Efficiency:

The variation of brake thermal efficiency with power output at constant engine speeds of 2000, 3000 rpm, at a compression ratio of 7.4 for high energy ignition system with and without the Platinum tipped electrode spark plug are presented in Figs.8.1, 8.2. The results are compared with the normal engine (normal compression ratio of 7.4, standard magneto-coil ignition with standard spark plug). It is observed from these figures that with the high energy ignition system, there is a considerable improvement in the brake thermal efficiency at all the speeds and for entire range of engine operation. Platinum tipped spark plug along with the high energy ignition system further improves the brake thermal efficiency. The drawbacks such as irregular combustion and low spark energy are eliminated with the high energy ignition system and hence the improvement in performance. The maximum brake thermal efficiency obtained at 2000 rpm, 1.4 kw Fig.8.1 increases from 14.5 to 18.0% for the high energy ignition system and from 14.5 to 19.5% for the high energy system with Platinum tipped electrode spark plug compared to normal engine.

At low engine speeds, in the conventional magneto-system, the voltage developed across the spark plug is low since voltage supplied to the primary side of the ignition coil is low at low speeds. The low ignition energies and the conditions near the spark plug are not suitable to ignite the air-fuel mixtures easily due to the presence of large exhaust dilution. This is the main reason for irregular combustion and misfiring at part loads. In the case of high energy ignition system, a high ignition
energy is supplied across the wide spark gap which burns the air-fuel mixtures effectively. Hence, a significant improvement in brake thermal efficiency is obtained at 2000 rpm. Similar improvements can also be noticed with the high energy ignition system at other speed 3000 rpm Fig. 8.2.

The Platinum tipped electrode spark plug provides higher gap with the reduced electrode diameter. It requires lower break down voltage which reduces the electrode wear caused by capacitive discharge. Hence, Platinum tipped electrode spark plug with high energy ignition system gives a better performance compared to normal spark plug with high energy ignition system.

8.4.1.2 Exhaust Emissions:

The Hydrocarbon emission with high energy ignition system for both normal spark plug and Platinum tipped electrode spark plug are depicted in Figs. 8.3, 8.4 at constant engine speeds of 2000, 3000 rpm respectively. Hydrocarbon emission is higher by about 400 to 600 ppm during the part load operation with the high energy ignition system.

Figures 8.5, 8.6 show the variation of Carbon monoxide emission with brake power at 2000, 3000 rpm for the high energy ignition system, Platinum tipped electrode spark plug-high energy ignition system and normal magneto-coil ignition system respectively. It is observed from these figures that a reduction in Carbon monoxide emission is obtained with the high energy ignition system and reduction is more when Platinum Tipped electrode spark plug is used with high energy ignition system. The maximum reduction in Carbon monoxide emission is about 2.4% at 1.4 kw, 2000 rpm Fig. 8.5, about 1.5% at 1.5 kw, 3000 rpm Fig. 8.6 for high energy ignition system with Platinum tipped electrode spark plug compared to normal ignition system. These reductions in Carbon monoxide emission are due to improved combustion and
Platinum in the electrode tip may enhance the oxidation process due to its catalytic effect. Hence, lower Carbon monoxide emission is obtained with Platinum tipped electrode spark plug along with high energy ignition system.

8.4.1.3 Combustion Parameters:

The variation of combustion parameters such as cylinder peak pressure, ignition delay and combustion duration with brake output are illustrated in Figs. 8.7, 8.8 at 2000, 3000 rpm respectively. The results obtained with high energy ignition system with and without the platinum tipped spark plug are compared with the normal ignition system. It is seen that high energy ignition system decreases the ignition delay and combustion duration and increases the peak cylinder pressure compared to normal ignition system. The maximum increase in cylinder pressure is about 10 bar at 1.4 kw, 2000 rpm, about 6 bar at 2.2 kw, 3000 rpm respectively. The corresponding reduction in ignition delays are 9°,2° crank angle respectively. The combustion duration decreases by about 5° to 10° crank angle, depending on the operating conditions. These improvements are mainly due to superior ignition conditions, better flame initiation and higher flame propagation speeds attained with high energy ignition system.

8.4.2 Performance of High Energy Ignition System at High Compression Ratio (9) with Lean Mixtures

The performance of the engine having high energy ignition system with lean jet (0.80 mm), a Platinum tipped electrode spark plug is compared with performance of normal engine at Compression ratio 9 and the details are discussed below.

8.4.2.1 Brake Thermal Efficiency:

The improvements obtained with high energy ignition system along with a Platinum Tipped electrode spark plug over normal engine at Compression ratio 9 and
lean jet (0.80 mm) at 2000, 3000 rpm respectively are illustrated in Figs. 8.9, 8.10. The results show an improvement in the brake thermal efficiency, in particular at higher speeds and at higher brake outputs for the high energy ignition system. The maximum percentage improvement in the brake thermal efficiency obtained with the high energy ignition system over normal ignition system is about 15.2% at 1.45 kw, 2000 rpm, 16.5% at 2.2 kw, 3000 rpm.

If an engine is to run effectively at higher Compression Ratios and lean mixtures, the discharge energy and spark duration must be longer. These requirements are fulfilled, by the use of the high energy ignition system. Hence, significant improvement in the performance over the entire range of engine operation is observed with the high energy ignition. The contact-less system is capable of supplying high voltage across spark plug gap which is independent of engine speed.

8.4.2.2 Exhaust Emissions:

The exhaust emission characteristics, viz., Hydrocarbons and Carbon monoxide are represented in Figs. 8.11, 8.12 and Figs. 8.13, 8.14 at constant engine speeds of 2000, 3000 rpm respectively for the high energy ignition system. The results of the normal ignition system are presented for comparison.

The Hydrocarbon emission increases by about 100 to 200 ppm with the high energy ignition at many operating points compared to normal ignition system. This increase in Hydrocarbon emission is to be expected due to bulk quenching of the gases at higher pressure. The higher gap between electrodes significantly affects hydrocarbon emission, in particular, when the mixture is leaner than the stoichiometric ratio [105]. Higher discharge energy requires the use of relatively larger diameter of electrodes and a larger gap between electrodes. A careful design of the electrodes and optimization of gap between electrodes are necessary to reduce the Hydrocarbon
emission under lean fuel-air mixture conditions. Incomplete flame propagation with very lean mixtures due to exhaust residual content could be an additional factor causing high exhaust Hydrocarbon emission.

Carbon monoxide emission also increase with the high energy ignition system Figs. 8.13, 8.14 the increase in Caron monoxide emission is about 0.2 to 0.8% by vol. in the range of engine operation tested.

8.4.2.3 Combustion Parameters:

Figures 8.15, 8.16 show the variation of combustion parameters such as cylinder peak pressure, ignition delay and combustion duration for both the high energy and normal ignition systems at 2000, 3000 rpm respectively. The pre-frame reaction starts earlier due to exchange of high energy from the spark to the lean mixture. Hence, lower ignition delays are obtained with the high energy ignition system in the entire range of engine operation. Cylinder peak pressures are higher and combustion duration is lower with the high energy ignition system compared to normal ignition system. The maximum increase in cylinder peak pressure is about 6.5 bar at 1.5 kw, 2000 rpm, 5.0 bar at 1.8 kw, 3000 rpm and the increase in cylinder peak pressure is mainly due to improved combustion as a result of higher flame propagation velocities and high discharge spark energy.

8.5 CONCLUSIONS

Based on the experiments of High Energy Ignition System with and without Platinum tipped electrode spark plug at two different compression ratios the following observations are made.
8.5.1 With High Energy Ignition System at Normal Compression Ratio 7.4

1. Breakerless high energy capacitive discharge system can be used to supply high spark discharge energy so as to overcome the drawbacks of normal magneto coil ignition system.

2. Platinum tipped electrode spark plug increases Brake thermal efficiency from 14.5 to 19.5% at 1.4kw, 2000 rpm.

3. Hydrocarbon emission is higher by about 400 to 600 ppm due to quenching of gases at higher pressures. Carbon monoxide emission is reduced by 2.4% at 1.4kw 2000rpm, 1.5% at 1.5kw, 3000 rpm.

4. The maximum increase in Cylinder peak pressure is about 10 bar at 1.4kw, 2000 rpm and 6 bar at 2.2kw, 3000 rpm. The ignition delay and combustion duration decrease by 5 to 12 degrees CA.

8.5.2 With High Energy Ignition System at High Compression Ratio 9 with Lean Mixture

1. Use of High Energy Ignition System with a platinum tipped electrode spark plug enhances the lean burn capability at high Compression ratio. The maximum percentage improvement on brake thermal efficiency is about 15.2% at 1.4kw 2000 rpm, 16.5% at 2.2kw, 3000 rpm.

2. Hydrocarbon and Carbon monoxide emissions marginally increase compared to the normal ignition system.

3. The cylinder peak pressure increases by 6.5 bar at 1.5kw, 2000 rpm, 5 bar at 1.8kw, 3000 rpm.
Fig 8A CIRCUIT DIAGRAM FOR HEIS
Fig. 88 SCHEMATIC TIMING DIAGRAM AT VARIOUS STAGES

Optical trigger pulse
60° before TDC

Variable pulse width from the monostable-1 stage
(To vary spark delay)

Variable pulse width from the monostable-2 stage
(To vary spark duration)

Opto-isolater output

CDI-drive output
Fig. 8.1 Variation of brake thermal efficiency with brake power for high energy ignition system.

Fig. 8.2 Variation of brake thermal efficiency with brake power for high energy ignition system.
Fig. 8.3 Variation of hydrocarbon emission with brake power for high energy ignition system.

Fig. 8.4 Variation of hydrocarbon emission with brake power for high energy ignition system.
Fig. 8.5 Variation of carbon monoxide emission with brake power for high energy ignition system.

Fig. 8.6 Variation of carbon monoxide emission with brake power for high energy ignition system.
Fig. 8.7 (a) Variation of cylinder peak pressure with brake power for high energy ignition system.

Fig. 8.7 (b) Variation of ignition delay with brake power for high energy ignition system.
Fig. 8.7(c) Variation of combustion duration with brake power for high energy ignition system.

Fig. 8.8(a) Variation of cylinder peak pressure with brake power for high energy ignition system.
Fig. 8.7(c) Variation of combustion duration with brake power for high energy ignition system.

Fig. 8.8(a) Variation of cylinder peak pressure with brake power for high energy ignition system.
Fig. 8.8(b) Variation of Ignition delay with brake power for High energy ignition system.

Fig. 8.8(c) Variation of Combustion duration with brake power for high energy ignition system.
Fig. 8.9 Variation of brake thermal efficiency with brake power for high energy ignition system.

Fig. 8.10 Variation of brake thermal efficiency with brake power for high energy ignition system.
Fig. 8.11 Variation of hydrocarbon emission with brake power for high energy ignition system.

Fig. 8.12 Variation of Hydrocarbon emission with brake power for high energy ignition system.
Fig. 8.13 Variation of carbon monoxide emission with brake power for high energy ignition system.

Fig. 8.14 Variation of carbon monoxide emission with brake power for high energy ignition system.
Fig. 8.15 (a) Variation of cylinder peak pressure with brake power for high energy ignition system.

Fig. 8.15 (b) Variation of Ignition delay with brake power for high energy ignition system.
Fig. 8.15(c) Variation of combustion duration with brake power for high energy ignition system.

Fig. 8.16(a) Variation of cylinder peak pressure with brake power for high energy ignition system.
Fig. 8.16(b) Variation of ignition delay with brake power for high energy ignition system.

Fig. 8.16(c) Variation of combustion duration with brake power for high energy ignition system.