Chapter - 7

COMBUSTION CHAMBER INSULATION

7.1 INTRODUCTION

By providing insulation to combustion chamber the performance of two stroke SI engine can be improved. The insulation improves the vaporization of gasoline resulting in better pre flame reactions and improvement in combustion. In the present work insulation of the CC is provided by the following two methods.

i) Composite piston and composite cylinder head.
ii) Thin Ceramic Partially Stabilized Zirconia coating on the combustion chamber walls.

7.2 COMPOSITE PISTON AND CYLINDER HEAD

A small increase in combustion chamber surface temperature can be made by a suitable design such as fixing an insert made of a low thermal conductivity material to the standard combustion chamber components made of Aluminium Silicon alloy. The material should have coefficient of thermal expansion equal to Aluminium Silicon alloy so that thermal stress increase at the interface will be minimum. Ni-resist, a form of Cast iron with high Nickel content was selected for the present work.

7.2.1 Composite Piston

The standard Aluminium alloy piston was machined to a lower height to fit the Ni-resist cap over the crown surface. The Ni-resist crown plate was separately machined with the same crown profile as that of standard piston.
The Ni-resist crown plate was placed on the piston crown and fixed with a bolt at the center. The adhesive can be used at the interface for better bonding.

7.2.2 Composite Head

The composite cylinder head is designed with Ni-resist insert, shrink fitted in the standard Aluminium alloy cylinder head. The Ni-resist insert is separately machined to the same geometry as that of standard cylinder head. A hole was also suitably drilled to accommodate the spark plug.

7.3 Ceramic Coating of the Combustion Chamber

Partially Stabilized Zirconia (PSZ) has got very good toughness, hot strength, thermal shock resistance, low thermal conductivity and thermal expansion coefficient and it is being widely used as thermal barrier coating on the Combustion Chamber walls. Even though this coating is suggested to diesel engines due to knock limitations, thin ceramic coatings can be applied to gasoline engines to improve the combustion.

In the present work the piston top and cylinder head were coated with PSZ material applied to the Combustion Chamber walls using plasma spraying technique. Plasma spray is a thermal spray process using an inert plasma stream of high velocity to melt and propel the coating material on to the substrate. First the Combustion Chamber surface was prepared with a wash coat of Ni-Al composite by 100 microns thick for better bonding of the Aluminium and PSZ material.

7.4 Experimental Programme

Experiments are conducted with composite piston and normal cylinder head, with ceramic coated piston top and cylinder head. Variable load tests are carried out at constant speeds 2000, 3000 rpm with Gasoline as fuel.
7.5 RESULTS AND DISCUSSION

7.5.1 Engine Performance with Insulated Combustion Chambers with Gasoline

The results obtained with composite piston and normal cylinder head, ceramic coated piston top and cylinder head are discussed below.

7.5.2 Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power at engine speeds 2000, 3000 rpm for the above two types of insulated combustion chambers and for the normal combustion chamber are shown in Figs. 7.1, 7.2.

It is noticed that brake thermal efficiency is improved with the insulation at part loads and low to medium speeds. The performance with ceramic coated combustion chamber is better than composite piston combustion chamber. Brake thermal efficiency increases from 14.5% to 18% at 2000 rpm, 1kw and from 18 to 20.5% at 3000 rpm, 2.2kw for the ceramic coated combustion chamber when compared to normal combustion chamber whereas with composite piston combustion chamber the brake thermal efficiency increases from 16.9% to 18.7% at 3000 rpm, 1.2kw.

Moderate rise in surface temp. of Combustion Chamber improves the performance at lower speeds and part loads because of better vaporization of rich mixture in Combustion Chamber which results in complete combustion.

7.5.3 Exhaust Emissions

The variation of Hydrocarbon emission with brake power at engine speeds 2000, 3000 rpm for the above two types of insulated combustion chambers and for the normal combustion chamber are shown in Figs. 7.3, 7.4.
It is noticed that with moderate rise in combustion chamber surface temp., flame quenching is reduced and combustion is improved thereby Hydrocarbon emission is reduced in exhaust. The maximum reduction in Hydrocarbon emission is about 2800 ppm for both insulated combustion chambers at 3000 rpm.

The variation of Carbon monoxide emission is shown in Figs. 7.5, 7.6 for both insulated Combustion Chambers and normal Combustion chamber. It is observed that insulation causes better vaporization and utilization of air leading to complete combustion and reduced Carbon monoxide emission. It is noticed that composite piston Combustion Chamber provides a significant reduction of Carbon monoxide emission compared to normal Combustion Chamber. The maximum reduction in Carbon monoxide emission varies from 1.3% to 1.8% at 2000 rpm for composite piston Combustion Chamber whereas for ceramic coated Combustion Chamber it varies from 1.1% to 1.7% at 2000 rpm depending on the operating conditions. Higher temp. in Combustion Chamber of ceramic coated Combustion Chamber leads to dissociation of Carbon dioxide in to Carbon monoxide and Oxygen there by higher Carbon monoxide emission is resulted.

7.5.4 Combustion Parameters

The variation of combustion parameters are shown in Figs. 7.7, 7.8 for engine speeds 2000, 3000 rpm for both insulated Combustion Chambers and for normal Combustion Chamber. It is observed that both ignition delay and combustion duration are lower and cylinder peak pressure is higher for both insulated Combustion Chambers due to complete combustion and higher flame velocity. At 2000 rpm peak pressure is higher by 1 bar, ignition delay is lower by 5 degrees and combustion duration is lower by 7 degrees for the ceramic coated Combustion Chamber over normal Combustion Chamber.
7.6 CONCLUSIONS

1. Brake thermal efficiency improves with insulation. Brake thermal efficiency increases from 14.5% to 18% at 2000 rpm, 1 kw and from 18 to 20.5% at 3000 rpm, 2.2 kw for the ceramic coated Combustion Chamber whereas with the composite piston Combustion Chamber, the brake thermal efficiency increases from 16.9% to 18.7% at 3000 rpm 1.2 kw.

2. Maximum reduction in Hydrocarbon emission is achieved at part load. The reduction in Hydrocarbon emission is about 2800 ppm for both insulated combustion chambers at 3000 rpm.

3. The composite piston Combustion Chamber shows a significant reduction in Carbon monoxide emission. The maximum reduction in Carbon monoxide emission varies 1.3% to 1.8% at 2000 rpm. However with the ceramic coated Combustion Chamber the maximum reduction in Carbon monoxide emission is only from 1.1% to 1.7% at 2000 rpm depending up on the operating conditions.

4. Ignition delay and combustion duration are lower and cylinder peak pressure are higher for both the insulated Combustion Chambers. At 2000 rpm peak pressure is higher by about 1 bar, ignition delay is lower by 5 degrees and combustion duration is lower by 7 degrees for the ceramic coated Combustion Chamber over normal Combustion Chamber.

5. Between the two configurations ceramic Combustion Chamber is better. However with Ni-resist Combustion Chamber, when cylinder head is also similarly provided with Ni-resist cap, improved performance can be obtained. But it may not be possible to provide Ni-resist cap on cylinder head due to its complicated profile.
Fig. 7.1 Variation of brake thermal efficiency with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.

Fig. 7.2 Variation of brake thermal efficiency with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.
Fig. 7.3 Variation of hydrocarbon emission with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.

Fig. 7.4 Variation of hydrocarbon emission with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.
Brake Power kw

Fig. 7.5 Variation of carbon monoxide emission with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.

Brake Power kw

Fig. 7.6 Variation of Carbon monoxide with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.
Fig. 7.7 (a) Variation of cylinder peak pressure with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.

Fig. 7.7 (b) Variation of ignition delay with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.
Fig. 7.7 (c) Variation of combustion duration with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.

Fig. 7.8 (a) Variation of cylinder peak pressure with brake power for Ni-resist and ceramic coated combustion chambers with Gasoline.