Chapter - 6

CATALYTIC COMBUSTION

6.1 INTRODUCTION

Catalysts are generally used outside the engine for the treatment of emissions. But if the catalysts are used in the combustion chamber in the form of coating on the walls to initiate combustion thereby improvement on thermal efficiency and lower emissions can be achieved.

The concept of catalytic combustion is that as a result of catalytic pre reaction the required ignition energy is reduced and flame velocity is higher. Further the oxidation of the fuel is brought out with the aid of catalyst. Catalytic combustion is considered since it does not need complicate fuel delivery, ignition or exhaust systems.

The concept of catalyst on the performance of two stroke SI engine is analyzed with various catalysts such as Copper, Nickel, and Chromium.

6.2 EXPERIMENTAL PROGRAMME

Various catalysts such as Copper, Nickel, and Chromium are coated on the combustion chamber wall and engine performance, combustion and emission aspects are studied. The effect of lean fuel air mixtures is studied with the best catalyst, copper. Coatings are applied using electroplating technique.

Experiments are conducted using different catalytic combustion chambers with Gasoline as well as Methanol. Variable load tests are carried out at speeds 2000 and 3000 rpm.
6.3 CATALYTIC COATING TECHNIQUE

Copper, Nickel and Chromium are coated on the piston top and cylinder head using standard electroplating process Fig.6A illustrates the schematic diagram of the electroplating process.

6.4 RESULTS AND DISCUSSION

The results obtained based on the experimental investigations of different catalytic combustion chambers are discussed below.

6.4.1 The effect of different catalytic coatings on the performance of the engine.

6.4.1.1 Brake Thermal Efficiency:

The variation of brake thermal efficiency with brake output for three coatings such as copper, nickel and chromium at speed 2000 rpm and for the normal engine without coating are shown in the Fig.6.1. It is observed that there is improvement in brake thermal efficiency with all the three catalysts due to better combustion. The percentage improvement in the brake thermal efficiency compare to the normal engine is 17% for Nickel, 16.5% for Chromium and 10.3% for Copper coating at brake power output 1.2kw, 2000 rpm. The difference in improvement is due to variation in chemical activity for Hydrocarbon mixture and surface temperature of catalyst.

6.4.1.2 Exhaust Emissions:

The variation of Hydrocarbon emission with brake power output for the above three coatings at speed 2000 rpm are shown in Fig.6.2. It is observed that Hydrocarbon emission is more for Nickel and Chromium at higher outputs and less for Copper over
the entire range of output. Haskill et. al.[128] reported higher Hydrocarbon emission with catalytic material on the piston head and higher emission is due to premature fuel oxidation. But Copper is a well known hydrocarbon oxidation catalyst which is helpful for lowering Hydrocarbon emission. The maximum reduction in Hydrocarbon emission is about 1900 ppm at part load 0.4 kw for Copper coating compared with normal combustion chamber.

The variation of Carbon monoxide emission with brake power output for the above three coatings at speed 2000 rpm are shown in Fig.6.3. It is observed that Carbon monoxide emission are reduced for all the three coatings is due to better combustion of charge, chemical activation of the charge and action of catalyst as oxidation agent to convert Carbon monoxide in to Carbon dioxide. The maximum reduction of 2.6% by vol. in Carbon monoxide emission is obtained for Chromium coating at 2000 rpm. From the results it is observed that Copper coating is effective for both Hydrocarbon and Carbon monoxide emission reduction and Nickel, Chromium better in reducing Carbon monoxide levels than reducing Hydrocarbon levels. However, copper coating is effective due to superior oxidation catalytic activity.

6.4.1.3 Combustion Parameters:

The variation of peak pressure, ignition delay and combustion duration with brake power output at speed 2000 rpm for the above three coatings and for the normal engine are shown in Fig.6.4. It is noted that the peak pressures are slightly lower for the three coatings compared to normal engine and lower ignition delays for three coatings than normal engine. In particular the reduction in ignition delay by 6° to 15° CA is significant for copper coating compared to normal engine. Reduction in ignition delay is due to initiation of primary hydrocarbon oxidation reactions prior to ignition by the catalyst there by necessary ignition energy can be decreased and can facilitate initial stages of flame propagation.
6.4.2 Effect of Copper Coated Combustion Chamber on Lean Combustion

By means of lean combustion both engine characteristics and emission characteristics can be improved. However, erratic combustion and other problems may arise beyond some air fuel ratio. The ignition delay and flame propagation are important factors in lean combustion engines. Ignition delay is the time required to produce sufficient pre flame chemical species for rapid reaction to occur [96] and more time is required when the mixture becomes leaner and leaner. Hence it is difficult to achieve complete combustion with increased ignition delay in lean mixture together with slow flame speed and with presence of exhaust gases inside the cylinder.

Even though several quite expensive methods are suggested to improve lean combustion [129,130] the concept of catalyst in combustion chamber is well suited since pre reaction can reduce the ignition delay, increase flame velocity and reduce ignition energy requirements. Hence copper the most effective catalyst is selected for experimentation along with two different carburetor jet sizes (0.88 mm for rich mixture, 0.8 mm for lean mixture) to vary the air fuel ratios.

6.4.2.1 Brake Thermal Efficiency:

Variation of brake thermal efficiency with brake power for fuel jets 0.88mm and 0.8 mm at speed 2000 rpm with and without the copper catalyst in the combustion chamber are shown in Fig.6.5. It is observed that brake thermal efficiency is improved with catalyst for both the fuel jets and more significant at lean mixture. The maximum percentage improvement is 8% with lean jet and 7% with rich jet at the output 1kw compared to normal engine. Normal engine itself show better thermal efficiency with lean mixture but the catalyst develops further the performance of the engine due to catalytic charge activation process. The maximum percentage improvement is 12% with lean jet and 10% with rich jet at 3000 rpm Fig. No. 6.6.
6.4.2.2 Exhaust Emissions:

Variation of Hydrocarbon emission with brake power for Copper catalyst with fuel jets 0.88 mm and 0.8mm for engine speeds 2000, 3000 rpm and for normal engine are given in Figs. 6.7, 6.8. Hydrocarbon emission is decreased for both fuel jet with Copper catalyst compared to normal engine due to good hydrocarbon oxidation property of copper which helps to complete combustion. The overall reduction in Hydrocarbon emission varies from 200 to 1700 ppm depending on the operating conditions and fuel jet size.

The variation of Carbon monoxide emission with copper catalyst with both fuel jets at speeds 2000, 3000 rpm and for the normal engine are given in Figs. 6.9, 6.10. It is noted that Carbon monoxide emission with copper catalyst is very low when compared with normal engine. The variation is significant at part loads where the normal engine has more Carbon monoxide emission due to incomplete combustion. The Carbon monoxide emission decreases from 4.1% to 1.2% vol. for Copper catalyst with jet 0.8mm and from 1.3% to 0.5% Vol. with jet 0.88 mm at speed of 2000 rpm Fig.No.6.9. Similar Carbon monoxide emission reduction is observed at 3000 rpm with Copper catalyst Fig.No.6.10.

6.4.2.3 Combustion Parameters:

The combustion parameters variation with brake power for Copper catalyst and normal engine with two fuel jets are shown in Figs. 6.11, 6.12 at engine speeds 2000, 3000 rpm respectively. It is observed that the peak cylinder pressure fall for lean mixture under normal engine operating conditions and higher pressures are obtained with Copper catalyst for both fuel jets. There is reduction in ignition delay by 5° to 11° CA with Copper catalyst with lean mixture and decrease in combustion duration by 2° to 5° CA with both jets with Copper catalyst.
6.4.3 Effect of Different Catalytic Coatings on Lean Combustion with Methanol Fuel

Methanol has better lean combustion characteristics compared to Gasoline due to wide flammability limits and higher flame speeds [105,112,115]. Lean combustion is preferred due to improved fuel economy and reduced exhaust emissions. But with normal SI engines the full advantage of lean combustion cannot be achieved due to rapid decrease in flame speed when the mixture becomes leaner and leaner. Hence the use of catalysts such as Copper, Nickel and Chromium in the combustion chamber along with Methanol fuel is proposed for improved fuel economy and reduced emission levels and experiments are conducted and results are discussed as follows.

6.4.3.1 Brake Thermal Efficiency:

Variation of brake thermal efficiency with brake power for engine with catalysts Copper, Nickel and Chromium with Methanol fuel at speed 2000 rpm and for the normal engine with Gasoline, Methanol as fuel are shown in Fig.6.13. It is noticed that brake thermal efficiency is improved with all the catalysts and superior performance is with the Methanol compared to Gasoline in the normal engine itself due to better combustion properties of Methanol.

The maximum percentage improvement in brake thermal efficiency for Chromium is 12%, Nickel is 10.5% and Copper coatings is 5% compared to normal engine with Methanol fuel. Although the performance of Nickel and Chromium is better at 2000 rpm, the catalytic effect of Copper is superior at higher speeds.

6.4.3.2 Exhaust Emissions:

Hydrocarbon and Carbon monoxide emission characteristics for the three coatings and normal engine are shown in Figs.6.14, 6.15 at 2000 rpm. It is noticed that
Hydrocarbon emission is reduced for all three coatings compared to normal engine. It is noticed that Carbon monoxide emission is reduced with methanol fuel compared to Gasoline fuel due to lean operation of Methanol fuel. Thus the effect of catalyst for Carbon monoxide oxidation is not felt with Methanol fuel.

6.4.3.3 Combustion Parameters:

The variation of combustion parameters for three coatings and normal engine are shown in Fig. 6.16 at 2000 rpm. It is noticed that higher peak pressure is obtained with catalysts compared with base engine for Methanol fuel.

6.5 CONCLUSIONS

The following observations are obtained.

1. Coating the combustion chamber wall has improved fuel economy and exhaust emissions.
2. Copper is found to be very effective coating in reducing emissions and improvement in brake thermal efficiency when compared with other coatings.
3. Catalytic activation is more effective with lean fuel air mixture.
4. With lean jet 0.8 mm, Copper catalyst increases brake thermal efficiency from 12 to 16% and decreases Hydrocarbon emission from 3800 to 3400 ppm and Carbon monoxide emission from 5 to 2.5% by vol. at 1 kw, 2000 rpm.
5. Ignition delay is lower by 5° to 11°CA and cylinder peak pressure is higher by 1 to 3 bar in the entire range of engine operation with Copper catalyst with lean mixture.
6. Methanol is superior lean combustion characteristics along with catalyst in the combustion chamber and increases brake thermal efficiency and decreases emissions during part loads.
7. The improvement in brake thermal efficiency over normal engine is 12% with Chromium, 10.5% with Nickel and 5% with Copper coatings.

8. Copper catalyst shows reduced ignition delay and combustion duration along with increased peak pressure with Methanol fuel.
1. Switch
2. Rheostat
3. Ammeter
4. Electrolite
5. Anode
6. Cast Iron ring
7. Piston acting as a cathode
8. Insulated top cover
9. Battery

Fig. 6a  SETUP FOR ELECTRO PLATING OF CATALYST ON THE PISTON CROWN
Fig. 6.1 Variation of brake thermal efficiency with brake power for different catalytic coatings.

Fig. 6.2 Variation of Hydro carbon emission with brake power for different catalytic coatings.
Fig. 6.3 Variation of Carbon monoxide emission with brake power for different catalytic coatings.

Fig. 6.4 (a) Variation of cylinder peak pressure with brake power for different catalytic coatings.
Fig. 6.4 (b) Variation of ignition delay with brake power for different catalytic coatings.

Fig. 6.4 (c) Variation of combustion duration with brake power for different catalytic coatings.
Fig. 6.5 Variation of brake thermal efficiency with brake power for copper catalyst at different fuel jets.

Fig. 6.6 Variation of brake thermal efficiency with brake power for copper catalyst at different fuel jets.
Fig. 6.7. Variation of Hydrocarbon emission with brake power for copper catalyst at different fuel jets.

Fig. 6.8. Variation of Hydrocarbon emission with brake power for copper catalyst at different fuel jets.
Fig. 6.11 (a) Variation of cylinder peak pressure with brake power for copper catalyst at different fuel jets.

Fig. 6.11 (b) Variation of ignition delay with brake power for copper catalyst at different fuel jets.
**Fig. 6.11 (c) Variation of combustion duration with brake power for copper catalyst at different fuel jets**

**Fig. 6.12 (a) Variation of Peak pressure with brake power for copper catalyst at different fuel**
**Fig. 6.12 (b)** Variation of ignition delay with brake power for copper catalyst at different fuel jets.

**Fig. 6.12 (c)** Variation of combustion duration with brake power for copper catalyst at different fuel jets.
Fig. 6.13 Variation of brake thermal efficiency with brake power for different coatings with Methanol.

Fig. 6.14 Variation of hydrocarbon emission with brake power for different coatings with Methanol.
Fig. 6.15 Variation of carbon monoxide emission with brake power for different coatings with Methanol.

Fig. 6.16 (a) Variation of cylinder peak pressure with brake power for different coatings with Methanol.
Fig. 6.16 (b) Variation of Ignition delay with brake power for different coatings with Methanol.

Fig. 6.16 (c) Variation of Combustion duration with brake power for different coatings with Methanol.