Emission Characteristics Of A Compression Ignition Engine Using Different Catalyst

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ABSTRACT

Catalytic converter with different catalyst for compression ignition engine to reduce pollute gases is chosen for present work. The emphasis is given on hydrocarbon (HC), carbon monoxide (CO) and oxides of nitrogen. The catalytic converter was designed and developed with different catalyst. The pellets are developed as catalyst The pellets are coated with copper oxide (CuO), cerium oxide (CrO_2) and zirconium dioxide (ZrO_2) . Pellets are held together in a circular housing at two ends of the converter shell. Cylindrical spacer was used in between circular housing containing pellets to vary the distance and to reduce back pressure on the engine. Experiments were carried out on computerized kirloskar single cylinder four stroke (10 B.H.P, 7.4 KW) diesel engine test rig with an eddy current dynamometer. The converter was tested with different catalyst. There is considerable reduction in HC , CO and NOx.

I. INTRODUCTION

Catalytic converter is an exhaust after treatment, emission control device. It is intended to convert harmful combustion byproducts from an engine cylinder into harmless products, by increasing the rate of reactions, with the use of catalytic reaction at comparatively lower temperature levels. A catalyst is an element or compound that promotes a chemical reaction without being affected by the reaction.

The purpose of using catalytic converter in spark ignition and compression ignition engines is same i.e to convert the harmful combustion byproducts into harmless products. But the combustion process of spark ignited gasoline engine and

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diesel engine differ considerably. Modern gasoline engines with closed loop emission controls produce exhaust i.e. near chemical stoichiometry and at temperature of 375°C to 850°C. The exhaust contains significant amount of hydrocarbon (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x) that must be reduced using catalytic converter. Compression ignition engines burn with lean air-fuel mixtures of less than 20:1 that produce exhaust temperatures of 100 to 400°C. This exhaust contains significant amount of particulate and pollute gases, that may require an after treatment device such as catalytic converter, in order to meet current requirements.

To meet the environmental legislations, it is essential to reduce the amount of NO_X in the exhaust gases

II. FABRICATION OF CATALYTIC CONVERTER

- Inlet cone was fabricated for converter housing.
  Exhaust gases from the engine are admitted through inlet cone

- Outlet cone was fabricated .Eco-friendly exhaust gases come out at this end.
- Cylindrical spacer and two circular housing with provision for putting pellets were fabricated.
- Pellets of different catalytic materials were developed.
- The components were assembled and fitted to engine exhaust manifold**.**

III. DESIGN CALCULATION

SHAPE OF CATALYTIC CONVERTER
The cylindrical shape was considered due to ease of fabrication, minimum assembly time, rigidity and easier maintenance.

VOLUME OF CATALYTIC CONVERTER
Assuming space velocity (for single cylinder engine) = 30000 hr $^{-1}$

The space velocity is calculated as under

$$\text{Space velocity} = \frac{\text{Volume flow rate}}{\text{Converter Volume}} \qquad (1)$$

The converter volume was calculated as

$$\text{Converter volume} = \frac{\text{Volume flow rate}}{\text{Space Velocity}} \qquad (2)$$

$$\text{Volume flow rate} = \text{Swept Volume} \times \text{Number of intake stroke / hr.}$$

$$= \frac{\pi}{4} \times (0.102)^2 \times 0.11 \times 1500 / 2 \times 60$$

$$= 42.63 \,^{m^3}/_{hr}$$

$$\text{converter volume} = \frac{42.63}{30000}$$

$$= 1421\,ml$$

Shell Dimensions
The Shell is the central cylindrical part between the two inlet and outlet cones. This part contains circular discs with coated pellets.

$$V_{cylinder} = \frac{\pi}{4} \times (D)^2 \times l \qquad (3)$$

Inlet Cone

The inlet cone is longer than outlet cone to take care of any thermal stresses. One end of the cone is matched with exhaust pipe diameter.

$$\therefore \qquad Volume\ of\ Cone = \pi \times \frac{h}{3} \left[(r_1)^2 + r_1 \times r_2 + (r_2)^2 \right]$$

(4)

Outlet Cone
Outlet cone is smaller in size than inlet cone as temperature of the exhaust gases is reduced while flowing through the inlet cone and shell. Thus there is no possibility of thermal stresses.

$$\therefore \qquad Volume\ of\ Cone = \pi \times \frac{h}{3} \left[(r_1)^2 + r_1 \times r_2 + (r_2)^2 \right]$$

(5)

Spacer

Cylindrical spacer is located in between the circular housing containing pellets to reduce back pressure and restricting the movement of circular housing.

Catalysts

The catalysts used are

- copper oxide (CuO) pellets
- cerium oxide (CrO_2) pellets.
- zirconium dioxide (ZrO_2) pellets.

Insulating Material

For the proper chemical reaction within the converter, the exhaust gas temperature should be 300-400°C. To maintain this temperature insulation is provided over the shell, inlet and outlet cones. Asbestos was used as insulation material.

IV. EXPERIMENTAL SETUP
Computerized single cylinder four strokes diesel engine with eddy current dynamometer set was used in experimentation. It is water cooled, vertical four stroke compression ignition engine. Other equipments used are as under.

- AVL smoke meter for smoke density measurement
- AVL five gas analyzer for measurement of HC, CO and NOx.

Engine specification
- Compression ratio – 17.5 : 1
- Bore – 102 mm
- Stroke – 116 mm
- Power – 10 BHP (7.4 KW)
- Arm Length – 180 mm
- Maximum torque – 32 N-m
- RPM – 1500

EXPERIMENTATION
Engine jacket cooling water flow rate was kept constant at Throughout the trails engine speed was kept constant (1500 rpm) 324 kg/hr. During the trials every time circular discs and catalyst pellets were cleaned by water and then by carbon tetrachloride solution and dried. To reduce the back pressure on the engine two circular housing were used in the converter.

The observations for various trials are as under:

- Smoke opacity of diesel exhaust at every operating condition was measured with AVL make smoke meter.
- CO, HC and NOx: were measured with the AVL make five gas analyzer.
- Temperature was measured with the help of thermocouples fitted in the exhaust system.
- Engine back pressure was measured with the help of manometer.
- Air flow and fuel flow were directly measured by digital indicators.

The trials were conducted on computerized single cylinder 4-stroke kirloskar diesel engine with eddy current dynamometer to evaluate the performance of catalytic converter using cerium oxide, copper oxide and zirconium dioxide. The trial were conducted by considering the maximum allowable back pressure within permissible limit i.e. 50 mm of H_2O. The parameters were compared with converter and without converter, for same engine output conditions. The speed of engine was kept constant at 1500 rpm.

V. RESULTS AND DISCUSSION

Figure I shows variation in HC. Considerable reduction in HC emission was observed by using catalytic converter. Catalysts using zirconium dioxide shows reduction of HC emissions from 90 ppm to 39.2 ppm.

Figure II shows variation in CO. Considerable reduction
in CO emission was observed for all catalysts.

Figure III shows variation in NO_x emission. By using zirconium dioxide + cerium oxide, shows reduction of NOx emissions from 160 ppm vol.to 120 ppm vol.

Figure IV shows variations in smoke opacity . By using catalytic converter the concentration of smoke opacity increases, and this was due to exhaust gases.

Figure V shows variation in brake thermal efficiency. Negligible reduction was observed by using catalytic converter.

Figure VI shows variation in brake thermal efficiency due to back pressure . Insignificant variation in brake thermal efficiency was observed with increase in back pressure due to converter.
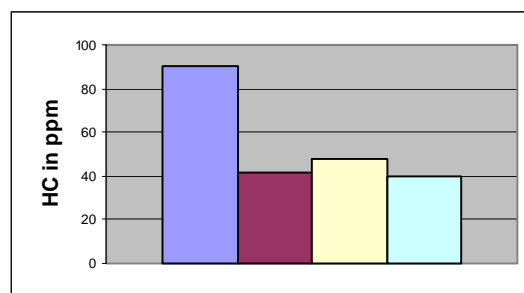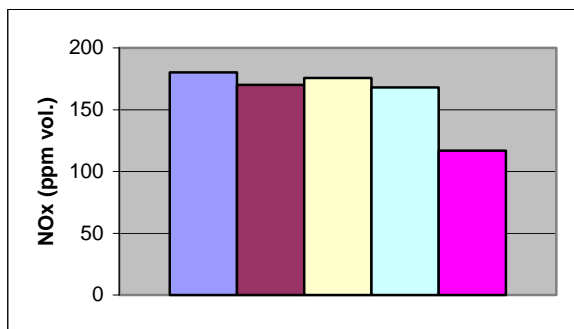

1)   Without converter
2)   Converter with copper oxide catalyst
3)   Converter with cerium oxide catalyst
4)   Converter with zirconium dioxide catalyst,
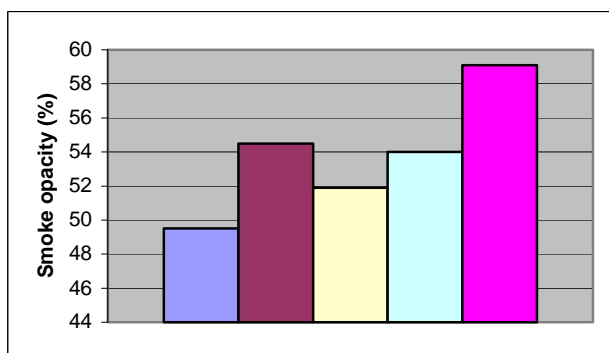
Figure I: Comparison of HC emission (constant rpm 1500)
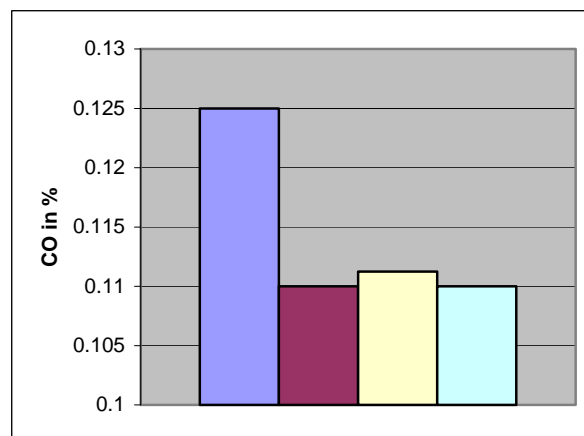
1)   Without converter
2)   Converter with copper oxide catalyst
3)   Converter with cerium oxide catalyst
4)   Converter with zirconium dioxide catalyst

Figure II: Comparison of CO emission (constant rpm 1500)

1) ▮ Without converter

2) ▮ Converter with copper oxide catalyst

3) ▮ Converter with cerium oxide catalyst

4) ▮ Converter with zirconium dioxide catalyst

5) ▮ Converter zirconium dioxide + cerium oxide catalyst

Figure III: Comparison of NOx emission (constant rpm 1500)

1) ▮ Without converter

2) ▮ Converter with copper oxide catalyst

3) ▯ Converter with cerium oxide catalyst

4) ▮ Converter with zirconium dioxide catalyst

5) ▮ Converter zirconium dioxide + cerium oxide catalyst

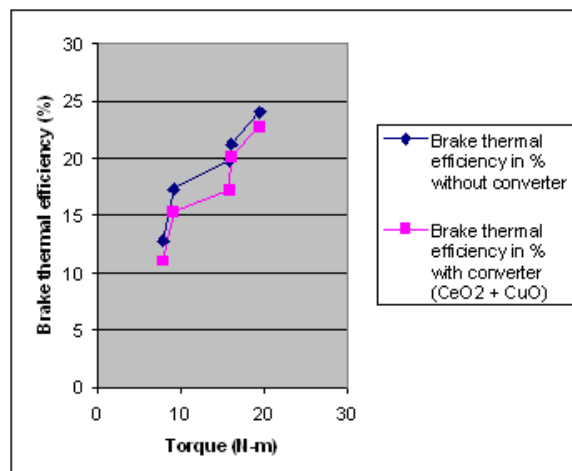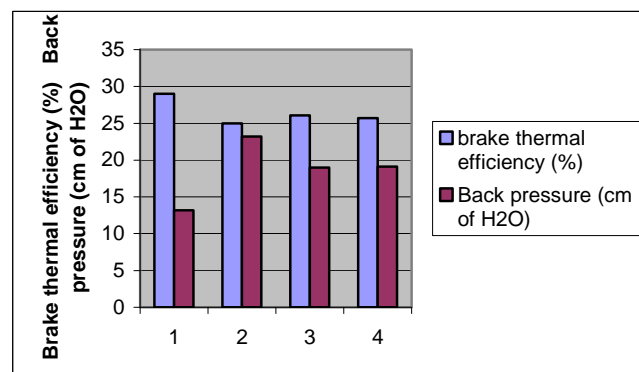**Figure IV: Comparison of smoke opacity (constant rpm 1500)**

Figure V: Variation in brake thermal efficiency vs. torque (constant rpm 1500)

1) Without converter

2) Converter with copper oxide catalyst

3) Converter with cerium oxide catalyst

4) Converter with zirconium dioxide catalyst

Figure VI: Comparison of brake thermal efficiency and back pressure (constant torque and rpm 1500)

Figure VII: Catalytic converter, catalysts coated pellets and circular housing.

VI. CONCLUSION

The conclusions from the investigation are summarized as under:

1. Zirconium dioxide catalysts reduces HC emission .
2. All three catalysts (zirconium dioxide, cerium oxide and copper oxide) reduce CO emissions.
3. The catalyst (zirconium dioxide + cerium oxide), reduce NOx emission
4. Brake thermal efficiency decreases with. Catalytic converter. However, this decrease is marginal and it can be accepted in view of benefits on environment and health of human being in particular.

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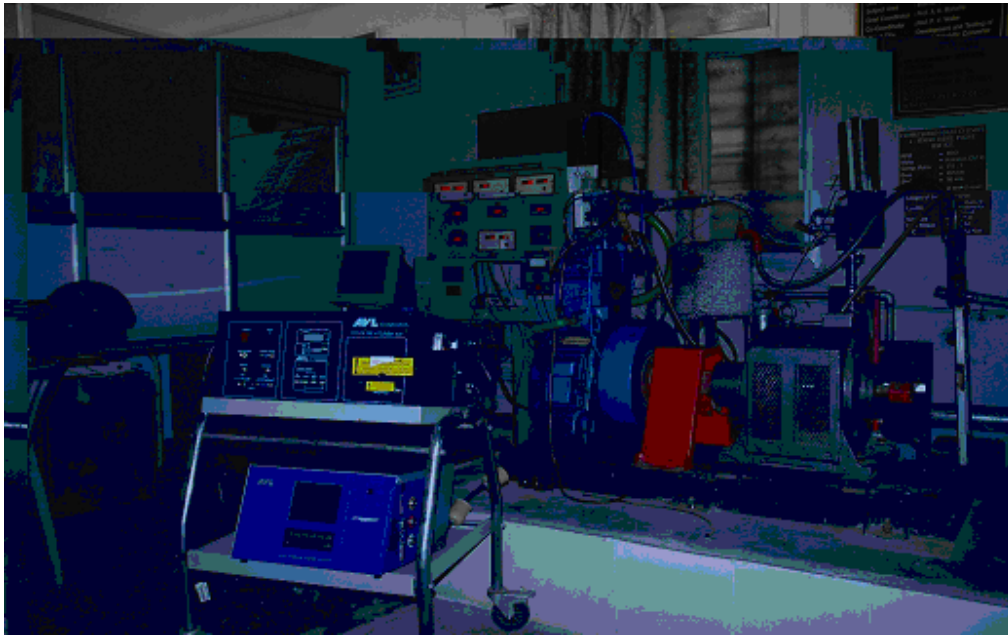
Figure VIII : Computerized single cylinder four stroke diesel engine with eddy current dynamometer, AVL Five gas analyzer and smoke meter.

Figure IX : Diesel engine set up with Catalytic converter.