# Diesel Particulate Filter by using Copper Oxide as a Filter Medium

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**Abstract -** *This dissertation concentrates on decreasing the carbon monoxide content from the exhaust of compression ignition engines to reduce its hazard intensity. Searching various options of after treatment devices for I. C. engines is essential because particulate matter is designated as a major cancer material. It is must to use diesel fuels to boost performance parameters of engines but it causes slump in emission parameters. Backpressure rise because of the use of after treatment devices is unavoidable but with a specific level of backpressure, an after treatment device can be used to achieve a perfect control over emissions. Critical analysis of the diesel engine's exhaust before and after use of the after treatment devices gives a very clear idea about the emission performance of engines. Use of copper oxide is done to create a favorable environment where a chemical reaction between carbon monoxide and copper oxide can take place at approximately 400-500°C.*

***Key Words***: carbon monoxide, I. C. engines, particulate matter, backpressure, copper oxide.

## 1. INTRODUCTION

We are talking about 2019 where the world is at the edge where Internal Combustion Engines are supposed to get vanished and the reason is continuous increase in pollution on the earth and its negative impact on the human life. The major role in this pollution is of Internal Combustion Engines used in either Industries for power generation purpose or in vehicles. The government is taking very strict and quick decisions towards the ban of Internal Combustion engines as soon as possible. This task is very difficult for developing countries with extremely low economy. Switching from Internal Combustion Engines towards Electric Vehicles is not an easy task if we consider the facts like; skills of labour, available technology, economy of country, financial condition of the citizens and performance of the new technology.

Some temporary arrangements can be done to achieve a control over pollution by Internal Combustion Engine's emission and then with time a research will give us affordable alternatives for Internal Combustion Engines. One of the solutions of this problem is introduction of various filter materials which will help to achieve a control over emissions. In this paper, how the introduction of copper oxide filter material to the exhaust of engine can be done and how the amount of carbon monoxide can be taken down is elaborated.

## 2. WORKING PRINCIPLE

The device which is used to trap the particulate matter available in the exhaust of Internal Combustion Engines is called as Diesel Particulate Filter (DPF). For various particulate matters like CO, $CO_2$, NOx, HC, $SO_2$, soot etc. which are generated because of incomplete combustion of fuels, multiple filter materials can be used to reduce the free release of these pollutants to the environment. In this study copper oxide spheres of size 1.5cm diameter are introduced in the DPF to decrease the Carbon Monoxide percentage in the exhaust.

The high temperature exhaust of the engine passes through various accessories like Exhaust Gas Recirculation cooler, exhaust lines, silencer etc. and at the end enters into the DPF. DPF consists of a diverging section, a cylinder and a converging section respectively, as shown in the design. The task of diverging section is to increase the area of contact in between exhaust and the filter material available in the cylinder simultaneously reducing its velocity. The cylinder portion acts as a storage tank of the filter material. This is the place where copper oxide spheres are placed which reacts with the exhaust matter and convert extremely hazardous carbon monoxide (which causes major human health problems like cancer) into slightly less hazardous gas $CO_2$. The purpose of last converging section is to release the exhaust into environment with high velocity.

Chemical Reaction;

$CuO + CO \rightarrow Cu + CO_2$

(250-450°C temperature is required for this reaction to take place)

There is no compulsion of using such filters in any country but it is the only way to satisfy the criteria of emission norms set by government.

## 3. DESIGN

Cylinder = L*D = 152.4mm*152.4mm

Diverging Section = h*D*d = 152.4mm*152.4*mm*38.1mm

Converging Section = h*D*d = 152.4mm*152.4mm*38.1mm

End Pipes (2 nos.) = d = 38.1mm

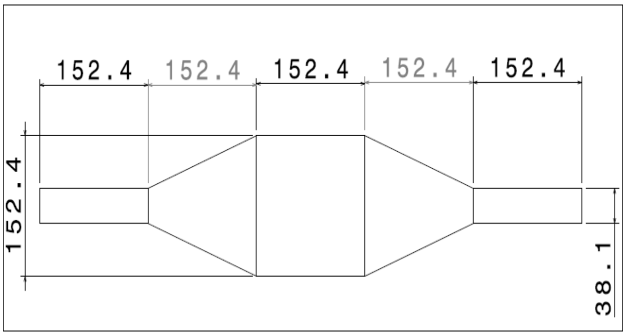


**Fig – 1:** Design

## 4. EXPERIMENTATION

### 4.1 Procedure

1. Open the water supply to Engine loading, Dynamometer and Exhaust calorimeter. Adjust mass flow rate of engine jacket cooling water to 300 Litres Per Hour (LPH) and exhaust gas calorimeter to 75 LPH.
2. Turn on the direct fuel supply to engine.
3. Set the rheostat of dynamometer to zero position.
4. Use manual lever operated cranking method to start the engine.
5. Run engine for 4-5 minutes at No Load Condition.
6. Gradually increase the load on engine till Full Load Condition.
7. Now at Compression Ratio 16, note the readings for the parameters mentioned on the worksheet. (worksheet is explained in Results and Calculations section)
8. Analyse the exhaust on AVL gas analyzer.

### 4.2 Engine Test Plan

1. Testing of engine at various load conditions without using Diesel Particulate Filter.
2. Testing of engine at various load conditions using Diesel Particulate Filter.

## 5. TESTING AND RESULTS

**Table – 1:** Worksheet

| CR | LOAD (Kg) | SPEED (rpm) | HW (mm) | MF (Kg/hr) |
|---|---|---|---|---|
| 16 | 0 | 1540 | 88 | 0.4386 |
| 16 | 2 | 1537 | 86 | 0.5263 |
| 16 | 4 | 1532 | 84 | 0.5727 |
| 16 | 6 | 1525 | 81 | 0.6192 |
| 16 | 8 | 1515 | 79 | 0.6862 |

**Table – 2:** Readings without DPF

| CR | LOAD (Kg) | TORQUE (Nm) | BP (KW) | BSFC (Kg/KW.hr) | ηBTE (%) |
|---|---|---|---|---|---|
| 16 | 0 | 0 | 0 | 0 | 0 |
| 16 | 2 | 3.6493 | 0.96 | 1.698 | 25.98 |
| 16 | 4 | 7.298 | 1.58 | 0.821 | 30.41 |
| 16 | 6 | 10.947 | 2.09 | 0.59 | 35.65 |
| 16 | 8 | 14.597 | 2.54 | 0.42 | 42.69 |

**Table – 3:** Readings without DPF

| ηVOL (%) | FP (KW) | IP (KW) | ηITE (%) | ηMECH (%) | BMEP (Bar) |
|---|---|---|---|---|---|
| 87.95 | 2.4 | 2.4 | 83.73 | 0 | 0 |
| 87.24 | 2.4 | 3.36 | 80.24 | 32.37 | 0.963 |
| 86.54 | 2.4 | 3.98 | 75.08 | 40.5 | 1.59 |
| 85.07 | 2.4 | 4.49 | 72.68 | 49.05 | 2.42 |
| 84.26 | 2.4 | 4.94 | 70.24 | 60.77 | 2.89 |

**Table – 4:** Readings without DPF

| OPACITY (%) | CO2 (%Vol) | O2 (%Vol) | HC (ppm) | CO (%Vol) | NO (ppm) |
|---|---|---|---|---|---|
| 16.01 | 1.05 | 16.76 | 11 | 0.019 | 68 |
| 18.7 | 3.34 | 18.05 | 11 | 0.061 | 71 |
| 27.5 | 4.82 | 18.91 | 13 | 0.049 | 73 |
| 28.7 | 4.73 | 17 | 15 | 0.064 | 152 |
| 37.2 | 5.12 | 17.51 | 19 | 0.0388 | 198 |

**Table – 5:** Readings with DPF

| CR | LOAD (Kg) | TORQUE (Nm) | BP (KW) | BSFC (Kg/KW.hr) | ηBTH (%) | ηVOL (%) |
|---|---|---|---|---|---|---|
| 16 | 0 | 0 | 0 | 0 | 0 | 90.9 |
| 16 | 2 | 3.649 | 0.587 | 0.8961 | 10.71 | 90.10 |
| 16 | 4 | 7.298 | 1.1 | 0.4895 | 19.61 | 89.34 |
| 16 | 6 | 10.94 | 1.748 | 0.3541 | 27.10 | 88.13 |
| 16 | 8 | 14.59 | 2.314 | 0.2965 | 32.37 | 87.62 |

**Table – 6:** Readings with DPF

| FP (KW) | IP (KW) | ηITH (%) | ηMECH (%) | BMEP (Bar) | BACK PRESS. |
|---|---|---|---|---|---|
| 3.5 | 3.5 | 76.6 | 0 | 0 | 3.5 |
| 3.5 | 4.087 | 74.55 | 14.37 | 0.693 | 3.7 |
| 3.5 | 4.67 | 78.27 | 25.05 | 1.38 | 4 |
| 3.5 | 5.248 | 81.36 | 33.37 | 2.079 | 4.23 |
| 3.5 | 5.814 | 81.33 | 39.8 | 2.7709 | 4.5 |

**Table – 7:** Readings with DPF

| OPACITY (%) | CO2 (%Vol) | O2 (%Vol) | HC (Ppm) | CO (%Vol) | NO (Ppm) |
|---|---|---|---|---|---|
| 0.928 | 0.528 | 17.21 | 15 | 0.052 | 5.9 |
| 3..312 | 0.34 | 17.39 | 16 | 0.079 | 12.93 |
| 8.3 | 0.28 | 17.56 | 17 | 0.089 | 20.3 |
| 11.56 | 0.312 | 17.05 | 18 | 0.103 | 83.56 |
| 15.89 | 0.359 | 16.56 | 19 | 0.109 | 152.3 |

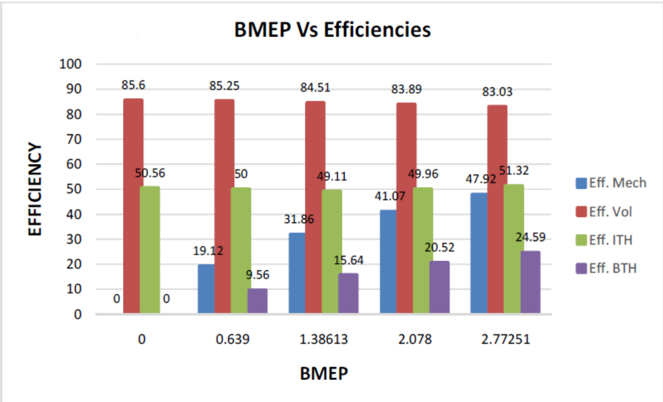


**Chart – 1:** BMEP Vs Efficiencies without DPF

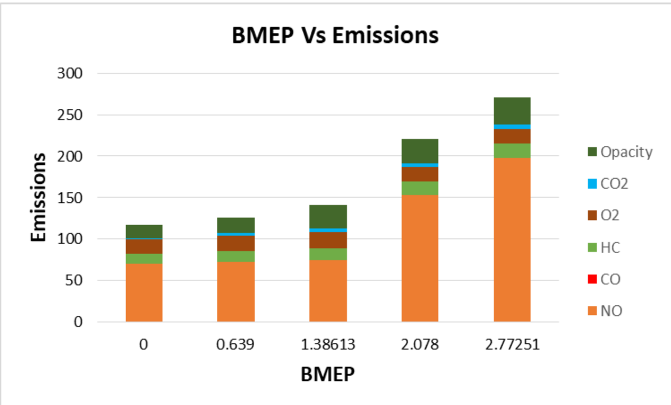


**Chart – 2:** BMEP Vs Emissions without DPF

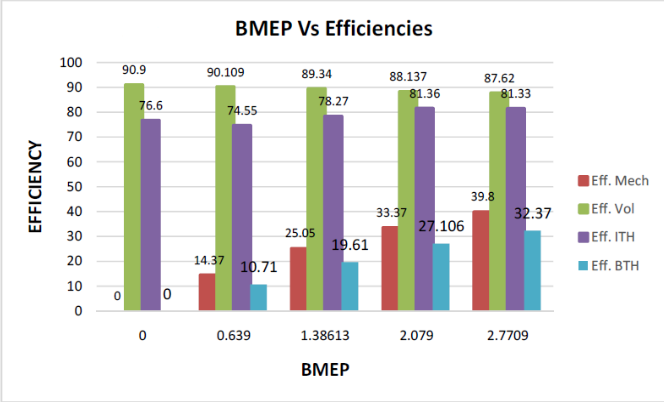


**Chart – 3:** BMEP Vs Efficiencies with DPF

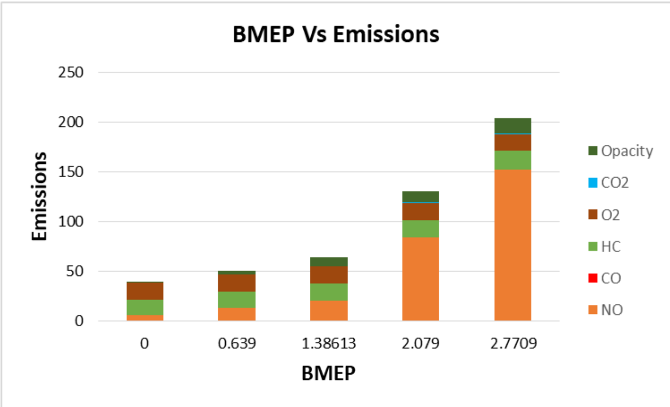


**Chart – 4:** BMEP Vs Emissions with DPF

## 6. SAMPLE CALCULATIONS

Given Data –

CR 16, Load = 2Kg, Hw = 86mm, Mf = 10.1996cc/min,

N = 1537rpm, CV = 37.5MJ/kg, Cd = 0.64, D = 87.5mm,

L = 110mm, d = 20mm.

Solution –

| | | |
|---|---|---|
| Torque | = | 186*10^-3*9.81*load |
| | = | 186*10^-3*9.81*2 |
| | = | 3.6493 Nm |
| Brake Power (BP) | = | (2πNT)/60000 |
| | = | (2π*1537*3.6493)/60000 |
| | = | 0.5873 KW |
| Mf | = | 10.1996 cc/min |
| | = | 10.1996*10^-6*860*60 |

= 0.5263 Kg/hr

BSFC = Mf/BP

= 0.5263/0.5873

= 0.8961 Kg/kw.hr

η Brake Thermal = (BP*3600)/(Mf/CV)

= (0.5873*10^3*3600)/(0.5263*37.5*10^6)

= 0.1071

= 10.71%

Va = Cd*Ao*((2*g*Hw)*(ρw/ρa)^0.5*3600)

= 0.64*3.141*10^-4 *(2*9.81*86*10^-3 *(1000/1.17))^0.5*3600

= 27.48 cubic m/hr

Vs = (π/4)*D^2*L*(N/2)*60

= (π/4)*(87.5*10^-3)^2 *110*(1537/2)*60

= 30.49 cubic m/hr

η Volumetric = Va/Vs

= 27.48/30.49

= 90.10

Friction Power (FP) = 3.5 Kw (By William's Line Method)

Indicated Power (IP) = FP + BP

= 3.5 + 0.5873 Kw

= 4.087 Kw

η Indicated Thermal = (IP*3600)/(Mf*CV)

= (4.087*10^3*3600)/(0.5263*37.5*10^6)

= 74.55%

ISFC = Mf/IP

= 0.5263/4.087

= 0.1287 Kg/Kw.hr

η Mechanical = BP/IP

= 14.37%

BMEP = (BP*60)/(π/4)*D^2*L*(N/2)

= (0.5873*10^3*60000)/(6.61452*10^-4*7)

= 0.693 Bar

## 7. CONCLUSIONS

From the above results, conclusions drawn are;

1. All the efficiencies go on increasing with increase in BMEP i.e. with increase in load at constant compression ratio.
2. With increase in BMEP, CO2, OPACITY, NO and HC increases whereas O2 and CO decrease.
3. Diesel engine without DPF has better performance parameters than the Diesel engine with DPF but the emission parameters decrease by 0.8 to 2.5% with use of the DPF.

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