Experimental study of *Exhaust Emissions from Diesel Engines using Gas Analyser and Smoke Meter with Activated Carbon Filter*

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**Abstract.** The adsorption technique has proven a better solution to reduce emission in diesel engines. Activated carbon is taken as an adsorbent for the study to investigate the engine behaviour on its performance and emissions. The experimental setup along with testing of the emission for gas analysers as well as for smoke meters was performed. In this paper, the emissions from diesel engines are reviewed. To reduce the emissions from an automobile, experimental methods of adsorption using activated charcoal in diesel engines is set up. Activated carbon is one of the best adsorption materials due to its high porosity and capture capacity, when reacted with other reagents in order of activation. The measurement of emissions from the diesel engine is obtained using gas analyser and smoke meter, both before and after the installation of filter. After successive results obtained by using these devices, the performances of the devices and efficiencies of the filter used is compared. In this experiment, we can see that the filter (activated carbon) has efficiently reduces the value of HSU by 43.73% and K value by 48.94%. Hence, the overall efficiency of activated carbon used is about 46%.

**Keywords:** activated carbon, gas analyser, smoke meter

1. **Introduction**
Air Pollution is one of the most dominating problem that can be seen nowadays. One of the main causes of an Air Pollution is Transportation Industry. These automobiles release an emission which then pollutes the atmosphere. This is a serious issue and 26 out of 40 most deteriorated cities of the world falls in India. With regards to purifying exhaust gases and complying with emission, the available method differs vastly from each other depending on type and origin of pollution. This project will be dealing with the fatal gases released from the vehicles. The Carbon dioxide released from other sources like industries have cut their emission level since 1990, but as people are becoming more mobile, the rate of CO2 emission is increasing rapidly. Adsorption is a process based on intermolecular force [1] which is between the gases including Carbon dioxide and the surface of specific solid adsorbents. Adsorption can be explained as the deposition of molecules on the
periphery called adsorbate whereas the periphery where adsorption takes place is called adsorbent. The adsorbent used in this study is Activated Carbon having a structure of micro porous inert carbon matrix with large internal surface (700 to 500 m^2/g) \[2\]. This internal surface is mainly used for adsorption of exhaust gases like carbon dioxide. It is formed with the help of a thermal process, where volatile components which are present in gas is removed from carbon laden material in the presence of an oxygen. Activated carbon is a positively charged carbon that appeals negatively charged contaminants and chemicals like chlorine. It is more porous form of carbon having larger surface area for contaminants adsorption, making it a better choice for filtration than its original form. It is capable to block contaminants with size from 50 microns to 0.5 microns making it more preferable from the majority of manufacturers and consumers. Blocki S.W. Environ et.al \[3\] concluded activated carbon as highly effective in absorbing the gas molecules released by combusting fuel inside the engine by creating a thin film of adsorbent which can adsorb large amounts of pollutants on the surface. P.B.Balbuena et.al \[4\] compared the different amount of emission coming from automobile sector, industries and other manufacturing units throughout the world and concluded China as a leading country in emitting the carbon dioxide. Elanthikkal et.al \[5\] studied various methods to produce activated charcoal and produced it through the cultivation of bananas and mechanization creating enough waste mostly rich in cellulose and starch. Tirzha et.al \[6\] concluded that Carbon Dioxide, the most abundant greenhouse gas, has increased from 280 parts per million (ppm) to over 365ppm at present in pre-industrial levels. Akhil Anil Kumar et.al \[7\] compared the emissions from engine with simple silencer, with 2-way catalytic convertor, using silencer with activated carbon and with 3-way catalytic convertor using silencer with activated carbon & lime water. Anupam Mukherji et.al \[8\] suggested a dual bed converter that combines two way and three-way convertor fit within a single part that increases the life of the converter and reduces use of catalyst like rhodium.

2. Research Methodology
The devices (gas analyser and smoke meter) are used for the measurement of the pollutants emitted by the diesel engine. Then, the emissions obtained using gas analyser before and after the fixing of activated charcoal as a filter are compared. After that the emissions obtained using smoke meter before and after the fixing of activated charcoal as a filter are compared. After above comparisons, the accuracy of the output by measured using gas analyser and smoke meter without filter are compared likewise. Finally, the accuracy of the output measured using gas analyser and smoke meter with filter is compared.

3. Experimental Setup
The most commonly used devices for the measurement of emissions from diesel engine are gas analyser and smoke meter.

- **Gas analyser**- Gas analyser is a device that measures the presence of amounts of different gases available in the atmosphere surroundings.

- **Smoke meter**- A device that measures the density of smoke in exhaust gases emitted by exhaust system. It is a measuring instrument that calibrates smoke that depends on visual characteristics. A wide variety of methods to alike devices is found. Many of them measures opacity directly using the smoke column whereas if the column, only a sampled fraction is used by others.

3.1 Test Procedures for Gas Analysers

- The power supply as specified by the manufacturer and electrical earthing is checked.
- The accessories required by the manufacturer \[9\] is ensured to be available and functions well.
- The span and zero tuning is checked through the exhaust gas taken as a sample.
- The tuning of all electrical parts is ensured to inherit.
• The system included for samples shall not leak.
• The printer is ensured to work properly.

3.2 Test Procedures for Smoke Meters
• The tuning of the meter should be at zero and mid-scale point should be available with the impartial density filter, after the preparation of the meter. The value shall come below 0.1 m⁻¹.
• The typical equipment as stated by the manufacturer shall be included in the meter. The sample hose, internal pipes etc are ensured to be undegraded or undamaged to be leakproof.
• The working of temperature of oil and sensor measuring rpm should be ensured.
• The optical chamber should be ensured to heat properly.
• The air removal system is functioning properly.
• Visual displays are ensured to work properly.
• The printer is ensured to work properly and the details are accurate.
• The covering of the device is right and perfect electrical earthing is done.
• Free acceleration test is done using a vehicle and the details in the printed form is corrected.

3.3 Specification of the engine

| Sr. No. | Parameters         | Specifications                                    |
|---------|--------------------|--------------------------------------------------|
| 1.      | Engine             | 2982cc, 4 cylinders inline, 4 valves/cylinders    |
| 2.      | Engine type        | D-4D Diesel with intercooler Turbocharger        |
| 3.      | Fuel type          | Diesel                                           |
| 4.      | Max Power (bhp @rpm) | 171@3600                                      |
| 5.      | Max Torque (Nm @rpm)   | 343@1400                                      |
| 6.      | Emission Standards  | Bharat Stage IV                                 |

4 Material selection
The adsorbents that are in high usage in industry are activated charcoal, activated alumina, silica gel, and zeolite. Some of the requirements for fulfillment of adsorbent motto are size of port and distribution, size of particle, chemical reactivity, surface area and polarity on periphery.

4.1 Activated Carbon
Activated carbon lies in a class of amorphous carbonaceous materials having high porosity and internal surface area. Mainly anthracite and bituminous coals are the sources of activated charcoal having wide usage in the treatment of waste-waters and emissions. Activated charcoals are treated sorts of carbon and are the foremost adsorbent signified for their porosity with large extent starting from 500.0 to 3000.0 m²/g [10]. Most activated charcoals undergo two main processes, first carbonization and then activation. At first, carbonization, which enriches the carbon content and makes an initial porosity and after that, activation that helps in improving the structure of the pores. The larger the interior area, volume of pores, size distribution of pores and particularly the surface chemistry, the activated charcoal has more capability to adsorb. The adsorption capacity depends highly on the size distribution of pores due to which small difference causes change in
molecules of various sizes and shapes. The efficiency to remove pollutants can be improved with the help of the electrical force between the surface of the carbon and the adsorbate.

5 Result and Discussions

The testing and the comparison are done with the help of two main parameters. They are explained below as:

*HSU (Hartridge Smoke Unit)* - In case of diesel vehicles, the smoke density is checked. From the pictures, we cannot have a good idea of smoke opacity. A ‘0’ denotes perfect transmission (zero opacity) whereas 100 signifies complete absorption (complete opacity). This is written (in case of HSU) having a transmission length of 430mm, at 100°C and atmospheric pressure. If density of smoke emitted by the vehicle is less than 65 HSU, the vehicle is certified as non-polluting. While ‘0’ HSU means smoke is invisible. 100 HSU means smoke is thick and opaque.

*K Value* - Light absorption is used to measure the emissions from the diesel engines. The amount of light absorbed by the particles is an accepted standard measure for the engine’s emissions. The percentage of light arriving at the other side of a tube is taken as light absorbed. To assure that all parts give on with a relatable value, the percentage of light absorbed is calculated taking a reference on an opacity coefficient denoted as K. The service limit of most of the countries has the value of K as 2.50 m⁻¹ for non-turbo and as 3.0 m⁻¹ for turbocharged models. During a sudden acceleration emission test, the value of K lies between 1.50 to 2.50 for a good non-catalyst mounted vehicle.

Experimental Results

The experiments are carried under two cases to compare the performance of the devices used for measuring the pollutants under different conditions.

Case 1: Measurement of pollutants emitted using gas analyser

Case 1.1: Measurement of pollutants emitted using gas analyser without filter (activated carbon)

Using gas analyser, the values of HSU and K value is measured by varying the rpm of the engine and their average value comes out to be 32.08 and 0.90 respectively before the installation of filter i.e. activated carbon.

(a) RPM ranges from 600-2770 and temperature is in range 41-43 degree Celsius.

(b) The values of HSU are 35.39, 29.2 and 31.64 respectively.

(c) K values are 1.02, 0.80 and 0.88 respectively.

![Figure 1. Emissions measured using gas analyser without filter.](image)

Case 1.2: Measurement of pollutants emitted using gas analyser with filter (activated carbon)
Using gas analyser, the values of HSU and K value is measured by varying the rpm of the engine and their average value comes out to be 16.51 and 0.42 respectively after the installation of filter i.e. activated carbon.
(a) RPM ranges from 920-2290 and temperature was in range 58-60 degree Celsius.
(b) The values of HSU are 15.88, 16.12 and 17.53 respectively.
(c) K values are 0.40, 0.41 and 0.45 respectively.

Figure 2. Emissions measured using gas analyser with filter.

Case 1.3 Comparative study of emissions with and without filter

| Sr. No. | Parameters | Without filter | With filter |
|---------|-----------|----------------|-------------|
| 1       | HSU       | 32.08          | 16.51       |
| 2       | K value   | 0.9            | 0.42        |

After comparing the values of emissions measured by using gas analyser with and without filter, we can see the value of HSU is reduced by 48.53% and the K value is reduced by 53.33%.

Figure 3. Emissions measured using gas analyser without and with filter.

5.2 Case 2: Measurement of pollutants emitted using smoke meter

Case 2.1: Measurement of pollutants emitted using smoke meter without filter (activated carbon)
Using smoke meter, the values of HSU and K value is measured by varying the rpm of the engine and their average value comes out to be 35.16 and 1.01 respectively before the installation of filter i.e. activated carbon.
(a) RPM ranges from 760-2840 and temperature was in range 71-75 degree Celsius.
(b) The values of HSU are 32.03, 34.95 and 38.51 respectively.
(c) K values are 0.90, 1 and 1.13 respectively.

Figure 4. Emissions measured using smoke meter without filter.

**Case 2.2: Measurement of pollutants emitted using smoke meter with filter (activated carbon)**

Using smoke meter, the values of HSU and K value is measured by varying the rpm of the engine and their average value comes out to be 21.47 and 0.56 respectively after the installation of filter i.e. activated carbon.

(a) RPM ranges from 830-4790 and temperature was in range 45-48 degree Celsius.

(b) The values of HSU are 21.18, 22.12 and 21.11 respectively.

(c) K values are 0.55, 0.58 and 0.55 respectively.

Figure 5. Emissions measured using smoke meter with filter.

**Case 2.3 Comparative study of emissions with and without filter**

Table 3. Emissions measured using smoke meter without and with filter.

| S No. | Parameters | Without filter | With filter |
|-------|------------|----------------|-------------|
| 1     | HSU        | 35.16          | 21.47       |
| 2     | K value    | 1.01           | 0.56        |

After comparing the values of emissions measured by using smoke meter with and without filter, we can see the value of HSU is reduced by 38.93% and the K value is reduced by 44.55%.
Figure 6. Emissions measured using smoke meter without and with filter.

5.3 Comparison of pollutants emitted before and after the fixing of filter (activated carbon)

5.3.1 Emissions measured before fixing of filter (activated carbon)

Figure 7. Emissions measured before installation of filter.

5.3.2 Emissions measured after fixing of filter (activated carbon)

Figure 8. Emissions measured after installation of filter.

5.3.3 Comparison of values obtained by measurement using gas analyser and smoke meter

Table 4. Emissions measured without and with filter.

| Sr. No. | Device      | without filter | with filter |
|---------|-------------|----------------|-------------|
| 1       | Gas analyser| 32.08          | 16.51       |
|         |             | 0.9            | 0.42        |
|   | Smoke meter |   |   |   |
|---|-------------|---|---|---|
|   | 35.16       | 1.01 | 21.47 | 0.56 |

From the above table, we can see that the filter (activated carbon) has efficiently reduced the value of HSU by 43.73% and K value by 48.94%. Hence, the overall efficiency of activated carbon used is about 46%.

6 Conclusions

- This article reviews the characteristics of the main pollutants that are released by a diesel engine. These pollutants are CO, HC, PM and NOX. Among above pollutants, the Carbon Monoxide and Hydro-carbon are emitted as the combustion inside an engine cylinder is incomplete and the fuel remains unburned.
- With the help of Gas analyser, the values of Hartridge Smoke Unit (HSU) and K value was measured by varying the rpm of an engine and the values comes out was to be 32.08 of HSU and 0.90 as of K value before installing the filter (Activated carbon). After installing the Activated carbon filter, it was noted that the value of HSN and K value coming out was 16.51 and 0.42 respectively.
- With the help of Smoke Meter, the value of HSU and K value was measured by varying the rpm of an engine and their average value comes out to be 35.16 and 1.01 respectively before using an Activated carbon filter. After installing the Activated carbon filter, the value of HSU and K value comes out to be 21.47 and 0.56 respectively.
- The use of Activated carbon filter has efficiently reduced the value of HSU by 43.79% and K value by 48.94%.
- The overall efficiency of Activated carbon used as a filter was about 46%.
- Using an Activated carbon filter, other pollutants has also been reduced like HCs, carbon monoxide, nitrogen, and particulate matter.
- Overall, we have effectively reduced the emissions from diesel operating engines.

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