International Conference on Mechanical, Industrial and Materials Engineering 2019 (ICMIME2019)
17-19 December, 2019, RUET, Rajshahi, Bangladesh.
Paper ID: TE 11

Diesel Exhaust Particulate Matter Emission Reduction by Electrostatic Precipitation Method

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Abstract

Nowadays environment pollution is one of the biggest concern all over the world because it is one of the great contributor to human death. It is also a great alarm in the large cities of Bangladesh which is caused mainly due to particulate matter pollution. The main contributors of environment pollution are motor vehicles, brick kilns, diesel generators and industries. Recently in Rajshahi, Bangladesh, particular matter (PM) is the most harmful air pollutant to public health and environment when compared to other measured standards pollutants. About 30–50% of the PM10 mass in Rajshahi (depending on location) is in fine particles with aerodynamic diameter less than 2.2 µm. If PM10 concentration can be reduced about 80%, then it would be possible to avoid 3500 deaths, 235 million cases of sickness and a large amount of health cost savings. The aim of this study is to reduce these particulate matters and an experimental arrangement has been constructed in case of a BECO diesel engine for black carbon free exhaust. The electrostatic precipitation method has been used to clean the diesel exhaust gas with the constant high voltage of 50 KV as well as different variables, such as load and speed of the engine. From the observation it is found that the particulate collection efficiency is 98.13% which can eliminate 99% of pollutant particles from the exhaust.

Keywords: Diesel exhaust, Electrostatic precipitation method, Particulate matter emission.

1. Introduction

Air pollution is increasing at an alarming rate with the other environmental pollutions all around the world [1-4]. Diesel emission is one of the major cause of air pollution and it results 38,000 deaths per year [5]. In recent years many research attention has been performed on atmospheric particles as they have major influence on climate change and cause adversative health effects. Common air pollutants includes carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter less than 2.5µm (PM 2.5) and 10µm (PM 10) in aerodynamic diameter. During recent years, the govt. of Bangladesh has strained to control PM emissions coming from anthropogenic sources. About 30–50% of the PM10 mass in Dhaka (conditional on location) is in fine particles with aerodynamic diameter less than 2.2 µm. Generally, the off-road engines contribute about 50 % of the total particulate emissions from combustion engines [6]. **Fig. 1** shows the emission of particulate matter in different major cities which is very low in Sao Paulo where as in Dhaka city the emission is quite large. Diesel engines produce a complex mixture of air pollutants, including both gaseous and solid material. The solid material in diesel exhaust is known as diesel Particulate matter (DPM). More than 90% of DPM is less than 1 µm in diameter (about 1/70th the diameter of a human hair), and thus is a subdivision of particulate matter less than 2.5 microns in diameter (PM2.5). Various devices may be engaged to remove the particles from a gas stream. The electrostatic precipitator is one of the most broadly used collection devices for particulates. An electrostatic precipitator (ESP) is a particulate collection device that eliminates particles from a flowing gaseous stream (such as air) using the force of an induced electrostatic charge [8].

ESP eliminates the both diesel particles and smoke by the electrostatic force applied on the particles when the high voltage is applied on the discharge electrode. ESP can archive 99 percent of removal efficiency for a certain type of

particulate [8]. Particles are charged with electrical field and are involved by the opposite charge and are collected in the collection plate. ESP can be functioned at high temperature and pressures and its power requirement is low. The purpose of this project is to reduce diesel emissions with the electrostatic precipitation method which is efficiently used because of its high efficiency of removal of pollutants, low operating cost, and capability of handling large amount of high temperature gas.

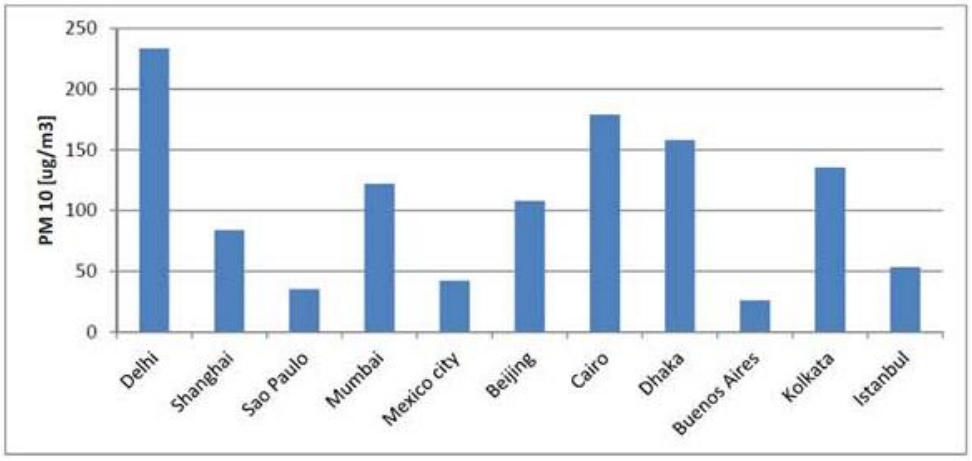

Fig. 1. Air pollution due to PM10 particles in major cities of the world [WHO's Urban Ambient Air Pollution Data 2016]

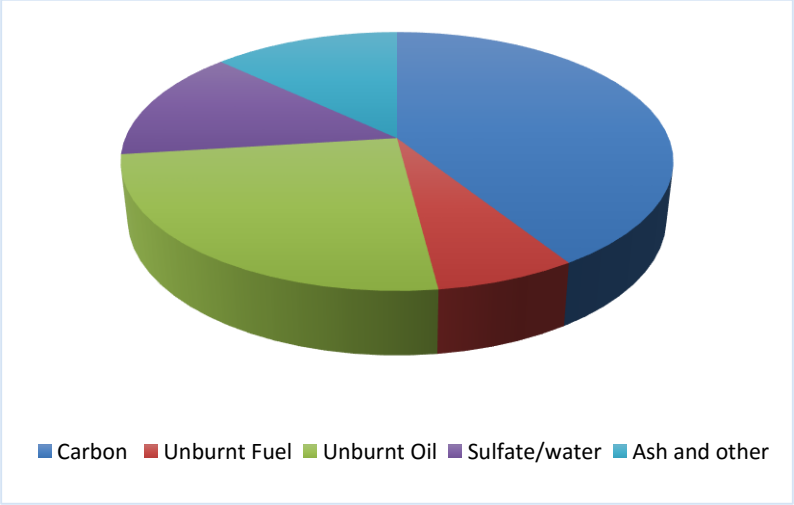

Fig. 2. Particle composition of a heavy duty diesel engine [7]

2. Materials and Methodology

The principal action of an ESP is the charging of dust particles and forcing these particles to the collecting plate. Alloy steel sheet of (116.18×33.44) cm have been selected as the collection plate because of its hardenability, corrosion

resistance and formability. Mild steel of 0.2 cm was used for the discharge electrode wire because of its sustainability of vibration and temperature. **Fig. 3** illustrates a simple design of ESP of the design to reduce diesel exhaust emission.

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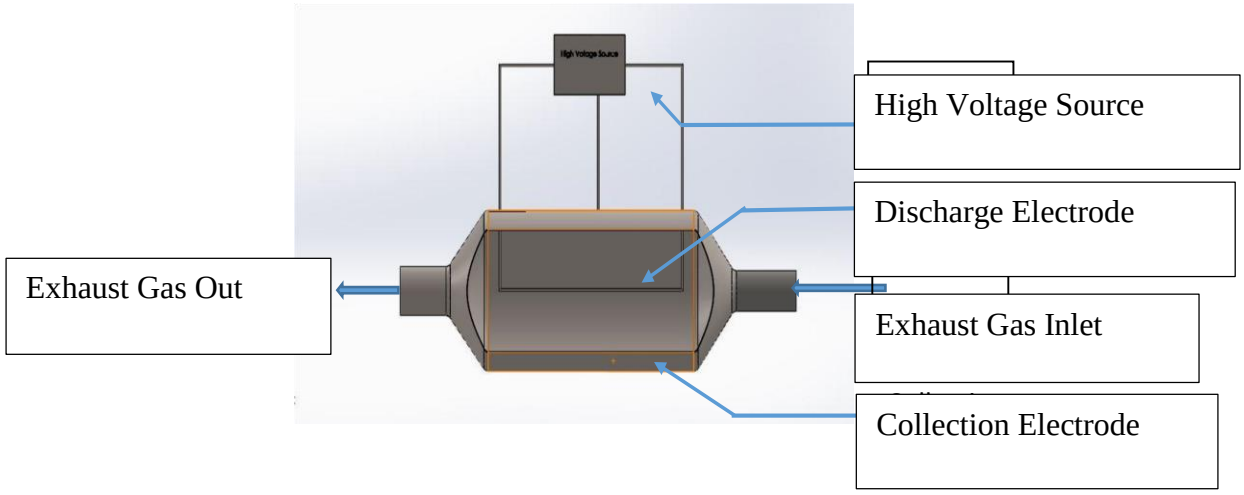
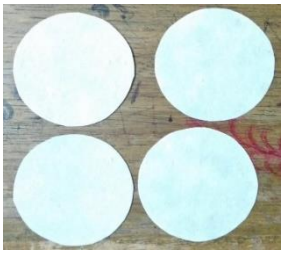


Fig. 3. Simple Design of ESP of the project.

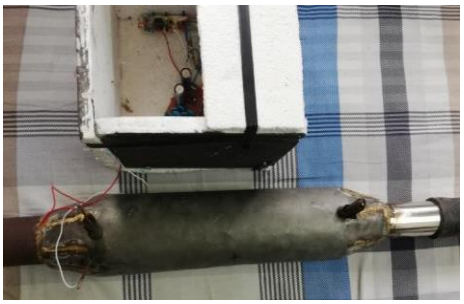
(a) Precipitation Body

(b) Filter Holder



(c) Filter papers

(d) Electrical circuit



(e) Full Set Up

Fig. 4. Experimental full setup with different individual parts

Fig. 4 shows different individual equipment with full experimental setup. The apparatus have been used for measuring various values for the experiment are as anemometer, tachometer, filter papers and paper holder, and digital weight balance with diesel engine exhaust line. The methodology accepted includes a study of existing condition, real- time work made to explore the general system followed in the DPM reduction measure. The flow diagram of the experimental procedure is illustrated in **fig. 5**.

Table 1. Proposed Dimensions of the ESP

SI. No	Items	Diameter (cm)	Length (cm)
01	Exhaust inlet	5.4	11
02	Divergence and convergence		6.5
03	Particle collecting surface	10.65	37
04	Exhaust exit	6.5	8.5
05	Discharge electrode wire	0.2	37
06	Plate thickness		0.08

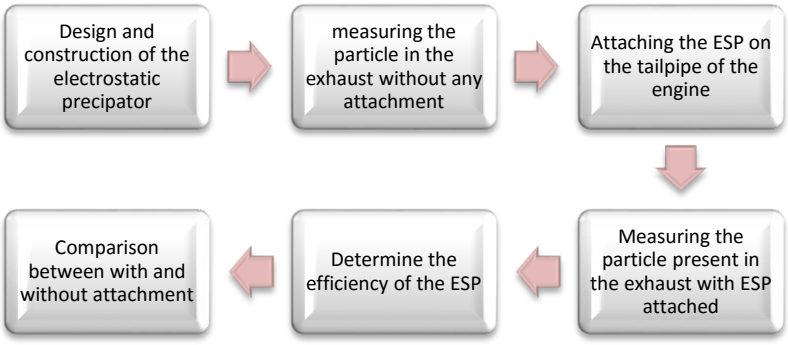


Fig. 5. Flow Diagram of Methodology.

The experimental setup consists a single-cylinder, light-duty diesel engine, electrically operated electrostatic precipitation system as well as inlet and exhaust lines. A burette indicates the amount of fuel flow from the diesel tank to the engine. The middle portion which is known as particulate collection portion, is made of iron sheet. Third portion of body is convergent portion which is made of cast iron. Filter paper was placed at the tail pipe of the diesel engine before the precipitation system attachment. The observation was carried out for different loads and rpm. When load was kept constant the rpm was different.

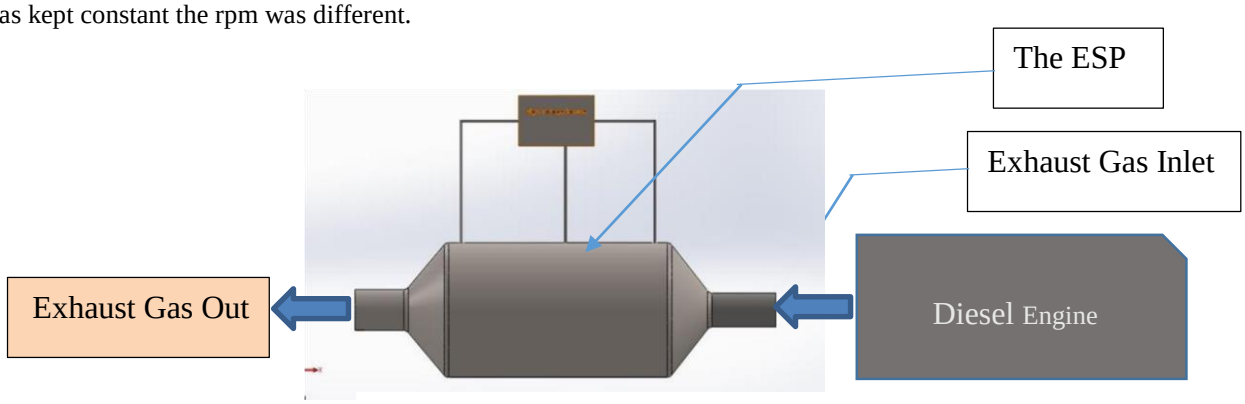


Fig. 6. Experimental setup for ESP.

3. Results and Discussion

In Various condition keeping the rpm or load constant and varying these variables the result was taken keeping the voltage constant at 50 KV. The exhaust gas velocity (m/s) and the Exhaust gas temperature (°c) were at a range of 6.7-12.3 m/s and 47-60°c respectively. These values of velocity and temperature wasn't exceeded to the assumed value for this experiment. The above graphs show that the maximum amount of particles collected in percentage was found 61.99% and this decreases with the increasing in load when the speed was kept constant at 1000 rpm and particles were positively charged. And the percentage was found 94.34% and this decreases with the increasing in load when the speed was kept constant at 1000 rpm and particles were negatively charged.

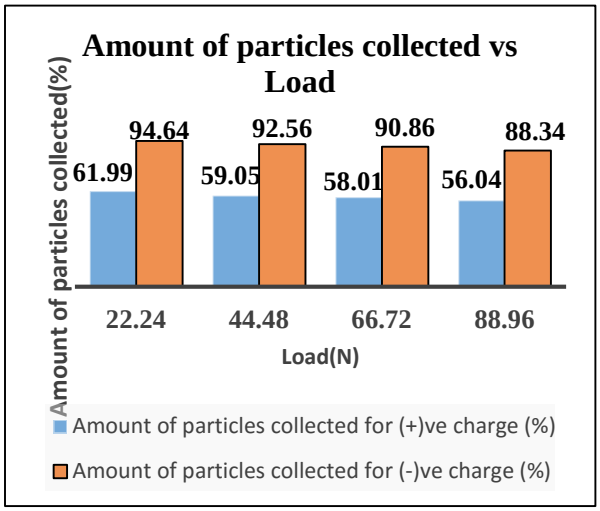


Fig. 7. Amount of particles vs. Load

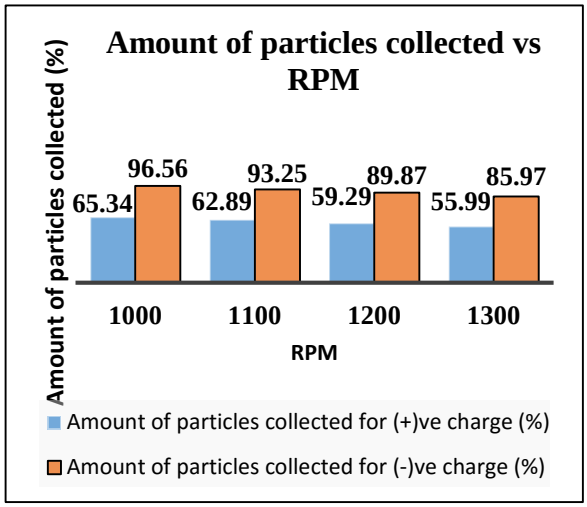


Fig. 8. Amount of particles vs. RPM

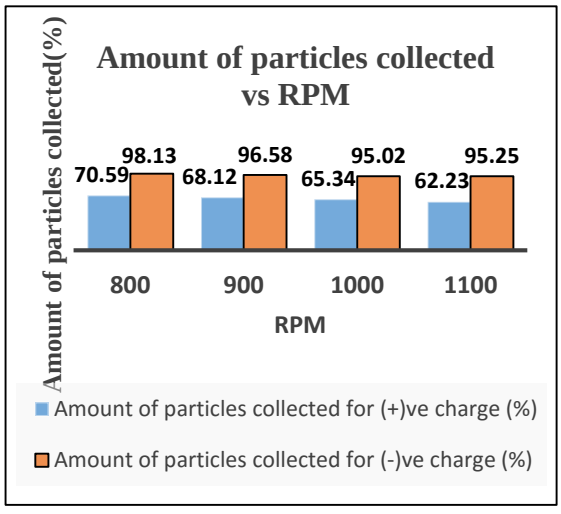


Fig. 9. Amount of particles collected vs. RPM

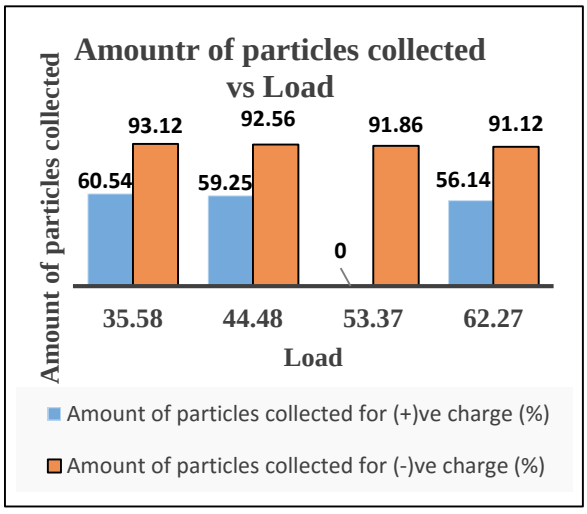


Fig. 10. Amount of particles collected vs. RPM

As for the RPM, the maximum amount of particles collected in percentage was found 65.34% and this decreases with the increasing in RPM when the load was kept constant at 10 lb. or 44.48 N and particles were positively charged and for negatively charged 96.56% and this decreases with the increasing in RPM when the load was kept constant at 10 lb. or 44.48 N. **Fig. 7-10** shows that that the maximum amount of particles collected was found 70.59% and this decreases with the increasing RPM when the load was kept constant at 5 lb. or 22.24 N and particles were positively charged. Again when negatively charged the maximum amount of particles collected was found 98.13% and this also decreases with the increasing in RPM when the load was kept constant at 5 lb. or 22.24 N.

4. Conclusion

The concept of using electrostatic precipitation method offers a quite good result in cleaning the diesel exhaust gas or reducing the particulate matters from the exhaust gas. Environment is polluted rapidly because of the exhaust gas from the various diesel fuel engine and other fuel engines as well as diesel power plants and different industries. From this study, it is possible to accumulate 98.13% particulate matters from the negatively charged particles with 50 KV supply, keeping the load constant at 5 lb. and the operating engine at 800 rpm. By this process avoiding of 3500 deaths, 235 million cases of sickness is possible which will be a huge turn over for human civilization.

5. Acknowledgments

The authors would like to express their sincere gratitude and thanks to all the teachers involved directly or indirectly especially head, Department of Mechanical Engineering, RUET for his kind co-operations and permission for using the instruments of the Laboratory of the Department. The Author would also extend their thanks to Prof. Dr. Md. Shamim Akhter, RUET for his valuable suggestions and guidelines during the work.

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