Removal of Diesel Soot Particles by Cyclone and Hydro Cyclone

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ABSTRACT

Diesel exhaust is composed of two phases; either gas or particle and both phases contribute to the risk. The reduction of particulate emissions from diesel engine is one of the most challenging problems in modern society. As a special report on global exposure to air pollution and its disease burden 2017, Exposure to $PM_{2.5}$ the leading environmental risk factor for death, accounting for about 4.2 million deaths ranks 5th worldwide among all risks, including smoking, diet, and high blood pressure.The main particulate fraction of diesel exhaust consists of ultra fine particles. The research aims to reduce the emissions of diesel soot particles from diesel electrical generator using Cyclone and Hydro Cyclone. The Cyclone separator designed as Salcedo model achieved about 8% of soot removal efficiency from a total soot mass concentration (1.2 g/m^3). Hydro Cyclone designed by Combine Salcedo Cyclone with Venturi constriction, wherein the exhaust gas stream is contacted with higly pressure liquid stream at least 140 bar to produce a substantially liquid saturated exhaust gas stream. Wet Filtration remove about 90% of soot particles mass in the flow rate of spray water to exhaust gas (0.62 l/m^3) below the universally recommended values (1.7 - 0.67 liter water / m^3).

Keywords : Diesel soot particles; Cyclone; Hydro Cyclone; Venture; Wet Filtration.

1 INTRODUCTION

Diesl engine exhaust emissions are a complex mixture of gases, vapours, liquid aerosols and substances made up of particles, including known carcinogenic substances. They contain the products of combustion including:
Carbon (soot), Nitrogen, Water, Carbon monoxide, Aldehydes, Oxides of nitrogen, Oxides of sulphur, polycyclic aromatic hydrocarbons [1].

Diesel soot particulates have a bimodal size distribution, which includes small nuclei mode particles and larger accumulation mode particles. Most of diesel particle mass is contained in the accumulation mode but most of the particle number found in the nuclei mode [2].

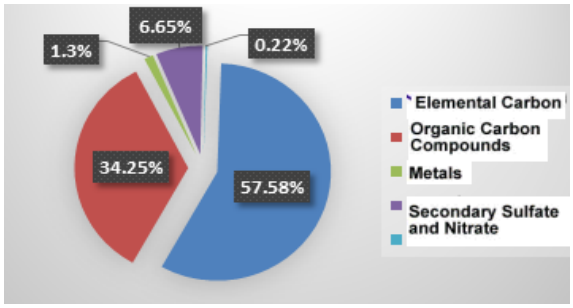

Fig. 1 Diesel Soot Particle compestion from Syrian diesel motors

Soot formation occurs when a hydrocarbon-based fuel is combusted in a low-oxygen environment. It described as the incomplete combustion of a hydrocarbon fuel (such as alkane, alkene, alkyne, cycloalkane and alkadiene). When hydrocarbon fuel combusts in a low-oxygen environment, it leads to the formation of benzene-like rings and chains that form PAHs with higher molecular weight.

These PAHs undergo polymerisation until the primary particle is formed that is normally in spherical form. These particles then cluster together through surface bonds and aggregate into larger particles that eventually agglomerate into the macroscopic soot structures. These soot particles can undergo oxidation and agglomerate further into sizes ranging from 50 nm to 10 µm [3].

The Environmental Protection Agency EPA has set the allowable emission rates for diesel engines of different engine output at 0.025 g / kWh ISO 8178. [4]

Diesel Soot particles emission control strategies, based on both engine design and aftertreatment, this paper explain the comparison of soot capture between using Cyclone and Hydro Cyclone.

2 Cyclone Separator designe

Cyclone separators CS are popular systems by which solids removed from a gas. There are many standard engineering designs for Cyclone Separator; Salcedo Model approved agood efficieny for removal fine particles $PM_{0.2}$ [5].

The cyclone designed and implemented according to Salcedo Model [5, 6] and examined for diesel soot particles removal. Figure 2 shows the Cyclone Separator dimensions:

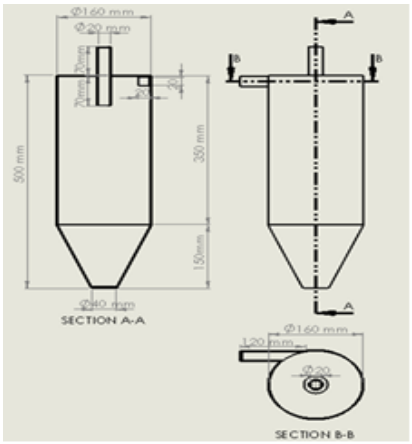

Fig.2: the Cyclone Separator dimensions

The experimental study was applied to the Perkins diesel engine (120kW / 150kVA Perkins generator). Table 1 shows the output of the diesel engine:

Table .1 exhaust gas from diesel engine:

motor load	Tgas	d_p	gas density	gas viscosity	Q_{gas}	dust loading	dust density
%	C°	µm	kg/m³	Pas	m³/h	mg/m³	kg/m³
75-80	250-340	0.2	0.67	2.81E-05	30	1200	500

Nomenclature

$PM_{2.5}$	refers to atmospheric particulate matter (PM) that have a diameter of less than 2.5 micrometers
d_p	Soot particles Diameter (micrometer)
Q_{gas}	Exhaust gas flow m^3/h

2.1 Diesel Soot Particles Removal Using Cyclone:

The cyclone shown in Fig. 1 examined and the capture efficiency of the soot particles recorded after half an hour to ensure the stability of combustion process. Figure 3 shows the soot particles capture efficiency because of the change in the concentration of the input mass particles:

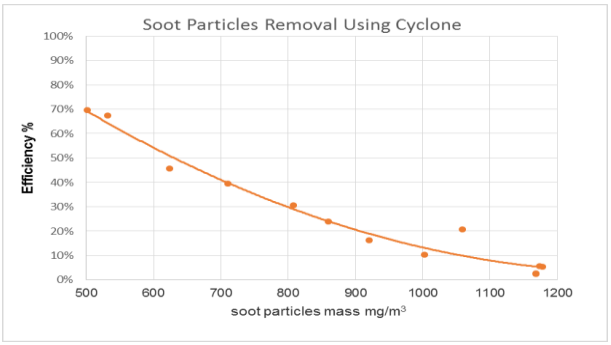

Fig.3 Soot Particles Removal Using Cyclone

The diesel engine load rate ranges between (20 – 80%)
Dry Filtration using Cyclone Separatoe capture around 70% for soot mass concentration 500 mg/m³. For the maximum engine load (1200 mg/m³), the Cyclone achieve 5% of soot removal efficiency.

3 Diesel Soot Particles Removal Using Hydro Cyclone

Hydro Cyclone designed by Combine Salcedo cyclone with Venturi constriction (fig.4).
wherein the exhaust gas stream is contacted with higly pressure liquid stream (spray) at least 140 bar to produce a substantially liduid saturated exhaust gas stream, particles and droplets in the water saturated gas stream then are separated in Hydro Cyclone Under the influence of gravity and centrifugal forces. We provide a good mixing of gas with the washing liquid within the Venturi constriction to match diameters of the washing liquid which not exceeding 0.3 micrometer with the mean diameter of the soot particles, which estimated at 0.2 micrometer.

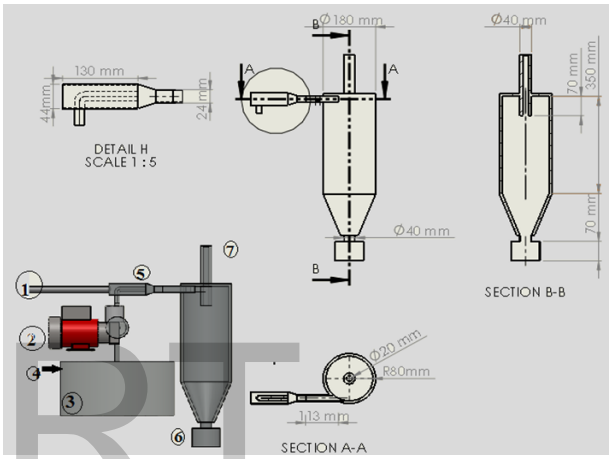

Fig .4 Hydro Cyclone dimentions

1- Diesel exhaust gas ,2- high pressure liduid pump , 3- washing liquid tank , 4- adding water , 5- venturi , 6- waste water tank , 7- cleaned gas.

The Hydro Cyclone examined in these operating parameters:

- The washing liquid (drinking water) pumped using a high-pressure pump, Operating pressure at least 140 bar.
- One Spray nozzle used in the inlet of venturi is made of stainless steel, spray angle: 60 °.

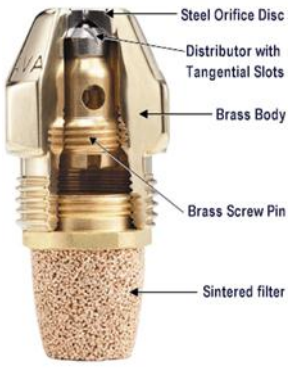

Fig.5 spray nozzle

- Soot praticles consentration between (500 – 1200 mg/m³).
- The flow rate of spray water to exhaust gas is between (0.015 – 0.65 l/m³).

3.1 EXPERIAMENTAL STUDY USING HYDRO CYCLONE

Figure 6 shows the efficiency of the capture of soot particles because of the change in both the concentration of the input mass soot particles and the flow rate:

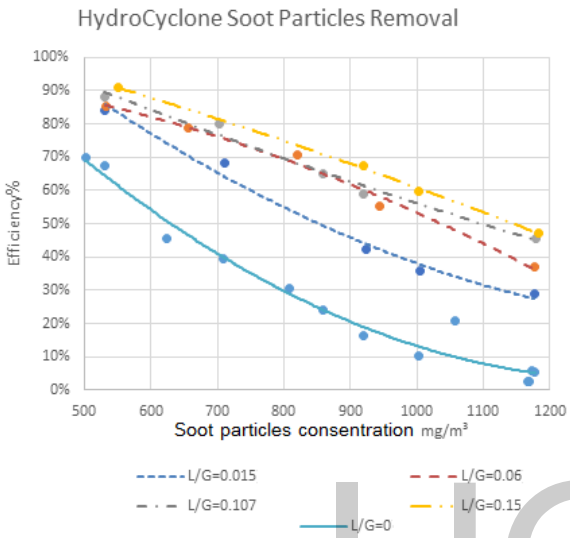

Fig .6 Hydro Cyclone Soot Particles Removal

The efficiency of soot capture within the Wet Filtration process is proportional to the increase in the flow rate of the washing fluid (drinking water spray) to the exhaust gas.

For a maximum load rate of 1.2 g / m³ soot particles.The Wet Filtration using Hydro Cyclone accomplished an increase efficiency of about (20 , 28 , 37 , 39%) for the loading rate of the drinking water spray (0.015 , 0.066 , 0.107 , 0.15 l/m³) respectively, compared to the Cyclone Filtration.

For the high diesel engine load 80% which emissions 1.2g/m³ of soot particles, the Hydro Cylone soot removal illustrate in fig.7:

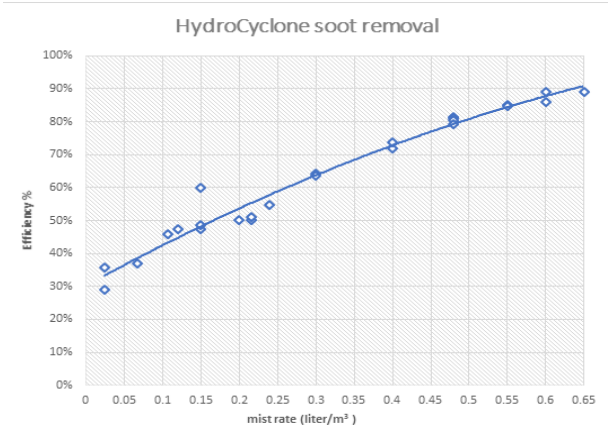

Fig. 7 Hydro Cyclone soot removal in high load engine 80%

Soot removal efficiency increases incremental by rising flow rate of spray water to exhaust gas.

The wet fiteration accomplished high efficiency between (29 – 90 %) from the total soot concentration (1.2g/m³).

4 CONCLUSION

The study was applied to the Perkins (120kW / 150kVA Perkins generator) diesel engine for a high load rate of 1200 soot mg /m³.

Comparing between Salcedo Cyclone and the Hydro Cyclone that designed includes both Salcedo Cyclon and Venturi contraction.

The Salcedo Cyclone achived 8% of diesel soot capture from the total mass concentration.

The results of the new Hydro Cyclone design accomplished in the soot capture efficiency of at least 90% for Wet Filtration (washing with drinking water spray) at a flow rate of (0.62 liter / m³) Below the universally recommended values (1.7 - 0.67 liter water / m³)[7].

5 RECOMMENDATIONS

- Filtrate the wastewater and reuse in closed –cycle.
- Using the soot in the tire industry.
- Determination of the efficiency of combustion gases absorption in Hydro Cyclone after Wet Filtration.

ACKNOWLEDGMENT

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