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Design and Fabrication of Soot Collector and Filtration of Soot

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ABSTRACT
Unburnt carbon particles from industries and vehicles can adversely affect health and can cause premature death. The particulate matter emitted from the exhaust in the form of soot contains mainly Carbon monoxide, Nitrogen Oxide, Sulphur compounds, Aldehydes, Benzene and low molecular weight Polycyclic Aromatic Hydrocarbons (PAHs), Nitro-PAHs, and Diesel Particulate Matter. The norms and guidelines on emission standards exist, but they are seldom adhered to, especially for diesel engines that have been running for years. Hence, the emission from diesel engines is an immense problem. The device “Carbon Soot Collector” is fabricated at an early stage to collect the soot. It has an activated carbon filter held in between fine-grade stainless steel wire meshes. The collected soot is made to react with solvents like n-Butanol, Ethyl Acetate, Isopropyl Alcohol, Toluene and Polyvinyl Chloride is used as a resin. The filtered soot can be used to replace carbon black or pigment black and dyes in ink cartridges and chemical industries. The production of carbon black involves the thermal decomposition of hydrocarbons. This requires large amounts of energy. The soot in exhausts that are released into the atmosphere can be collected and recycled to use in the place of carbon black.

Keywords - Diesel, exhaust, filtration, ink, soot

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I. INTRODUCTION

Air pollution is one of the major concerns in this world today. The rapid increase in industrialization is causing very serious harm to both human beings and the environment. The need to understand the harmful effects of these pollutants and find ways to control them effectively is the primary step towards a pollution-free environment. Unburnt carbon particles from industries and chimneys are more than just smelly and unsightly. They can adversely affect health leading to shortness of breath, asthma, stroke, cancer, heart attack, bronchitis and premature death. With time, technology has proved that stuff that can’t be touched can also be recycled and repurposed in the form of ink [1]. Substances causing pollution in the air are called air pollutants. These air pollutants can be categorized as primary and secondary Primary pollutants are directly emitted into the atmosphere. The intermingling and reactions between these primary pollutants form secondary pollutants.

Key primary pollutants include oxides of Nitrogen, Sulphur (SO_2), Carbon (CO, CO_2), Methane (CH_4) Particulate matter (PM), non-methane Volatile Organic Compounds (NMVOCs), Black Carbon (BC). Nitrogen monoxide and Nitrogen dioxide are together called Nitrogen Oxides or NO_X. NMVOCs include benzene (C_6H_6) and certain metals and Polycyclic Aromatic Hydrocarbons (PAHs) including benzo[a]pyrene (BaP). Key secondary air pollutants include PM, ozone(O_3), NO2 and several oxidized VOCs. The precursor gases for secondary PM include SO_2, NO_X, VOCs and NH_3 [2]. Exhaust gas or flue gas is a result of the combustion of fuels such as natural gas, gasoline, diesel fuel, fuel oil, biodiesel blends, coal, etc. The components of the exhaust gases mainly depend on the type of engine being used [3]. Diesel engines are widely used in industries due to their durability, reliability and low maintenance. They also have a very high energy density, that is for the same amount of gasoline more energy can be extracted. Due to this, it can be regarded as thrifty and efficient. But diesel engines are also one of the largest contributors to air pollution. This is because they produce high amounts of particulates also called Soot.

Black Carbon (BC) commonly called as Soot is a particulate material produced by incomplete combustion of fuels which contains carbon in large amounts. 80% or more by mass of soot constitutes carbon atoms. The morphology of black carbon is similar to the carbon black. Thus, this soot can be replaced with Carbon black. Carbon black is a material produced with the thermal decomposition method or the partial combustion method using hydrocarbon such as oil or natural gas as raw material. In contrast to this soot may be derived from waste oil, gasoline oil, diesel fuel, coal, coal-tar pitch, oil shale, wood, paper, rubber, plastics, resins or household refuse [4].

Carbon black is primarily used as a reinforcing agent in rubber, a black pigment in inks, coatings, and plastics, and to impart conductivity to rubber and plastics. The characteristics of carbon black vary depending on the manufacturing process, and hence carbon black is classified by manufacturing process as Furnace Black process, Channel process, Acetylene Black process and Lampblack process. The Carbon black produced with the furnace process is called as furnace black [5]. This soot is generally regarded as a waste whereas carbon black production uses a lot of hydrocarbons. The project is mainly about how to collect this soot and use it effectively. To reduce the pollutants in industrial processes, we use dust and particle filtration systems. Depending on the particle shape and its size considering flowability we use the collectors. The five main types of collectors used in industries are Cyclones, Electrostatic precipitators, Wet scrubbers, Fabric filters and High-temperature filters [6]. Although the wet scrubbing process is used these days in industries, the particulate matter is washed out into nearby water streams and landfills, which in turn causes pollution of water bodies.

The soot collector we are using is a cylindrical component that is retrofitted to the tail pipe of the engine exhaust. The active carbon filter along with the electrostatic filter aids in trapping the soot. The electrostatic filter charges the soot particles in the exhaust gas and makes them stick to the filter paper. The trapped soot is collected. The soot further undergoes a few chemical treatment processes.

The collected soot can be further used for different applications, for example- the paper was written with the vision of using carbon black waste – a hazardous solid residue generated from gasification of crude oil bottom in refineries – was successfully used for making an absorbent material [7]. In another case, the authors explained the generation of waste soot from diesel engines of merchant ships that have ≥ 2 μm agglomerates consisting of 30–50 nm spherical particles, whose morphology is identical to that of carbon black (CB) used in many industrial applications. It was found that waste soot generated from ship engines can be converted to novel and useful energy material through a heat-treatment process [8].

II. METHODOLOGY

1. 1. DESIGN

The soot collector is a device that is designed to collect the soot that is being introduced into the atmosphere through exhaust gases. Exhaust gases have many sources mainly in industries and automobiles. This project was done on a single-cylinder four-stroke diesel engine. An active carbon filter was used as a filter in order to trap the soot. It was paired with a stainless-steel mesh in order separate other large particles like dust from the soot. The soot collector was designed with reference to the design of a muffler or silencer. The standards of a muffler generally used for diesel generators are presented in Table 1. The soot collector was designed similarly to an End-inlet and End-outlet silencer. An End-inlet and End-outlet silencer has the inlet and the outlet connections with the centerline along the axis of the silencer itself.

The soot collector is designed in order to not affect the efficiency of the diesel engine to the extent that it worsens the performance of the engine. The main characteristic that causes a decrease in the efficiency of diesel engines is because of the created backpressure. Backpressure can be defined as the resistance or force opposing the desired flow of fluid through pipes, leading to friction loss and pressure drop**.** As the backpressure increases it becomes difficult to evacuate the exhaust gases from the combustion chamber. The more exhaust gases remain in the chamber, the lesser the efficiency. It also increases the temperatures inside the engines. It can also be said that the backpressure affects the piston work. The more the back pressure the harder the piston must move to evacuate the gases. This means there is more piston work. This leads to less power being given to the engine in order to run. Thus, it can be said that backpressure plays a very important role in the performance of the engine.

1.1 Design of Soot Collector

The design of Soot Collector is based on End-inlet and End-outlet Silencer of Industrial grade.An End-inlet and End-outlet silencer has the inlet and the outlet connections with the centerline along the axis of the silencer itself [9].

The pipe diameter was considered as 4.2cm which is the diameter of the exhaust pipeline of the diesel engine. With the help of suitable ratios, the length and diameter of the body of the soot collector are decided. Taking the ratios as-

Body/Pipe = 2
Length/Pipe = 6.5
The following parameters can be found below
Pipe Inlet diameter = 2”
Pipe Outlet diameter = 4”
Length of the soot collector = 13”
Based on the above parameters, a soot collector is designed in SOILDWORKS 2016 software.

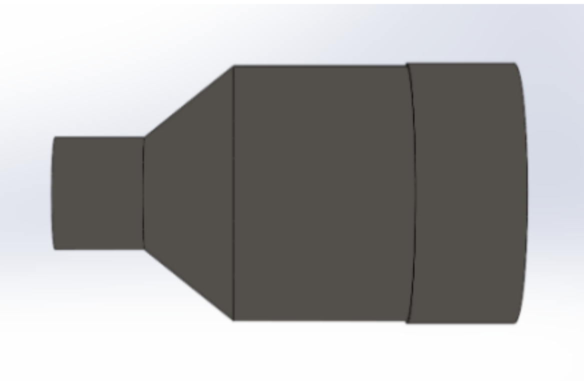


Fig. 1.1 Front view of Soot Collector

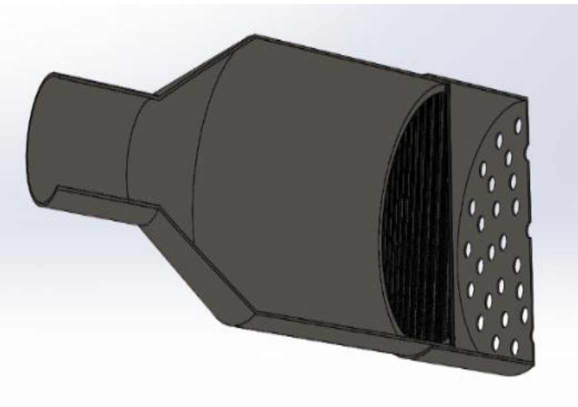


Fig. 1.2 Sectional view of Soot Collector

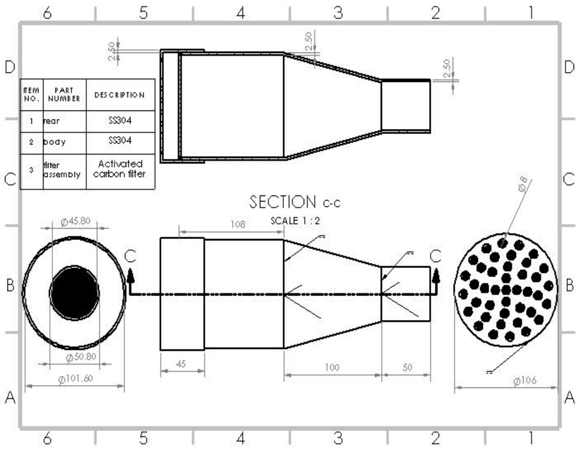


Fig. 1.3 Sheet drawing of Soot Collector

1.2 Design of Heat Exchanger

The heat exchanger design is as a shell-tube heat exchanger in SOLIDWORKS 2016. It consists of a copper coil inside the outer shell of the heat exchanger through which the coolant passes.

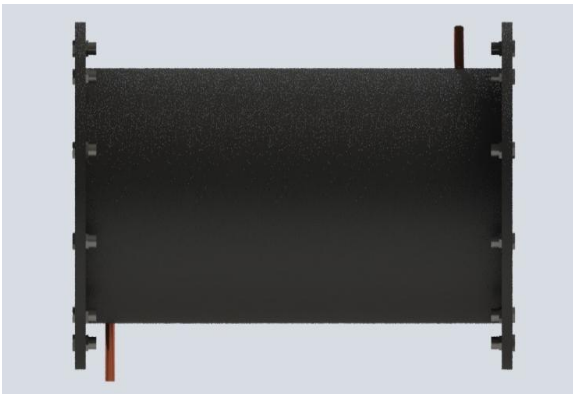


Fig 1.4 Front view of Heat Exchanger

III. ANALYSIS/ SIMULATIONS

The CFD simulations for the Soot Collector are done on ANSYS 2022 R1. ANSYS is a general-purpose, finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/dynamic, structural analysis, heat transfer, and fluid problems, as well as acoustic and electromagnetic problems.

2.1 Analysis of Soot Collector

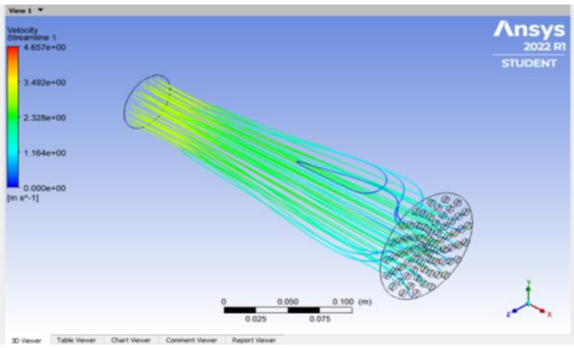


Fig. 2.1 Velocity Streamline

The above figure shows the velocity streamline of the exhaust gases in the Soot collector. The inlet velocity of the exhaust gases coming from the heat exchanger is 3m/s. It shows the path that is being traced by the fluid particles.

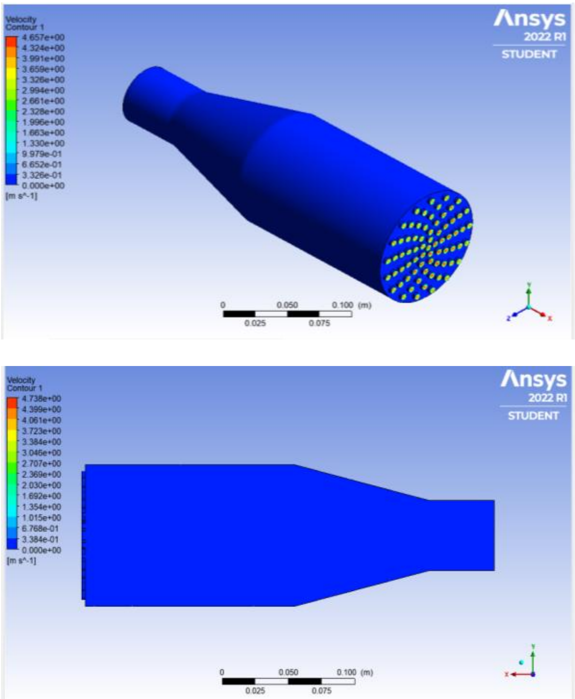


Fig 2.2 Velocity Contour

The velocity contours tell about the velocity at different positions. The velocity at the inlet is 3m/s and the velocity at the outlet i.e., at holes is 3.95m/s. The velocity is slowly decreasing until it reaches the end where the area is reduced because of the presence of holes on the cap.

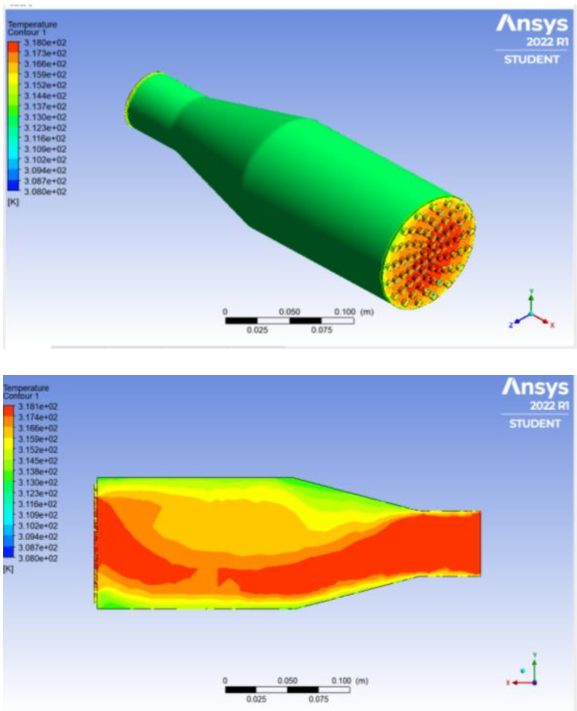


Fig 2.3 Temperature Contours

The above simulations show the temperature of exhaust gases throughout the Soot Collector. The temperature at the inlet, Temperature at the Outlet, and Temperature at the wall are 318K, 308K, and 313K respectively.

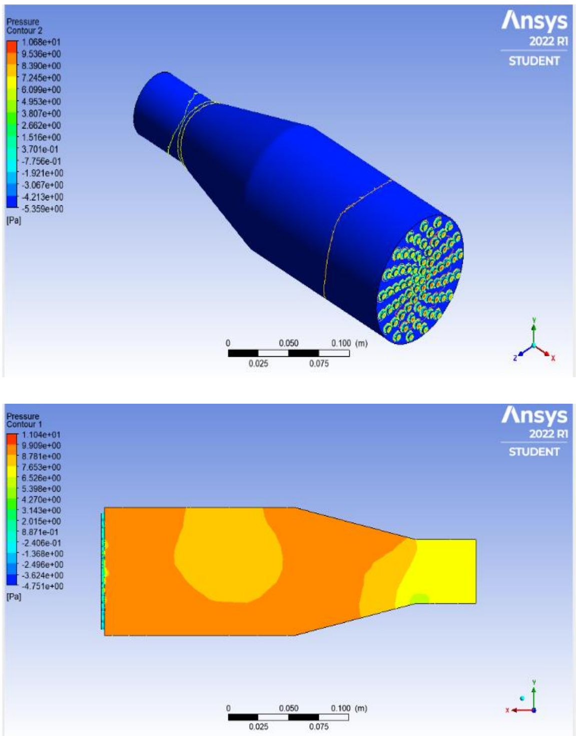


Fig. 2.4 Pressure Contours

The simulations tell us about the Pressure Contour. It is observed that the change in pressure is consistent there is no sudden rise or fall in the pressure this is because of the tapered cross-section that is given to the Soot Collector. The maximum gauge pressure is 1.068e+0.1 and the minimum is -5.359e+00.

2.2 Analysis of Heat Exchanger:

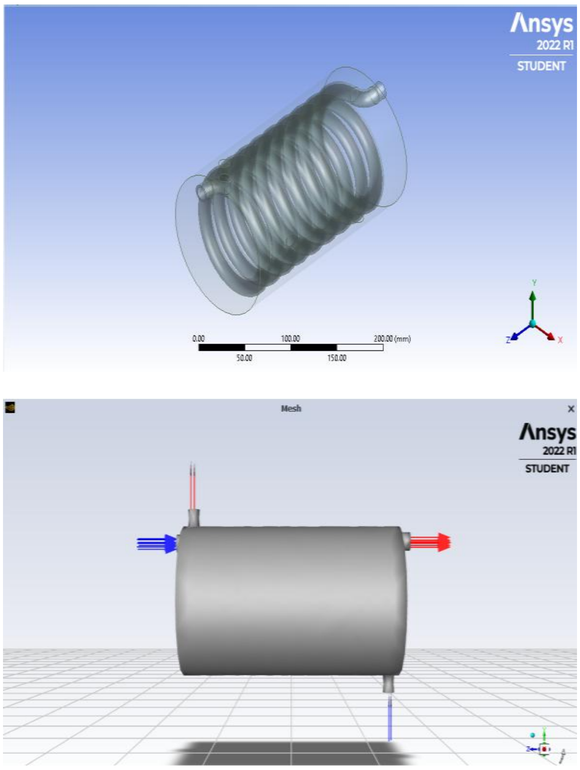


Fig. 2.5 Heat Exchanger model in Ansys

The above figure clearly shows the flow of both hot fluid and cold fluid. It can be seen that the hot fluid is flowing through the coil and the cold fluid is flowing in the outer shell. The heat is exchanged between hot fluid and cold fluid. Thus, the temperature of hot fluid decreases. The red line is indicating higher temperatures and the blue line is indicating lower temperatures. Here the hot fluid is exhaust gases i.e., nitride-carbon-oxide (nco) and the cold fluid is water-liquid.

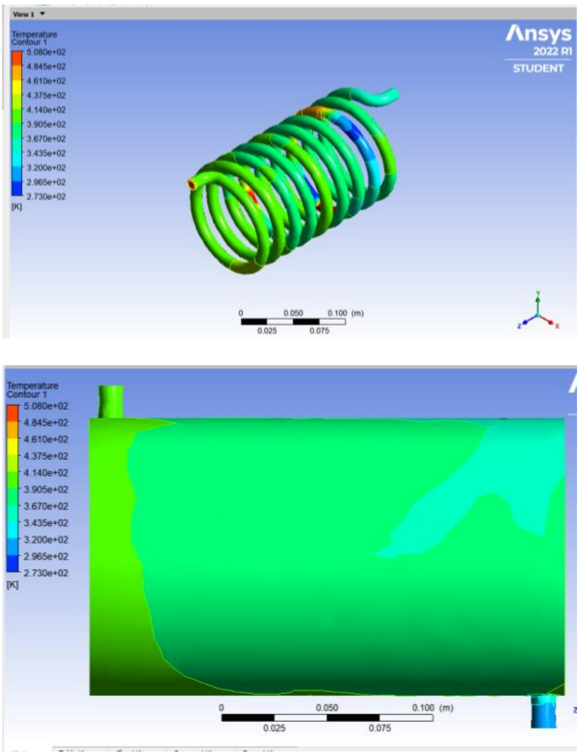


Fig. 2.6 Temperature contours of heat exchanger

These temperature contours tell us the temperatures at different places in the heat exchanger. Here the exhaust gases (Hot fluid) are entering the heat exchanger at 508K and leaving the heat exchanger at 318K. While the water is entering at 300K and exiting at 305K. The temperatures were taken after recording the values using thermocouples.

IV. FABRICATION

3.1 Fabrication of Soot Collector

The setup was fabricated at Matrusri Engineering College. There were a series of modifications to reach the final design. We approached a trial-and-error method so that we can process errors while manufacturing.

The soot collector was fabricated using AISI 304 stainless steel (UNS S30400) pipes. The soot collector is attached to a shell tube heat exchanger in order to decrease the temperature of exhaust gases. The soot collector mainly has 3 components-

- Inlet: The inlet of the pipe is where the soot collector is attached to the outlet of the heat exchanger. The inlet is a combination of three different cross-sections. A 2” pipe and a 4”-2” tapered section and then a 4” pipe. This is designed in order to make sure there is a gradual increase in cross-section area so that there is no sudden increase in pressure or decrease in velocity.

- Filter: The filter is having a combination of 3 parts. It consists of a metal mesh, an activated carbon filter and beading to hold the mesh and activated carbon together.

- Exhaust: The exhaust again has a fabric filter in order to catch any extra soot that is not filtered and is suspended in the air. The exhaust section of the soot collector is a cap attached to the end where the filter is placed.

Since the exhaust gas temperatures are very high, a heat exchanger is installed in between the exhaust tailpipe and the soot collector. The heat exchanger is a concentric tube counterflow heat exchanger. The heat exchanger consists of a shell of 180mm in diameter and 400mm in length. A copper coil is circulated inside the copper coil. Water absorbs the heat from the exhaust gases and reduces temperatures from 240°C to 50°C

The shell of the heat exchanger is covered with a sponge in order to avoid convection and the sponge is secured by a sheet metal casing. Thermocouples are placed at the inlet of the exhaust gases, the outlet of the exhaust gases, the inlet of water in the coil, and the outlet of the water in the coil. Thermocouples record the reading of respective temperatures. The heat exchanger also has a drain where the water that is heated from the exhaust gases is let out. placed inside the shell.

Fig. 3.1 Heat Exchanger

T_{h1}= Inlet temperature of the exhaust gases
T_{h2} = Outlet temperature of the exhaust gases
T_{c1} = Inlet temperature of the coolant
T_{c2} = Outlet temperature of the coolant

Fig. 3.2 Soot Collector

The soot collector is attached to the cold gas outlet of the heat exchanger. The inlet is a 2” diameter SS304 pipe. The area of cross-section gradually enlarges to twice its size i.e., 4”. The total length of the pipe is 13”. The Soot collector has a thickness of 25mm.

To the body of the Soot collector, a filter is soldered to its periphery. The filter is a combination of an active charcoal filter placed in between 40-grade Stainless Steel mesh. The active charcoal filter and the mesh are together beaded with Aluminium. The active charcoal fiber helps in trapping the soot and the metal mesh helps to filter out large dust particles. The collected soot must be as fine as possible. The body is again enclosed with a cap that is perforated and also contains filter paper. This filter paper traps the soot if there is any possibility of a fallout. The exhaust gas enters the inlet with a certain velocity and slowly loses it as the cross-sectional area as well as increases. This helps in the effective collection of soot. The length aids in collecting soot as the length increases it has ample time to settle down inside the pipe. It is made sure that there is very less backpressure involved in this case.

3.2 Fabrication of ink

The collected soot from the soot collector is carefully taken out and stored in a container. Fabrication of ink involves the following steps.

I. **After treatment of the soot**: the soot is first mixed with water in order to separate impurities. It is then heat-treated to improve its mixability. A small amount of oil is further added to make it into a pigment.

II. **Mixing of solvents and binders**: Solvents such as n-Butanol (NBA), Ethyl Acetate, Isopropyl Alcohol (IPA) and Toluene and

Polyvinyl Acetate (PVAC) or Polyvinyl Chloride is used as a resin. These are mixed together using a stirrer. They are thoroughly mixed and the pigment is then added to the mixture. The solvents then get the colour black because of the presence of the soot in them.

III. **Ink testing**: Stalagmometry method or Drop count method. The principle of this method is to measure the weight of drops of a fluid of interest falling from a capillary glass tube and thereby calculate the surface tension of the fluid [10] and [11]. A stalagmometer device is used in this method as shown in Fig 3.3. Once, the surface tension of the ink is measured and compared with standard ink surface tension.

Experimental procedure:

1. Soot is collected in a container and heated in a furnace.
2. The heated soot is mixed thoroughly in 2M HNO_3.
3. Using filter paper, the soot mixture is separated from the solution. The mixture is dried until it has no noticeable moisture
4. Castor oil or petroleum jelly is added to the soot.
5. 6ml of Toluene, 6ml of IPA, 2.5ml NBA and 3ml of Ethyl Acetate is mixed with 6mg of resin Polyvinyl Chloride which is available in Fevicol.
6. To this mixture 0.5mg soot is added to give the colour to the medium.
7. The prepared ink was tested using Stalagmometer and compared with the ink available in the market.

Fig 3.3 Stalagmometer with ink

Fig 3.4 Collected soot

Fig 3.5 Preparation of ink.

III. TABLES AND OBSERVATIONS

Table 1 Standard Design values of Silencer of different grades

Grade	Ratio
Industrial/Commercial Grade	
Body/Pipe	2 to 2.5
Length/Pipe	5 to 6.5
Residential Grade	
Body/Pipe	2 to 2.5
Length/Pipe	6 to 10
Critical Grade	
Body/Pipe	3
Length/Pipe	8 to 10
Super Critical Grade	
Body/Pipe	3
Length/Pipe	10-16

The experiment was carried out for two days on a single-cylinder 4-stroke diesel engine. The experiment was done two times, with a Heat exchanger and Soot collector and without a Heat exchanger and Soot Collector. The experiment was conducted on 23-04-2022 and 12-05-2022. Four different loads are applied to the setup. The trapped Soot is collected and measured. All the values are put together in tables and graphs are drawn.

For Soot Collector and Heat Exchanger:

Table 2 Performance of Diesel engine without Heat exchanger and Soot Collector

Load (Kg)	**Speed (rpm)**	**Water meter reading in cm**		**Outlet temperature in °C**	**η_{Vol} %**	**$V_{exhaust}$ m^3/s**
		h_1	**h_2**			
No-load	1611	7.5	7.7	235	68.70%	8.62×10^{-3}
1	1572	7.2	7.5	265	69.17%	8.98×10^{-3}
2	1563	7	7.3	295	68.62%	9.35×10^{-3}
3	1555	6.9	7.1	322	68.23%	9.69×10^{-3}
4	1548	6.7	7	340	67.80%	9.88×10^{-3}

Table 3 Performance of Diesel engine with Heat exchanger and Soot Collector

Load (Kg)	**Speed (rpm)**	**Water meter reading in cm**		**Outlet temperature in °C**	**η_{Vol} %**	**$V_{exhaust}$ m^3/s**
		h_1	**h_2**			
No-load	1606	7.6	7.6	32	68.36%	5.27×10^{-3}
	1582	7.4	7.4	43		
1	1579	7.3	7.3	39	67.48%	5.28×10^{-3}
	1564	7	6.9	50		
1.5	1562	7.2	7.2	42	67.02%	5.3×10^{-3}
	1549	7	6.9	54		
2.5	1552	6.8	7.2	46	65.84%	5.3×10^{-3}

Table 4 Effect of Heat Exchanger

Load (kg)	**Exhaust gas Temperature at Heat exchanger inlet in °C**	**Exhaust gas Temperature at Heat exchanger outlet in °C**
0	84	32
	192	43
1	130	39
	193	50
1.5	136	42
	230	54
2.5	149	46
	246	58

Surface tension of ink by Stalagmometry or Drop count method:

Table 5 Surface tension of ink

Liquid sample	**No. of drops**			**Average no. of drops (n)**	**Weight of the sample with beaker (g)**			**Average weight (g)**	**Density (ρ) (g/ml)**	**Surface tension (γ) (dyne/cm)**
	1	**2**	**3**		**1**	**2**	**3**			
Distilled water	39	42	42	41	59.9	59.4	59.5	59.6	0.99	72
Soot (Ink)	71	73	74	73	59.7	59.8	59.8	59.8	1.01	41.2

Table 6 Soot Collected and respective load

LOAD (kg)	**SOOT COLLECTED (mg)**
0	50
1	60
1.5	110
2.5	170

IV. CALCULATIONS

Performance of Diesel Engine without Heat Exchanger and Soot Collector

At no load:

1. $h = h_1+h_2 = 7.5+7.5 = 15.0$ cm

2. Velocity of air

$$V_a = \sqrt{\frac{2gh}{100} \times \left(\frac{\rho_w}{\rho_a} - 1\right)}$$

$$= \sqrt{\frac{2\times9.81\times15.0}{100} \times \left(\frac{1000}{1.29} - 1\right)} = 48 \text{ m/s}$$

3. $V_{act} = C_d \times A_o \times V_a$

$$= 0.6 \times \frac{\pi}{4} \times 15^2 \times 10^{-6} \times 48.05$$

$$= 5.095 \times 10^{-3} \text{ m}^3/\text{s}$$

4. $V_{th} = \frac{\pi}{4} \times D^2 \times L \times \frac{N}{2\times60}$

$$= \frac{\pi}{4} \times (80 \times 10^{-3})^2 \times 110 \times 10^{-3} \times \frac{1611}{2\times60}$$

$$= 7.42 \times 10^{-3} \text{ m}^3/\text{s}$$

5. $\eta_{vol} = \frac{V_{act}}{V_{th}} = \frac{5.095\times10^{-3}}{7.42\times10^{-3}} = 68.7\%$

6. $V_{exhaust} = \frac{T}{300} \times V_{act}$

$$= \frac{(235+273)\times 5.095\times10^{-3}}{300} = 8.62\times10^{-3} m^3/s$$

Performance of Diesel Engine with Heat Exchanger and Soot Collector

At no load:

1. $h = h_1 + h_2 = 7.6 + 7.6 = 15.2$ cm

2. $V_a = \sqrt{\frac{2gh}{100}\times(\frac{\rho_w}{\rho_a}-1)}$

$$= \sqrt{\frac{2\times9.81\times15.2}{100}\times(\frac{1000}{1.29}-1)} = 48.05 \text{ m/s}$$

3. $V_{act} = C_d \times A_o \times V_a$
$= 0.6\times\frac{\pi}{4}\times15^2\times10^{-6}\times48.05$
$= 5.095\times10^{-3}$ m^3/s

4. $V_{th} = \frac{\pi}{4}\times D^2\times L\times\frac{N}{2\times60}$
$= \frac{\pi}{4}\times(80\times10^{-3})^2\times110\times10^{-3}\times\frac{1606}{2\times60}$

$= 7.399\times10^{-3}$ m^3/s

5. $\eta_{vol} = \frac{V_{act}}{V_{th}} = \frac{5.095\times10^{-3}}{7.399\times10^{-3}} = 68.36\%$

6. $V_{exhaust} = \frac{T}{300}\times V_{act}$

$$= \frac{(37.5+273)\times5.095\times10^{-3}}{300} = 5.27\times10^{-3} m^3/s$$

Surface tension of ink by Stalagmometry or Drop count method:

Weight of the beaker = 51.51 g
W_1 (Weight of the distilled water)
= Average weight of the distilled water with beaker-Weight of the beaker
= 59.68 - 51.51
= 8.17 g
W_2 (Weight of the ink)
= Average weight of the ink with beaker – Weight of the beaker
= 59.81 – 51.51
= 8.3 g

Density of the ink (ρ_2) = $\frac{\text{Mass of the liquid (ink)}}{\text{Mass of equal volume of water}}$

$$= \frac{W_2}{W_1} = \frac{8.3}{8.17} = 1.016 \text{ g/ml}$$

Density of water at room temperature
(ρ_1) = 0.997 g/ml (Standard value)

Surface tension of water at room temperature
(γ_1) = 72 dyne/cm (Standard value)

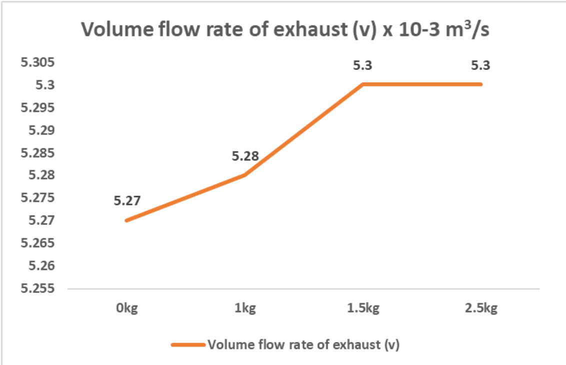
Surface tension of ink (γ_2) = $\frac{\rho_2\times n_1}{\rho_1\times n_2}\times\gamma_1$

$$= \frac{1.016\times41}{0.997\times73}\times72$$

= 41.21 dyne/cm

Most inks fall into the range of 25-60 dynes/cm, but when it is subjected to dynamic conditions, their surface tension behaves like it has a value of 40 dynes/cm [12].

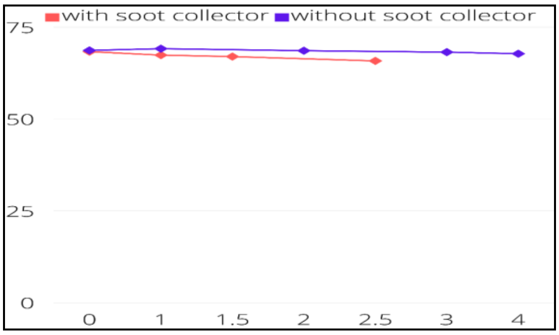
V. GRAPHS



Graph 1 Exhaust Flow rate

The above graph tells us about the volume flow rate of the exhaust gases at different loads. It can be observed that the volume flow rate is increasing as the load increase.

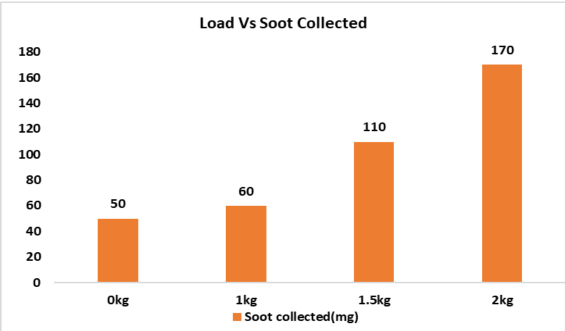
Comparing the performance of the engine before and after installation of Soot Collector.



Graph 2 Efficiency of Diesel Engine with and without Soot Collector

The above graph tells us that there is a very little difference in the efficiency of both setups. This is because of the back pressure that is being created because of the filter that is installed inside the soot collector. As the flow area is very low it might increase the back pressure.

The collected soot at different loads is measured. The Table 6 shows the soot collected in milligrams with the respective loads applied.



Graph 3 Soot collected at different loads

The above graph shows that as the load on the engine increases the mass of the soot collected also increases. This is because as the load is more the engine needs more fuel to run this will in turn increase the soot generation.

V. CONCLUSIONS

Based on the experiments the following conclusions were drawn-

The total collected soot on a 40min run of a Single cylinder four-stroke diesel engine at different loads is 430mg. The total ink that can be formed from 0.5g of Soot is 5ml. The efficiency of the engine without a Soot Collector is around 68.504% and with Soot Collector is around 67.175% which shows a decrease in efficiency but not considerable. The Soot Collector is increasing the back pressure but it does not exceed the maximum allowable. The surface tension of the ink that is measured by the stalagmometer is 41.21dyne/cm. The manufactured ink is water resistant and also UV resistant. The process is quite long and time taking. There is more material that is being wasted in the process of filtration. The disposal of filtered-out products in the process of preparation might affect the environment.

Therefore, Using the Soot Collector did decrease the percentage of particulate matter in the exhaust gases. The ink was successfully prepared from the collected Soot. It can be said that it is feasible for a filtration process. This will decrease pollution in the environment and also safe to use on vehicles. This project can be improved in the following ways by providing future work in-

The Soot Collector filter should removable so that it is easier to collect the soot from the filter. Sensors that can detect particulate matter can be added to the system to indicate the level of particulate matter that is trapped in the filter. Soot also contains PAHs along with heavy metals. Procedures to remove these PAHs must be introduced. It can also be designed such that it can be used for all purposes which emit soot with exhaust gases. The exhaust gases are very high in temperature. The filters might not be able to withstand such high temperatures. The filters must be installed such that they are heat resistant. The system should be made such that it can be portable. So that it is easy to collect the Soot. The Soot Collector should not only collect soot but also should be able to eliminate harmful gases like NOx and CO gases.

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