SOOT REMOVAL SYSTEM USING ELECTROMAGNETIC WAVE HEATING FOR VEHICLE EXHAUST AFTER TREATMENT

MUHAMMAD FARHAN MOHD YATIM

MECHANICAL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

JANUARY 2020

SOOT REMOVAL SYSTEM USING ELEGTROMAGNETIV WAVE HEATING FOR VEHICLE EXHAUST AFTER TREATMENT

by

MUHAMMAD FARHAN MOHD YATIM

24769

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical)

JANUARY 2020

Universiti Teknologi PETRONAS

Bandar Seri Iskandar,

32610 Seri Iskandar,

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

SOOT REMOVAL SYSTEM USING ELEGTROMAGNETIV WAVE HEATING FOR VEHICLE EXHAUST AFTER TREATMENT

by

MUHAMMAD FARHAN MOHD YATIM
24769

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL)

Approved by,

AP Dr Zainal Ambri Bin Abdul Karim

10-4-2020

UNIVERSITI TEKNOLOGI PETRONAS

SERI ISKANDAR, PERAK

JANUARY 2020

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

MUHAMMAD FARHAN MOHD YATIM

Date : 10-4-2020

ABSTRACT

The electromagnetic soot removal system trap particulate particles from the exhaust gas of diesel engines. The efficiency of the trap is defined by the effectiveness of the trap to filter the particles. Since the new prototype was used, the effectiveness of the soot removal system has not been ascertain. This can be done by laboratory experiment to analyze the electromagnetic soot removal system. The objective of this research focused on analyzed the electromagnetic wave soot removal system regarding gas velocity after soot trap(filter) element at various outlet opening and gas velocity with different soot particle loading in filter element. From the experiment has been done, the finding shown various outlet opening and different soot particle loading in filter element give significant different in gas velocity measured.

ACKNOWLEDGEMENT

In the name of Allah SWT The Most Gracious and the Most Merciful all praise to Him that His will I managed to complete this final year project within allocated time. Deepest gratitude to my family, who is always giving moral support and encouragement that has been a great inspiration to survive all difficulties in completing this project. Special appreciation is dedicated to project supervisor, Dr Zainal Ambri bin Abdul Karim for precious advices and guidance not only limited to project completion but also for future undertaking. Thank you for the countless hour in knowledge and valuable experiences sharing throughout the supervision. May Allah bless and repay all the kindness and good deeds.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

\

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, car pollution is one of the major issue among us. This issue have been highlighted for a long time since transportation such as diesel vehicle had been common transport among us in our country. The main reason why the issue need to be highlight due to diesel engine produce variety of particle during combustion of fuel due to incomplete combustion. This including excessive amount carbon dioxide and other dangerous gasses emission toward environment that cause harm toward health, also to environment such as global warming.

One of the ways to reduce the emission of these excessive amount of dangerous gas toward environment is installation of Diesel Particulate Filter (DPF) in the vehicle. DPF is a filter that capture and store exhaust soot in order to reduce emission from diesel car. Since the DPF that available in current market have finite capacity, these trapped soot periodically has to be emptied or burn off to reuse the DPF.

The electromagnetic wave soot removal system prototype is shown in Figure 1.1. As shown, there are 2 crucial part that affect the performance of prototype which was the filter and the magnetron. The filter act as the trap of soot particles and the magnetron supplied the heat energy to burn the soot particle in filter element.

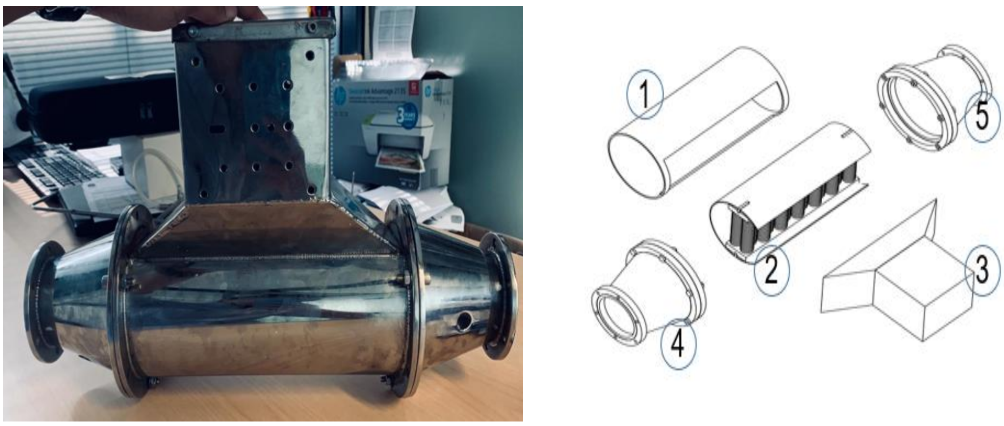


Figure1.1: Electromagnetic wave soot removal system prototype

Table1.1: Diesel Particulate Filter (DPF) prototype

NUMBER	Name
1	Body cover
2	Filter Element
3	Magnetron and Transformer
4	Inlet
5	Outlet

The process of empting and burning off trapped soot called regeneration. This regeneration process cleanly burn off the excess soot deposited in the filter, reducing the harmful exhaust emission and help to prevent the black smoke that used to see from diesel vehicle, particularly when accelerating.

The engine will ultimately cease to function if no action is applied to remove the accumulating particles. Passive regeneration, active regeneration, and mixed passive-active regeneration are the three main regeneration methods. After the regeneration process occur, the burnt particle leaved the DPF through exhaust gases. This recycle will repeat until the filter become clogged. When the filter turns clogged, efficiency of DPF to filter the soot will drop and the filter needs to be replaced. To overcome these problem, one of the idea is to eliminate the excessive particle in filter by electromagnetic wave heating.

Basically, the DPF used for the project was similar to the current DPF available in market but with addition function of eliminate the excessive particle in filter by electromagnetic wave heating. With this addition function, the filter does not need to be replaced and can be used repeatedly and efficiency of the DPF can be maintained.

The pressure drops increase with the soot deposits on the filter wall, the microwave generator starts to work when the pressure drop reach into certain value. It can provide microwave energy to the filter and then to heat the soot trapped on the filter wall to its ignition temperature until its complete combustion.

The working principle of the microwave generator can be seen in Figure 1.2. A portion of the alternating current generated by the power source is converted into high voltage direct current through a low voltage transformer. High voltage transformer and rectifier voltage doubling circuit are loaded on the anode of the magnetron to produce a strong electric field. Another part of the alternating current is converted into filament voltage by low voltage transformer to heat up the cathode of magnetron to emits electron. The microwave power from the magnetron is transmitted through coaxial cable to DPF and propagated through circular waveguide in the DPF to heat the filter body and soot particles.

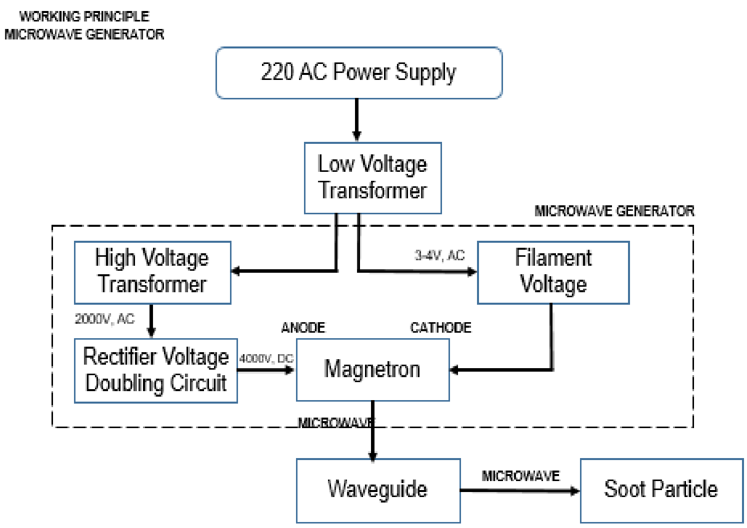


Figure1.2: Microwave heating working principle

1.2 Problem Statement

Diesel Particulate Filter (DPF) is a device that act as soot removal system in the vehicle. New design of DPF already been build in addition the function of microwave heating inside the DPF. Eventhough prototype DPF already been build, the effectiveness of the filter and efficiency of the soot removal have not ascertain yet..

.

1.3 Objective

The objectives is proposed in the following part to ensure the project is conducted with a set target, and at the same time does not exceed the defined boundary of the research to produce the desired output.

Based on the initial study, the objectives of the project are listed below:

- To analyse the electromagnetic wave soot removal system prototype regarding gas velocity after soot trap element at various opening.
- To analyse the electromagnetic wave soot removal system prototype regarding gas velocity with different soot particle loading in filter element.

1.4 Scope of study

The scope of study of project involved experimental work to analyse the electromagnetic wave soot removal system for diesel engine in:

- Gas velocity after soot trap element at various opening
- Gas velocity with different soot particle loading in filter element

CHAPTER 2

LITERATURE REVIEW

2.1 Diesel Particulate Filter

DPF is a filter that capture and store exhaust soot in order to reduce emission from diesel car. Since the DPF that available in current market have finite capacity, these trapped soot periodically has to be emptied or change the filter to reuse the DPF. Like any filter, the DPF will gradually get clogged with the soot that it traps. However, the car is designed to clean it by heating this residue up, turning it to ash and expeling it.

Firstly, soot particle from the engine will go inside the cross-section of filter element. Inside the filter element, there are two main important process occur which is filtration phase and regeneration phase. After the soot particle been filtered, the particle will release through filtered exhaust emission.

According to Orihuela et al. [3] The filtration efficiency of DPF can be calculated by comparing the number of concentration at inlet and outlet of DPF and comparing the pressure drop. For the experiment of the DPF, many different parameter can be varied such different fuel can be used because according to Yi Guo et al. [1] The performance of DPF varied for different fuels. It was shown that the increase in oxygen content of the fuel led to the emission of lower mass and particle number and changed size distribution as compared to diesel. Below is the example of result that have done by Yi Gu et al [1].

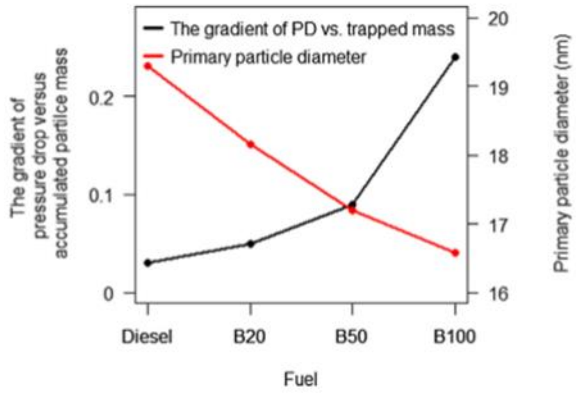


Fig. 11. The gradients of pressure drop as function of loaded particle mass (Primary Y axis) with primary particle diameter (Secondary Y axis) as a function of biodiesel blend percentages.

Figure2.1: The gradient of pressure drop versus accumulated particle with primary particle diameter. [1]

According Zhongwei Meng et al. [6] Efficiency of DPF can be calculated by:

$$\eta = \frac{M_2 - M_1}{M_1 - M_0} \times 100\% \quad (1)$$

$$Q_{in} = \int_{t_0}^{t} C_p q_m (T_1 - T_0) dt \quad (2)$$

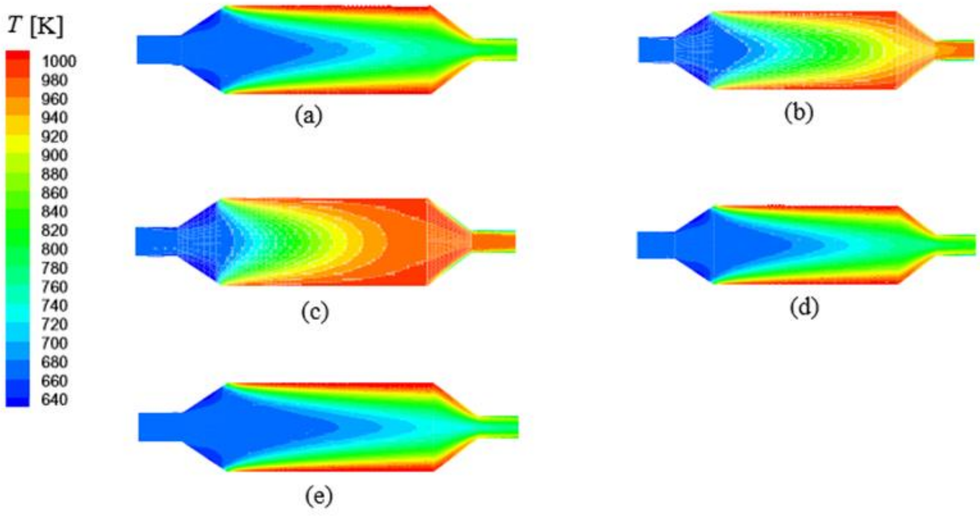
$$\varepsilon = \frac{\eta}{Q_{in}} \quad (3)$$

where *M0*, *M1*, and *M2* represent the mass of DPF before loading, the mass of DPF before regeneration and represents the mass of DPF after regeneration, respectively. *ε* represents a regeneration performance ratio and equal to the regeneration efficiency dividing the input heat (efficiency/energy). Where for ε or efficiency equation, *Qin*, *Cp*, *qm*, *T1*, *T0*, and *t* represent the heat quantity of air that flows into the DPF, the specific heat capacity, the mass flow rate of air, the regeneration temperature of DPF, the initial temperature of the incoming flow, and the regeneration time, respectively.

2.2 Electromagnetic wave heating

Microwave heating is a process whereby microwaves produced by magnetrons are directed toward reactants or heating medium, which absorb the electromagnetic energy volumetrically to achieve self-heating uniformly and rapidly. According to the proposed idea, microwave heating function will be installed inside DPF in order to burn out left particle in filter of DPF after regeneration phase.

According to E. Jiaqiang et al. [5] In order to stimulate the microwave assisted regeneration of the DPF when the trapped particle of the exhaust gas with high temperature lead to great pressure drop through porous media. Therefor some assumption of the model should be as (1) the mass fraction of carbon particle is little or negliable in transient emission. (2) Particle in channels of porous media are pure carbon particle with the same size in diameter and distributed uniformly on the channel wall. (3) All gasses are regarded as ideal gas and they meet with ideal gas equation. Below is the example result that have done by E. Jiaqiang et al. [5]



(a)v=12m/s; (b)v=24m/s; (c)v=36m/s; (d)v=48m/s; (e)v=60m/s

Figure2.2: Temperature contours under different inlet velocities [5]

From the above figure shown E. Jiaqiang et al. [5] Shown the particulate combustion is affected by the oxygen content. When the small velocity number causes the air flow through the particle trap is relatively slow and the oxygen brought into the filter is not enough to burn. When the airflow velocity increase from 12m/s to 60m/s, the amount of air brought into the filter body increase lead to the oxygen content more and more abundant. These will resulted a large number of particles in the filter body can be burned, making the temperature in the filter body more uniform after reaction.

E. Jiaqiang et al. [5] Also state that when the inlet velocity increase from 12m/s to 60m/s, the amount of air in wall-flow filter will increase. From the figure below E. Jiaqiang et al. [5] Show that a large number of particles in the wall-flow filter can be burned with sufficient oxygen content, which make the temperature in the particle filter more uniform after combustion reaction. (a) measurement value (b) simulation value.

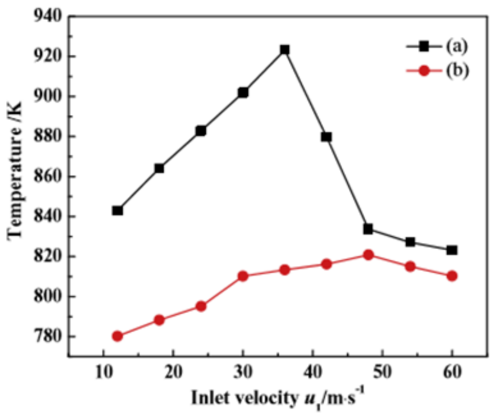


Figure 2.3: Temperature of the wall-flow filter under different inlet velocities [5]

CHAPTER 3

METHODOLOGY

3.1 Process Flow Chart

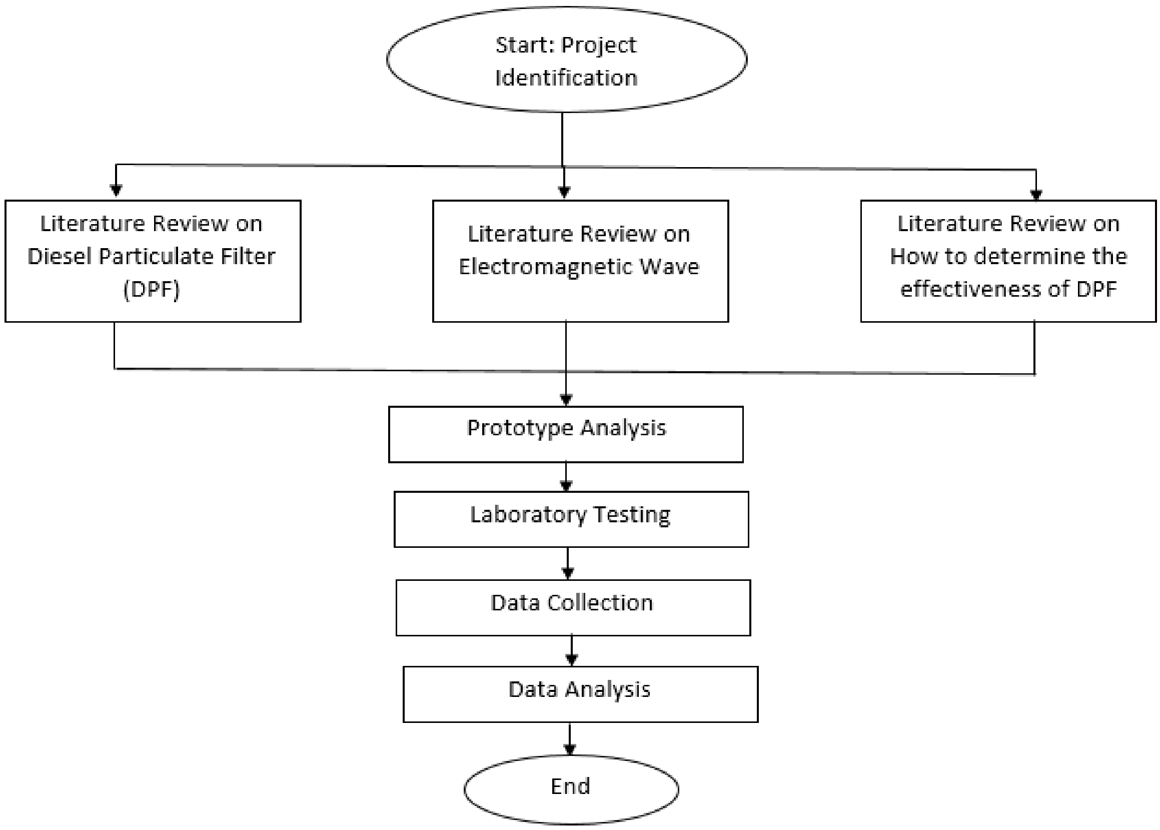


Figure3.1: Process flow chart

3.2 Laboratory Setup

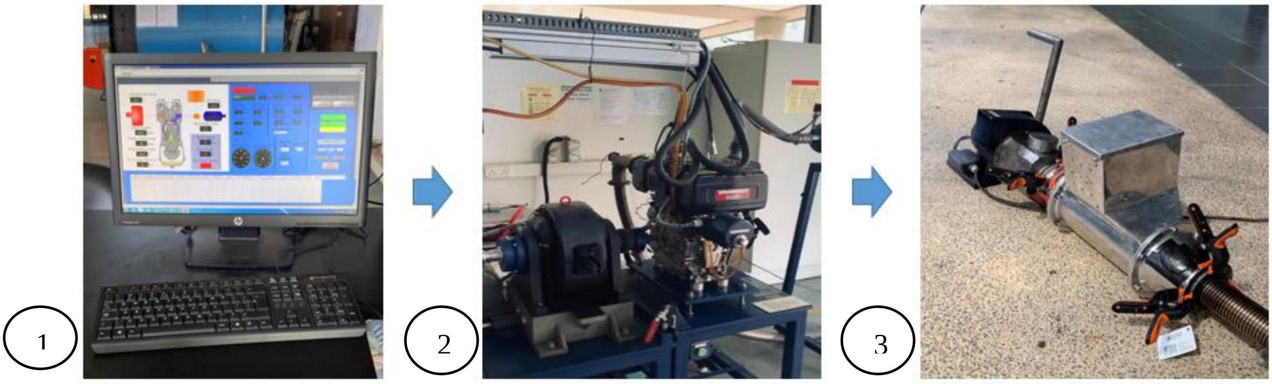


Figure 3.2: Laboratory setup arrangement

Table3.1: Laboratory setup description

NUMBER	EQUIPMENT	DESCRIPTION
1	Engine dyno software	Control the Diesel Engine
2	Dynometer and Diesel engine	Dynometer act as measurement equipement for diesel engine Diesel engine supply soot particle
3	Electromagnetic wave soot removal system	Act as filter for soot particle

• Engine supply soot particle to be tested.

• Different size of outlet opening used to get different condition flow rate along electromagnetic wave soot removal system since different condition (eg: no outlet opening, 25% outlet opening, 50% outlet opening, 75% outlet opening) needed to test in each set of experiment.

• Digital pitot tube is used to measure at inlet and outlet of DPF,

• Digital weight scale is used to measure trapped soot particles in filter.

3.3 List of variable

Fixed variable:

1. Type of engine: Vertical cylinder, four stroke cycle, air cooled diesel engine
2. Type of diesel: Petronas diesel Euro 5
3. Load applied: 75%
4. Electromagnetic wave soot removal system prototype

Manipulated Variable:

1. Percentage opening of blower (no outlet opening, 25% outlet opening, 50% outlet opening, 75% outlet opening)
2. Measured time engine run (1hour, 3 hour, 6 hour)

Responding Variable:

1. Gas velocity measured after soot trap(filter)
2. Gas Velocity with different soot particle loading in filter element.

3.4 Gantt Chart and Milestone

Table3.2: Final year project 1

DETAIL/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PROJECT DISCUSSION WITH SV	■													
IDENTIFY PROBLEM STATEMENT	■													
FIND DETAIL ON DPF		■	■											
FIND DETAIL ON ELECTROMAGNETIC FUNDAMETAL		■	■											
CONSTRUCT LITERATURE REVIEW ON RELATED TOPIC				■	■	■								
FIND ALL POSSIBLE EXPERIMENTAL DETAIL				■	■	■								
ESTABLISH GAP IN LITERATURE REVIEW				■	■	■								
COLLECTION OF PREVIOUS EXPERIMENT DATA							■	■	■					
METHODOLOGY PLANNING							■	■	■					
PROPOSAL DEFENSE										■				
EXPERIMENT SETUP											■	■	●	
PREPARATION OF INTERIM REPORT														■

Table 3.3: Final year project 2

DETAIL/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PROTOTYPE ANALYSIS	■	■												
LABORATORY TESTING			■	■	■	■	■	■						
DATA COLLECTION			■	■	■	■	■	■						
DATA ANALYSIS			■	■	■	■	■	●						
PREPARATION OF PROGRESS REPORT									■	■				
PRESENTATION											■			
PREPARATION OF FINAL REPORT DRAFT												■	■	
PREPARATION OF TECHNICAL PAPER												■	■	
PREPARATION OF PROJECT DISSERTATION													■	■

CHAPTER 4

RESULT AND DISCUSSION

4.1 Time engine run vs Trapped soot particles

Table 4.1: Time engine run vs Trapped soot particles

	Trapped Soot Particles in Filter, g
Clean Filter	0
1 Hour Engine Run	0.05
3 Hour Engine Run	0.89
6 Hour Engine Run	1.6

Based on the value obtained, highest value of trapped soot particles is recorded after 6 hour engine run. Also shown the value of trapped soot particle is directly proportional to how long the engine run.

4.2 Velocity vs Outlet opening (%)

Table 4.2: Velocity after soot trap element vs Outlet opening (%)

	100% outlet opening	75% outlet opening	50% outlet opening	25% outlet opening
0g, Velocity (m/s)	4.8	4.5	4.3	3.8
0.07g,Velocity (m/s)	4.8	4.5	4.3	3.7
0.94g, Velocity (m/s)	4.2	3.8	3.5	3.1
1.69g, Velocity (m/s)	3.4	3	2.8	2.5

Based on the value obtained, for 100% outlet opening condition record highest velocity compare to 25% outlet opening condition which is get smallest velocity (for clean filter). Smaller the percentage outlet opening caused velocity to decrease. The outlet opening is decreasing the blower used cannot be controlled. So by control the percentage of outlet opening, amount of gas went out can be controlled.

There are no significant change in velocity from 0g soot particle trapped in filter mass to 0.07g soot particle trapped in filter mass. These due the different value of trapped soot filter is too small to cause the velocity change happen. The difference is too small due to only short time engine run for the time being which only hour. Short time taken will affect less amount of soot particle trapped in filter element.

Also shown on the table, beside outlet opening, the velocity after filter element also affect by mass of trapped soot particle. Higher the mass of trapped soot particles will affect velocity decreasing due high pressure at outlet of electromagnetic wave soot removal system.

4.3 Velocity vs Outlet opening (%) trend

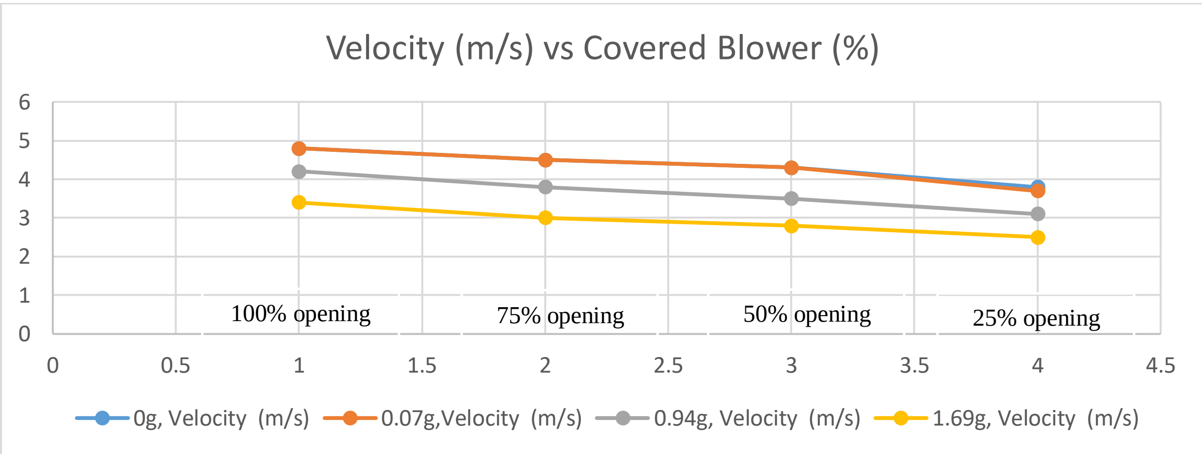


Figure 4.1: Velocity vs Outlet Opening (%)

As shown below, the line for 1.60g mass of trapped soot particle is at lowest part compare to the others. Line for 0g mass of trapped soot particles and 0.07g mass of trapped soot particles shown no significant difference since only 1 hour time of engine run. There no much soot particles inside the filter which will affect the velocity measured.

Also shown for for line 1.60g mass of trapped soot particle, 100% opening have the highest velocity compare to the 25% opening which have the lowest. These condition also applied for the other line which were 0.94g, 0.07g, 0g mass of trapped soot particle in filter.

The assumption can be made that higher mass of trapped soot particle in filter will affect the velocity measured after the filter element will decrease. Other factor also give significant difference to velocity measured after the filter element which is percentage of opening of outlet.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Electromagnetic wave soot removal system are the most popular after treatment system for the abatement of soot particles in the exhaust of diesel and gas vehicle. Decade of development have generated a deal of literature system. The magnitude of the automotive market worldwide, together with the increasing strict regulation in order to save environment, are still pushing the research activity in this field, which likely to continue growing over a long period.

Within the existing research studies on electromagnetic wave soot removal system, it is generally difficult to conclude about their level of development. Beside electromagnetic wave soot removal system are relatively complex system. Testing or experimental work of electromagnetic soot removal system need variability in experimental procedure make it difficult to compare result from different source.

The study of analyze the effect of velocity in electromagnetic wave soot removal system has shown there are several factor will give significant difference in value measured which is mass of soot particle trapped in filter and outlet opening.

As shown at previous chapter, higher mass of soot particle trapped in filter will cause the velocity will decrease due high pressure at outlet compare to at filter element. While for outlet opening, smaller percentage outlet opening will affect the velocity also decrease.

5.2 Recommendation

As stated above, there are many type of experimental work that can be done in study of electromagnetic wave soot removal system. Since these research only focus on effect of outlet opening and mass of trapped soot particle in filter element to velocity after element, in the future work analyze of electromagnetic wave soot removal system with regeneration can be done.

REFERENCES

[1] Guo Y, Stevanovic S, Verma P, Jafari M, Jabbour N, Brown R, Ristovski Z, "An experimental study of the role of biodiesel on the performance of diesel particulate filters," *Fuel*, vol. 247, pp. 67-76, 2019.

[2] Patil V, Navale, L. G, & Talib M, "Effect of Silica Gel based Diesel Particulate Filter on a C.I. engine," *Materials Today: Proceedings,* vol. 4, no. 8, p. 7680–7685, 2017.

[3] Orihuela, M. P, Gómez-Martín, A Miceli, P Becerra, J. A, Chacartegui R, & Fino D, "Experimental measurement of the filtration efficiency and pressure drop of wall-flow diesel particulate filters (DPF) made of biomorphic Silicon Carbide using laboratory generated particles," *Applied Thermal Engineering,* vol. 131, p. 41–53, 2018.

[4] Zhong C, Gong J, Liu W, & Liu G., "Low temperature, medium temperature and high temperature performance of the continuous regenerative diesel particulate filter assisted by electric regeneration," *Chemical Engineering Science,* vol. 207, p. 980–992, 2019.

[5] Jiaqiang E, Zhao X, Xie L, Zhang B, Chen J, Zuo Q & Zhang Z. , "Performance enhancement of microwave assisted regeneration in a wall-flow diesel particulate filter based on field synergy theory," *Energy,* vol. 169, p. 719–729, 2019.

[6] Meng Z, Li J, Fang J, Tan J, Qin Y, Jiang Y, Liang K, "Experimental study on regeneration performance and particle emission characteristics of DPF with different inlet transition sections lengths," *Fuel,* pp. 116-487, 2019.

[7] E J, Zhao X, Liu G, Zhang B, Zuo Q, Wei K, Gong J., "Effects analysis on optimal microwave energy consumption in the heating process of composite regeneration for the diesel particulate filter," *Applied Energy,* vol. 254, pp. 113-736, 2019.

[8] Houston A, Clyne T, "Highly Porous Hybrid Particle-Fibre Ceramic Composite Materials for use as Diesel Particulate Filters," *Journal of the European Ceramic Society,* vol. 40, no. 2, pp. 542-551, 2019.

[9] Kong H, Yamamoto K., "Simulation on soot deposition in in-wall and on-wall catalyzed diesel particulate filters," *Catalysis Today,* vol. 32, pp. 89-93, 2018.

APPENDIX

FYP2

ORIGINALITY REPORT

16%	8%	6%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

Skip to Main Content

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Muhammad Farhan Mohd Yatim
Assignment title:	Dissertation
Submission title:	FYP2
File name:	FYP_baru.pdf
File size:	735.46K
Page count:	29
Word count:	3,408
Character count:	20,317
Submission date:	10-Apr-2020 06:03AM (UTC+0800)
Submission ID:	1293941755