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The performance of wire mesh particulate type trap to reduce smoke opacity from compression-ignition engine

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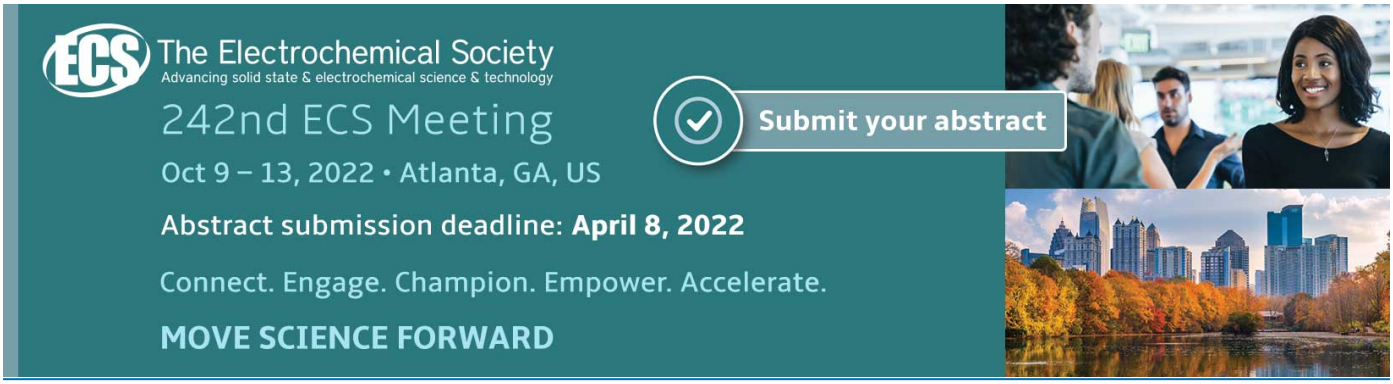

The performance of wire mesh particulate type trap to reduce smoke opacity from compression-ignition engine

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Abstract. Soot, as a material that forms PM emissions, is generally composed of solid carbon particles resulting from combustion. The PM is then managed by absorbed and condensed organic composition. PM is a hazardous emission for health, especially a very subtle one like PM 2.5. This type of PM can enter without passing through filtering in the respiratory system so that it can interfere with the function of the function in the gas exchange. One of the technologies offered is a diesel particulate trap (DPT), where this technology has the potential to carry out the filtration of more than 95%. One of the technologies provided is a diesel particulate trap (DPT), where this technology has the potential to carry out the filtration of more than 95%. The purpose of this study is to screen PM and measure the extent of DPT efficiency used in diesel engine vehicles. This study uses SNI 09-7118.2-2005 as the testing standard for the Isuzu C190 diesel engine. The test is carried out by accelerating the engine under no-load conditions according to SAE-J11667 standards. The main finding of this research is that the use of DPT can reduce smoke from 85.4% to 98.4%. Thus it was concluded that the DPT could be applied to diesel engines to be able to support various programs related to sustainable development.

1. Introduction

In general, internal combustion engine pollutants, mainly diesel engines are produced from four sources. First, as much as 65-85% of pollutants are produced by exhaust pipes. Through the exhaust pipe emissions of dangerous exhaust gases such as hydrocarbons (HC), nitrogen dioxide (NOx), carbon monoxide (CO), particulate matter (PM), and sulfur dioxide (SOx) are produced. Second, as much as 20% comes from crankcase breather and HC emissions, both burning and not burning. Third, as much as 5% of pollutants are produced by the respiratory tract from the fuel tank. The main factor is the weather, where HC has volatile characteristics when it is in hot weather. Fourth, as much as 5-10% of pollutants are produced from spills and evaporation of fuel from carburetors [1]. Knowing this, the limitation of exhaust emissions, especially PM produced by diesel engines must be increased before going out into the environment [2].

This increase can be achieved if the exhaust gas produced during the combustion process is first passed to the trap filter or better known as the diesel particulate trap (DPT) [3]. In theory, DPT has the potential to have a filtration efficiency of more than 95%. Also, to avoid decreasing engine power output and fuel efficiency, DPT requires a relatively low reduction in operating pressure [4,5]. The capture and combustion of PM emissions collected at the DPT result in a self-cleaning cycle that is useful for preventing clogging of filters [2]. But unfortunately, the concept of self-cleaning at DPT also has some weaknesses. First, any filter media placed in the exhaust system has the potential to increase exhaust gas back pressure, this simultaneously has an impact on reducing engine power. Second, the increased flue gas back pressure is caused by the buildup of PM on the wire mesh surface as a filter material. Third, a system of self-cleaning or regeneration is almost impossible at normal speeds. Then the last fourth, when regeneration occurs, careful control needs to be done so that overheating does not occur, which can cause disrupted engine work [6].

By his theory, soot that forms diesel exhaust particulates can burn at temperatures of 500°C to 600°C [7], while the diesel engine exhaust temperature is generally in the range of 200-500°C [5]. To overcome this problem, there are two options offered so that the exhaust gas temperature can be increased or the PM ignition point can be lowered. The first option is to install a thermal reactor or electric heating element in an area adjacent to the DPT. Then the second option is to coat or use DPT with a catalyst base metal. In this case, the recommended material is stainless steel. The result is that the particle flash point can be reduced to 200°C, while at the same time, CO and HC emissions can be oxidized with exhaust gases that pass through the DPT. Trap oxidizers can effectively be used for diesel engines with small engine capacity and tend to run with high exhaust gas temperatures. But on the contrary, in diesel engines with greater capacity, the trap oxidizer is difficult to regenerate PM because the number of particulates produced is relatively more while the exhaust gas operates at low temperatures.

Besides that, in terms of health, PM is a very dangerous emission, especially a very subtle one like PM 2.5 [8]. This type of PM can enter without passing through the filtering in the upper respiratory system and attach to the lung bubbles, thereby reducing the ability of the lungs to exchange gas [9]. It also has the potential to cause cardiovascular disease and cancer [10].

2. Research method

2.1. Test equipments

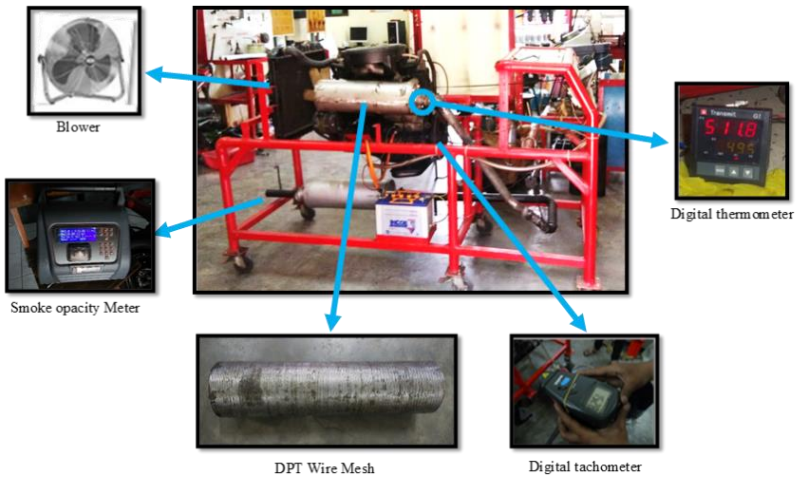

Figure 1. Experimental set-up.

The engine used in this study is the Isuzu C190 which is equipped with 1 standard exhaust and 3 modified knapot (DPT) with wire mesh sizes of 12, 14, and 18. Spesifikasi mesin yang digunakan meliputi: (1) engine manufacture from Isuzu; (2) engine code C190; (3) four cylinders inline; (4) engine

capacity of 1951 CC; (5) bore and stroke of 84 x 86 mm; (6) compression ratio of 20:1; and (7) engine rpm idle at 675 – 725 rpm. While the specifications of the instrument and research equipment are shown by Table 1.

Table 1. Specifications of research instruments and equipment.

Specification		Smoke opacitymeter	Digital thermometer	Digital tachometer	Blower
Merk	:	Technomotor	RKC	Krisbow	Krisbow
Type	:	G-820	REX C-900	KW06-303	EF-50S
Voltage/power	:	220 V – 50 Hz/80 W	AC 220V 50/60HZ	4 x 1,5 V AA/6 V	230 V, 60 A
Range	:	0 - 9,99 m-1	0 – 1000ºC	0 – 20.000 rpm	1200

2.2. Testing method

This study uses SNI 09-7118.2-2005 as a testing standard for the Isuzu C190 diesel engine. The test is carried out by speeding the machine in a no-load condition at full speed according to the SAE-J11667 standard [11]. Then the research data is explained and compared with the Minister of Environment Regulation No. 05 of 2006 concerning Exhaust Emission Limits on Old Motorized Vehicles [12]. Thus researchers can measure whether the modified DPT exhaust technology can meet emission test standards or not.

3. Results and discussion

3.1. Results

To find out the extent of the effect of using diesel particulate trap (DPT) technology based on stainless-steel wire mesh sizes 12, 14 and 18 on the Isuzu C190 modified exhaust pipe to reduce exhaust gas opacity/particulate emission (PM), can be seen in table 2.

Table 2. Reduction of Isuzu C190 exhaust gas opacity using DPT made from stainless-steel wire mesh.

Muffler type	Average exhaust gas opacity (%HSU)	Reduction of exhaust gas opacity (%)
Standard muffler	75,5	
Modified muffler with DPT wire mesh size 12	11,0	85,4
Modified muffler with DPT wire mesh size 14	1,2	98,4
Modified muffler with DPT wire mesh size 18	8,6	88,6

From the data in table 3, when displayed in the form of bar charts about exhaust gas opacity, as shown in Figure 2 below.

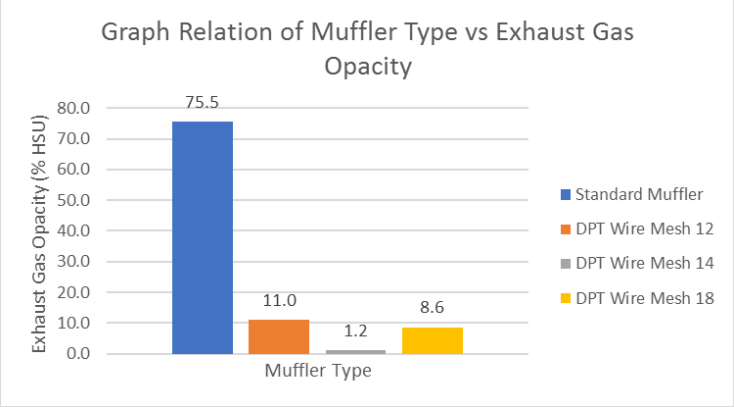

Figure 2. The relation between muffler type toward exhaust gas opacity.

In general, it can be concluded that the use of stainless-steel wire mesh particulate type trap (DPT) can significantly reduce the Isuzu C190 exhaust gas opacity compared to standard exhaust. The exhaust gas capacity produced by the standard Isuzu C190 engine exhaust is 75,5% HSU. The high exhaust gas opacity is due to the degradation of the engine due to age and usage [13]. Whereas exhaust gas opacity produced by the Isuzu C190 engine modified muffler with DPT technology based on stainless-steel wire mesh size of 12 mm is 11.0% HSU. It can reduce exhaust gas opacity by 85,4%. The exhaust gas capacity generated by the Isuzu C190 engine modified muffler with DPT technology made from stainless-steel wire mesh with a size of 14 mm is 1.2% HSU. It can reduce exhaust gas opacity significantly, which is 98,4%. While the exhaust gas opacity produced by the Isuzu C190 engine modified muffler with DPT technology made from stainless-steel wire mesh size of 18 mm is 8,6% HSU. It can reduce exhaust gas opacity by 88,6%.

In a standard muffler, the exhaust gas flowing out of the combustion chamber into the atmosphere is not filtered/trapped by any material, so the exhaust gas just comes out without filtering. The impact of exhaust gas opacity tends to be higher. While the reduction of exhaust gas opacity in the modified muffler is due to particulate emissions coming out of the combustion chamber flowing into the exhaust to the DPT first. In the DPT, the particulate emissions will pass through a stainless-steel wire mesh material installed between the perforated stainless-steel inner cylinder and perforated stainless-steel outer cylinder. In this stainless-steel wire mesh material, the particulate emissions will be absorbed and filtered. Furthermore, the flue gas that has been filtered will flow through the holes (perforated) contained in the perforated stainless-steel inner cylinder to the muffler and atmosphere.

From the results of the study it was also shown that the larger the size of stainless-steel wire mesh, the greater the reduction of exhaust gas opacity produced to a certain size (size 14). When the size of the stainless-steel wire mesh is increased to 18, the exhaust gas will be difficult to pass through the stainless-steel wire mesh pores due to the greater cross-sectional area and the smaller the exhaust gas pass so that the exhaust gas will be retained at the front end of the DPT. As a result the exhaust gas is difficult to get out and the opacity reduction cannot be optimum and tends to increase the back pressure of the exhaust gas thereby increasing fuel consumption.

3.2. Discussion

Soot that forms PM emissions is generally composed of solid carbon particles resulting from combustion. The PM is then coated by adsorbed and condensed organic compounds such as unburned hydrocarbons and oxygenated hydrocarbons. However, there are several other inorganic substances which in the process can be condensed, such as sulfur dioxide, nitrogen dioxide, and sulfuric acid [14]. Soot is generally formed in the combustion chamber, more precisely in the area of fuel bursts that spread and weaken until the process of expansion. During the combustion process, soot is identified as a ball with a diameter of 2 x 10-6 cm. In these conditions, the soot collides and joins in a cluster, or they can band together to resemble a chain [15].

Diesel particulates consist principally of combustion generated carbonaceous material (soot) on which some organic compounds have become absorbed. The composition of the PM-forming material depends on the condition of the muffler and its collection system. At temperatures above 500^{o}C, individual particles form a collection of many small spheres with diameters of about 15 to 30 mm [14]. When the temperature drops below 500^{o}C, the particles become coated with heavy organic compounds that are absorbed and condensed. Condensed materials also include inorganic substances such as sulfur dioxide, nitrogen dioxide, and sulfuric acid [14]. There is equipment that can be used to measure the number of particles coming out into the environment. The equipment is known as the smoke opacity meter. The way this tool works is by measuring the amount of exhaust gas that comes out through the exhaust using light reflection, which is then piled on filter paper. The smoke opacity meter does not measure mass directly, but only by estimating the level of mass emissions [14].

How many grams of particulate emissions (PM) can be absorbed by DPT made from stainless-steel wire mesh size 12, 14, and 18? To calculate it, before testing, DPT made from stainless-steel wire mesh size 12, 14, and 18 is weighed first using a digital scale to determine the weight of the DPT. The weight

of DPT is made from stainless-steel wire mesh size 12 before testing, which is 3,070 gr. After testing, the weight of the DPT increases to 3,100 gr. It shows that there are 30 grams of particulate emissions (PM) filtered by DPT based on the 12-size stainless-steel wire mesh. The weight of DPT is made from stainless-steel wire mesh size 14 before testing, which is 3,150 gr. After testing, the weight of the DPT increases to 3,200 gr. It shows that there are 50 grams of particulate emissions (PM) filtered by DPT based on the 14-size stainless-steel wire mesh. The weight of DPT is made from stainless-steel wire mesh size 18 before testing, which is 3,270 gr. After testing, the weight of the DPT increases to 3,310 gr. It shows that there are 40 grams of particulate emissions (PM) filtered by DPT based on the 18-size stainless-steel wire mesh. To find out the standard muffler and modified muffler equipped with DPT technology made from knitted stainless-steel wire mesh sizes 12, 14, and 18 on the Isuzu C190 type engine, whether it meets the exhaust gas threshold in accordance with the Regulation of the Minister of Environment Number 05 of 2006 concerning Threshold of Old Motor Vehicle Exhaust Emissions [12], it is necessary to make a comparison between the use of standard muffler and modified muffler equipped with DPT technology. Categories used for compression-ignition engine (diesel engine) vehicles under 2010 with a maximum opacity standard of 70% HSU under the free running acceleration test conditions as shown in table 3.

Table 3. Comparison of smoke opacity test result between standard muffler and modified muffler with wire mesh particulate type trap size 12, 24, and 18.

Muffler types	Testing Results (%HSU)	Minister of Environment Standards (%HSU)	Description
Standard muffler	75,5	70	Not Passed
DPT size 12	11,0	70	Passed
DPT size 14	1,2	70	Passed
DPT size 18	8,6	70	Passed

From table 4, it can be seen that the Isuzu C190 engine standard muffler does not pass the exhaust emission test because it produces exhaust gas above the predetermined threshold. While the modified muffler of Isuzu C190 engine with DPT technology made from knitted stainless-steel wire mesh sizes 12, 14 and 18, all passed the exhaust emission test because it produced exhaust gas capacity far below the threshold set by the government. From the results of the study it can be concluded that the use of diesel particulate trap (DPT) technology based on stainless-steel wire mesh sizes 12, 14, and 18 in the Isuzu C190 modified muffler can reduce exhaust gas opacity by an average of 85.4%, 98, 4%, and 88.6%.The results of this study are better compared to the previous research, such as Vasanthan's study which is only able to reduce exhaust gas opacity by 60-70% by using copper oxide-based DPF [16]. Warju's & Marsudi's research was concluded that the DPT can reduce exhaust gas opacity by 70% by using DPT made from stainless-steel plates and 100 grams of glasswool [17]. Ariyanto's & Warju's research was concluded that the DPT can reduce exhaust gas opacity by 75% by using copper plate-based DPT and 100 gr glasswool [18]. Moreover, Muliatna's and Wijanarko's research also was concluded that the DPT can reduce exhaust gas opacity by 82% by using DPT made from brass plate and 100 gr glasswool [19]. Just to note that the exhaust gas opacity testing on new types of motorized vehicles is already using Euro II Emission Standard based on the Regulation of the Minister of Environment Number 04 of 2009 concerning the Threshold of New Type of Motor Vehicle Exhaust Emissions with the ECE R 83-04 test method.

4. Conclusions

The main conclusions are as follows: the use of DPT sizes 12, 14 and 18 can reduce exhaust gas opacity by an average of 85.4%, 98.4%, 88.6% when compared to standard muffler. All variations of DPT sizes 12, 14 and 18 have passed the opacity test based on the Minister of Environment Regulation Number 5 of 2006 concerning the Threshold of Old Motor Vehicle Exhaust Emissions.

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