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A Novel Dual Effect Soot Filtering System

Saud Aldajah*, Yousef Haik and Emad Elnajjar

Mechanical Engineering Department, United Arab Emirates University, Al-Ain, UAE

Abstract

A newly developed novel technique for filtering soot from an exhaust gas system is presented. The proposed filter surface is capable of synthesizing carbon nanotubes. Two filters were designed and tested; the first is made of carbon steel plate and the second was made of nanomagnetic particles mounted on a polymeric surface. The filters were placed along the pathway of an exhaust streamline with an inclination of 5o to ensure a laminar flow condition. The results showed that the proposed systems produced carbon nanotubes by converting the exhaust waste.

Keywords: Soot Filter; Carbon Nanotubes; Nanoparticles.

1. Introduction

The widespread use of compression-ignition-direct-injection (CIDI) diesel fueled engines in automotive and truck vehicles will have a major economic and environmental impact. Because of the higher efficiency of the CIDI engines, their use will result in significant reduction in both fuel consumption and consequently greenhouse gases emission. An estimate of as much as 30-35% reduction in greenhouse gases has been predicted as a result of this fuel consumption reduction from CIDI or diesel engines[1]. Lower fuel consumption will also translate to less dependence on imported oil, which has economic and security implications.

A major obstacle to the commercialization of diesel engines, especially for automotive applications, is their high level of nitrogen oxides (NOx) and particulate emissions, both of which have possible negative effects on health. Major efforts by governments and industry are thus currently being directed at development of technologies to reduce diesel engine emissions.

Among the newly developed technologies is the utilization of oxidation catalysts that convert hydrocarbon and carbon monoxide into carbon dioxide and water which are known in the literature. Ceramic filters that are known for their efficiency to remove 90% of the particulates require 500oC and oxygen rich exhaust condition. Another effective approach to reduce NOx emissions in both gasoline and diesel engines is exhaust gas recirculation (EGR). Oxides of nitrogen (NOx) are formed when the combustion chamber temperatures are too high. Any measure that reduces the combustion temperature will lead to reduction in NOx formation and emission. EGR involves recirculation of exhaust gas into the intake stream. The recirculated gas displaces some of the normal intake charge, which slows and cools the combustion process, thereby reducing NOx formation. However, recirculation of exhaust product back into the engine combustion chamber has detrimental effects. Engine durability is compromised by EGR due to oil contamination by engine exhaust products [4,5]. Additional technologies include Fuel switching which utilizes a lower fuel bound nitrogen, Combustion control techniques including low excess air firing, staged combustion, water/steam injection, Flue Gas Treatment methods including selective non-catalytic reduction and selective catalytic reduction (these are post combustion methods that reduce NOx emissions after formation), finally fuel reburning which involves injection of natural gas after primary fuel combustion. It is typically used on very large boilers firing residual oil or coal.

The proposed technology insinuates the utilization of a new effective filter which synthesizes the carbon nanotubes from the exhaust gas at low and moderate temperatures. During the past two centuries, carbon nanotubes have attracted the attention of many researchers because of their unique electrical and mechanical properties [6]. Traditionally, carbon nanotubes are synthesized via various techniques such as arc-discharge [7], laser ablation [8], plasma enhanced chemical vapor deposition (CVD) [9] and thermal CVD [10]. The proposed technique utilizes the use of nanomagnetic particles placed on a metallic plate as a catalyst in the exhaust system of an automotive engine. This filter will have a dual benefit of filtering the exhaust gas by reducing soot formation and the formation of carbon nanotubes.

* Corresponding author. s.aldajah@uaeu.ac.ae

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2.Experimental Method

A simple single cylinder diesel engine is used to perform this experiment. The experimental setup is shown in figure 1. The specimen is carefully designed from a metallic plate with an adhesive to which Nanomagnetic particles were added. The specimen holder is designed as shown in figure 1, the holder services two purposes: it controls the position of the specimen (flat/ 5^o inclined with respect to the exhaust flow stream), also it is designed in such a way where it will eliminate any disturbance to the flow in order to ensure a laminar flow over the specimen. The holder is located close to the combustion chamber to ensure the highest possible temperature. All test samples are collected at similar engine operation conditions. The engine was running at 1100 rpm at an average load of 60N, the air temperature varied from 16^oC to 25^oC.

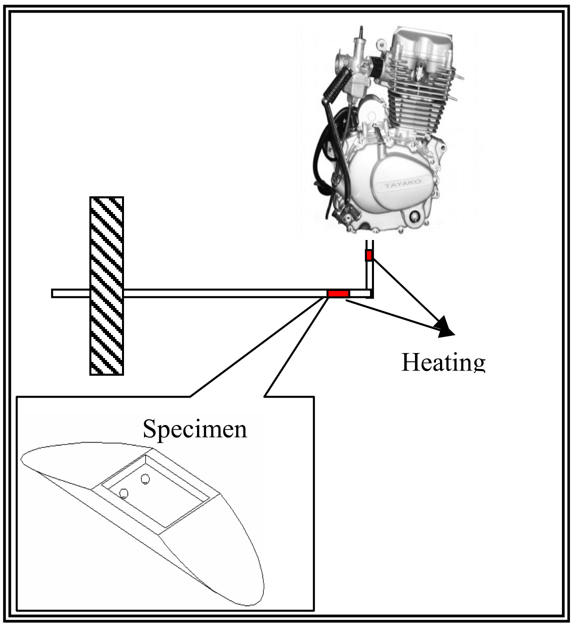

Figure 1.The experiment setup, with a zoomed view of the specimen holder.

2.1 Test Schedule

Two sets of samples were designed. The first samples were made of carbon steel which was highly polished and chemically itched in order to show the grains. The second set was made of samples were made out of iron oxide nanoparticles mounted on an adhesive on a plate. All samples were collected according to the conditions shown in table 1. The engine and flow parameters were the same for all tests (engine speed of 100 rpm, engine force of 60 N, air flow temperature of 37^oC and exhaust stream temperature of 96^oC).

3.Results and Discussion

The samples were characterized and analyzed using the scanning electronic microscope (SEM). SEM images of CNTs are shown in figure 2 (a), (b), (e) and (f), these images are shown an evidence of having CNT growing on the catalyst metal specimen. Images (c) and (d) are the base line where for these two samples the tests were reproduced under the same operation conditions without heating of the specimen. The two images are showing typical carbon particles without any trace of CNT. These two cases demonstrate the fact that having the metal catalysts specimen at the exhaust temperature (100oC) was not enough to produce CNT. Figure 3 shows the SEM images of sample 13 where it can be clearly seen that the CNTs had grown on the nanoparticles.

The right environment believed to enhance the growth of CNT using this technique can be summarized by the following: firstly, the precise design of the specimen and the holder to ensure quality laminar flow of the exhaust gas. Secondly, heating the sample to a temperature higher than 300oC and finally, the quality of the specimen surface which is polished to a very high levels of smoothness in the case of the metal plate.

4.Conclusions

This paper demonstrated an innovative, environmental friendly technique of producing carbon nanotubes from diesel engine exhaust stream flowing at a moderate temperature. The carbon nanotubes grew on a heated carbide metallic catalyst specimen and on a sample that contains nanoparticles positioned in the exhaust stream. The diesel exhaust stream temperature was kept at around 100^o C, whereas the specimens were heated to a moderate temperature of 250^o C (in the case where heating was applied to the sample). This filtering technique is a promising one; it can be used alone or in combination with other filters.

Table 1. The test samples conditions

Sample No.	Heating		Sample Position	Engine %Load	Comments
	Sample	Exhaust line			
1	Yes	No	Flat	75	
2	Yes	No	5º Inclination	75	
3	No	No	Flat	75	Base Line
4	Yes	Yes	Flat	75	
5	No	No	Flat	50	Base Line
6	No	No	Flat	100	Base Line
7	No	No	5º Inclination	50	Base Line
8	No	No	5º Inclination	100	Base Line
9	Yes	Yes	Flat	50	
10	Yes	Yes	Flat	100	
11	Yes	No	5º Inclination	50	
12	Yes	No	5º Inclination	100	
13	Yes	No	Flat	100	

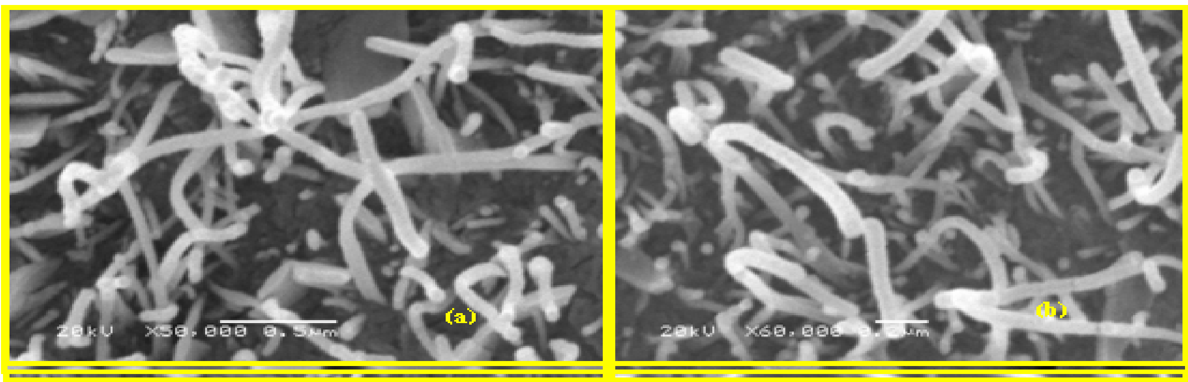

Figure 2. SEM images (a) sample 1 (Flat/ heated), (b) sample 2 (Inclined/ heated), (c) sample 4 (Flat/Non heated), (d) sample 6 (Inclined/Non heated), (e) sample 8 (Flat/ heated) and (f) sample 10 (Flat/ heated).

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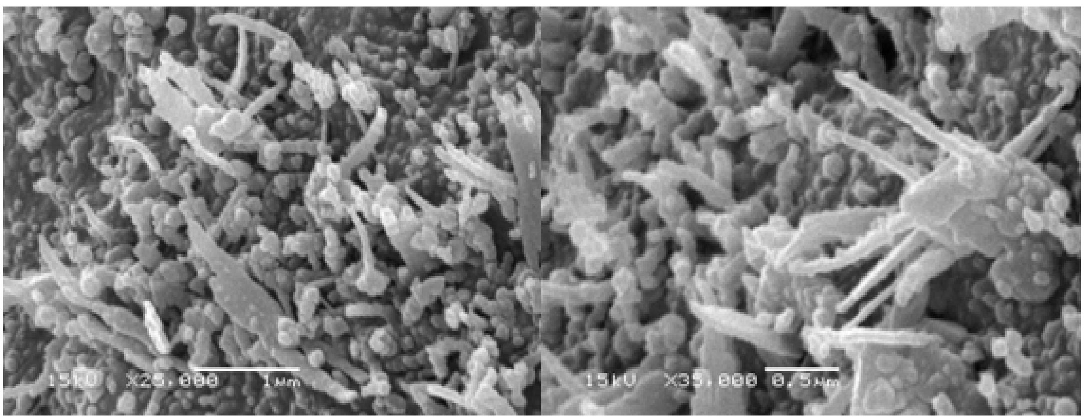

Figure 3. SEM images of sample 13

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