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# Nanostructure Investigation of Particle Emission by Using TEM Image Processing Method

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**Abstract**

Particulate matters (PMs) must be removed from the exhaust gas emitted from engines to protect the environment and human health. The problem of particulate emissions from diesel engine can be reduced in many ways, for examples: development of modern engine, fuel additives, diesel particulate filter (DPF) and oxygenated fuel. This paper describes a part of an ongoing research project in PM reduction as emitted from combustion. The main part is study of PM nanostructure by using Transmission Electron Microscopy (TEM). The primary size distributions as well as PM structures were presented by TEM images. The average primary sizes of biodiesel and diesel fuels PMs are approximately 30-40 nm and 50-60 nm, respectively. The average carbon platelet sizes of both PMs are in the range of 0.1-7.0 nm. Moreover, approximately 830 carbon atoms per cubic nanometer of PMs also could be estimated and presented in the present report. The results of this research would be used as basic information for design and develop removing process of PM emitted from engine combustion which using in diesel and biodiesel fuels.



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## 1. Introduction

Among internal combustion engines (ICE), diesel or compression-ignition (CI) engines have the highest thermal efficiency for a given output power. However, particulate matters (PMs) and NOx must be removed from the exhaust gas emitted from diesel engines to protect the environment and human health. Therefore, regulation of vehicle emissions has become increasingly strict. However, it is very difficult to develop internal combustion engine and after treatment systems for simultaneous removal of PM and NOx.

The problem of particle emissions from diesel engine should be improved by developing the high efficiency modern engine, after-treatment and pre-treatment technologies. Diesel Particulate Filters (DPFs) play an important role in PM trapping and oxidation. A DPF is generally made of ceramic materials, such as cordierite or silicon carbide, consisting of many rectangular channels with alternate channels blocked using cement at each end. The exhaust gas is forced to flow through a channel wall having numerous micron-scale pores that trap the PM. Furthermore, the collected PM must be oxidized to regenerate the DPF and reduce the back pressure on the diesel engine [1-3].

The nanostructures of soot primary particles have been characterized using scanning electron microscope (SEM) and transmission electron microscopy (TEM) to understand them in detail. The mean diameter of the primary and agglomerated particles is usually in the range of ultrafine particle and fine particle, respectively. A primary soot particle has two distinct parts: an inner core and an outer shell. The inner core is located at central region of the primary particle [4–11]. The composition of PMs from a diesel engine may vary widely depending on the operating conditions and fuel composition. Based on analysis performance with a combination of physical and chemical methods, PM is traditionally divided into three main fractions: solid fraction (SOL), soluble organic fraction (SOF), and sulfate particulates ($SO_4$) that consist of sulfuric acid and water. The SOL of diesel PMs is composed primarily of elemental carbon, sometimes referred to as inorganic carbon. This carbon, not chemically bound with other elements, is the finely dispersed carbon black or soot substance responsible for black smoke emission. HCs adsorbed on the surface of the carbon particles are present in the form of fine droplets from the SOF of diesel particulates. At times, this fraction is also referred to as the volatile organic fraction (VOF). The SOF fraction contains most of the polycyclic aromatic HCs (PAHs) and nitro-PAHs emitted with diesel exhaust gases. PAHs are aromatic HCs with two or more benzene rings joined in various forms that are more or less clustered. These require special attention because of their mutagenic and, in some cases, carcinogenic character. The water, unburned HC, carbon and ash regions are verified for oxidation reaction by Thermogravimatric Analysis (TGA) and Temperature Program Oxidation (TPO) [12–17].

Applications of renewable oxygenated fuels is nowadays a widespread means to reduce amount and particle size of regulated pollutant emissions produced by internal combustion engines because oxygen atoms inside fuel molecules promote more completed combustion, as well as to reduce the green house gas resulting from carbon neutral. The combustion of bio-oxygenated fuel emits carbon dioxide ($CO_2$) to the atmosphere for the growth of plants, which are produced by biodiesel fuel and released out of the atmosphere as carbon by photosynthesis. More advantages of biodiesel over other fuels are that it contains much lower sulfur and aromatic HC content [18].

The objective of the present research is to study diesel and biodiesel PMs nanostructure by using TEM images. The report would be successfully described as the useful information of diesel and biodiesel PM nanostructures for better understanding and future design of DPF configuration for diesel and biodiesel blends engine application in Thailand and Asian countries.