International Journal of Automotive Technology (2024) 25:71–82
https://doi.org/10.1007/s12239-024-00012-y

ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, ENGINE AND EMISSIONS, FUELS AND LUBRICANTS, HEAT TRANSFER, FLUID AND THERMAL ENGINEERING

Comparative Study on Brake PM_{10} Emissions of Vehicle and Brake Dynamometer Under Different Road Conditions

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Received: 4 August 2023 / Revised: 22 August 2023 / Accepted: 22 August 2023 / Published online: 16 February 2024

Abstract
This study proposes a system that can collect and analyze the brake particle matter generated from a vehicle and brake dynamometer. A dust cover is developed to collect brake particle matter, and the number of particle matter by size is measured using a portable aerosol spectrometer. Brake PM_{10} generated when the vehicle is driving on highways, country and city roads is collected and analyzed. Based on the vehicle driving data, the test mode for the brake dynamometer is developed using the relationship between brake energy and brake power. The same brake fine dust collection and measurement system as the vehicle is installed on the brake dynamometer, and brake PM_{10} generated according to the test mode for each road condition is collected and analyzed. As a result, the total number of brake PM_{10} collected from the vehicle and brake dynamometer shows about maximum of 20% error rate for each road condition. The Pearson correlation coefficient for the test results is 0.9988, and it means that the vehicle and brake dynamometer test results has a strong positive relationship.

Keywords Vehicle · Brake dynamometer · Brake particle matter · Dust cover · PM_{10} · Test mode

1 Introduction

As 99% of the world's population of 8 billion is exposed to air pollution and 6.7 million people die every year due to air pollution, air pollution is becoming a great threat to mankind (World Health Organization (WHO), 2023). Particulate matter (PM), a representative air pollutant, is generated from industry, power plant, automobiles, etc., except for natural occurrence. PM_{10} is a particulate matter smaller than 10 μm and causes heart or lung disease when absorbed in the human body (United States Environmental Protection Agency (USEPA), 2023). 56% of the world population is living in urban area (The World Bank, 2021), and 44% of PM_{10} generated in the urban area is caused by traffic (Diapouli et al., 2017). Thus, efforts to analyze the cause and mechanism of the vehicle PM generation and to reduce the amount of that are being actively performed.

PM generated from vehicles is divided into exhaust PM and non-exhaust PM. The amount of exhaust PM is rapidly decreasing as regulations such as EU 6 and China 6 are strengthened (Hwang & Lee, 2021; Wang et al., 2022). However, there is no regulations related to non-exhaust PM, so its amount is not being controlled. According to Harrison et al. (2012)'s study, PM_{10} from brakes accounts for 21% of the total vehicle PM_{10}, and 55% of non-exhaust PM_{10}. Therefore, brakes are the most important source of vehicle PM.

The particle measurement program (PMP) in the EU is developing a standard method for sampling and measuring the brake PM emissions (IWG, 2023). PMP has designated the brake dynamometer as a reference test rig for the brake PM emission tests (IWG, 2021), and set up the novel worldwide harmonised light-duty vehicles test procedure (WLTP)–brake cycle (Mathissen et al., 2018) as the reference test mode. The WLTP-brake cycle is based on real-world driving data measured from five different world regions with a total mileage of about 740,000 km, and consists of 303 stops at a distance of 192 km. Although Mathissen et al. (2018) mentioned that the WLTP-brake cycle is statistically close to the real-world driving data, further study seems to be necessary to prove that the

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