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Using a chassis dynamometer to determine the influencing factors for the emissions of Euro VI vehicles

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ABSTRACT

In order to explore the influence of different factors on the emissions of heavy diesel vehicles, a chassis dynamometer was used to test and analyze a Euro VI standard heavy-duty diesel vehicle under different load, fuel, driving conditions, and resistance conditions. The full load condition was found to increase NOx emissions by about 0.107 g/km (30%) and the particulate matter (PM) by 0.003 g/km (18%) compared to the empty load condition. Compared with the China V diesel, the NOx emissions of the Beijing VI diesel were reduced by 0.065 g/km (18%), and PM decreased by 0.004 g/km (25%). The HC, CO, PM, and NOx emissions measured during the Chinese World Harmonized Transient Cycle (C-WHTC) were 0.002 g/km (27%), 0.0005 g/km (14%), 0.0024 g/km (15%), and 0.092 g/km (25%) higher, respectively, than those measured during the European Transient Cycle (ETC). The HC, CO, PM, and NOx emissions measured by using the test resistance were 0.002 g/km (28%), 0.001 g/km (25%), 0.003 g/km (18.7%), and 0.09 g/km (25.7%) higher, respectively, than those calculated with the recommended formula.

1. Introduction

The development of the automobile industry in China has increased the problems of energy shortages and environmental pollution. Heavy diesel vehicles make up only 5% of the total number of vehicles, but their emissions of nitrogen oxide (NOx) and particulate matter (PM) make up 78% and 82%, respectively, of the total vehicle emissions, which directly affect human health (Burtscher, 2005; Ouyang, 2013). Many studies have shown that the fuel quality, vehicle load, driving speed, road conditions, and post-processing technologies affect the emissions of heavy diesel vehicles (He and Chen, 2013; Fontaras et al., 2014). Han (2013) studied the effect of fuel characteristics on the low-temperature combustion process of a diesel engine. The results showed that the cetane number of the fuel has a large impact on the PM emissions. However, other characteristics were found to have little effect on the combustion process. Tian et al. (2016) used the computer programme to calculate emissions from road transport (COPERT) 4 model and vehicle emission system to measure the change in pollutants as the vehicle speed was increased. The NOx and hydrocarbon (HC) emissions showed a "U" pattern for a China Stage III diesel vehicle and China Stage IV bus driven in the Beijing area. Chen et al. (2012) analyzed the effect of loading on the emission characteristics of Euro III diesel vehicles in a simulation. The high drained area at a full load was extended outward from the high speed area at a half load. Wang et al. (2014) studied the effect of working conditions on pollutants from a China Stage III diesel vehicle. Emissions of gaseous pollutants and PM were increased by about 30% under the conditions of a low average speed and long idle time. Advanced emission control technology can effectively reduce vehicle emissions. A diesel particulate filter (DPF) can clean PM in the exhaust, and a diesel oxidation catalyst (DOC) can reduce the HC and

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Table 1
Correlation between CVS and PEMS.

	PEMS (Qin et al., 2009)	SEMTECH (Nam et al., 2005)	RAVEM (Weaver and Petty, 2004)
HC	$R^2 = 0.9968$	$R^2 = 0.925$	/
CO	$R^2 = 0.9984$	$R^2 = 0.933$	/
NOx	$R^2 = 0.9981$	$R^2 = 0.883$	$R^2 = 0.9952$
CO_2	$R^2 = 0.999$	$R^2 = 0.981$	$R^2 = 0.9938$
PM	$R^2 = 0.9939$	/	$R^2 = 0.9833$

carbon monoxide (CO) emissions of diesel engines (Lou et al., 2016).

Emission factors refer to the vehicle running unit mileage, unit time, or pollutant discharged by the unit fuel and reflect the actual emission levels of the vehicle. Techniques used to research emission factors of heavy-duty diesel vehicles at home and abroad mainly include calculation models, bench tests, vehicle tests, and chassis dynamometer tests (Hasegawa et al., 2015; Gallus et al., 2016; Subramanian et al., 2013). A calculation model can be used to study the main emission factors and emission inventory in different regions, but it is greatly affected by the vehicle driving state, and there is a certain error between its results and the data of actual road condition emissions (Dai et al., 2009). The bench test guarantees the accuracy of the emission results, but there is a large difference between the engine operating conditions and vehicle operating conditions; the actual traffic emissions of the vehicle cannot be perfectly replicated (Gao et al., 2012). In the vehicle test, a portable emission test system is placed directly in the vehicle, and the vehicle parameters and pollutant emission concentration can be collected under actual road conditions in real time. This reflects the true emission characteristics of a motor vehicle on an actual road, but the test has poor repeatability (Wu et al., 2012). The chassis dynamometer test is not to be affected by the weather and other traffic because it is performed on an indoor bench under simulated work conditions. It provides improved accuracy, repeatability, and comparability for the measurements and provides experimental conditions and environment for determining the accuracy of regulations. It has obvious test advantages (Lahood et al., 2013). A test cycle that corresponds to real-world conditions determines the accuracy of the emission results. If the driving cycle cannot represent the actual usage conditions of the vehicle, the measured vehicle pollutant emission level will deviate greatly from the actual emissions. Emission factors of vehicles under real-world conditions can be measured with a portable emission measurement system (PEMS). Scholars have studied the difference between emission factors according to the constant volume sampling (CVS) system and PEMS, and the correlation of the test results for emission factors are presented in Table 1. With the same test cycle, most of the emission factors measured by PEMS and CVS have a good correlation, but there are some deviations in the measurement of low-concentration pollutants.

Scholars have studied the factors that influence the emissions of China Stage III and China Stage IV standard diesel vehicles. However, there are few reports on the influencing factors for Euro VI standard heavy vehicles after being upgraded by emission control technology. In this study, a chassis dynamometer was used to examine the impact of the load, fuel, driving conditions, and resistance conditions on the emissions of Euro VI standard heavy-duty diesel vehicles. The results provide a reference for establishing heavy diesel vehicle test standards and oil upgrades in China.

2. Test equipment and scheme

2.1. Test equipment

This test was carried out on a four-chassis dynamometer (MAHA Group, Germany) that can meet the test requirements of 4 × 4, 6 × 6, 8 × 8, and other driving types. The dynamometer has a sensitive control system and electronic inertia simulation device and can simulate a truck weight of up to 35 t and vehicle inertia of 2500–60,000 kg. The pollutant emissions were measured with CVS i60, AMA i60, and PSS i60 devices complying with 2005/55/EC requirements. CVS i60 controls the temperature of the CVS and acquisition capacity of the dilution tunnel. The AMA i60 exhaust measurement system measures the transient pollutant emissions during vehicle operation: non-spectral infrared analysis of CO, measurement of hydrogen flame ions for totally hydrocarbons (THC), and measurement of the non-spectral UV chemiluminescence for NOx. PSS i60 mainly controls the PM collection system to ensure that the sampling conditions within the limits prescribed by regulations.

2.2. Test prototype and program

The test sample was a heavy-duty diesel city bus that meets the Euro VI emission standard. Table 2 presents the main technical parameters.

The driving conditions were the Chinese World Transient Vehicle Cycle (C-WTVC) and European Transient Cycle (ETC). C-WTVC is based on WTVC, but the acceleration and deceleration are adjusted to match China's actual road conditions. Urban, road, and high-speed conditions were considered during the test. The total running time was 1800 s: 900 s under urban conditions, 468 s under road conditions, and 432 s under high-speed conditions. The running distance was 20.51 km (SAC, 2011). The main difference between C-WTVC and WTVC is the high-speed conditions. The average speed of C-WTVC is 61 km/h under the high-speed condition. The average speed of WTVC is 76 km/h under the high-speed condition. Compared with the WTVC, the high-speed condition speed of C-WTVC is reduced by 15 km/h (20%). ETC includes urban road, rural, and high-speed conditions with a running time of 600 s for each