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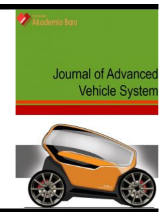

Comparison Fuel Consumption and Emissions of Light-Duty Diesel Vehicle Fuelled with Malaysian Diesel Grade Euro2M and Euro5

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ABSTRACT

Introduction of Euro5 grade diesel fuel in Malaysia started in November 2014 at Johor. This is due to stringent regulation for diesel-powered vehicle entering Singapore that came into effect that year. Now, the Euro5 grade diesel fuel has been supplied through out Klang Valley in order to supply motorist with cleaner and higher grade fuel. This study will analyse the differences of fuel consumption and exhaust emissions of light duty diesel vehicle fueled with Euro2M and Euro5 grade diesel fuel.

1. Introduction

The diesel engine has the highest thermal efficiency among internal combustion engine due to its very high expansion ratio and inherent lean burn. It has been operated since 1897 and can use many type of fuels including biofuels [1]. However, exhaust emissions from diesel engine becoming issues due to stringent emission standard around the globe.

In order to meet these emission standard, a cleaner diesel fuel has been introduced by reduction of sulfur contain since 1993.

In Malaysia, the Euro2M grade diesel fuel (Euro2M) is widely used since 2009 replacing Euro2 grade diesel fuel. The Euro2 grade diesel fuel contains very high sulfur as well as other variables such as lead, benzene and olefins which is the basis of severe damage to the environment and to the engine [2]. As for Euro2M grade diesel, the maximum sulfur content has been reduced from 3000ppm to 500ppm. Reduction of sulfur contain capable to reduce emission of sulfur dioxide and sulfur trioxide that can cause acid rain. Moreover, according to the US EPA, approximately 2% of the sulfur in the diesel fuel is converted to direct PM emissions. A part from sulfur content other fuel properties such as cetane number also has been increased from 47 to 49. This will directly effect nitrogen oxide (NOx) emission of diesel engine.

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Now, Malaysia has been introduced to Euro5 grade diesel fuel (Euro5) started in Johor in 2014 and recently in Klang Valley. Maximum sulfur content is only 10 ppm with cetane number minimum of 51. Altough the use of Euro5 grade diesel fuel is not enforced by Malaysian government, it is a good news for "going green" motorist. It is an interesting matter to know what Euro5 can offer compared to Euro2M. Therefore, this study has conducted an experiment using both type of fuels in a light-duty diesel vehicle operated on a chassis-dynamometer to compare fuel consumption and exhaust emissions.

2. Test Procedure

A one-ton truck (Isuzu NHR type) was used for this study as the test vehicle. Engine for this vehicle is a four cylinders, four stroke direct injection diesel engine and it is designed to meet Euro 2 emission standard. The other detailed specifications of the test vehicle are given in Table 1. Experiment was conducted using two different test fuels known as Euro2M and Euro5 grade diesel. The fuel properties of the test fuels are shown in Table 2.

Table 1
Detailed specifications of the test vehicle

Parameter	Specification
Model	Isuzu NHR 55E (4JB1)
Fuel injection system	Direct injection
Cylinder	4 cylinders, in-line
Cooling system	Water-cooled
Displacement (L)	2.8
Maximum output (Ps/rpm)	59(80)/3600
Maximum torque (kg-m/rpm)	175(17.8)/2000
Bore x stroke (mm)	93 x 102
Compression ratio	18:2:1
Full tank capacity (L)	75

Table 2
Fuel properties of test fuels

Properties	Unit	Euro2M	Euro5
Calorific Value	MJ/kg	45.280	45.598
Density @ 15 °C	kg/L	0.8538	0.837
Viscosity @ 40 °C	mm^2/s	4.642	2.43
Distillation temperature, 90% recovery	°C	367.9	361.6
Flash Point	°C	93.0	>55
Cetane Number	-	54.6	>51
Sulphur content	ppm	500	10

An experiment was carried out using a test vehicle placed on a chassis dynamometer as shown in Fig. 1. The chassis dynamometer used to simulate vehicle inertia and road load. The type of chassis dynamometer used in this study is Rotronics Autoscan X4 ET X4+. The roller bench of the chassis dynamometer is 600mm diameter type which is suitable for two or four wheel drive road vehicles. This device integrated with high speed electronic management, to ensure accurate and extremely responsive control of the load applied to the vehicle. The load applied is controlled according to the look-up table without time lags or delays, thus ensuring an accurate correlation with the real driving conditions. It is also equipped with an eddy current brake located at the rear bench that applies force to all the rollers. The test vehicle drive wheels are positioned so that they are in contact with roller. The rollers can be adjusted to simulate friction losses and aerodynamic resistance.

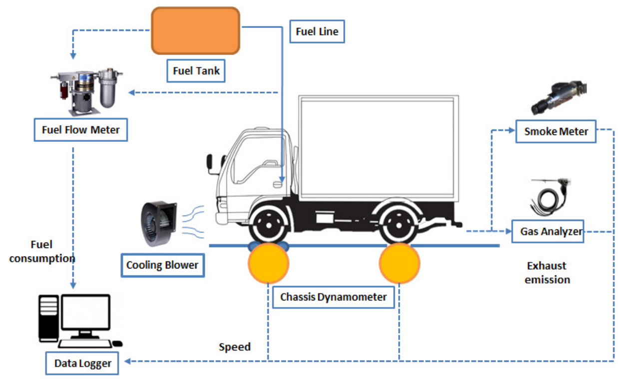

Fig. 1. Chassis dynamometer setup

This test was executed in accordance to the West Virginia University (WVU) 5-Peak Cycle Standard in order to quantify vehicle emissions under distinct driving conditions. This cycle was selected compared to other driving cycle because it is specifically designed for general truck chassis testing. WVU 5 Peak-Cycle consists of five segments, each segment with acceleration to a peak speed, followed with a brief steady state operation and deceleration back to idle. As in Fig. 2, the five peak speeds are 32.19, 40.23, 48.28, 56.33 and 64.37 km/h, which also indicating the number of accelerations. The total duration for this cycle is 900s and the driving distance is approximately 8km. This cycle accelerates to the steady speed using the highest possible acceleration. To comply with the legislative cycle, the driver was assisted by a driver aid system. The driver performed the testing by adjusting the vehicle speed by acceleration, deceleration and idling with proper gear changing in order to achieve the WVU 5 Peak-Cycle speeds. The measurement protocol was repeated three times per fuel, assuring the comparability of the emission measurements.

Gaseous analyzer (Testo 350) was used to measure nitrogen oxides (NO_x) as well as carbon monoxide (CO). As for the smoke density, a smoke meter of sampling pump type (EFAW 65 BOSCH) was used. Blackness number is the degree of blackening of the soot filter paper as displayed by the evaluating unit. The numbers are from the range of 0 to 9 where 0 represent the total absence of the smoke from tail pipe and, 9 represent a maximum blackness. Fuel consumption measured using Onnosokki flow meter (FP-2240H).

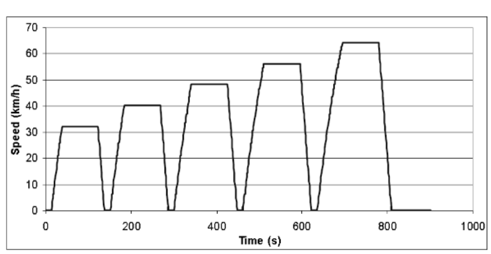

Fig. 2. Speed profile of WVU 5-Peak Cycle

3. Result and Discussion

The average fuel consumption produced by Euro2M and Euro5 are presented in Fig. 3. There is very small difference of fuel consumption between these two test fuels and the different can considered as negligible. This is due to almost similar amount of energy cotent in both fuels as shown in Table 2. Fig. 4 shows the comparison of emission characteristics between Euro2M and Euro5. The emissions include NO_x, CO and smoke number. The continuous NOx emission illustrates that the transient NOx increased in the accelerating mode and tend to be higher at certain higher speeds and drop during deceleration mode. According to Wang *et al.*, [3], this is due to the high temperature condition, high peak pressure and larger regions of close to stoichiometric burned gas. For CO, it can be observed that it is highest during cold engine operation up to 35s for Euro2M and Euro5. However, the level of CO fluctuated highly depending on the accelerating and decelerating modes. This cycle continuously repeated based on the five cycle of WVU driving cycle.

From this figure, it also can be seen that there is large difference for NO_x and CO emissions between these test fuels. Obviously, Euro2M emits higher NO_x (in average by 50.3%) and CO (in average by 50.6%) compared to Euro5. Higher NO_x for Euro2M is mainly caused by the higher sulfur content of Euro2M (500 ppm) than Euro5 (10 ppm). Moreover, for CO, the highest CO emissions occur during engine start up for both test fuels is because of the engine is running fuel rich and with poor fuel evaporation [4]. This is due to the higher distillation temperature, density and viscosity of Euro2M, reduces its volatility. As a result, Euro2M must reach higher temperature before the fuel can vaporize and combust with air. Thus, fuel preparation took longer and resulted in less fuel was ready at the initial state of the combustion, and finally caused the high production of CO.

However, for smoke number, it can be observed that the smoke number production from Euro2M and Euro5 did not change significantly, except at initial state where Euro5 emits low smoke.

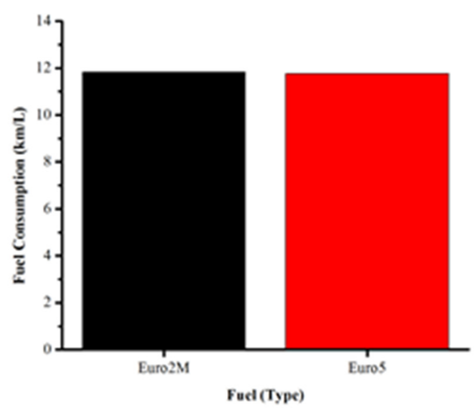

Fig. 3. Average fuel consumption

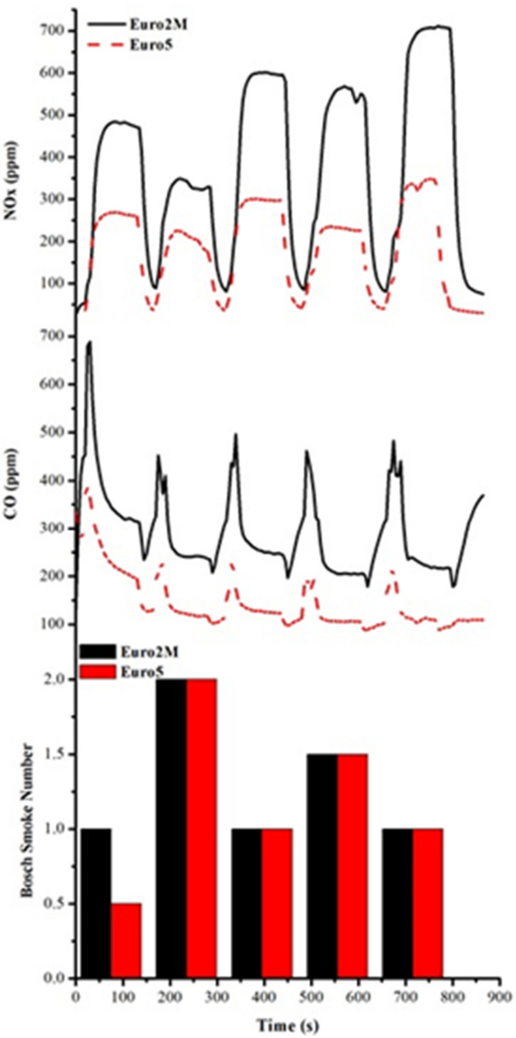

Fig. 4. Comparison of emission characteristics between Euro2M and Euro5

4. Conclusions

The following conclusions are drawn based on the experimental results using Euro2M and Euro5:

1. There is no significance difference in fuel consumption between Euro2M and Euro5.
2. Euro2M emits higher amount of NOx and CO compared to Euro5. However, the smoke number for both test fuels posed no significant changes.

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