Fuel Economy of Jeepneys Using 2% and 5% CME-Diesel Blends in the Philippines

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Abstract—This study presents the results of drive cycle tests conducted on in-use public utility jeepneys running on 2% (B2), and 5% (B5) by volume Coconut Methyl Ester (CME)-Diesel blends. The tests measured fuel consumption of sample jeepney units on a chassis dynamometer driven following the European ECE1504 Drive Cycle fueled with B2 and B5 CME-Diesel blends. These tests were part of an overall study examining the effects of B2 and B5 blends on the economic operation and fuel economy, measured on-road and in the laboratory, of jeepneys conducted by the University of the Philippines National Center for Transportation Studies (UP NCTS) and UP Vehicle Research and Testing Laboratory (VRTL) for the Philippine Coconut Authority (PCA). Data from the study will be used as an input to deliberations to decide for the introduction of 5% CME-Diesel blend in commercial diesel fuel. The drive cycle tests of seven (7) jeepney units range from about 0.5% to 11% specific fuel consumption (gm/km) improvement for B5 relative to B2 for an overall average SFC improvement of 4.6%. The change in mileage for B5 relative to B2 ranged from -2.40 to +11.91 percent for an overall average improvement of around 3.0%. The mileage results were affected by the observed relative density of B5 with respect to B2 – a lesser B5 density than B2 adversely affects B5 mileage versus B2. Both positive and negative (or “mixed”) relative mileage changes were observed. The amount of fuel economy change when using B5 compared to B2 in jeepneys is thought to also depend on in-use engine conditions and drivetrain configuration. The observed overall better fuel economy of B5 relative to B2 tends to favor a shift to B5 diesel blend implementation.

Index Terms—CME, biodiesel, jeepney, fuel economy, drive cycle

I. INTRODUCTION

The Philippines signed into law in January 2007 the “Biofuels Act of 2006” which declared as a state policy to reduce dependence on imported fuels with due regard to the protection of public health, the environment, and natural ecosystems consistent with the country’s sustainable economic growth that would expand opportunities for livelihood by mandating the use of biofuels [1]. This law mandated the use of biodiesel, which since 2009 up to now is at 2% by volume (B2), in commercial diesel fuel. Philippine biodiesel is primarily coconut methyl ester whose specifications are covered by a Philippine standard designated as PNS/DOE QS 002:2007. The shift to 5% biodiesel (B5), although scheduled by the end of 2013, is still under review by the National Biofuels Board (NBB). With the recommendation in 2013 to increase the biodiesel blend from B2 to B5, one of the requirements is the testing of B5 in public transport vehicles. In this regard, the Philippine Coconut Authority (PCA) has commissioned the University of the Philippines National Center for Transportation Studies (UP NCTS) together with the University of the Philippines Vehicle Research and Testing Laboratory (UP VRTL) to conduct on-road and laboratory testing of the B5 blend [2] on public utility jeepneys. Jeepneys are locally assembled vehicles with shop-fabricated bodies and chassis, fitted with second-hand diesel engines, drivetrain components, and other vehicle parts. They typically are designed for 20-22 passengers. Data from this study will be used as one of the inputs to deliberations on actual B5 diesel blend implementation in the Philippines.

Chassis dynamometer tests of seven (7) sample jeepney units were conducted between September 2013 and May 2014 for the project at the UP VRTL to measure vehicle fuel economy using B2 and B5 diesel blends. Detailed technical analysis of fuel economy in relation to engine or vehicle design and operating parameters are not part of this study.

II. METHODOLOGY

The in-use jeepney units used in the study were chosen from those nominated by operators belonging to transport groups identified by Philippine Coconut Authority and the Department of Energy (DOE). Jeepneys are vehicles assembled from locally built chassis and bodies while the engine, drivetrain and other components are second-hand or “surplus” imported parts. The jeepneys involved in the study underwent and passed inspection at the North Motor Vehicle Inspection Center (MVIC) of the Land Transportation Office to ensure compliance with roadworthiness and emission regulations, see Figs. 1 and 2. Drivers and operators of most jeepneys tested reported that their units’ injection pumps were calibrated within a year before the tests. The study consisted of both on-road tests during actual operation in their respective routes and
laboratory tests on the chassis dynamometer. Table I shows summary information of the jeepney units that underwent testing on the chassis dynamometer. The estimated gross vehicle weight (GVW) values shown in the table were used in the chassis dynamometer runs to simulate fully-loaded condition of the respective jeepney units.

Samples of pure CME (B100), B2, and B5 fuel blends provided by PCA were sent to the Processed Fuels Section of the Geoscientific Research and Testing Laboratory of the Department of Energy for analysis. Results of the fuel analyses shown in Appendix A and B indicate conformance of the fuels to Philippine National Standards.

Fuel economy tests were conducted in the UPME VRTL using the AVL AN 40720 48” Chassis Dynamometer where the jeepney units were run on a selected driving cycle. Fuel consumption during the dynamometer runs was measured with the AVL 735 Fuel Mass Flow Meter together with the AVL 753 Fuel Temperature Control unit.

Prior to the chassis dynamometer runs, a pre-test inspection of the test jeepney unit was conducted to reasonably ascertain that the vehicle was in good running condition. This included general inspection of the tires, checking of tire pressures, and checking for smooth and stable running of the engine. The test vehicle was then mounted on the chassis dynamometer, secured, and instrumentation attached. After a pre-set warm up time, a baseline run is conducted by driving the vehicle on commercial B2 diesel blend using the European ECE1504 drive cycle three times and the measurement results averaged.

Local drive cycles for public utility jeepneys developed by Thaweesak, S. [3], and those being developed by Abaya, E.B. [4], at the time of the present study, were not adopted due to the insufficient practice time available for the test driver and jeepney units. It was decided that these drive cycles will be used for a more rigorous study than at present. Initial trial runs using the Japanese 10-15 Mode driving cycle, consisting of three repetitions of 10-mode (urban) cycle followed by a 15-mode (highway) cycle, indicated failure of some jeepney units to completely follow this drive cycle at higher speeds. The European ECE1504 drive cycle, or ECE150 [5] repeated four times, was eventually selected for the tests as this was what the jeepneys could completely follow on the dynamometer. This particular cycle, among the standard drive cycles available was also deemed to have some semblance to actual jeepney on-road driving. The chassis dynamometer runs were set assuming the jeepney units were fully loaded. Figures 3 and 4 show respectively the Japanese and European drive cycles mentioned.
After the baseline test runs, a similar set of runs using B5 diesel blend were conducted within the same or next day to determine the same performance parameters. Figs. 5 and 6 show a jeepney unit being tested on the chassis dynamometer.

III. RESULTS AND DISCUSSION

The fuel economy of the jeepneys tested was measured as mass flow rate in kg/hr but are presented here both in terms of specific fuel consumption (SFC), in grams/kilometer (g/km), and mileage, in kilometers/liter (km/l or km/ltr).

Figure 7 shows the SFC of the jeepney units for B2 and B5 diesel blends. It can be seen from this graph that all jeepney units showed reduced SFC when using B5 relative to B2.

Figure 8 shows the same data in terms of B5 SFC percent change relative to B2. All the jeepney units gave improvement in SFC ranging from about 0.5 to 11%. The drive cycle tests indicate that the seven (7) jeepney units tested gave an overall average specific fuel consumption improvement from 140.3 to 133.8 g/km (4.6%) [2].

Figure 9 shows the mileage obtained for the jeepneys tested while Fig. 10 indicates the B5 mileage percent change relative to B2. It is seen that four jeepneys have better, two units about similar, and one jeepney less mileage with B5.
The B5 mileage change relative to B2 ranged from -2.40% to 11.91%. Such occurrence of both negative and positive values are described as “mixed” results. On an overall basis, an improvement in mileage from 5.97 km/ltr to 6.15 km/ltr was seen, or about 3.0% improvement for B5 relative to B2 [2].

This mixed behavior of mileage, compared to SFC’s consistently lower value for B5 versus B2, may be due to the variation in fuel densities observed during the tests. Figs. 11 and 12 show respectively the measured and corresponding B5 relative fuel densities for the tests.

The B2 blends were purchased from commercial gas stations right before the tests while the B5 blend was prepared one time. The varying B2 diesel fuel densities may be due to the fuel being obtained from different commercial gas stations during the test period. The first three jeepneys were tested in September 2013, the fourth in November 2013, and the last three in May 2014. The fourth to the seventh jeepneys used B5 fuel blend leftover from the September tests. Leftover B5 blend fuel properties may have been affected by handling and storage prior to the dynamometer tests. It was decided not to “correct” the measured density values used in the calculations and consider the fuel density variation as being lumped together with other variable factors, such as ambient weather conditions and B2 blend source, affecting fuel economy. Such variable factors are what jeepney drivers encounter in actual operation as they estimate their fuel consumption. The parameters that were repeatable in the chassis dynamometer tests for fuel economy were then vehicle load, driving cycle, and fuel supply temperature (set at 30°C).

Examination of Figs. 12 & 10 shows that as the relative density of B5 becomes lesser than B2, B5 relative mileage becomes adversely affected. The improvement in fuel economy of B5, expressed as SFC in gm/km, may be offset by B5’s lower density when expressed as mileage in km/ltr.

The varying SFC and mileage changes of B5 relative to B2 shown by the different jeepney units are thought to be also related to the vehicles’ differences in engine conditions and drivetrain configurations.

IV. CONCLUSION

A study commissioned by the Philippine Coconut Authority to the UP NCTS and UP VRTL was conducted to examine, among other things, the drive cycle fuel economy of in-use public utility jeepneys running on B2 and B5 CME-Diesel blends. Data from this study will be used as input to deliberations on actual B5 diesel blend implementation as commercial fuel mandated by the Biofuels Act of 2006. The study measured fuel consumption of seven (7) sample jeepney units on a chassis dynamometer driven following the European ECE1504 Drive Cycle fueled with B2 and B5 diesel blends.

The drive cycle tests of the jeepney units gave a range of about 0.5% to 11% specific fuel consumption (gm/km) improvement for B5 relative to B2. An overall average SFC improvement of 4.6% for B5 relative to B2 was calculated. The change in mileage for B5 relative to B2 ranged from -2.40 to +11.91 percent for an overall average improvement of around 3.0%. The mileage results were affected by the observed relative density of B5 with respect to B2 – a lesser B5 density than B2 adversely affects B5 mileage versus B2. “Mixed” mileage results were observed. The amount of fuel economy change when using B5 compared to B2 in jeepneys is thought to depend also on in-use engine conditions and drivetrain configuration. The observed overall better fuel economy of B5 relative to B2 tends to favor a shift to B5 diesel blend implementation.

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REFERENCES


APPENDIX

A. Fuel analysis for B100 used in the study

B. Fuel analysis for B2 and B5 used in the study