Fuel Consumptions of Scooter on the Real-World in Taiwan

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Abstract: Scooter is often considered as a mode of fuel efficiency; therefore the characteristic of fuel consumption of scooter in real world has not been well identified yet. This study takes advantage of available technology of on-board emissions measurement devices then design on-road experiments to capture data from real world. With data reflecting real world driving conditions, analysis and results of this study could contribute to orientations of research on energy efficiency improvement of scooter to realize energy saving of urban transportation sector on road of emerging economy.

Keywords: Scooter, Fuel Consumption, On-Board Emissions measurement, Road Type

1. INTRODUCTION

The energy scarcity calls for needs of fuel consumption reductions in all sectors of economy. Transportation sector counts for over 61.5% of world oil consumption of year 2010 (IEA, 2012); therefore energy saving of vehicle is prior to the issue at stake. However, scooter is often considered as a mode of fuel efficiency; the characteristic of fuel consumption of scooter in real world has not been well identified yet. Regarding scooter is the most common private vehicle in Asian urban area where demand of private vehicle has been, and will be, growing faster than other regions, it is necessary to better understand factors affecting fuel economy performance of scooter in real world. This paper is trying to fill this gap to contribute orientations of researches on energy efficiency improvement of scooter to realize energy saving of urban transportation sector on road of emerging economy.

Fuel consumption of scooter has been investigated in laboratory via the standard testing procedure. Though it is well aware that conditions of traffic flow and road configurations are significantly affecting fuel consumption, it has not yet been clarified nor quantified. Chen, et al., (2003) and Tsia, et al., (2005) tried to sample driving cycles of motorcycle driving in actual urban and rural environment and develop representative driving cycles for laboratory tests. Zamboni, Carraro and Capobianco, (2011) investigated instantaneous speeds of motorcycles in various road classes to identify speed profiles most representing two-wheelers on the chassis dynamometer to improve the standard driving cycles. However, it could be up to 20% of measurement deviations between the dynamometer of laboratory and real world driving conditions.

One reason of this unmet gap is technology fail of measurement device for real world driving conditions. The credible and reliable device which is capable to measure real-time instantaneous fuel consumption while scooter is moving on roads did not be there. The on-board emissions measurement systems available could not be fit into scooter because of size larger than and weight heavier over capabilities of scooter.

Owing to research and development of devices in recent years, the on-board emissions measurement system could be much smaller now in terms of volume and weight; at the same time, keep its reliability and credibility above acceptance while operating on road driving conditions. As a result, it is now possible to apply an on-board device detecting and recording emissions and fuel consumption second-by-second while scooter travelling on roads. This study takes advantage of available technology then design on-road experiments to capture data from real world. With data reflecting real world driving conditions, our analysis will contribute to forward understandings of energy consumption characteristics of scooter in urban settings.

2. EXPERIMENT DESIGN

2.1 Test Scooter

We choose the Kymco 125 c.c. as our tested model. There are reasons for the scooter selection. The configuration of our test scooter is listed on Table 1.

1) The model of Kymco 125c.c. has been dominated sales of scooter market in Taiwan. It counts for 15-20% of the yearly new scooter fleet in Taiwan consecutively for the past 11 years (see Figure 1) and sums up to be more than 1.3 million out of 7.6 million of the total numbers of scooter sold during year 2002 to 2012. Given that the average age of scooter in-use fleet of Taiwan is 10.5 years old according to the most updated MOTC survey (MOTC 2012), we believe the Kymco 125 c.c. will be the most representative model of in-use scooter in Taiwan.
2) The powertrain technology on the Kymco 125cc. is similar to those popular scooter types sold in Asian countries. We expect the trands of scooter energy characteristics in real world we found here are highly possible to be transferred to nearby Asian countries.

Table 1. Characteristics of the test scooter

Brand	KYMCO
Engine Type	Single Cylinder, 4 Stroke
Dry Weight Amount (kg)	110
Displacement (cc)	124.6
Max. Horsepower (ps/rpm)	9.6/7,500
Max. Torque (kg-m/rpm)	0.98/6,500
Transmission System	CVS
fuel supply system	Fuel Injection
Bore*Stroke (mm)	$\psi 52.4 \times 57.8$
Fuel Capacity (L)	6.0
Homologation(R.O.C.)	Phase 5
Age (year)	2.7
Travelled Distance (km)	9,815

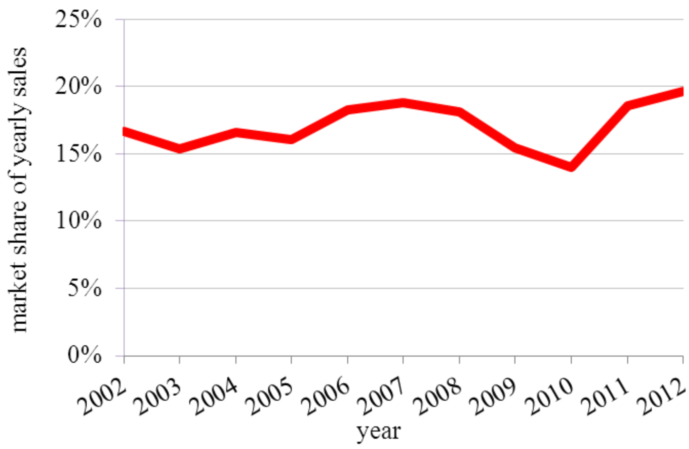

Figure 1. The market share of Kymco 125 c.c. out of the yearly sales between year 2002 to 2012

2.2 On-Board Emissions Measurement System: OBS-584

The on-board emission measurement system is crucial to the study. Available systems mostly are designed for testing on light/heavy duty vehicles, namely as Horiba OBS-2000 Series of Horiba Ltd., Japan, MEMS of West Virginia University, USA, PEMS/OEM-2100/Montana system of Clean Air Technologies International Inc., USA, SEMTECH-DS/SEMTCH EFMS of Sensors Inc., USA, TRL GasScan of Transport Research Laboratory, UK, and VPEMS of Imperial College, UK/SIRA. It has to be much more compact and lighter to be able to fit into scooter in road driving conditions. To have a desired on-board system for scooter on-road test, the research and development team of Automobile Research and Testing Center (ARTC) have been devoted in more 2 years.

The system we use for scooter tests is named as OBS-584 which is the third generation of the prototype. It is composed of the analyzer of MEXA 584L of Horiba Led., Japan. Together with the gas flow meter, it is capable to provide instantaneous emissions data with reliability (IOT 2012). There is an engine sensor in OBS-584 to access information of working conditions of the engine. Moreover, OBS-584 is equipped with humidity and temperature meter, the moving speed sensor onto the front wheel, and the global positioning system (GPS) in order to record information of the environment while moving. All data is synchronized and second-by-secondly recorded into the hard disk of OBS-584.

Figure 2. OBS-584 installed onto the test scooter

2.3 Test Routes

The popularity of scooter in Taiwan has long been well recognized. The number of in-use scooter is more than 15 million in year 2012, resulting in 2 scooters per household in average.

In metropolitans elsewhere than Taipei, where diversified urban travel demand is not well served by public transportation, it is heavily depend on scooter as being with the most convenience and economy among modes of private transportation. For example, in Taichung metropolitan, where is central to Taiwan with population over than 1 million in downtown and 3.5 million in metropolitan area, it is estimated that 50% or more trips is made by scooter for all trip purposes (MOTC 2010).

Given this backdrop, we select two typical roads in Taichung metropolitan area to represent urban and rural arterials. As shown on the Figure 3, the selected urban arterial is located in the very central downtown of Taichung city. The street blocks are quite short and traffic flow is highly mixed with scooters, cars, buses on urban arterials. While with the rural arterial, we pick up a major road in the west outer area of the metropolitan. It is quite obvious from the map that the blocks of rural arterial are much longer than in urban arterials. The directions of traffic movement on the rural arterial are divided by raised crossing islands; and mixture of scooters from light/heavy duty vehicles is managed by pavement markings.

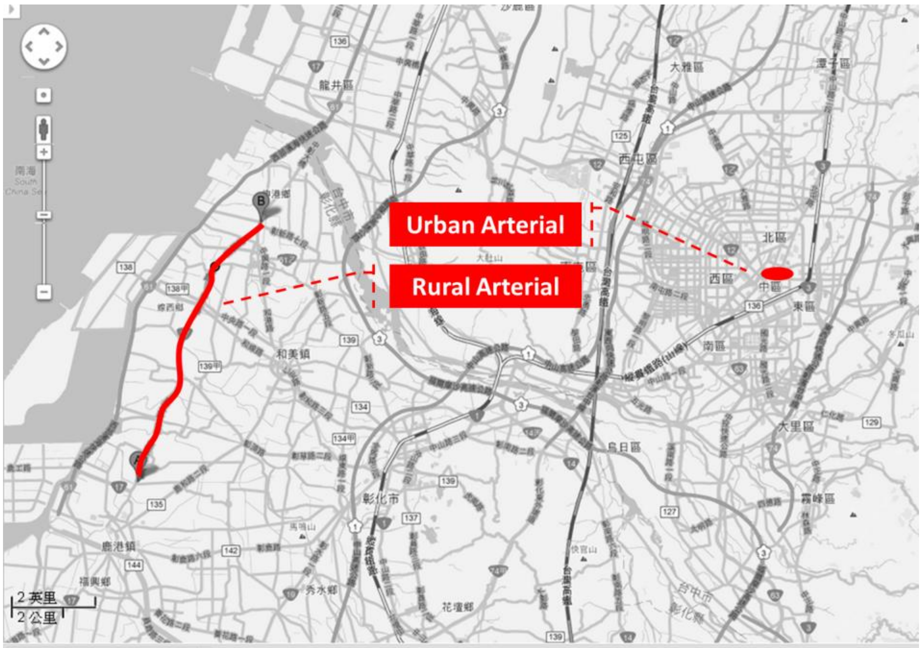

Figure 3. The test routes of typical road type in Taichung Metropolitan, Taiwan

3. RESULTS AND DISCUSSIONS

3.1 Data Collected

We collected data from the test scooter with OBS-584 identically to each road type. One specific team member is responsible to the on-road test to avoid driver's deviation. He is subject to follow the traffic flow in am and pm rush hours in non-raining weekdays. The tests were conducted in June and July 2012. The data collected counts for 13,207 seconds on the urban arterial and 14,266 seconds on rural arterial, with driving distance of 77.3 km and 157.8 km respectively.

3.2 Sample distributions

The speed distributions of collected data are shown in Figure 4. There is 38.1% of samples from urban arterial, 5,040 seconds, when scooter is not moving; ie., speed is zero; while 14.3% from rural arterial, ie., 2049 seconds when speed is zero. The speed in urban arterial is more evenly distributed in lower part of speed axle comparing to in rural arterial which is more concentrated on higher speed between 40-60 kph.

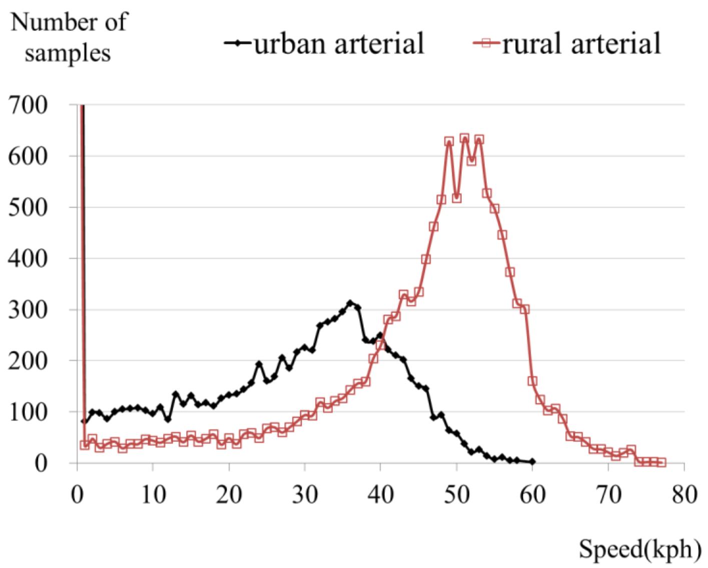

Figure 4. Speed Distributions of data collected

3.2 Fuel Consumptions

We calculate the average fuel consumption and standard deviation for every speed on either road type then plug the results onto Figure 5. We may see those means of fuel consumption at each speed on urban arterial are with smaller stander deviation comparing to rural ones. Furthermore, the positive correlation trends of fuel consumption and speed is more significant on the rural arterial than on the urban one.

To quantify and clarify the correlation, we use speed as the independent variable to fit a simple regression of fuel consumption for each road type. The fitted statistics are shown in Table 2. The adjusted R^2 and coefficients of the fitted equations shows that the speed could be a good variable to explain fuel consumption on rural arterial but not works that well for the urban one.

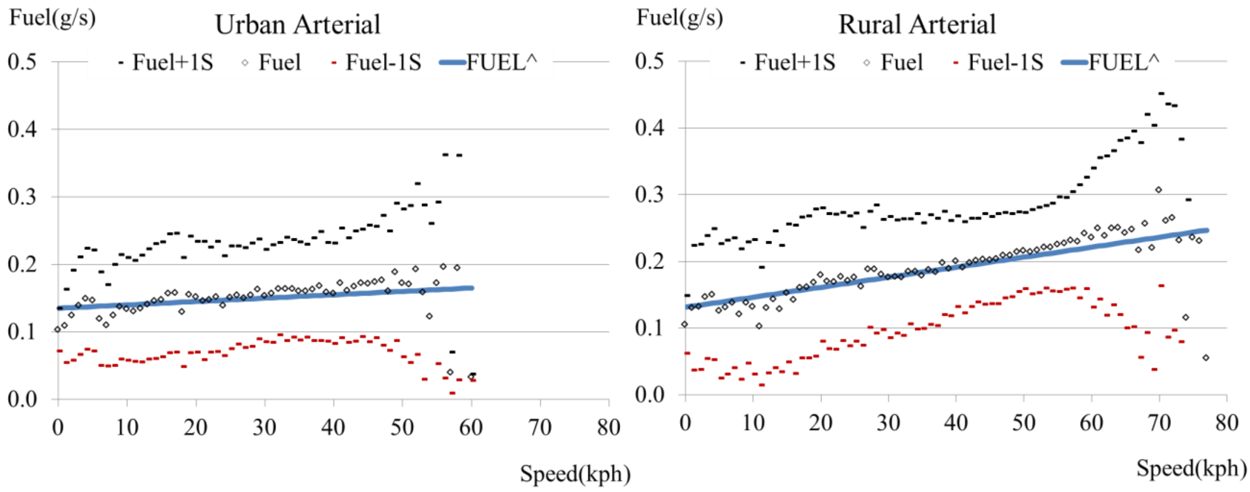

Figure 5. Means and standard deviations of fuel consumptions by speeds

Table 2. Coefficients of fitted regressions by road types

Fuel (g/sec)		Constant	Speed (kph)	Adj. R^2
Urban	Coefficients	0.13518213	0.00049993	0.0736
	t value	18.84***	2.38**	
Rural	Coefficients	0.13134879	0.00150053	0.5475
	t value	19.04***	9.70***	

Note: * p<0.05; ** p<0.01; *** p<0.001.

3.3 Accelerations and Declarations

To further compare traffic flows of two kinds of arterial on test, the accelerations and decelerations are analyzed with speed and fuel consumption. Comparing two of the three dimension diagram of Figure 6, there are following trends of fuel consumptions.

1) For the same speed, the higher accelerations lead to higher fuel consumptions. It is all true to both road types for all speeds.
2) For the same acceleration, fuel consumptions are about similar levels regardless speed variations.
3) The scooter riding on the urban arterial tends to have less percentage of aggressive accelerations/decelerations; by aggressive means accelerations is greater than 1 m/sec^2 or decelerations stronger than -1 m/sec^2. As to scooter driving conditions on the rural arterial, it is more often to have aggressive accelerations and decelerations which leads to larger variations of fuel consumptions at the same speed comparing with of the urban arterial.
4) Because of more aggressive accelerations at speeds over 15kph, the fuel consumptions on the rural arterial are higher than on the urban one.

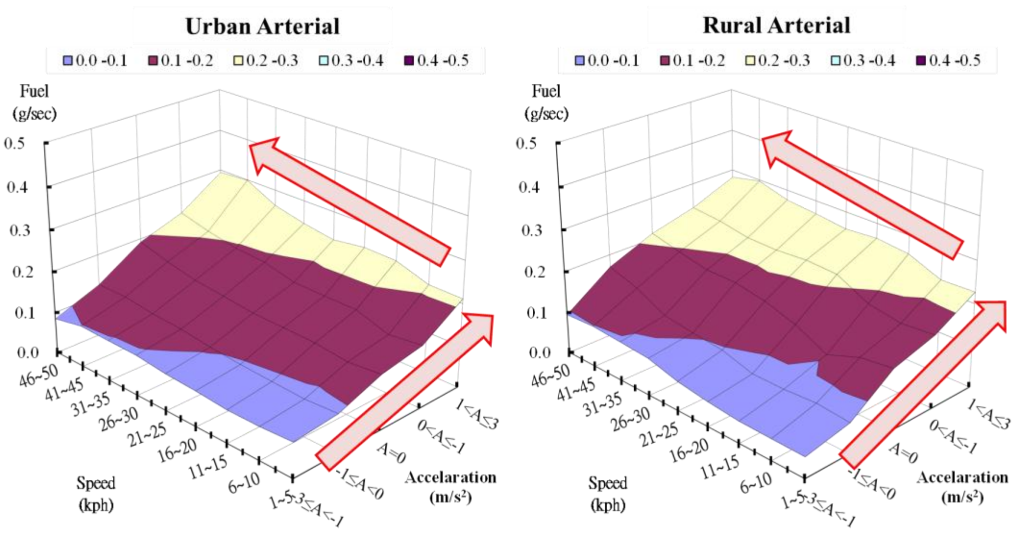

Figure 6. The 3D diagrams of fuel consumptions, speeds and accelerations/decelerations

4. CONCLUSIONS AND SUGGESTIONS ON FURTHER STUDIES

1) This study successfully deploys a compact on-board emission measurement device to record instantaneous emissions while scooter is moving on the roads. It is helpful to progress our understandings of fuel consumption characteristics of scooter in real world.
2) The data collected from the real world shows different fuel consumptions by road types. It is of larger variations and higher positive slop with speed on the rural arterial than on the urban arterial.
3) The 3D diagrams of fuel consumptions, speeds and accelerations/ decelerations help to clarify main reasons behind the fuel consumption differences on two types of road. More aggressive accelerations/decelerations on the rural arterial leads to higher fuel consumption than on the urban arterial at the same spped.
4) Given the results of this study, it is with highly potential to investigate data collected from the real world to clarify and quantify fuel consumption of scooter with the urban settings.
5) Taking the advantage of the on-board emissions measurement, it is possible to investigate fuel consumptions of scooter based on real world data. It will leads to better understanding of characteristics affecting fuel efficiency as well to higher credibility and reliability of estimated fuel consumptions of scooter moving in the real world.

ACKNOWLEDGMENTS

The Institution of Transportation, Ministry of Transportation and Communications, is acknowledged for providing funding for ***the series studies of On-Board Measured Fuel Consumptions and Green House Gas Emissions from Vehicle Tailpipes***. The data analyzed here is collected for the project MOTC-IOT-101-PDB001.

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