Comparative Study on Fuel Consumption and Different Driving Cycles for a Passenger Car in Malaysia via 1-D Simulation

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Abstract. The purpose of this study is to analyze the fuel consumption of passenger cars in Malaysia by using 1D-simulation. The analysis of fuel consumption will focus on common model of cars in Malaysia and will be carried out by using existing driving cycle. New European Driving Cycle (NEDC), Federal Test Procedure (FTP75) Driving Cycle, and Worldwide Harmonized Light Vehicle Test Procedure (WLTC) Driving Cycle were used as the established driving profiles. The new local driving cycle which was developed by UniMAP Motorsport Technology Research Unit (MoTECH) was used as the main driving profile for the simulation. A 1.3L Perodua Myvi 2012 with manual transmission was selected as the vehicle model for the project. The simulation results were compared with the established driving cycles. The results show the average fuel consumption and emissions of passenger cars is critically affected by the driving behaviors' and vehicle engines condition. The aggressive driving gives the higher rate of fuel consumption and also the cold start-up engine affecting the fuel devours and emissions rate. In addition, comparison of the obtained simulation results with manufacturer’s published data showed a good agreement thus indicating suitability of the model to be used in further research.

1. Introduction
Fuel consumption is the measure of fuel that vehicle utilized it to travel a particular range at a specific velocity. It is rate at which an engine uses fuel, which is expressed in units as miles per gallon or liters per kilometer. Malaysia is a quickly creating nation in Asia, where the interest for traveler autos expands each year. The increasing of demand for passenger cars in Malaysia was caused the rate of air pollution becomes higher since the rate of exhaust emissions from the cars was increased indirectly by...
large uses of fuel consumption. The larger uses of fuel consumption will increased the rate of exhaust emissions that indirectly can pollute the air quality. Hence, it is important to carry out the study on average fuel consumption and exhaust emission from the cars as a measure of energy optimization and environmental quality. Fuel consumption is the amount of fuel a vehicle utilizes to travel in a particular space at a particular velocity. It is rate at which an engine uses fuel, expressed in units such as miles per gallon or liters per kilometer. Fuel consumption or fuel utilization is an essential engineering degree which straightforwardly leads towards to fuel devoured per 100 kilometres. It is valuable since it capable as a coordinate degree of fuel optimization [1]. The fuel consumption has utilized as a standard to calculate the fleet normal fuel utilization execution for the urban and interstate cycles.

The exhaust emissions and fuel utilization were critically affected by the vehicle start-up conditions factor [2]. The cold start-up and hot start-up are depends on the catalytic converter. The hot start-up prefers a better fuel proficiency and lower emission rate compared to the cold start-up. Speeding up mode is critical factors that influencing the fuel utilization. A study has been conducted by Iftishah [3] which is to evaluate the fuel utilization from the graphic data obtained precisely. The study is divided into two parts, simulation and experiment.

In this project, fuel consumption of passenger cars in Malaysia was analyzed by using the GT-SUITE simulation software. A 1.3L Perodua Myvi model has been selected as the projects’ model and the driving profile are based on the local driving cycles. The simulations will give the outcomes about the average of fuel consumption. Then, the simulation results will be validated by made a comparison with the real world data and also with the specification data from the manufacturer.

2. Development of a car modelling

The car modelling was developed based on 1.3L Perodua Myvi model using GT-Suite software. The specifications of the car are given by Table 1.

| Engine Type | 1NR-VE, 4-cylinders |
|-------------|---------------------|
| Engine Displacement | 1329 |
| Maximum Output, kW/rpm | 70/6000 |
| Maximum Torque, Nm/rpm | 121/4000 |
| Kerb Weight, kg | 975 |
| Wheelbase, mm | 2200 |

A complete car was modelled in GT-Suite consists of nine parts of component which are engine, clutch, transmission, vehicle body, driveshaft, differential, axles, tires, and environment as shown in Figure 1. The attributes for each parts of components is filled by using the approximately real car specifications. There were several attributes that set to the default since certain data cannot retrieved from the manufacturer. However, the input parameter still in standard ranges and approximately to the real data. Among the parts of components for car modelling, there were several critical parts that highly affected the result which is engine, vehicle body, transmission and environment. Table 2 shows the input parameter for several parts of components of car modelling.
Table 2. Parameters of 1.3L Perodua Myvi 2012 model. [3]

| Parameter                                      | Value          |
|------------------------------------------------|----------------|
| Maximum engine torque $T_{engine}$            | 116 Nm         |
| Total gear ratio                              |                |
| Gear ratio $1^{st}$ gear                      | 11.01          |
| Gear ratio $2^{nd}$ gear                      | 6.15           |
| Gear ratio $3^{rd}$ gear                      | 4.03           |
| Gear ratio $4^{th}$ gear                      | 2.81           |
| Efficiency of gear transmission $H_t$         | 0.85           |
| Area of frontal $A$                           | 2306 m$^2$     |
| Coefficient of air drag $C_d$                 | 0.32           |
| Density of air $\rho$                         | 1.225 kg/m$^3$ |
| Radius of tire $r$                            | 0.288 m        |
| Mass of driver + mass of vehicle $m$          | 1055 kg        |
| Coefficient of rolling resistance             | 0.01           |

For the driving profile, there were three types of existing driving cycle is used for the simulation process which is New European Driving Cycle (NEDC), Environmental Protection Agency Federal Test Procedure (FTP75), and Worldwide Harmonized Light Vehicle Test Procedure (WLTP). All this type of driving cycles were selected to make a comparison with the simulation analysis by using local driving cycle which named as Urban Driving Cycles (UDC). Hence, all four type of driving cycles were used during the simulation analysis and some comparisons between them would be made.

3. Results and Discussions

According to the fuel performance factory claims made by Zal [6], the 1.3L Perodua Myvi 2012-2014 made products has used the NEDC for their fuel economy and performances. The Perodua claims that their 2012’s 1.3L Myvi had average fuel consumption at 11.9 km/L. The simulation has been conducted as 1D simulation in GT-Suite for each of the driving cycle. The results were tabulated and represented in Table 3.

Table 3: Comparison of Simulation Results between Different Type of Driving Cycle

| Type of Driving Cycle | Parameter               | Unit | WLTP  | FTP75 | NEDC   | UDC  |
|-----------------------|-------------------------|------|-------|-------|--------|------|
| Engine Total Fuel Consumption | g          | 675.90 | 1427.29 | 1358.88 | 928.33 |
| Total Distance Travelled | m          | 11001.91 | 17717.06 | 22613.55 | 13259.05 |
| Average Vehicle Speed | km/h       | 33.57 | 34.03 | 45.23 | 31.82 |
Maximum Vehicle Speed km/h 120.03 91.20 123.09 87.35
Average Fuel Consumption km/L 12.30 9.38 12.64 10.80
Average CO Emissions Rate g/h 0.17 0.13 0.15 0.15
Total CO Emissions g 203.76 237.48 266.47 220.19
Average NOx Emissions Rate g/h 0.03 0.04 0.03 0.03
Total NOx Emissions g 38.00 74.29 62.03 49.56
Average HC Emissions Rate g/h 0.01 0.01 0.01 0.01
Total HC Emissions g 11.22 14.58 14.45 13.38

Thus, the simulation result that used the NEDC and UDC as the driving cycle profile is been critically compared since the claims made by Zal [6] also state the factory data used the NEDC as their parameter input data. By referring the engine total fuel consumption criteria, the NEDC simulation result gave 1358.88g based on its profile transient while the UDC simulation result give 928.33g of engine total fuel consumption based on its own profile transient. To calculate the average mass of fuel consume per kilometre for each driving cycles simulation results, the Equation 1 is been used.

$$\text{Average Mass of Fuel Consumption} = \frac{\text{Engine Total Fuel Consumption}}{\text{Total Distance Travelled}}$$ (1)

The average mass of fuel consumption for the NEDC is 60 g/km while the average mass of fuel consume for the UDC was about 70g/km approximately. It was about 14% percentage errors between both simulations data. Table 4 shows the comparison for average fuel consumption between NEDC, UDC and factory data claim by Perodua.

Table 4: Comparison of Average Fuel Consumption between NEDC, KLDC and Factory Data Claims by Perodua

| CRITERIA          | FACTORY DATA (1.3L PERODUA MYVI) | NEDC SIMULATION RESULTS | UDC SIMULATION RESULTS |
|-------------------|---------------------------------|-------------------------|------------------------|
| Average Fuel Consumption | 11.9 km/L                      | 12.3 km/L                | 10.8 km/L               |

To verify the vehicle car modelling developed from this project, some comparison are been made by referring the factory data claims and compared it with the NEDC simulation results. Equation 2 was used to calculate the percentage error between the simulation data and factory claimed data.

$$\text{Percentage Error(\%) =} \left| \frac{\text{Original data} - \text{Simulation data}}{\text{Original data}} \right| \times 100\%$$ (2)

By applying the Equation 2, the percentage error between NEDC simulations data and factory data was about 3.36% approximately. The percentage error between both data is very acceptable and improve the accuracy of the results. Thus, it can validate the vehicle car model that has been developed during the car modelling stage of the project and make the car modelling by using the GT-SUITE software was able to used for simulation analysis.

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Figure 2: Comparison of average fuel consumption for different driving cycles and Perodua Data.

Figure 2 shows the comparison of average fuel consumption between different driving cycles and compared to the factory data claims by the manufacturer. From the results, the average fuel consumption of NEDC is the nearest with the factory data claims. The second nearest with the factory data claim was the UDC simulations data which is 10.8km/L. The percentage error between the UDC simulation data and factory data claim was about 9.24%. This shows that Malaysian driving behaviour are more aggressive, thus the fuel consumption is higher. Moreover, the developed driving cycle was based on data from urban area, which consist much of deceleration-acceleration conditions. Nutramon [7] had claims that the rough driving behaviour has used the brake for multiple times during sudden deceleration and acceleration, may affect the condition of engine states which may used larger power for the braking mechanism. FTP75 gave the highest average fuel consumption rate while WLTC gave the lowest average fuel consumption rate, which are 9.38 km/L and 12.64 km/L, respectively.

4. Conclusion
This study had compared the fuel consumption for a passenger car in Malaysia through four different driving cycles by using GT-SUITE. The tested car modeling has been developed based on 1.3L Perodua Myvi Model 2012. Data specifications from the previous study and Perodua factory data had been used for modelling. One of the driving cycles was developed for urban area in Malaysia. This driving cycle will reflect the driving behaviour of Malaysian, namely UDC. From the results, Malaysian driving behaviour were more aggressive, thus the fuel consumption is higher compared to NEDC and factory claims fuel consumption. For validation of car modelling, the simulation results of NEDC was compared to the factory data that also used the European drive cycle as its driving profile and give a percentage error about 3.36%, which is acceptable. This study is the preliminary study to the fuel consumption and exhaust emission investigation in Malaysia using driving cycle that reflects driving behaviour of Malaysian.

5. References
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Acknowledgments
The authors would like to acknowledge Malaysia Automotive Institute (MAI) for funding this study and PERODUA for technical supports.