Recording of parameters characteristic to engine and vehicle in order to validate a simulation model for fuel consumption

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Abstract. Present paper aims to validate a simulation model through experimental research in order to determine fuel consumption of a vehicle. To this purpose, the experimental test consisted in the usage of a specialized tester in order to record several parameters characteristic to vehicle and engine functioning. Specific data were subsequently used to determine real fuel consumption. To perform a comparative analysis, the theoretical fuel consumption was determined with the use of data acquired during experimental tests and simulated graphical software.

1. Introduction
Main aspect considered when buying a vehicle, apart from pollutant emissions, is fuel consumption. Because this parameter is influenced, among others, by the type of driver, it arises the need to conduct a study in order to highlight the correlation between vehicle speed and engine speed or selected gear. To compare the efficiency of an internal combustion engine, it is used the graphical representation of fuel consumption. It has been proven that higher engine speeds determine higher intake flow of fuel and at lower engine speeds, for example below 1400 rev/min, the time frame between two burning cycles increases and the fuel consumption also increases due to longer periods of time when heat transfer is directed to cylinder walls.

Moreover, the ratio of the gearbox has influence on fuel consumption because it can change the operating mode of engine. Therefore, same engine power can be obtained for lower or higher fuel consumption, depending on engine parameters (engine speed, engine torque), which can be modified by using an appropriate gear.

For lower fuel consumption it is recommended to run the engine at average engine speeds, by avoiding, as much as possible, higher values of engine speeds. In most situations, minimum flow of fuel is obtained for quite lower engine speeds that the one characteristic to maximum engine torque. Therefore, in case of optimal usage of gear ratios, without overlooking possible drawbacks like noise, vibrations and startup capability, fuel consumption can significantly be reduced.

2. Experimental part
The experimental tests were conducted with a Volkswagen Touareg vehicle, with a mass of 2313 kg, equipped with a V-6 gasoline engine of 3597 cm³ cylinder capacity, a maximum power of 206 kW (280 CP), at rated engine speed of 6200 rev/min and a maximum engine torque of 360 Nm, at 3500 rev/min engine speed. The vehicle is four-wheel drive, with a maximum speed of 227 km/h and it can accelerate from 0 to 100 km/h in 8.6 s. The motor vehicle has a 09D transmission, built by the Japanese company Aisin, with 7-speed gearbox.
For vehicle stationing with the engine running, the gear selector must be positioned past the button P (parking) and must press the braking pedal and the lock button of lever.

For reverse running, the lever must be positioned past the R button, and must press the lock button. To disengage the engine from the drive train and wheels, the selector is at N position, and if this mode lasts for a longer period of time, it must be pressed the brake pedal in order to use the gear selector. In D - Drive mode, gears change automatically, without the intervention of the driver. To automatically change gears by a strategy stored in the electronic control unit, it must be selected the S - Sport mode; changes will happen later and the gearbox will remain in a certain gear for longer period of time than in case of Drive mode [5].

![Figure 1: Selecting gear lever of VW Touareg 7L](image)

The position of lever past buttons „+“ and „-“ allows the control unit to enter in Tiptronic mode by establishing an electric contact which allows manual change of gears in the automatic gearbox.

In figure 2 there are presented main components of automatic gearbox 09D (MPS- simple planetary gear mechanism, MPR- Ravigneaux planetary gear set).

![Figure 2: Section of automatic gearbox 09D](image)
Experimental results have been recorded with the use of a specialized tester, able to read and record data such as engine speed, vehicle speed, throttle shutter’s position, specific gear etc.

Therefore, by performing a test with the vehicle on the test stand, there have been recorded data with the use of a specialized tester, such as: time variation of vehicle speed and corresponding gear ratio, in order to identify the driving mode.

Yet again, there have been taken into account parameters like: air density of 1.2 kg/m³ and air temperature of 20°C.

Other data used to determine real fuel consumption of vehicle, were: gear ratio, total cylinder capacity, caloric efficiency of gasoline, minimum engine speed of 800 rev/min, minimum rotational speed of first shaft of gearbox of 500 rev/min, performance level characteristic to gear ratios of 98%, width of tire 235 mm, height/width ratio of 65%, diameter of wheel 17 inch, and the radial type of tire.

Apart from parameters recorded with the use of a tester, there have been considered two values obtained from computing: gear ratio of conic assembly, whose value was 7.036, as well as wheel inertia which resulted 0.45 kg/m².

Based on these data and with the use of a modeling and simulation software (AMESIM simulation software for educational purpose), there have been obtained graphs of fuel consumption per unit time (seconds) and total fuel consumption of vehicle [2].

Data regarding fuel consumption of vehicle, which were obtained from simulation (both in case of Drive mode and manual mode), were later compared with specifications provided by the vehicle manufacturer.

3. Results

In figure 3 it is shown the graph of fuel consumption per second in case of Drive mode. During the entire period of simulation, gearshad beenchaged automatically, according to vehicle’s on-board computer. As it can be observed from the graph, the engine recorded a maximum fuel consumption of nearly 9.5g/s. During the rest of experimental test, fuel consumption reached lower values per second.

![Figure 3 Flow of fuel per unit time – Drive mode](image-url)
In figure 4 is shown the flow of fuel per unit time in case of manual shifting of gears (Tiptronic mode), with the use of gear selector towards „+“ and „-“. In comparison with Drive mode, during manual mode have been recorded multiple periods of time when the fuel consumption reached higher values. The maximum fuel intake was 10.5g/s, furthermore, during the entire simulation period the on-board computer recorded multiple values above 2g/s. From figure 3 and figure 4 it can be concluded that during Drive mode, depending on vehicle speed and distance traveled, the vehicle consumption was higher than in manual mode [3].

Another parameter regarding fuel efficiency it totals fuel consumption. In figure 5 there are shown results in case of automatic driving and figure 6 consists results specific to Tiptronic mode. From figure 5 and 6, it can be observed that total intake of fuel is considerably lower in case of Drive mode (53.77g of fuel consumed during the entire simulation time of 80 s) than in manual mode (130.29g of fuel in 80s).
The distance traveled by the motor vehicle was simulated according to AMESIM software and it is shown in figure 7 (for Drive mode) and figure 8 (for manual mode). The corresponding values are 0.280 km and 0.130 km.
Figure 8 Total distance traveled by the vehicle-manual mode

Considering testing period of 80s, and knowing total fuel consumption and the distance traveled by the vehicle from upper graphs [3], it can be calculated the fuel consumption at 100 km, for both manual and Drive mode.

In case of manual mode, the value calculated was [1]:

\[
C_{100\text{km}}^{kg} = \frac{C_T}{D} \times 100 = \frac{0.130}{0.67} \times 100 = 19.17 \text{ [kg km]} \tag{1}
\]

Where \( C_T \) [kg] is total fuel consumption in 80 s and \( D \) [km] is distance traveled by the VW Touareg.

According to [1], fuel consumption in liters/100km is:

\[
C_{100\text{km}}^{l} = \frac{C_{100\text{km}}^{kg}}{\rho} = \frac{19.17}{0.73} = 26.26 \text{ [l/100 km]} \tag{2}
\]

where \( \rho \) [kg/l] is density of gasoline.

Similarly, for Drive mode, the value of fuel consumption at 100 km, indicated in liters, is:

\[
C_{100\text{km}}^{l} = \frac{C_{100\text{km}}^{kg}}{\rho} = \frac{19.25}{0.73} = 26.36 \text{ [l/100 km]} \tag{3}
\]

By introducing same data within the modeling-simulation software as those from experimental research, and by performing a comparative analysis of vehicle speed, it has been observed a difference between calculated speed with the simulation software and the value recorded by the specialized tester. Differences have been of ± 9km/h in case of Drive mode and of ±6km/h in case of manual mode, as it can be observed from the figure 9 and figure 10.
4. Conclusions

Data recorded by the specialized tester, which have been later used to develop a modeling - simulating software, able to simplify and increase efficiency of the computing process of vehicle’s fuel consumption, have led to the conclusion that simulated fuel consumption is approximately equal to the value offered by the vehicle manufacturer.

Moreover, the model can be extrapolated in order to determine fuel consumption for other vehicles, as long as it is owned a tester able to provide parameters that have been used during present simulation.

Nevertheless, the usage of an educational version of modeling-simulation software has certain drawbacks and these were highlighted through the computing error of speed. The result consisted in differences between vehicle speed obtained by experimental research and the value from simulation,
which was previously indicated in the text. However, this limitation did not influence the studied parameter.

In both situations, during experimental tests and simulation part, the fuel consumption was higher in case of manual shifting of gears than in Drive mode, which was expected.

In conclusion, it can be stated that the virtual model created allows high precision simulation of fuel consumptions in case of a tested vehicle.

References
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