AUTOMOBILE FUEL CONSUMPTION CHANGES AS AFFECT OF LOAD

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Abstract. Load is one of the fuel consumption affecting factors and is hard to measure. A new methodology for load impact measurement was carried out for both: on-road and chassis dynamometer experiments. Three driving cycles were introduced: impulse, gradual and pulsing. The gradual driving cycle was chosen as best suitable for further experiments. The experiments were performed using the chassis dynamometer, fuel consumption meter, global positioning system data logger, automobile diagnostic equipment and automobile scales. The experiments were made with Renault Trafic automobile with three different load regimes: near mass full, near mass equipped and near half of difference of the previous two. The fuel consumption is increasing by increasing the load, every 100 kg load increases the fuel consumption by 2.58- 2.95 % varying from the driving cycle in on-road, and 2.57-2.89 % on chassis dynamometer experiments.

Keywords: fuel consumption, load, on-road experiments, chassis dynamometer.

Introduction

Nowadays fuel prices are only growing, so it is important to find ways to use less fuel and explore factors that affect its consumption. One of less talked about factors is the load. Sure, every driver knows that adding weight to the vehicle will increase the fuel consumption, but how much and what are the tendencies of fuel consumption increase? There are few ways how to determine the fuel consumption (by on-road or chassis dynamometer experiments) using various methods (mass, flow or capacity).

The problem is that fuel consumption is affected by the factors such as traffic, driving style, weather, etc, so that any small change has a big impact. To solve this problem, vehicle industry has developed a series of standard tests so that the vehicle can be measured under repeatable conditions, and different vehicles compared in same conditions to each other. To avoid the changes of the weather and other outside factors, the test is conducted indoors on a chassis dynamometer (also known as a "rolling road", "inertial roller stand" or just "dyno"). For new vehicles factory experimental fuel consumption results are given in brochures and other technical information.

But are these simulated conditions showing the real fuel consumption that can be reached in daily driving? Otherwise, this data misinforms the vehicle owners and drivers, that could be crucial, for example, for automobile fleet fuel consumption quota determination. So, it is important to make research in differences between on-road and chassis dynamometer experiments. The experiment vehicle should be tested at various speed and load regimes to get the relationship between the load and fuel consumption and on-road and chassis dynamometer results.

Fuel consumption is affected by four main factors: load, speed regime, exploitation conditions and automobile and engine construction differences. The load can be divided in subcategories: mass or resistance (air, upslope, rolling, inertia and trailer resistance).

Materials and methods

In experiments Renault Trafic 2007 year model was used. The main automobile and engine technical data: engine type – turbo diesel, maximum seats – 9, engine displacement – 1995 cm^3, maximum power – 66 kW, direct injection system common rail BOSCH EDC16, full mass– 2835 kg, equipped mass– 1957 kg, manual gearbox.

To carry out fuel measurement experiments, such devices were used:

- AVL KMA Mobile Fuel Consumption Meter;
- Mustang MD-1750 chassis dynamometer;
- Canyon CNS-GPS2 global positioning system data logger;
- Technotest Smart Module 5041 automobile diagnostic equipment;
- VTEQ Safety Test Lane 3000 automobile scales.

Fig. 1. **AVL KMA Mobile fitted to automobile:** 1 – computer for data collecting; 2 – measuring module; 3 – conditioning module; 4 – fuel supply hoses

AVL fuel consumption meter was fitted to the automobile so that the original fuel tank could be used (see Fig. 1). AVL KMA Mobile fuel consumption meter can be used for diesel, petrol or biofuels measurements, it enables continuous measurement of instantaneous flow rates from 0.35-150 l/h. It uses short measuring times to ensure high data quality. The device can be used for fuel systems with and without return flow to the tank. The inlet pump delivers fuel from the automobile tank through the fuel inlet to the system pressure regulator (see Fig. 2). To avoid degassing fixed pressure is set at this system pressure regulator and any excessive fuel flows back to the tank through the heat exchanger and the fuel return line (inlet circuit). The outlet pump delivers the fuel via the outlet to the engine. The fuel returns via the fuel return line back to the heat exchanger. The same amount of fuel which is consumed by the engine is feed in through the flow meter [1].

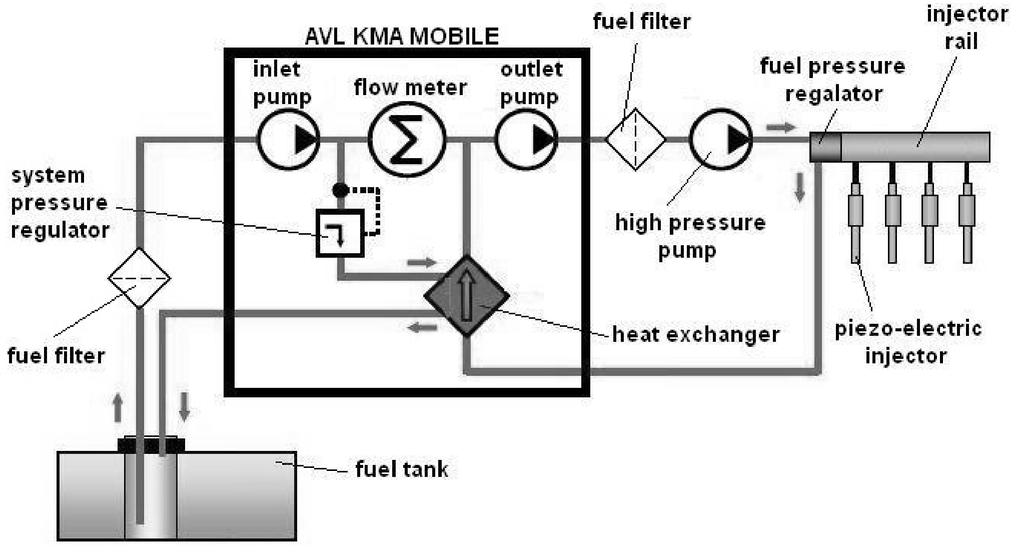

Fig. 2. **AVL KMA Mobile fitting scheme [1]**

During the on-road driving tests the car was equipped with the data logger CANYON CNS-GPS2 for determination of the GPS (Global Positioning System) coordinates and travelled distance. The logger software allows to export the data also to .csv, .txt, and .gpx formats for more detailed inspection in spreadsheet application [3]. It is possible to export the data via a KML file to Google earth, to visualize the travelled route and distance.

The Mustang MD-1750 chassis dynamometer consists of mechanical, electro-mechanical, and electronic modules, that simulate actual road loads to get repeatable and valid data not only for performance, but also emission and driving cycle tests. Specification: maximum horsepower- 1750 hp, maximum speed- 100.56 $m \cdot s^{-1}$, controls- Pentium-based PC, MD-7000 control platform, roll decelerator- allows vehicle deceleration without use of vehicle brakes, rolls- precision machined and dynamically balanced; 1.27 m diameter roller per wheel, 0.71 m face length, 0.71 m inner track width, 2.13 m outer track width [2]. The automobile must be fixed on the chassis dynamometer with straps from the front and back, to keep the automobile straight and in place (see Fig. 3). The inertial rolling stand operates with automobiles driving wheels proportionally to the driving speed, imitating driving conditions. The air and rolling resistance sum at 80 km/h must be typed in the chassis dynamometer control platform [5] from its manual. The control platform also allows to change the automobile mass.

Fig. 3. **Renault Trafic on chassis dynamometer:**
1 – automobile; 2 – roll; 3 – straps; 4 – control platform

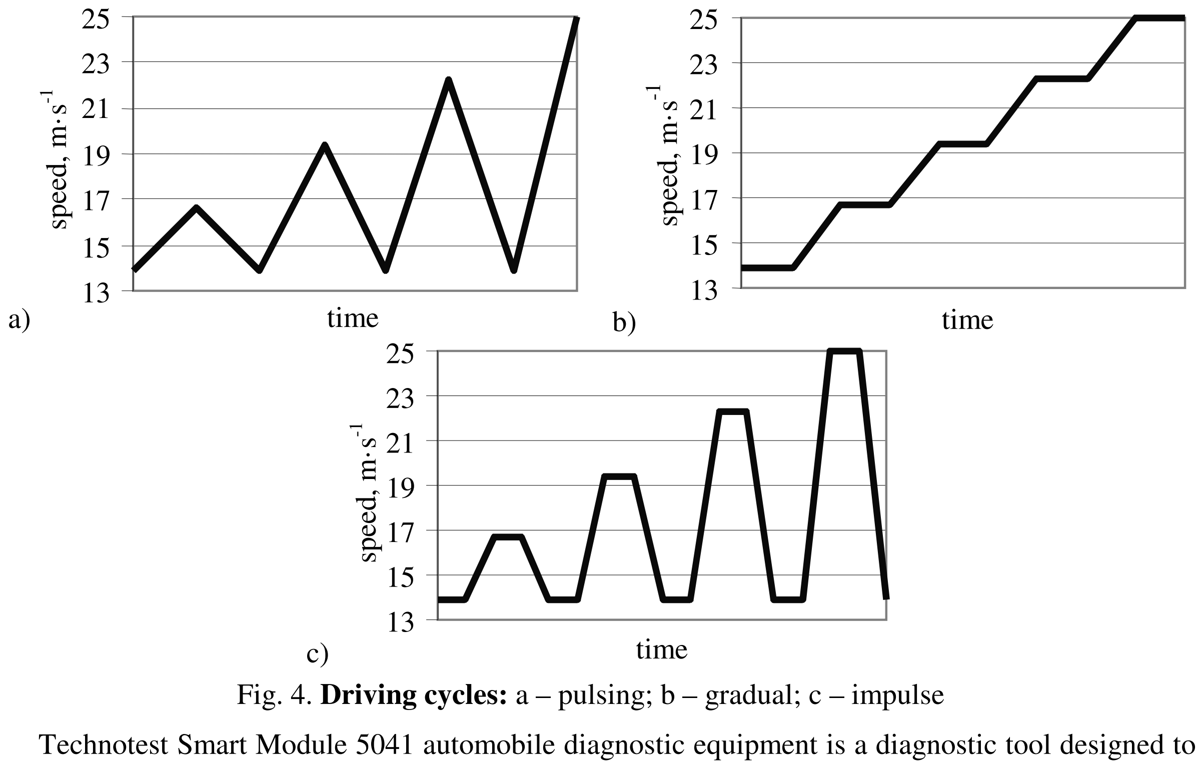

Fig. 4. **Driving cycles:** a – pulsing; b – gradual; c – impulse

Technotest Smart Module 5041 automobile diagnostic equipment is a diagnostic tool designed to connect the ECUs of cars and motorbikes to any computer. The data can be recorded during a road test, and then replayed later on computer display. For on-road experiments this device can be used to monitor precise automobile speed. Smart Module has also functions of a typical scan tool, such as fault code reading, live data, actuator testing and settings [4].

Three load regimes were used: near mass full (3000 kg), near mass equipped (2035 kg) and near half of the difference of the previous two (2540 kg). The weights must be distributed evenly and should not be stored in the automobile for a long time not to cause any harm to the suspension or handling. In chassis dynamometer experiments there is no need for weights, because the automobile weight is simulated by the control platform.

Different speed cycle regimes were used. Every mode was repeated three times. All experiments were made in the fifth gear. The automobile was tested in three driving cycles: pulsing, impulse and gradual (see Fig. 4). In the gradual and impulse cycle every constant speed hold is 10 seconds.

Results and discussion

The experiments were made on the roads near Jelgava and in the Scientific Laboratory of Biofuels in Jelgava. The minimal person number to make the experiments is two. One person needs to drive the automobile and maintain the needed speed regime, the second- to collect the data. The collected data need to be exported later into spreadsheet application to be processed, because the included software allows only monitoring the processes.

The experiment results are given in Table 1. The impulse driving cycle uses less fuel, but the gradual- more than the pulsing cycle. Despite the impulse cycle being longest to perform, having long accelerating periods, its deceleration periods provide the lowest overall fuel consumption.

The pulsing cycle is similar to the pulsing driving method for reducing fuel consumption (only acceleration is always to one speed) [6].

Table 1

Experiment results

Weight	Fuel consumption in cycles, $l\cdot(100\ km)^{-1}$			Experiment type
	pulsing	impulse	gradual	
2035 kg	6.55	6.70	7.19	on-road
	6.95	7.52	7.97	chassis dynamometer
2540 kg	8.36	8.45	8.53	on-road
	9.36	9.72	10.58	chassis dynamometer
3000 kg	8.83	9.08	10.20	on-road
	9.36	10.58	11.20	chassis dynamometer

Comparing different driving cycles (see Fig. 5 and 6), the fuel consumption is increasing when the load increases. The gradual cycle is least fuel efficient, but it is easiest and shortest to perform, so it is suited for experiments with many fuel or load regimes, or repeats. The fuel consumption difference between empty and fully loaded automobiles is 25.8 % for pulsing, 26.1 % for impulse and 29.5 % for gradual driving cycles in the on-road experiments, but on the chassis dynamometer 25.7 % for pulsing, 28.9 % for impulse and 28.9 % for gradual driving cycles.

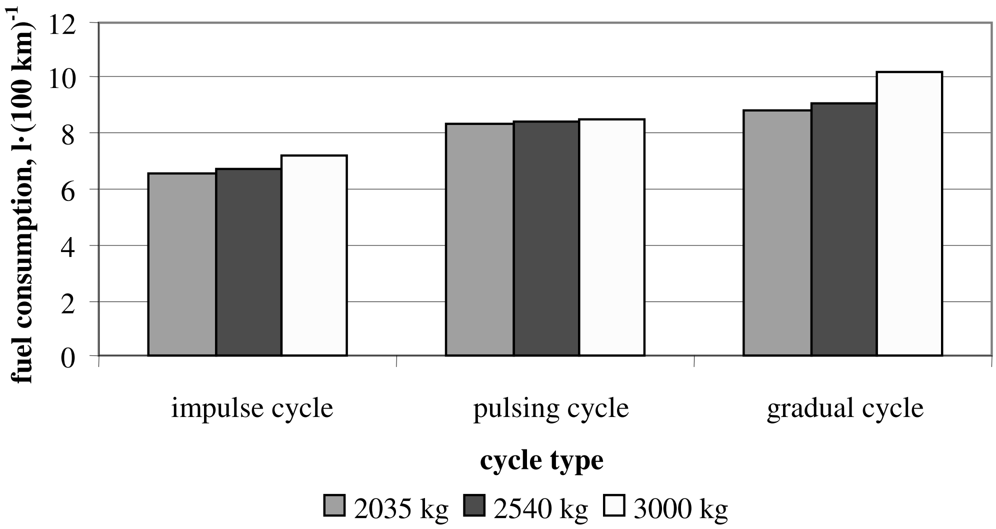

Fig. 5. **On-road experiment results**

Driving in constant speed mode the differences would not be so significant, because there is no inertial resistance. The differences between the on-road and chassis dynamometer experiment results can be caused by the air and rolling resistance factor, that needs to be typed in the control platform before the experiments or chassis dynamometer mechanical, electromechanical, electrical and electronic modules, that work together- cannot imitate all automobile influencing factors.

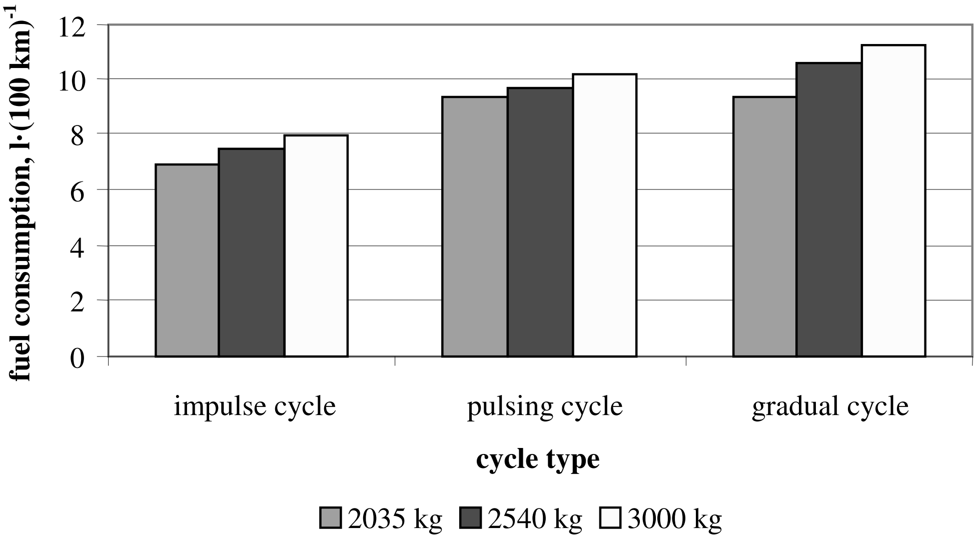

Fig. 6. **Chassis dynamometer experiment results**

Conclusions

1. Three driving cycle types were created: impulse, pulsing and gradual. As the best for measuring the load impact on the fuel consumption the gradual cycle was chosen.
2. Increasing the automobile load for every 100 kg, the fuel consumption increases in the on-road experiments for about 2.58 % in impulse, 2.61 % in pulsing and 2.95 % in gradual cycles, but on the chassis dynamometer- about 2.57 % in impulse, 2.89 % in pulsing and 2.89 % in gradual cycles.
3. All driving cycles can be performed on the chassis dynamometer or in on-road conditions. The results show differences between the two, it is suggested to calculate the air and rolling resistance factor individually, not to choose from the given chassis dynamometer manual.

References

1. AVL Product Description [online] [20.03.2011]. Available at: www.avl.com/c/document_library/get_file?uuid=babff1d2-4c12-49bb-a4a4-e14d45e5ec7a&groupId=10138
2. MD-1750 Chassis Dynamometer [online] [12.03.2011]. Available at: http://www.mustangdyne.com/pdfs/MD1750_IN.pdf
3. CNS-GPS2 GPS Sports Watch [online] [18.03.2011] Available at: http://www.canyon-tech.com/news/newproducts/CNS-GPS2
4. TECNOTEST - 5041 - SMART MODULE [online] [18.03.2011] Available at: http://www.tecnotest.com/tcn/5041_-_SMART_MODULE_/prodotti_dett.asp?id_cbu=6&id_cam_app=14-
5. Putnieks U. Consumption of fuel depending on automobile load. Research papers of Lithuanian University of Agriculture, 2010, Vol 42, No 2-3, pp 214 – 221, ISSN 1392-1134
6. Putnieks U. Automobiļa degvielas patēriņa izmaiņas slodzes ietekmē (Automobile fuel consumption changes as an affect of the load). Bachelor paper. Jelgava, 2009, p 21. (In Latvian)