

The impact of roof box on fuel consumption

František Synák¹, Vladimír Rievaj¹

¹ Department of Road and Urban Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 1, Žilina, 010 26, Slovak Republic

Abstract Passenger vehicles are major petroleum consumers and contributors of greenhouse gas and criteria pollutant emissions in many countries around the world. The amount of fuel consumed affects the environment, status of health of human population as well as financial costs that are associated with vehicle operation. The roof box is one of the often used vehicle attachments. The aim of the paper is to measure the increase of fuel consumption affected by an installed roof box. The impact of roof box on the increase of fuel consumption is measured at the speeds of 50 km.h⁻¹, 90 km.h⁻¹ and 130 km.h⁻¹. The introduction of the paper describes particular harmful constituents of exhaust gases and their effects. Another part of the article includes the methodology of measurement and its results. The last part of the article involves the evaluation of results and recommendations relating to reduction of the increase of fuel consumption affected by roof box.

Keywords air resistance, emissions, fuel consumption, roof box

JEL L92

1. Introduction

Personal vehicles account for a large proportion of consumption of fuels derived from oil and they contribute to pollution of the environment in the world. A transport in the roof box of a vehicle is one of the most widely-used ways of cargo transport. The aim of the research is to measure the increase of fuel consumption affected by the installation of a roof box.

2. Effects of Fossil Fuels Combustion

Every motor vehicle fuelled by petrol or diesel produces carbon dioxide emissions. Combustion of 1 litre of petrol leads to production of 2.5 kg of the gas. Carbon dioxide has the biggest impact on global climate changes [1]. It is considered to be the most harmful greenhouse gas and accounts for about 55 % in the greenhouse effect [2]. Combustion of fossil fuels can also produce other harmful emissions. Carbon monoxide is produced as a result of incomplete oxidation of carbon and is highly toxic. Combustion of fossil fuels further produces particulate matter with its responsibility for 32,000 premature deaths per year. Other harmful constituents are nitrogen oxides, sulphur dioxide, benzene, benzine and others. It is needed to point out that combustion of 1 kg of fuel means combustion of approximately 15 kg of air [3]. The increase in fuel consumption of diesel vehicle with an average annual driven 20,000 km by 1 l.100 km⁻¹ means the increase in annual costs

of fuel by 220 € at a price of 1.10 €/l. The amount of fuel consumed has thus an impact on the environment, on the state of human population health as well as on the economic situation.

An engine must do the work in order to overcome the driving resistances. These are rolling resistance, acceleration resistance, inertia resistance and air resistance [4]. A roof box increases air resistance that further results in the increase in the work of engine needed for overcoming such resistance, and thus the increase in fuel consumption. The increase in fuel consumption affects the increase in production of emissions. According to [4], fuel consumption caused by a roof rack is about six times larger than the expected fuel savings from vehicles with fuel cells. And, only one quarter or, according to some studies, only one eighth of the drives with a roof box is realized with using a box for luggage transport. The vast majority of drives are therefore realized with an empty box [4]. The air resistance depends on air density, vehicle speed, or head wind speed, coefficient of air resistance and size of vehicle front face. The relation for calculation of air resistance can be seen as follows:

$$Q_a = 0.5 \cdot \rho \cdot v^2 \cdot c_x \cdot S \quad (1)$$

ρ	air density [kg.m ⁻³]
v	vehicle speed [m.s ⁻¹]
c_x	coefficient of air resistance [-]
S	vehicle front face [m ²] [5]

By increasing a front face together with coefficient of air resistance, there is also an increase in air resistance [6].

3. Methodology of Measurement

Measuring the impact of roof box on fuel consumption was conducted by driving tests on the road. It was carried out by personal vehicle Škoda Fabia II with diesel engine 1.9 PD, 77 kW. The roof rack was Moby Dick with volume of 305 l.



Figure 1. Vehicle with installed roof box

The fuel consumption was measured by software VCDs 15.7. During the measurement, there was also the air flow rate measured continuously by means of anemometer in order to avoid the distortion of results. Prior to the start of measuring, it was needed to mark out two fixed points on the road indicating the beginning and the end of the section where the measurement was carried out. The measurement was performed always on the same section, in one direction to avert the impact of elevation profile of the road. The impact of roof box on fuel consumption was measured at the speeds of 50 km.h⁻¹, 90 km.h⁻¹ and 130 km.h⁻¹.

Process of measuring:

- Acceleration of a vehicle at given speed,
- stabilization of the required vehicle speed,
- running of the fuel consumption measurement when passing the first marked point,
- fuel consumption measurement at the stabilized vehicle speed,
- stopping of the fuel consumption measurement when passing the second final marked point,
- check of the value of anemometer and driving back to the beginning of the measuring section.

Each measurement was repeated 3 times. The measured data are shown in the Table 1.

Table 1 Measured values

	50 km.h ⁻¹	90 km.h ⁻¹	130 km.h ⁻¹
Fuel consumption without roof box [l.100km⁻¹]	3.4	4.3	6.3
Fuel consumption with roof box [l.100km⁻¹]	3.6	4.9	7.8

The results are also shown in the form of graph to provide better display. Fig. 2

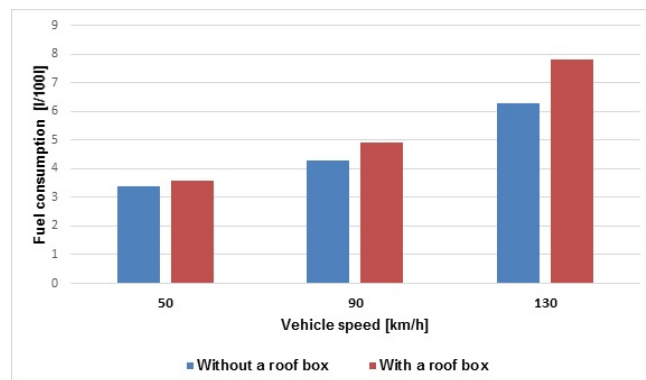


Figure 2. Graphical display of the measured results

4. Assessment of the Results of Measurements

The installation of roof box caused the increase in fuel consumption; specifically, at the speed of 50 km.h⁻¹ by 0.2 l.100 km⁻¹, at the speed of 90 km.h⁻¹ by 0.6 l.100 km⁻¹, and at the speed of 130 km.h⁻¹ the vehicle consumed more than 1.5 l.100 km⁻¹. The results of measurement have shown that a roof box has relatively big impact on fuel consumption. The installation of roof box led to increase in the vehicle front face as well as the increase in air resistance coefficient c_x [7]. The roof box disturbs the air flowing around the vehicle body and increases a proportion of turbulent flow at the expense of laminar flow [8]. The results also indicate that it is necessary to focus on the limitation in the number of drives of vehicles with empty roof box. It is essential to review the possibilities in the legislation, education of future drivers in the driving schools as well as producers of boxes. Concerning the legislation, there should be mandatory energy labelling that will make consumers to buy roof boxes with aerodynamic shape, and producers to develop and produce boxes with lower c_x . Education of drivers regarding the impact of roof box on fuel consumption is also very important. Issues of eco-driving and impacts of particular factors on fuel consumption should be, in a great extent, included in driving schools' syllabi. Concerning the producers, it is necessary to pay attention to those solutions of design that would lead to shortening of time needed for mounting and dismounting of a roof box. It is assumed that shortening of time needed for mounting and dismounting would reduce the number of drives with empty boxes. In relation to measured values, it is necessary to take into consideration the fact that these were measured in specific conditions, with particular vehicle and type of roof box. Using of other vehicle and type of roof box would lead to the change in measured values. The change could also occur due to the change of air pressure or air temperature, since these values affect the air density. Despite all the specific conditions of each measuring, it is obvious that a roof box significantly increases fuel consumption, and hence causes the increase in emissions and costs of fuel. For this

reason, it is necessary to use a roof box only justifiably and to minimize the operation of vehicle with an empty roof box.

Acknowledgment

The article has been written within the framework of institutional research of PEDAS Faculty of University of Zilina - 7/KCMD/2017 Reducing of road vehicles' air resistance and its impact on the environment.

REFERENCES

- [1] Šarkan, B., Stopka, O., Gnap, J., Caban, J. "Investigation of Exhaust Emissions of Vehicles with Spark Ignition Engine within Emission Control," In: *Procedia Engineering*, vol. 187, pp. 775-782. 2017.
- [2] Šarkan, B., Caban, J., Marczuk, A., Vrábel, J., Gnap, J. "Composition of Exhaust Gases of Spark Ignition under Conditions of Periodic Inspection of Vehicles in Slovakia," In: *Przemysl Chemiczny*, vol. 96(3), pp. 675-680. 2017
- [3] Rievaj, V., Synák, F., "Does Electric Car Produce Emissions?" In: *Scientific Journal of Silesian University of Technology – Series Transport*, vol. 94, pp. 187-197. 2017
- [4] Meier, A., Chen, Y. "Fuel Consumption Impacts of Auto Roof Racks." In: *Energy Police*, vol 92. 2016.
- [5] Skrúcaný, T., Harantová, V., Kendra, M., Barta, D. "Reducing Energy Consumption by Passenger Car with Using Non-Electrical Hybrid Drive Technology" In: *Advances in science and technology*, vol. 11, pp. 166-172. 2017
- [6] Skrúcaný, T., Šarkan, B., Gnap, J. "Influence of Aerodynamic Drag Trailer Devices on Drag Reduction Measured in a Wind Tunnel", In: *Eksplatacja Niezawodnos-Maintance and Reliability*, vol.18, no.1, pp.151-154, 2016.
- [7] Szabo, M., Majdan, R., Lindak, S., Hajdak, V. "Special Monitoring Devices for Evaluation of Driving Style of Car Drivers" , 15th International Scientific on Engineering for Rural Development, Jelgava, Latvia. pp. 696-701, 2016.