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ANALYSIS OF IMPACT OF SELECTED GROUP OF FACTORS OF VEHICLE WORK CONDITIONS ON THE FUEL CONSUMPTION

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Introduction

The motor vehicle works when performing its transport role under various conditions, which have a significant impact on it. Said conditions are gradually changing in the given delimited space and time. These conditions can be characterized as facts having a significant impact on riding a vehicle, method of its operation, wear of its parts and last but not least on fuel consumption.

There is a direct relationship between the transport and energy consumption or respectively fuel consumption. It is given by the fact that each of transport means needs some kind of fuel for its performance. The transport in general is globally responsible for consumption of around 25% of totally produced energy and requires annually more than 55% out of the total volume of yielded oil.[3]

The fuel consumption has especially in relation to the growth of motorization in the 21st century become one of the key areas. The fuel consumption is important also with regard to negative impacts of the transport industry on the environment, as reduction of emissions is conditioned with reduction of fuel consumption by motor vehicles. Approaches and procedures in the area of reducing fuel consumption by motor vehicles are diverse and respective methods for examination of such impact correspond to it accordingly.

Specification and determination of examined issue

All effects having a possible impact on the fuel consumption can be divided to external and internal factors. Indicators of properties of structural-functional groups and quality of a motor vehicle in operation can be deemed internal factors. External factors represent the surroundings of the vehicle in which the vehicle is situated during the performance of its transport function. These factors of individual conditions for vehicle operation impact to a

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[3] see www.dolceta.eu

certain extent the consumption of such vehicle and then *costs for operation* of freight vehicles or buses can significantly grow especially in the case of transport companies, what is then reflected also in revenues.

Today, when fuel prices are growing, each transport agent or motorist strives to reduce the fuel consumption. It is a big problem in the transport industry and therefore this contribution is aimed at the assessment of impact of selected operation conditions on the fuel consumption of motor vehicles.

In order to achieve our aim we focused on *factors derived from working conditions of the vehicle,* i.e. preferentially related to *transport (road) conditions (representing external factors).*

We divided these factors to two primary groups according to the impact of features typical for them [1]:

- factors characterizing the impact of communication,
- factors characterizing the transport infrastructure.

We included among factors characterizing the impact of road communication on the ground of our findings the following:

- communication macro-profile (inclination, directional and altitude conditions on the road),
- nano-profile (has impact on vehicle tires and on the grounds of that impacts also the rolling resistance and adhesion coefficient),
- road surface and pattern (has impact on radial load of individual vehicle axles),
- communication width,
- road cover,
- general condition of communication.

Another group is formed by factors characterizing the transport infrastructure, among which we included:

- properties of traffic flow:
  - intensity
  - speed
  - density
- traffic flow composition,
- congestions,
- management, regulation and organization of transport.

Due to the extensiveness of examined issue we will further on focus on analysing impacts acting on the vehicle and based on factors characterizing the transport infrastructure. These impacts will particularly stem from *traffic flow properties*, which often cannot be influenced by any action of the driver.

Analysis of the impact of selected range of factors on fuel consumption

One of the most desired properties of motor vehicles is the energy efficiency or economy, which is, as we have already mentioned in the introduction to this contribution, very important for both transport agents and motorists, especially with regard to impacting the amount of total operational costs. On one hand it depends on internal factors (technical properties of a vehicle), which were provided for the vehicle by its manufacturer, such as:

- structural properties of the vehicle engine,
- gear mechanism,
- shape of body (dependence from drive resistances) etc..

From the complex point of view, the motor vehicle has as smaller fuel consumption as more energy efficient engine, better total gear ratio and smaller drive resistances (i.e. smaller rolling resistance in dependence to vehicle tires, smaller air resistance depending on the body design, smaller persistence and ascend resistance) it has.

Contribution authors deal already in [2] with the change of fuel consumption under various technical conditions, to which the given testing vehicle was adapted. Laboratory measurements were made under simulations of urban driving cycle, based on relevant regulations of UNECE[4].

On the other hand it can depend on external factors, among which factors we included characteristics of traffic flow. The traffic flow can be defined as the movement of vehicles one after another or in lines next to each other in the same direction. It can consist also of several drive lines. The traffic flow or group of traffic flows does have its specifics which specify their movement on the road communication under various operation conditions.

[4] see regulations (UN ECE) No. 83 - Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements, (UN ECE) No. 84 - Uniform provisions concerning the approval of passenger cars equipped with an internal combustion engine with regard to the measurement of fuel consumption, (UN ECE) No. 101 - Uniform provisions concerning the approval of passenger cars powered by an internal combustion engine only, or powered by a hybrid electric power train with regard to the measurement of the emission of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range

The theory of the traffic flow itself, which theory deals with the movement of a vehicle, distinguishes movement of either single vehicle or a group of vehicles. On one hand, various influences affect the traffic flow; on the other hand also the traffic flow impacts the external environment, either qualitatively or quantitatively. Various simulation models can be used for the description of these impacts. Real situations of the selected traffic problem are applied into such simulation models so as to simulate the reality in the best possible manner. The said traffic problem can include in itself characteristics of [3]:

- motor vehicle,
- driver,
- road communication, or
- traffic relations.

The vehicle moves within a certain environment in the traffic flow. This element can include several impacts, namely:

- natural, which cannot be influenced by man, or
- artificially created environment, which can include:
  - construction-technical facilities,
  - transport-technical facilities, being the result of human work.

The speed with which motor vehicles move on a respective communication depends largely on the type of the given communication. Each type of communication is defined or limited by its capacity. The capacity can be defined as the maximum intensity of the traffic flow on the respective communication and the determination of capacity always takes into account parameters impacting the throughput of the communication.

The basic element of the traffic flow is the drive circulation. That can be in the sense of cybernetics understood as a certain regulating process. An often occurring phenomenon in the traffic flow is driving in a line of vehicles. Here especially basic parameters as the density of the traffic and speed of drive of vehicles gain ground.

The speed of the traffic flow is indirectly proportional to the density of the traffic flow. Increase of the density results in decrease of speed and vice versa, decrease of the density of the traffic flow results in the increase of speed. The density of traffic on roads forces the driver of a motor vehicle to adapt to the speed of other vehicles, what can in return significantly impact the fuel consumption. The driver strives to adapt the speed of his/her car especially to the speed of vehicle going in front of him/her. [4]

Space-time measurements prove that the vehicle driver can assess only the speed and distance setbacks between vehicles, but not time setbacks, i.e. the intensity. Four states in the movement of a traffic flow can be determined on the grounds of behaviour of drivers in the traffic flow, in relation to the deterioration of conditions of traffic on the road communication:

- uninfluenced movement (free),
- partially influenced movement,
- influenced movement,
- congestion.

Depending on the speed of driving in the traffic flow, the driver has to put in also the corresponding position of the speed gear. Fig. 1 shows achieved dependences if we would measure fuel consumption upon various speeds on individual positions of speed gear. Points A and C represent the lowest possible consumption on the respective position of speed gear. Point B represents a situation when the driver exchanges gear to the higher the position. Then the rated fuel consumption on the higher position (II.) will not be at its minimum, but at the same time it will be lower than the minimum of the preceding gear position (I.) and thereby also the fuel consumption in l/100km will be reduced.

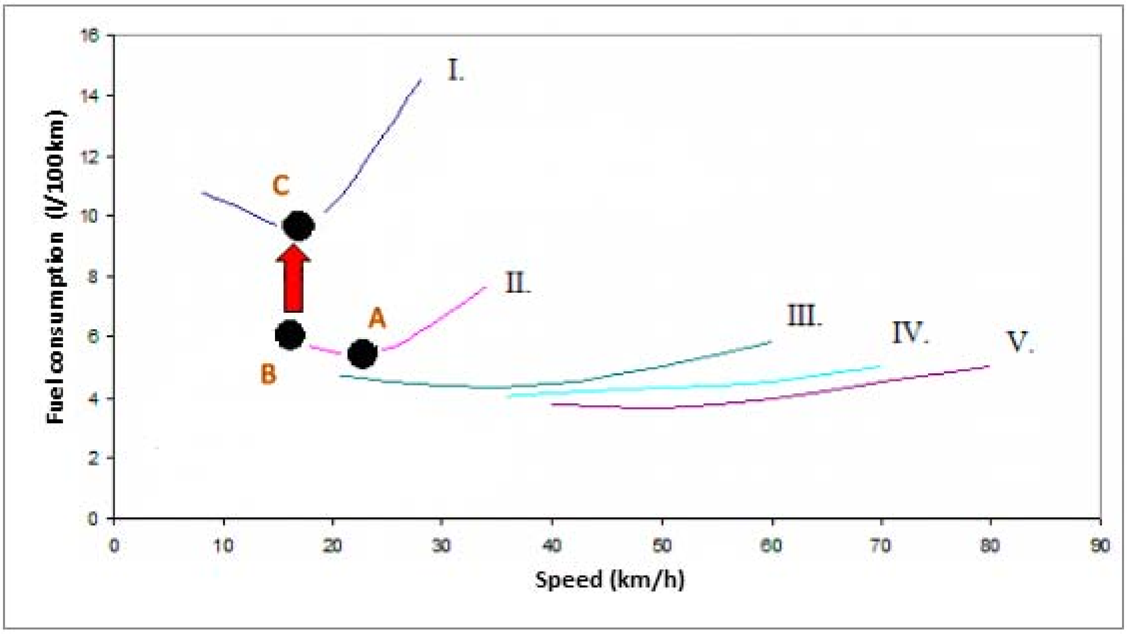

Fig. 1 Fuel consumption in dependence on the vehicle driving speed

Source: Elaborated by authors according to [6]

It can be clearly seen on the diagram that the highest fuel consumption is reached on the first gear position. Fig. 2 records complete characteristics of the combustion engine with consumption maps under various loads. The said characteristics shows courses of two torque curves under the constant output (e.g. under 90 km/h and 130 km/h), which depends on the vehicle driving speed. The vehicle engine shall, without regard to currently used gear position, spend such output so as to overcome drive resistances under the given current speed.

It can be seen on the Fig. 2 that the higher position of gear is in place, the lower rated consumptions the engine works in (g.kW.h-1). Therefore the total fuel consumption in l/100km will depend on the position of gear in place, what is confirmed also by the Fig. 1. It could be state in general that the higher the gear position is in place, the lower our consumption will be. However, it is not completely true. A situation can occur when despite the increase of speed in the traffic flow the fuel consumption on the given gear position decreases, but with further acceleration will slowly grow again.

On the grounds of the aforesaid it can be stated that the total consumption depends especially, in addition to other factors (rated consumption, engine performance, rated weight of fuel etc.), from the speed of vehicle drive in the traffic flow (as is documented also by the Fig. 1).

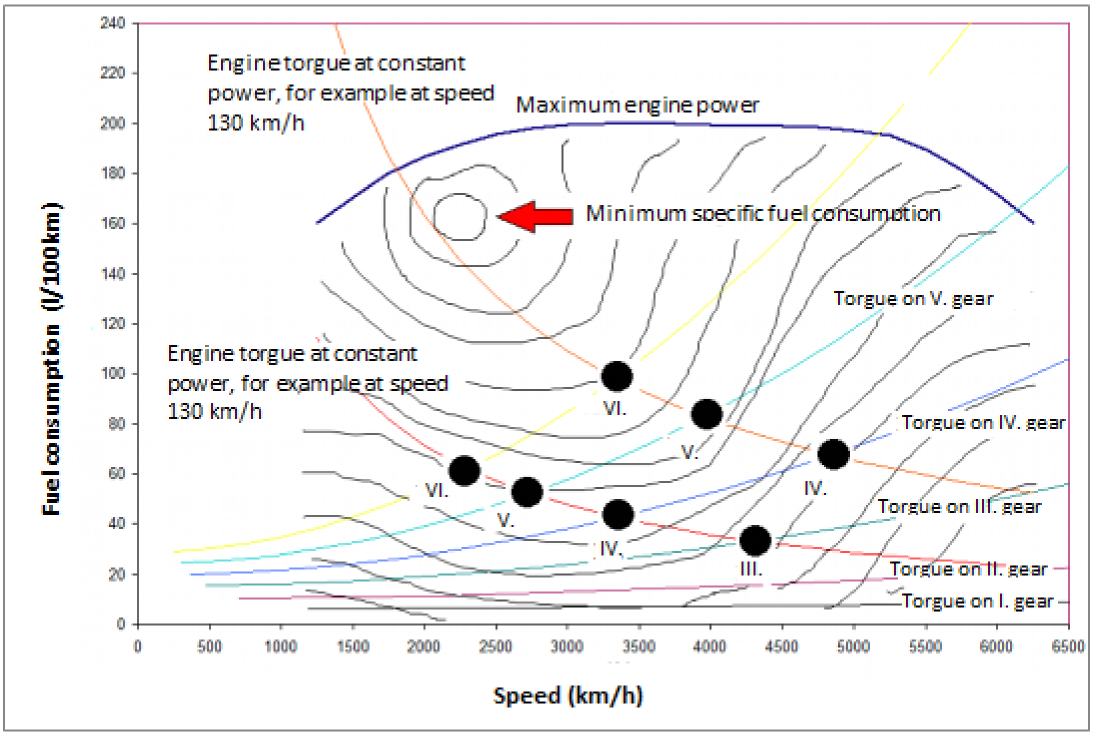

Fig. 2 Complete characteristics of the combustion engine

Source: Elaborated by authors according to [6]

As was already mentioned above, this is caused especially by the fact that the increase of the driving speed increases also the engine output due to overcoming growing drive resistances. The growing output necessary for overcoming growing drive resistances is depicted in the Fig. 3.

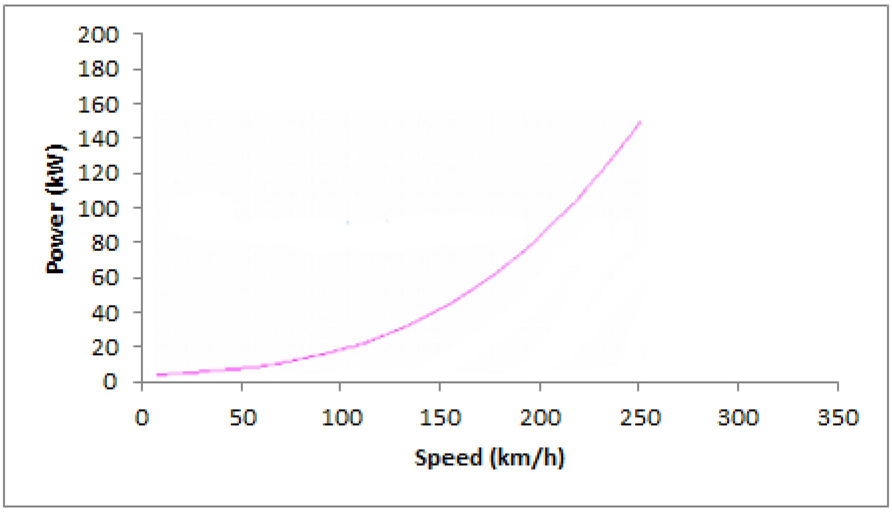

Fig. 3 Output necessary for overcoming drive resistances

Source: Elaborated by authors according to [6]

It can be seen that the growth of output has progressive nature. It is caused by the fact that if the driving speed increases, the engine output grows severalfold. And despite the fact that according to the complete engine characteristics (Fig. 2) we can be in lower rated consumption ranges, the total consumption will grow. That means that despite the decrease of rated consumption the total consumption in l/100 km will grow.

Proposed solutions of the examined issue

It could be said that in order to achieve the lowest consumption it would be necessary to drive with the highest possible gear position and relatively stabilized lower (corresponding to driving conditions) speed, as implied also by figures 1 and 2. The percentage of engine power used for overcoming friction in reality grows under the speed of more than 90-100 km/h without the useful transformation of drive train. Each vehicle therefore has speed defined as "economy speed", which mainly corresponds with ⅔ of maximum speed and provides the highest output of the engine with the lowest fuel consumption.

In conclusion we can say that the total fuel consumption of motor vehicles can be influenced by:

- appropriate changing of gear positions, by means of which we will influence the work of the engine in areas of lower rated consumption ranges,
- driving speed, by means of which we will influence the engine output.

Conclusion

The world has been experiencing in recent years a constant growth of motorization of the population. This growth of motorization is related also to growing demands for motor vehicles to be as energy saving as possible. This contribution deals with opposite respectively with external factors, which action on driving with the motor vehicle cannot be individually avoided. We tried in the contribution especially to describe and analyse in more detail influencing the vehicle and the driver with individual properties of the traffic flow.

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