THE ISSUE OF MEASURING THE FUEL CONSUMPTION OF ROAD FREIHT VEHICLES WITH A VOLUMETRIC FLOWMETER

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Abstract: Fuel consumption of motor vehicles is one of the most important operating characteristics, which directly define their operating cost ratio. Fuel trucks are the largest cost item in its operation. It is therefore necessary to examine and focus on the causes leading to its costs. It is influenced by the several important factors. These factors can be divided into three main groups: vehicle, person and operating conditions. For exact measurements, there is using equipment mounted directly to the vehicle fuel system. In particular, the volume of fuel flows meters, which meets accuracy requirements of different standards. In our research project, we had tested the truck „MAN". Tool for measurement was the volume flow „Datron DFL-3", which allows measurement of vehicles with gasoline as well as diesel. The flow meter is equipped with a pressure valve, heat exchanger and overflow branch (returning back to the tank). For measurements, we investigated the effect of the various components of the vehicle to its operating fuel consumption. The flow meter is equipped with a pressure valve, heat exchanger and overflow branch returning back to the tank. In measurements, we focused on the impact of the various components of the vehicle to its operating fuel consumption. In the article we focus on processing the results of the impact of air resistance and rolling resistance of tires. A setting of the slope of roof spoiler directly influences the impact resistance of the air vehicle. And the condition of the tire pressure influences the rolling resistance. All measurements were performed according the Slovak technical standard that precisely defines the conditions of execution of such tests.

Keywords: FUEL CONSUMPTION, FUEL FLOW METER, FACTORS AFFECTING FUEL CONSUMPTION

1. Introduction

Fuel consumption affect the direct economic costs. They increase proportional to the amount of consumed fuel. Currently, the demand for fuel increases, so prices are still rising. Therefore, whether it is a person doing business in transportation or person using the vehicle for private purposes, each is economically influenced by the consumption of its vehicle. The price of hydrocarbon fuels affects the price of crude oil on the international market, but also the cost for their production and distribution, and storage for local suppliers. Price of hydrocarbon fuels is also charged by the excise tax, so at present it is not a small cost item. This is demonstrated by the fact that transportation in international freight transport of semitrailer unit third of the operating costs are fuel.

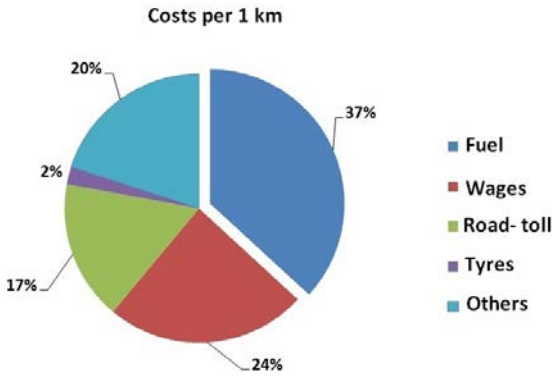

Fig. 1 *Costs of transport company*

It is not strictly defined one unit expressing fuel consumption, because the variety of performances vehicles is large. Therefore, due to the information value, there are used the several units, depending on the type of performance vehicles, or measurement methods. We may also use the absolute expression of fuel consumption in units of mass and volume (dm^3, m^3, l, g, kg), but the better informative value have the relatively expression relating to the performance of the vehicle.

Relatively expression is therefore fraction whose numerator represents the amount of fuel consumed. It can be given in units of volume or weight, according to the method of measurement. The most exact is using of gravimetric expression (scientific and professional activity), because the energy of fuel is dependent on the number of molecules, which have always been the same weight for all conditions, while the volume unit is imprecise, because of the changing density of the fuel with changing conditions (temperature and pressure). This means that if we consume the same number liters of diesel fuel at -5 ° C and 30 ° C, it is not consumed the same amount of energy contained in the fuel. The denominator is the unit expressing the vehicle's performance, depending on the type of vehicle, current use, adequacy, suitability for the calculation, etc. The most commonly used in transport is travelled distance, time of operation, the amount of transported goods (km, vehicles hours, t, pcs., passenger kilometres, tkm) etc.

2. Main factors affecting fuel consumption

Fuel consumption is dynamic, constantly changing quantity and it also responds to the least impact of the factors. We classified the factors into the following groups and subgroups for the easier review: a) physical - internal (technical characteristics of the car – engine efficiency and transmission device), external (road resistance directed against the movement of the vehicle - the characteristics of the traffic flow, drive in the city / non- city, temperature, landscape, road conditions), b) human - driver (driving technique), carrier (care and maintenance => technical condition of the vehicle, vehicle capacity utilization => average loading).

The main groups of factors (physical and human) should not be regarded as isolated because between them there are connections. Physical factors are directly given so the transport operator and drivers cannot it change. However, transport operator may change the level of their impact on the fuel consumption indirectly through changes of human factors.

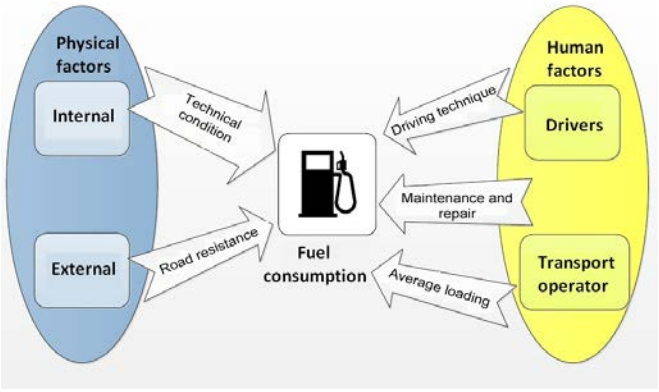

Fig. 2 Factors affecting fuel consumption

3. Methodology for measuring fuel consumption

Measurement of fuel consumption is very problematic issue. Fuel consumption is a quantity that is very dynamic and influenced by many factors. The same car with the same driver will not have the same fuel consumption if we change even the weight of the load, route, or the weather. The same applies if we change the driver or the vehicle in the same route with the same load. Due to all these effects there is need to follow the well-defined methodology that establishes the procedure and measurement conditions in determining consumption. The methodology should be as precise as possible and be as objective as possible to reflect the fuel consumption of the vehicle. In order to ensure the desired results of the measurements there have been created the several types of methodology which can be divided:

1 according place of performance: a) exterior - driving tests, b) interior - tests on a dynamometer;

2 according the vehicle operating modes: a) defined operating modes, b) normal operation of the vehicle;

3 according to methods for the detection of fuel used: a) volumetric (can be performed in laboratories, and outside), b) gravimetric (usually linked to the laboratory conditions).

4. Measuring of fuel consumption of truck Man

Process of measuring fuel consumption of the vehicle has been adapted to be applicable for the purposes of this article and its outputs applied in practice in the operation of a particular fleet of transport company. The measurement procedure and the use of equipment and processing results base on the basis of standard ,,STN 30 0515" (Slovac technical standard), but some aspects are modified, because the main essence of the measurement is usable result. The measurement is performed at the request of the carrier. Carrier requires three outputs of measurements on which he will take the necessary steps to reduce the fuel consumption of the vehicle fleet and thereby more efficient its operations. Carrier requires:

1, Quantify the impact of pressure of tires on fuel consumption,
2, Quantify the impact of deflector position on fuel consumption,
3, Quantify the fuel consumption at different operating speeds (80, 85, 90 kmh^{-1}).

4.1. Vehicle

For performance measurements were used vehicle ,,MAN TGL 12250". This vehicle belongs to a category of vehicles with a gross weight of 12 tones.

,,STN 30 0515" standard specifies that the measurement of fuel consumption shall be performed in instantaneous vehicle weight corresponding to its total vehicle weight, in special case in the different weight. To ensure the highest explanatory result for the carrier, the vehicle was loaded with load weighing 3900 kg, with two people and with measuring equipment weighing 170 kg. Weight of the load approximately corresponds to average loading of a vehicle.

Pallet units with concrete blocks were used as a load. Weight of one unit is 780 kg. During road test the vehicle was loaded with five pallet units, which corresponds to the mentioned average vehicle loading vehicle of this group.

They were stored in the load floor in order to meet legislative and structural conditions of the weights falling to the axle of the vehicle.

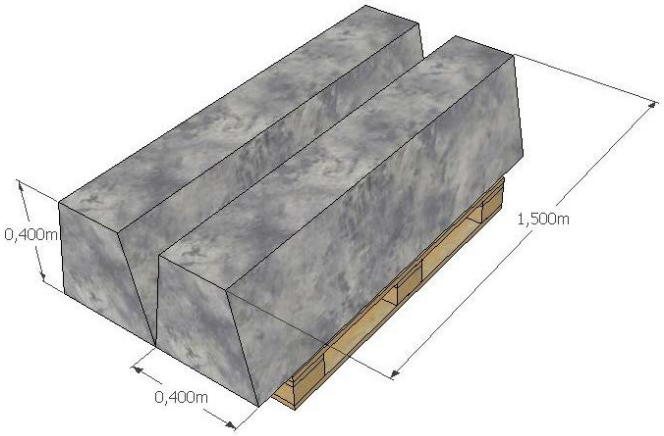

***Fig. 3** Load*

4.2. Route

the most suitable route, in view of the requirements of the standard ,,STN 30 0515" the runway determined to measure the fuel consumption, is on the first class road No. 61. It is a long straight road of almost 2 km (1940 m) between the villages of ,,Nove Mesto and Považany", between 97 and 99 kilometres. It is a renovated road where was given a new asphalt surface during the summer of 2012. So it is in the very good condition without tracks and potholes. Total longitudinal slope of the route is 0,14%, and there is a vertical elevation of about 2,67 m on the mentioned length 1940 m. The considered measuring road is length 1.5 km, so that ensure adequate track for acceleration and safe deceleration of the vehicle.

4.3. Measuring equipment's

For measuring fuel consumption there is need to use the main measuring equipments (for monitoring the amount of consumed fuel), evaluation equipments, but also the technique for measuring the secondary parameters as a the instantaneous velocity, running distance, time, temperature, pressure and technique used for documenting process. Below there are the main apparatus used for measurement. They can be divided by the measured quantity:

1. Measuring of volume of fuel consumption (Flow-meter Datron DFL – 3, fig. 4),

2. Processing and displaying data from the flow meter (Correvit a EEP – 2),

3. Recording speed, position and distance of the vehicle (TX 300),

4. Sensing the external weather conditions (Weather station),

5. Detecting the temperature of fuel in the tank (Glass thermometer).

The flow meter is connected directly on vehicle into the fuel system with added fuel hoses, quick connectors and reducers. It is located on the load floor. It is situated in the system in line between the fuel tank and fuel supply pump. Fuel supply pump pulls the fuel through the flow meter under pressure. It would not be possible to engage flow meter behind the pump, because it creates the pressure up to 11 bar and working pressure of a flow meter is only 5 bar.

The flow meter is also connected on fuel return line returning from the high-pressure injection pump back into the tank, so it counts only the amount of really consumed fuel.

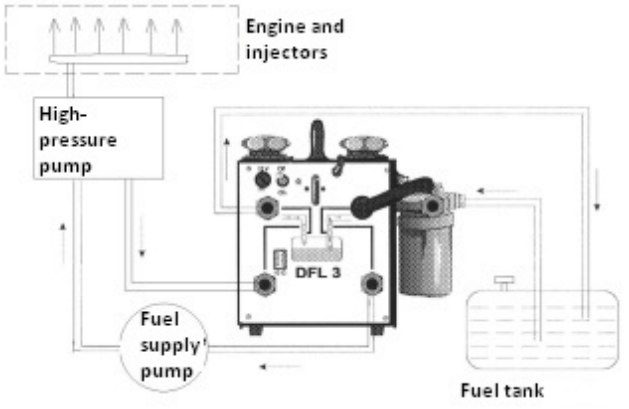

Fig. 4 *Connecting of flow meter in fuel system*

5. Measuring results

In volumetric measurement and measurement with the flow meter it is necessary to recalculate consumption due on reference conditions according to the following formula:

$$M=V[1+\alpha(t_0-t_K)]s.100$$

M- fuel consumption [l/100km], V- amount of fuel consumed during the test [l], α- temperature coefficient of volumetric expansion of fuel (α = 0,001 °C^{-1}) [-], t_K- fuel temperature during the test (arithmetic. average of the temperatures at the beginning and end of the measurement) [K], t_0- reference temperature of fuel (15°C), s- length of measured distance [km].

In Table 1 there is an example of the record and the conversion of the measured and referenced fuel consumption. For each trial were performed 4 rides with the vehicle and then from them calculated the average value of the reference fuel consumption.

Table 1: *Fuel consumption result*

No.	Consumed fuel (l)	Length (km)	Avg. speed (km/h)	Fuel consumption (l/100 km)	Reference fuel consumption (l/100 km)
1	0,256	1,5	86,7	17,06	16,58
2	0,280	1,53	87,5	18,28	17,77
3	0,258	1,53	88,2	16,87	16,4
4	0,269	1,5	86,3	17,9	17,4
Avg					**17,04**

5.1. Impact of pressure of tires on fuel consumption

In this measurement is concerned an expression of change the rolling resistance of the tires with regard on change of the pressure in them. Fuel consumption was measured when the tires was inflated to 70, 85 and 100 % of the pressure prescribed by the manufacturer. Three measurements were made. Each measurement consists of tire pressuring to the required pressure in the area of the company performance and from driving tests. It is concerned total 4 rides along the intended route for measuring (two runs in each direction along the route).

Table 2: *Fuel consumption at changing the tire pressure*

Tires pressure	Fuel consumption (l/100km)	Difference
100%	17,04	0%
85%	17,40	2%
70%	18,29	7%

5.2. Impact of deflector position on fuel consumption

Task of this test was to quantify the influence of the position of the deflector on fuel consumption. Deflector, colloquially called as spoiler, serves to direct circumfluent airflow over the cabin of the vehicle to could continue flow over the vehicle length.

It is one of the aerodynamic body elements serving to reduce aerodynamic resistance and thus reduce fuel consumption of the vehicle. Aerodynamic elements are placed on the body of vehicles in order to reduce coefficient of air resistance c_X (along the longitudinal axis of the vehicle) and to increase coefficient c_Z (in the direction of the vertical axis of the vehicle). Increase of c_Z is reflected by increase of the vertical compressive force of the vehicle on the road. It is mostly used in racing cars to achieve greater driving stability. In ordinary vehicles is monitored particularly reducing c_X and that for the mentioned purpose of reduction fuel consumption.

Fuel consumption was determined in three positions of the deflector shown in Fig. 5. Three measurements were performed, each from them consists of:

1, Set of the deflector on the desired location in the area of company,

2, Perform driving tests. It is a total 4 rides along the route intended to measure (two-rides each way along the route).

Table 3: *Fuel consumption at changing the deflector position*

Deflector setting	Fuel consumption (l/100km)	Difference
base (3)	17,04	0%
above (2)	17,38	2%
bellow (1)	17,77	4%

Fig. 5 *Deflector position*

5.3. Impact of vehicle speed on fuel consumption

Another task of this research was to quantify the impact of speed on fuel consumption. The impact of speed on fuel consumption of vehicles is very significant, because performance that must vehicle make is the conjunction of rolling resistances and the instantaneous velocity of the vehicle. So with higher speeds increase also the resistance performance. In rolling and air resistance is a non-linear growth. In rolling resistance speed affects the size of the coefficient of rolling resistance f_V and the power

required to overcome air resistance is increasing by the cube of the speed.

Fuel consumption was determined at three constant speeds of the vehicle (80, 85 and 89 km h^{-1}). There were performed 3 measurements. Each of it consists of:

1, Departure of the vehicle from the company area to the measurement place,

2, Perform the driving tests – totally 4 drives on the route intended for measuring - two runs in each direction along the route.

Table 4: *Fuel consumption at changing vehicle speed*

Speed	Fuel consumption (l/100km)	Difference
89 km/h	17,04	0%
85 km/h	15,46	-9%
80 km/h	14,40	-15%

6. Conclusion

Measurement of fuel consumption of trucks using volumetric flowmeter can be considered as one of the complicated tests of the vehicles. It is used especially when is need to perform the driving tests.

The laboratory of Department of road and urban transport is equipped with a flow meter ,,Datron DFL-3", which in connection with a recording device ,,Correvit EEP-2" allows to perform this kind of tests. Before the own measurement it is necessary getting to know the fuel system of the test vehicle. Technician must properly connect the flow meter into the fuel system of the vehicle.

The results of the fuel consumption of vehicles MAN TGL 12.250 indicate the following conclusions and recommendations for the operation of the vehicle.

1, Measurement results show what extent affects tire inflation pressure on consumption of the vehicle. Tire pressure reduced to 70% of the prescribed pressure represents the enormous increase in fuel consumption by as much as 7 % when driving at a steady speed on a flat surface. The pressure drop for such value may be caused by failure or by the gross negligence of the technical condition of vehicles. However, the pressure drop to prescribed 85 % is a common phenomenon that often occurs in the operation of vehicles. He can increase fuel consumption by 2 %, which represents approximately 0,4 l/100km.

2, Measurement results show how much deflector position affects at the fuel consumption. The verdict is clear. The lowest consumption was achieved in coordinating the height edge of the deflector and superstructure. However, also important is the fact that if edge of the deflector is higher than the body (position "above"), the vehicle achieves a better fuel economy than in the position where the edge of the defector under the superstructure (position "under"). This fact will help especially in questionable positions. Nowadays deflectors are made to could be adjusted to multiple positions. Between positions is the same difference in height, a few centimeters. It may happen that in one position the edge of the deflector is under the edge of the superstructure and in the next is over. View of the results of measurement we recommend choosing position slightly "above".

3, Speed is a quantity that directly affects only air resistance. However, if we describe the power required to overcome the road resistance, it performs at every member, even in air resistance its cube. Reducing vehicle speeds we achieve that, the vehicle will have to make less performance to overcome the road resistance, thus will be reduced the fuel consumption. Also engine speed is lower at lower vehicle speed. This means that the engine can work in a lower effective consumption also in expending the higher performance. This will reduce fuel consumption and wear of moving parts of the whole vehicle.

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