HOW TO REDUCE EMISSIONS ORIGINATED IN ROAD TRANSPORT?

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Abstract: *The road transport is an important polluter of the environment, mainly due to the production of exhaust gases, solid waste and outflow of petrol products, which support the rise of global warming. This is the reason why this article points out various possibilities of reduction of the negative impact of road transport on the environment. Technical progress in construction of vehicles and tightening of emission limits of road vehicles is indisputable. But there is still the scope for minimizing emissions by limiting rides with a cold engine and for short distances. There is the comparison of the production of emissions produced by cold engine and engine heated at operating temperature described in the article. We also analyze the influence of technological equipment of vehicles on the automotive consumption (the ride with cruise control and without it), the influence of choosing the appropriate gear on automobile consumption and the influence of the chosen route on the automotive consumption. The aim of the article is to highlight the possibilities of reducing the fuel consumption by not only technical measures but also by the effective organization of transport. There will be used laboratory measurement, vehicle driving tests and theoretical comparisons of the influences of different combinations of driving resistors for the final comparison and conclusion of the article.*

Keywords: EMISSIONS, ENVIRONMENT, ENGINE, DRIVING RESISTANCE, CONSUMPTION FUEL, VEHICLE

1. Introduction

It is obvious that transportation is a major greenhouse gas producer. These gasses seriously affect changes in our climate. These changes manifest themselves in higher temperatures, increased rainfalls. Ocean water levels a rising as a result of melting glaciers. It is essential to apply measures that will stop or slow this process.

The vast majority of greenhouse gasses produced in transportation are contained in exhaust gasses of automobiles. CO2 is considered the most important of the greenhouse gasses. 2.5 kilograms of CO2 are produced for every kilogram of burnt fuel. Exhaust gasses also contain NOx, CO, unburnt hydrocarbons HC, smut, formaldehydes and sulphur. These are not only affecting the greenhouse effect but are also dangerous to human beings. They are poisonous and carcinogenic.

2. Influences on fuel consumption[1]

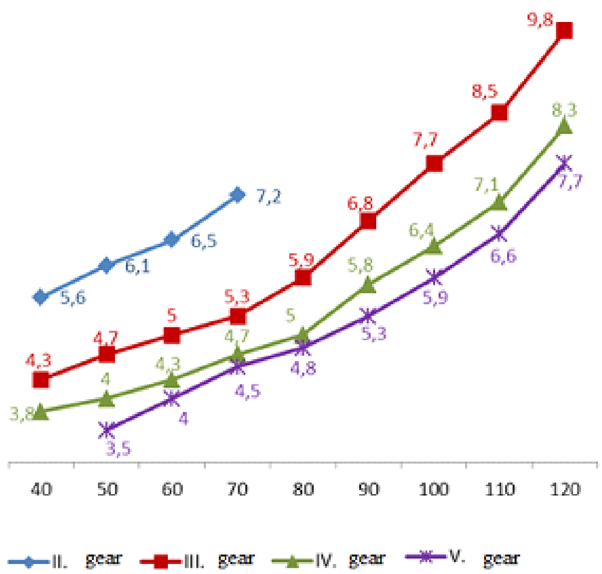
Car engine must expend some work to repress road resistance. The engine has to consume some amount fuel. Size consumption of vehicle is affected by the technical level of the vehicle and especially by the driver behavior. Following text presents some driver choices affecting fuel consumption.

Gear changes

The easiest way to reduce fuel consumption is correct driver behavior. Drivers tend not to use correct options for their vehicle. Gear changes significantly affect fuel consumption. Lets consider Suzuki SX4 as an example. The engine of this car meets the Euro 5 emissions limit. Its displacement is 1500 cm3 and power output is 82 kW at 6000 rev / min. The measurements were performed on chassis dynamometer MAHA 2000 LPS. It allows simulating constant speed drive by generating artificial drive resistance. For each driving speed the level of resistance used was based on real world aerodynamic resistance of the vehicle and the tire resistance. This results in comparable fuel consumptions of specific speed. Fig. 1 shows the measurement results.

For example for driving speed 50km/h can driver use gears II. III. IV. or V. Fuel consumption would change from 6.1 to 3.5 liters. This means consumption reduction of 42.6%. If we assumed the same composition of the exhaust gases, emission production

Fig. 1 *The consumption of Suzuki SX4 in dependence on the driving speed and gear usage1***.**



would be reduced by the same ratio. This statement is not absolutely precise when related to the engine load. During movement of the vehicle has to overcome variety of resistances. Correct driver choices and techniques can influence their amount and consequently the fuel consumption of the vehicle.

Tire resistance

Tire resistance depends on several conditions. Wheel size is one of the major factors. The driver is not able to affect this parameter because it depends on the particular vehicle design. Tire resistance also depends on the state of tires. Rolling resistance depends on the tire pressure. This dependency is shown in Table 1.

Table 1: *Estimated roll resistance and tire life based on inflation pressure*

% tire pressure	% life time	% change of rolling resistance
115	90	-
100	**100**	**100**
85	75	107
70	50	118
55	35	140
40	10	-

Source: Continental

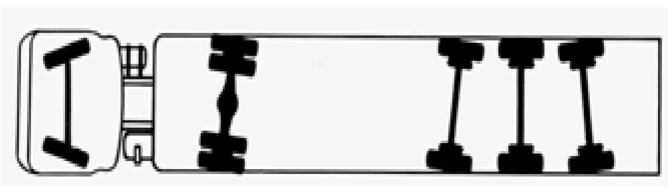
Research indicates that the vast majority of drivers are driving on the incorrectly pressurized tires. Most of them don't know the correct values or where to find them Consider 100% as the correct inflation. 15 percent lower tire pressure of 40 ton road train with 45% energy efficiency (50% engine, 90% of transmissions) results in fuel consumption increase by 1,03 l/100km. When driving 8 000 km per month, this results in fuel consumption increase of 82.32 liters. The emission production will be increased accordingly.

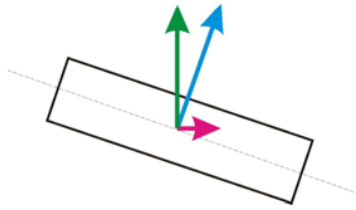
Table 2: *Effect of roll resistance coefficient f on fuel consumption and CO2 production*

rolling resistance coefficient f		0,009	0,006	0,0045
litres/100 km		22,2	14,8	11,1
consumption for 200 000 km [liter]		44 400	29 600	22 200
CO_2 for lifetime 200 000 km		110 500 kg	73 500 kg	55 500 kg
saving for drive 200 000 km – average lifetime of vehicle tire	fuel [liter]	0	14 800	22 200
	kg CO_2	0	37 000	55 500

15% lower tire pressure can't be detected visually. Driver must use measuring device. The construction of tires has an important influence on fuel consumption. Diagonal truck tire, reaches a friction coefficient f = 0.009. Radial for the same type of vehicle reaches rolling resistance coefficient f=0,006. The highest quality tires have a rolling resistance coefficient f=0,0045. Table 2 shows how this parameter can influence fuel consumption. The conversion was done by a road train weighing 40 at the 45% utilization of energy contained in the fuel. Average lifetime of vehicle tire is 200 000 km, when driving on quality road. The technical condition of the vehicle is also important. For example a 2 mm convergence error on the front axle with 6 ton load, can cause an 0.25 liters per 100 km consumption increase.

Fig.2 *Resolution of forces on front wheel*





Front axle:
Load of 6 tons
Tires 275/70 R 22.5
M = 0.8
45% efficiency in energy use

Incorrect convergence will cause the vehicle to produce about 650 kg of CO2 more when driving 100 000 km per year. Similarly when the vehicle is driving on curved road, forces decomposition occurs and the vehicle rolling resistance could be up to several times higher when compared to the straight road. Increased consumption of the vehicle may be cause by the brakes that fail to sop braking completely. Brakes remain in partially blocked position, generating more resistance and increasing vehicle fuel consumption. Dirty air cleaner will cause increased internal resistance of the engine and reduce engine power, and it leads to an increase in fuel consumption.

Aerodynamics resistance

It occurs whenever the vehicle is in motion. Its amount is defined by the following formula.

$$O_v \cong 0.0386 \cdot \rho \cdot c_d \cdot S \cdot V^2$$

c_d is a coefficient based on the shape of the vehicle,

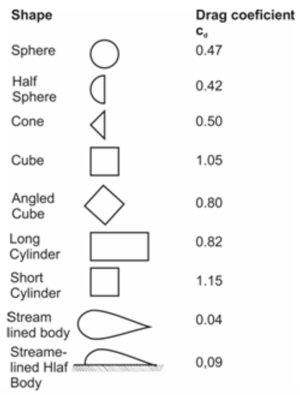
S is the size of the frontal area of the vehicle in m2,

ρ is the air density in kg/m3

V is the vehicle speed in km / h.

If all other parameters remain constant, with an increase in speed of 60 km / h to 100 km / h, the air resistance will increase 2.78 times. In Figure 1, this increase is only 1.9 liters per 100 km, it is increase of 41.5%. on V. the gear selected. The apparent contradiction can be explained by the argument that the vehicle results are also affected by tire resistance, which grows only about 26% due to changes in speed. Engine power is transmitted through the gearbox assembly, whose efficiency can be considered immutable. The results are collected in real measurements and engine vehicle changes its effectiveness depending on engine speed and load engine. Change of the size air resistance is proportional to the change of the frontal area size, as well as change of c_d coefficient. The same influence has got slight changes shape of the vehicle on air resistance coefficient, and mainly on the fuel consumption.

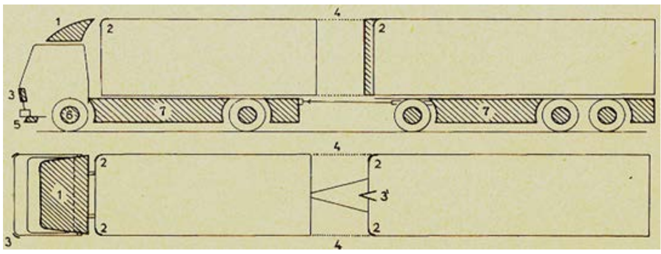
Fig. 3 *Effect of body shape changes on the drag coefficient cx*



Source: http://en.wikipedia.org/wiki/Drag_coefficient

The most widely used adjustments to the shape of a vehicle focused on air resistance coefficient c_d reduction are listen in figure 4:

***Fig.4** Elements reducing drag of trucks and road trains*



1 – deflector

2- edge rounding

3 – swirl stabilizer

4 – gap covering

5 - additional spoiler

6 - wheel disks covers

7 - body sides covers

***Table 3**: Comparison of power required to overcome roll resistance and drag in different speeds between car and lorry*

V		P_{Ov}	P_{Of}	Gear lost	Engine power
[km/h]		[kW]	[kW]	[kW]	
95	car	7,5	4,7	1,6	13,8
	vehicle	83,4	79,6	18,1	181,1
80	car	4,5	3,9	0,9	9,3
	vehicle	49,8	61	12,3	123,1
65	car	2,4	3,2	0,6	6,2
	vehicle	26,7	41,6	7,6	75,9
50	car	1,1	2,4	0,4	3,9
	vehicle	12,2	38,2	5,6	56

The size of the frontal area also influences the drag of the vehicle. This parameter depends on the vehicle design but it is affected by the installation of different superstructures. Speed of the vehicle is the most important influence. Speed is expressed as the second power of its value. If vehicle increases the speed 2x, air resistance will be increased 4x times. The part of engine power that is used to overcome the air resistance and rolling resistance is shown in Table 3. The calculation was made for truck weight m = 40 tonnes, the size of the frontal area S = 10 m2; gear efficiency ηp = 0.9; air resistance coefficient of cd = 0.7, and rolling resistance coefficient f = 0.007. For comparison served passenger car weight m = 1.5 tonnes, frontal area S = 2.1 m2, mechanical transmission efficiency ηp = 0.9, air resistance coefficient of cd = 0.3, rolling resistance coefficient f = 0.012. Temperature and pressure have influence on change the size of air resistance. Change the temperature from 0 °C to 38 °C results in decreased air resistance by 14%, change of the elevation by 1219 m decrease air resistance by 17%.

Gradient resistance

Road gradient results in major increase of fuel consumption. To determine the influence, we used a road train with weight 40 tons and with 45% efficient fuel energy (diesel engine with 50% efficiency and 90% efficiency of the gear system) utilization. The calculation makes provision for only the increase in potential energy of the vehicle at a constant other driving resistance. Recalculation is accomplished on the distance traveled of one kilometer! We did alike calculation for the comparison of passenger car with weight 1200 kg, the gasoline engine has 35% efficiency and effectiveness of the gear system is 93%. Lots of drivers think that higher consumption when driving uphill flattens while driving downhill. Part really save energy, but it's not true. We determined the consumption of the vehicle for comparison when driving on constant speed of 120 km / h. Average consumption was 6.2 liters per 100 km. Then we drove the vehicle with rising and falling gradients in the area of 2 km. The beginning and ending of measurement was the same elevation. We kept the speed 120 km / h by means of cruise control. The consumption of vehicle was 6,5 liters per 100 km/h. Difference efficiency of the engine caused the difference, because it worked in another a load mode against driving the plane.

***Table 4**: Fuel consumption required to overcome 1km uphill road*

Gradient [%]	Litrs/ 1 km	
	vehicle	car passenger
1	0,22	0,012
2	0,44	0,024
3	0,67	0,035
4	0,89	0,047
5	1,11	0,059
6	1,34	0,071
7	1,56	0,082
8	1,78	0,094
9	2	0,106

Acceleration of the vehicle

The vehicle obtains during acceleration the kinetic energy. Energy is converted to heat during braking and is irretrievably lost if it is not a hybrid vehicle. These vehicles are preferable on routes with frequent change of speed. For example, the supplying in the city, city bus, logistics of waste, etc. The advantaging of hybrid vehicles disappear when the vehicle is driven at a steady speed. To quantify possible savings of fuel, we calculated the unused kinetic energy attributable to one liter of fuel when the vehicle stops. To compare the results of road train with weight 40 tons with 45% efficient utilization of energy contained in the fuel (diesel engine with 50% efficiency and 90% efficiency of the gear system) and passenger car with weight 1200 kg, the gasoline engine has 35% efficiency and effectiveness of the gear system is 93%. Results are presented in Table 5.

***Table 5**: The amount of fuel wasted by 40 ton road train stopping from (50 km/h)*

V		P_{Ov}	P_{Of}	Gear lost	Engine power
[km/h]		[kW]	[kW]	[kW]	
95	car	7,5	4,7	1,6	13,8
	vehicle	83,4	79,6	18,1	181,1
80	car	4,5	3,9	0,9	9,3
	vehicle	49,8	61	12,3	123,1
65	car	2,4	3,2	0,6	6,2
	vehicle	26,7	41,6	7,6	75,9
50	car	1,1	2,4	0,4	3,9
	vehicle	12,2	38,2	5,6	56

Defensive driving

The minimalization of the vehicle resistance is base for economical driving. The driver is most important to the process of minimalization. The choice of driving regime has an influence on fuel consumption. Driving at the constant speed, without sudden changes in speed is an attribute of defensive driving. This way of driving greatly reduces fuel consumption.

The importance of the driver in relation to consumption and thus also to produce emission shows an attempt to form with

VOLVO F12 truck, which was pulling a road train with weight 38 tons.

The consumption of vehicle when the driver drove with suitably chosen gear grade at a constant speed of 75 km / h was chosen for basic consumption. The changes of speed between 73-77 km / h in well-chosen gear grade caused an increase in consumption at 114%. The consumption increased to 124% when the driver selects a gear grade on the one lower and maintain a constant speed of 75 km / h. The driver choose incorrectly - lower gear grade and speed drive was between of 73 to 77 km / h, the consumption increased to 154%. We did a comparison of driving the vehicle SUZUKI SX 4 on the highway. We realized the measurement during the ride of 160 km on the highway. The driver which tried to maintain a constant speed of 120 km / h, had an average fuel consumption of 6.9 l / km. The same ride was realized using cruise control system. In this case, consumption decreased to 6.7 litres/100 km. We also obtained the same consumption realizing second measurement during the ride of 420 km.

3. Conclusion

The purpose of this paper was to point out the importance of driver behavior and road parameters in relation to the fuel consumption. Every slow down, stop, climb and fast driving results in increased fuel consumption. The increased fuel consumption will increase emissions and greenhouse gas production. Emission levels are affected by technical state of the vehicle, correct routing and ability of the driver to correctly use the vehicle.

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