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CONSUMPTION OF FUEL DEPENDING ON AUTOMOBILE LOAD

DEGALŲ SANAUDOS PAGAL AUTOMOBILIO APKROVĄ

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The fuel consumption of automobile is influenced by different kinds of resistance-air, rolling, upslope, inertia and trailer resistance. Every kind of resistance can influence the consumption of fuel to a different degree. One of the factors influencing the fuel consumption is the automobile load or its weight. The research was performed with the automobile VW Passat with 1.8 l Otto motor on the inertial roller stand. The variation of the automobile weight was changed from 1200 kg to 2000 kg. The fuel consumption of the automobile at different constant driving speeds does not change essentially depending on the weight and its increase is in the range of 5%. The weight essentially changes the consumption of fuel in trials in driving cycles what presents evidence of the influence of inertia resistance on the consumption of the fuel.

Automobile, load, fuel consumption, inertial roller stand.

Introduction

Drivers always turn big attention to fuel consumption, because it composes one of biggest transportation expenses. Fuel consumption is affected by factors like exploitation conditions, speed regime, automobile and engine construction differences and load. Load influence is hard to measure, but due to inertial roller stand, a controlled conditions and precise data can be obtained.

Most drivers know that adding load to their automobile will increase fuel consumption, but almost none of them know how much. Gaining connection between load and fuel consumption, driver could choose more economical transportation regime and to change his driving style to gain fuel economy, which is important nowadays when fuel prices only grow, but oil resources reduce [4].

Fuel consumption values are used in automobile technical specifications, to determine amount of fuel needed for drive, to determine fuel consumption quota for automobiles in company, to compare automobile economy.

Fuel economy is important because it saves money, reduces oil dependence costs, reduces environmental pollution and increases energy sustainability.

Fuel consumption is the amount of fuel used per unit distance and its value usually is given in common measures such as litres per 100 kilometres (l/100 km) or miles per gallon (mpg).

Literature analysis

There are four main factors that affect fuel consumption: load (mass and resistances affecting automobile), speed regime (driving in appropriate and direct gear is more economical), automobile and engine construction differences (compression ratio, aspiration, fuel system, displacement, valve gear, transmission, etc.), and exploitation conditions (weather, road condition, driving experience, fuel quality, etc.).

Factors that limit load and factors that make load changes have to be defined to determine load impact on automobile fuel consumption and make conclusions.

There are many factors that make load changes:

- upslope resistance (evaluates mass of automobile and angle of upslope);
- rolling resistance (surface friction has main importance on hard roads, on deformable roads- ground resistance in relation to shear and tyre draught);
- air resistance (upcoming environment parts create pressure on automobile front area, behind, above and under automobile creates rarefaction, which resistance need to overcome [2]);
- inertia resistance (it is necessary to give acceleration not only to translation movement, but also to the rotating mass to accelerate automobile);
- trailer resistance (all the same resistances work on trailer as on automobile);
- mass (increasing mass- increases fuel consumption, also uneven mass distribution can change air resistance and create damage to such points as clutch, tyres and suspension).

There are few factors that limit load:

- legislation (maximal mass to two axle automobile is 18 tons, 3 axle- 25 tons, 4 axle- 36 tons and to 5 or 6 axle automobile- 40 tons, truck maximum load on surface from one axle is 10 tons[1]);
- carrying capacity (difference between full and self-mass, located in vehicle registration certificate) ;
- pass ability (automobile ability to overpass different obstacles and drive on bad roads or off-road).

Purpose of the research and objectives

Purpose of the research is to determine fuel consumption changes depending on automobile load and its influencing factors, to develop methodology and to approbate it with experiments on inertial roller stand.

Subject and test methodology

In experiments VW Passat made in 1997, front wheel drive, 1.8 litre petrol engine, 92 kW or 125 hp power, self-mass 1200 kg and full mass 2000 kg was used [7].

Experiment consists of three regimes: 50 km/h, 90 km/h and IM 240 driving cycle. For experiment start is chosen self-mass 1200 kg and end- 2000 kg with 200 kg step, what gives 5 readings. On inertial roller stand experiments can be done all year despite weather changes, but automobile must be kept at least 6 hours before experiments inside room with temperature +20…+30°C temperature, where experiments will happen [6].

Inertial roller stand „Mustang MD-1750" was used to perform experiments, which combines mechanical, electromechanical, electrical and electronic modules, that working together can imitate all automobile influencing factors.

Automobile original fuel supply system must be disabled to make fuel consumption experiments (see Fig. 1). For this particular automobile VW Passat, fuel pump contact was disconnected and fuel intake and outflow hoses were disconnected in engine bay and connected to „AVL KMA MOBILE", which replaces automobiles fuel supply system.

Rev detecting connector was attached to primary current wire in ignition system. For experiments three people are needed- first drives automobile, second changes load value in inertial roller stands computer and saves data, third saves data from fuel consumption meter „AVL KMA MOBILE" on another computer. Experiments were made at 50km/h in 4th, but at 90 km/h in 5th gear.

Combined cycle mode IM 240 consists of many acceleration and braking sections with average speed 47.3 km/h and even five second stop, to simulate city and highway driving. Driver must drive in inertial rolling stand computers monitor seen gear and speed, which is shown as curve in graph and has upper and lower border. To get precise and usable data- driver must stick between these two borders.

Inertial rolling stand operates with automobiles driving wheels proportionally driving speed, imitating driving conditions. Air and rolling resistance at 80 km/h must be calculated and typed in inertial rolling stand computer:

$$N = N_f + N_w \tag{1}$$

where N_f – power to overcome rolling resistance;
N_w – power to overcome air resistance.

Power to overcome air resistance:

$$N_w = kFv^3, \tag{2}$$

where k – coefficient of drag;
v – automobile speed, m/s;
F – automobile frontal area, m^2.

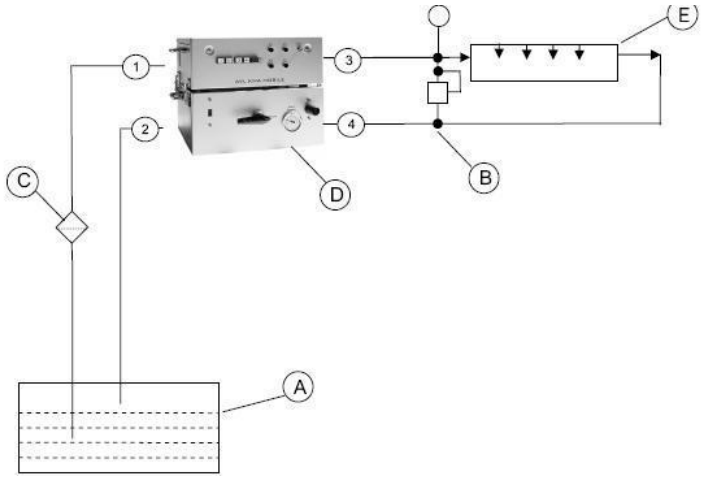

Fig. 1. Fuel consumption meter „AVL KMA MOBILE" working scheme [5]:
1 – measuring module fuel intake hose; 2 – conditioning module fuel outflow hose; 3 – measuring module fuel outflow hose; 4 – conditioning module fuel intake hose; A – outside fuel tank; B – outside fuel pressure regulator; C – fuel filter; D – „AVL KMA MOBILE" device; E – engine with pressure regulator
1 pav. Degalų matavimo pritaiso „AVL KMA MOBILE" veikimo schema [5]:
1 – matavimo modulis ant degalų įsiurbimo vamzdžio; 2 – matavimo registravimo modulis ant degalų grįžtamojo vamzdžio; 3 – matavimo modulis ant degalų išleidimo vamzdžio; 4 – registravimo modulis ant degalų įsiurbimo vamzdžio; A – išorinis degalų bakas; B – išorinis degalų slėgio reguliatorius; C – degalų filtras; D – „AVL KMA MOBILE" prietaisas; E – variklis su slėgio reguliatoriumi

$$F = 0.81B_g H, \tag{3}$$

where B_g – automobile width without mirrors, m;
H – automobile height, m.

Power to overcome rolling resistance:

$$N_f = fG_a v \cos\alpha, \tag{4}$$

where f – rolling resistance coefficient;
G_a – force of automobile weight, W;
α – angle of upslope, degrees.

To estimate impact of inertial resistance, power to overcome inertial resistance has to be calculated:

$$N_j = vmj\delta, \tag{5}$$

where j – acceleration, m/s^2;
m – automobile mass, kg;
δ – rotating mass coefficient.

$$\delta = 1.04 + 0.0025 i_k^{\,2} i_0^{\,2}, \tag{6}$$

where i_k – gearbox gear ratio;
i_0 – main transmission gear ratio.

Power to overcome resistances at 1200 kg and 2000 kg load at different speed are summarized in Fig. 2. By Fig. 2 curves, it is clear, that power to overcome rolling and air resistance is much smaller than power to overcome inertial resistance. Power to overcome inertial resistance increases by increasing speed noticeably more than power to overcome rolling and air resistance. So accelerating and braking car should consume more fuel than at constant speed, when there is no inertial resistance.

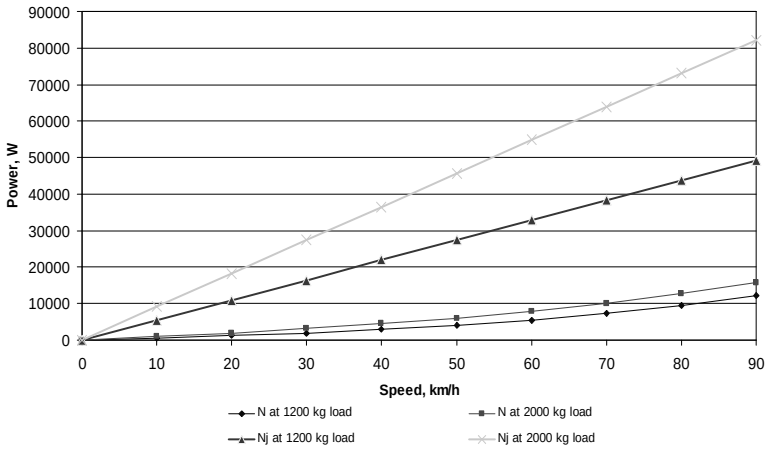

Fig. 2. Power to overcome resistances at different load
2 pav. Galia pasipriešinimams nugalėti prie skirtingų apkrovų

Results and discussion

Experiment results are summarized in Table 1 and Fig. 3.

Table 1. Fuel consumption changes, l/100km.
1 lentelė. Degalų sąnaudų kitimas**,** l/100km.

Fuel consumption, l/100 km	Load, kg				
	1200	1400	1600	1800	2000
at speed 50 km/h	5.83	5.87	5.81	5.80	6.23
at speed 90 km/h	6.57	6.56	6.59	6.50	6.81
in combined cycle mode	9.20	9.50	9.65	10.03	10.31

At constant speed fuel consumption is almost unvarying, but at 2000 kg big load at 90 km/h, an increase is occurring and reached 6.81 l/100km big value. At 50km/h big speed increase is occurring also at 2000 kg big load and reached 6.23 l/100km big value. For automobile driving at constant speed, fuel consumption increases near full mass because of engine overload [3]. In combined cycle mode with average speed 47.3 km/h fuel consumption is significantly more compared even to 90 km/h constant speed mode. So automobile driver should maximally drive at constant speed mode, for example- use roundabout if the drive target is in the other side of the city and the difference in the distance is not so significant.

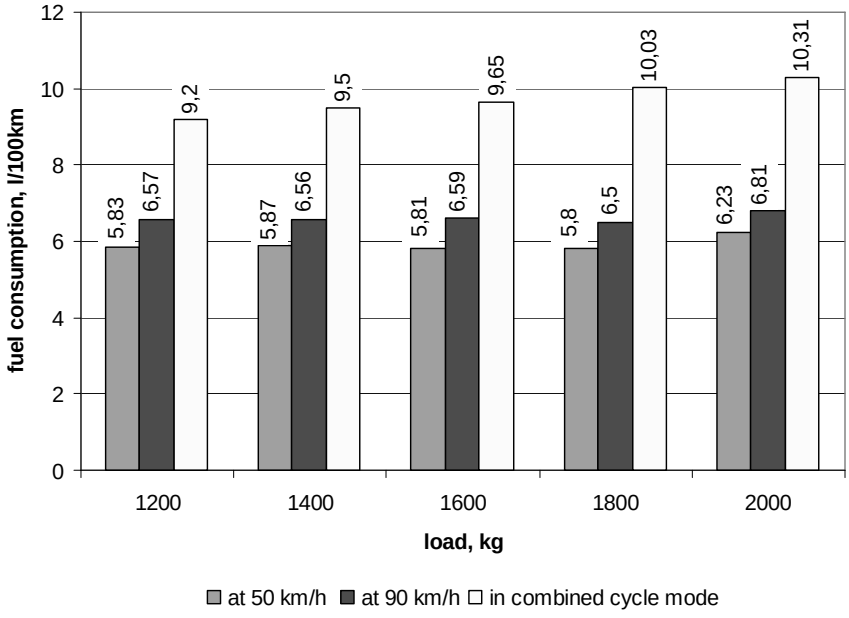

Fig. 3. Fuel consumption changes, l/100km
3 pav. Degalų sąnaudų kitimas**,** l/100km

In combined driving cycle fuel consumption increases almost linear, and difference between 1200 kg and 2000 kg big load is 1.11 l/100 km with maximum

value of 10.3 l/100km. This driving cycle consists of many acceleration and braking stages, so biggest fuel consumption changes are because of inertial resistance. Fuel consumption given in technical information for urban driving is 8.25 l/100km [8], what is close to combined cycle mode IM 240 with average speed 47.3 km/h, so the results are believable, but should be compared with real driving conditions, what is my next aim.

Other authors have compared dynamometer with on-road experiments by a group of experienced scientists specifically trying to obtain good quality data. It is obvious that the variability of the drive-cycle tests were very much less than the variability of the on-road tests. The statistical measure of variation, "standard deviation divided by mean", was 12.6% for the on-road data and 2.1% for the drive-cycle data. In other words, the drive-cycle results were six times more precise than the on-road results [9].

Conclusions

1. Power to overcome rolling and air resistance in considered testing in considered testing conditions was determined as being up to 7 times smaller than power to overcome inertial resistance.
2. Power to overcome inertial resistance increases fast increasing driving speed. Increasing load from 1200 kg to 2000 kg for VW Passat, power to overcome inertial resistance (at tested condition), consumes 40 % more power.
3. Fuel consumption changes for VW Passat in combined driving cycle IM 240 a are in average 0.28 litres for every 200 kg load because of inertial resistance.
4. Fuel consumption increases by 7% or 0.43 l/100km at 50 km/h speed and 4.5% or 0.31 l/100km at 90 km/h, speed, when load was increased from 1200 to 2000 kg.

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DEGALŲ SANAUDOS PAGAL AUTOMOBILIO APKROVĄ

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Reziumė

Automobilio naudojamų degalų kiekis priklauso nuo įvairių pasipriešinimų: oro, riedėjimo, inercijos jėgų ir priekabos pasipriešinimo. Kiekvienas iš pasipriešinimų degalų sąnaudas gali įtakoti įvairiais dydžiais. Vienas iš svarbiausių faktorių įtakojančių degalų sąnaudas yra automobilio masė ir masė krovinio. Tyrimai buvo atlikti bandant automobilį VW Passat su 1,8 l Otto varikliu ant inercinio būgninio stendo. Automobilio krovinys buvo keičiamas nuo 1200 iki 2000 kg ribose. Degalų sąnaudos automobiliui važiuojant pastoviu greičiu mažai priklauso nuo vežamo svorio ir kinta 5% ribose. Tačiau, degalų sąnaudos ypatingai didėja keičiant važiavimo ciklus, to priežastis yra inercijos jėgų atsiradimas.

Automobilis, apkrova, degalų sąnaudos, inercinis būgninis stendas.

Улдис Путниекс

ЗАВИСИМОСТЬ РАСХОДА ТОПЛИВА ОТ НАГРУЗКИ АВТОМОБИЛЯ

Резюме

Количество потребляемого топлива автомобилем зависит от различных типов сопротивления: воздушного, качения, наклонного, инерционного и сопротивления прицепа. Каждое из этих сопротивлений может влиять на расход топлива с разной степенью воздействия. Один из главных факторов, влияющих на расход топлива, это вес автомобиля и вес груза. Исследование было проведено на автомобиле VW Passat с 1,8 л Otto двигателем на инерционном роликовом стенде. Груз автомобиля был изменен в диапазоне от 1200 до 2000 кг. Расход топлива при постоянной скорости автомобиле мало изменяется в зависимости от перевозимого груза и варьирует в пределах 5%. Однако расход топлива существенно увеличивается в случае симуляции циклов езды, что происходит в следствие инерционного сопротивления.

Автомобиль, нагрузка, расход топлива, иннерционный роликовый стенд.