RESEARCH IN THE CONSUMPTION OF IDLE SPEED FUEL OF OTTO MOTORS DEPENDING ON THE FUEL TO AIR RATIO

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Abstract. The work researches in the consumption of fuel in Otto motors and the composition of exhaust gases using 1.4 l Otto motor the fuel system of which is modified in order to smoothly regulate the fuel to air ratio in the range from 0.8 to 1.5. The composition of waste gas and its proportions correspond to the general theory on the character of changes of exhaust gases depending on the fuel to air ratio. The optimal composition of waste gas and consumption of fuel are reached at $\lambda = 1.30$ that is recommended to regulate for Otto motors without catalytic waste gas neutralizers. The consumption of fuel in idle speed at this regulation in comparison to the consumption with rich fuel-air mixture with $\lambda = 0.82$ decreases by 43%.

Key words: composition of waste gas, fuel consumption, exhaust gases, motor stand, idle speed regime.

Introduction

Power vehicles are one of the main consumers of fossil fuels. With burning of fossil fuels, different exhaust gas components get into the surrounding environment. Some of them are toxic, for example, carbon monoxide CO, carbon hydrogen C_nH_m, hard particles or smoke. Some of the components are not toxic, for example, CO_2, nevertheless, it promotes the greenhouse effect on the earth. Due to this reason in recent years information is widely available to the public about the amount of CO_2 exhaust gases of the new automobiles, g/km. The amount of CO_2 is closely related to the amount of the consumed fuel. The bigger the amount of CO_2 exhaust gases, the more fuel is consumed by power vehicles [1].

Today the reserves of fossil fuel start to run out. Scientists have made much effort in investigation of new alternative fuels. Much research has been carried out in the consumption of fuel at different load regimes for motors. Also the impact of regulation of motors on toxicity of motors has been analyzed in literature. It has been mentioned that for motors with rich fuel-air mixture when the fuel-to-air ratio is less than 1 the consumption of fuel is higher than with lean fuel-air mixture. Nevertheless, there are little definite investigations depicting the consumption of fuel of Otto motors in idle speed. Due to this, it is set as the main aim of the research.

The aim of the research is to investigate the consumption of fuel in Otto motors and the composition of exhaust gases depending on the changes in the fuel to air ratio.

Equipment used in the experiment

Three basic devices have been used in the experiment:

- automobile motor stand;
- waste gas analyzer BOSCH BEA 350;
- device for determination of fuel consumption;
- digital hand chronometer with exactness of measuring 0.01 s.

BOSCH BEA 350 waste gas analyzer consists of modules. Using the inserted data on automobiles it is possible to measure all nominal and actual values that influence the composition of waste gases [1]. Operation of the waste gas analyzer is supplied with functional keys of the equipment, with a computer keyboard or remote control.

The waste gas components CO, CH, CO_2, O_2. are measured with the waste gas measuring module. For measuring of NO_x NO_x an additional module is needed. The fuel-to-air ratio λ is calculated using the corresponding waste gas components. Using the data on CH, CO, CO_2 and the concentration of oxygen the equipment determines the λ coefficient. For calculation of λ precise oxygen measurement is essential.

The amount of CO, CO_2 and CH is determined by the infrared ray method. The oxygen is determined by the sensor of electrochemical action.

The range of measurements of the waste gas analyzer is summarized in Table 1 [2].

Table 1

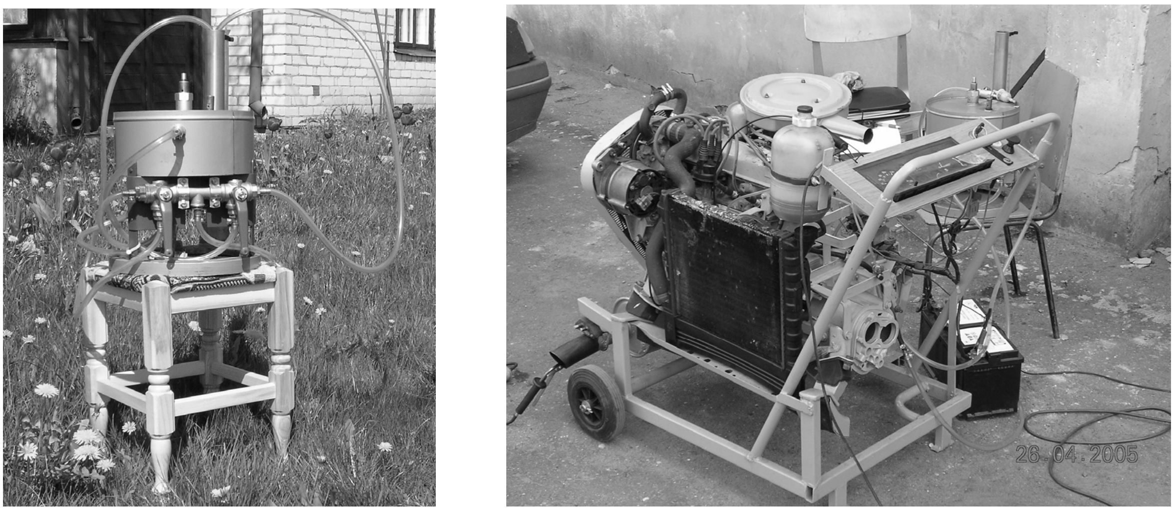
The range of waste gas analyzer Bosch BEA 350 measurements

Component	Range of measurements	Distinguishing ability
CO	0.000 – 10.00 %	0.001 %
CO_2	0.000 – 18.00 %	0.01 %
CH	0 – 9999 ppm	1 ppm
O_2	0.00 – 22.00 %	0.01 %
λ	0.500 – 9.999	0.001
Oil temperature	- 20 – +150 ^oC	0.16 ^oC
Frequency of crankshaft rotation	600 – 6000 min^{-1}	10 min^{-1}

The registered values of measurements can be printed with the equipment protocol printer or external A4 format printer.

For measuring of the consumption of fuel a measuring device with a graded measuring vessel can be used applying the volume method (Fig. 1). Two spherical three-direction flow distributors have been installed in the equipment. The flow distributors are installed in one unit that allows for comfortable re-switching of the fuel feeding regime [3].

For determination of the fuel consumption a measuring cylinder with the point value 2 ml is used the total volume of it being 250 ml. Distribution of fuel in the equipment from the measuring vessel of fuel tank is ensured by different conditions of flow distributors.



a) b)

Fig. 1. **Fuel consumption determination device (a) and motor stand (b)**

The experiments were carried out at the motor stand elaborated at the laboratory of the Motor Vehicle Institute (Fig. 1b). A motor C2J with the capacity 1.4 liters of the automobile Renault has been used for the stand. A fuel dosing device has been mounted on the motor λ of which can be regulated within the range from 0.8 – 1.5 maintaining stable operation regime of the motor.

Methods of measuring

8 fuel-to-air ratio λ regulation values have been used in the measurements. Five repetitions of measurements have been done at each regulation. The experiments have been carried out at the Motor Vehicle Institute, Faculty of Engineering, Latvia University of Agriculture, Čakstes blvd. 5, Jelgava on 26.04.2005. at the ambient temperature +16 ^oC.

Before the experiment the pipes of the measuring device are connected to the motor fuel system fuel feeding and exhaust pipes. In the basic tank of the measuring device Be-95 brand gasoline is filled and the system is bleed operating the motor. Before the experiment the technical condition of the motor is visually checked whether the dosing device is subject to regulation. In order to carry out the measurements the motor is heated up to the operation temperature. The measurements are done in the idle speed regime of the motor [4].

The waste gas analyzer is connected to the motor connecting the gas exhaust pipe, rotation measuring device contacts to the accumulator and the oil temperature-measuring device.

The measurements are carried out at the constant amount of fuel – 20 ml.

The time is checked in which the amount of fuel is consumed. The first fuel-to-air ratio value is set for the motor ($\lambda = 0.82$). The fuel consumption-measuring device is switched in the flow distribution condition when fuel is taken from the measuring cylinder and the measurement is carried out with the motor working in idle speed the drop of the fuel level is observed. In the moment when the level of fuel coincides with a fuel point of the measuring device the chronometer is switched on. After consumption of 20 ml of fuel the chronometer is switched off. Every measurement is repeated for 3 times [5].

After the experiment with one setting of the motor the experiment is repeated with the next setting of the fuel-to-air ratio.

The initial parameters to be determined:

- oil temperature T, ^oC;
- idle speed revolutions, min^{-1};
- fuel-to-air ratio, λ;
- composition of waste gases % and ppm (amount of particles on the million part of capacity);
- consumption of fuel Q_t, ml;
- time, s.

After the experiment mathematical processing of the data for the summarized measuring results (consumption of fuel) is carried out and the variation coefficient in the range $0.51\% \le V_n \le 2.63\%$ is obtained showing high exactness of measurements.

Results and their analysis

In the experimental measurements the data on the consumption of fuel at different values of fuel-to-air ratio and the composition of waste gases have been obtained. The consumption of fuel of the motor depending on the fuel-to-air ratio is shown in Figure 2.

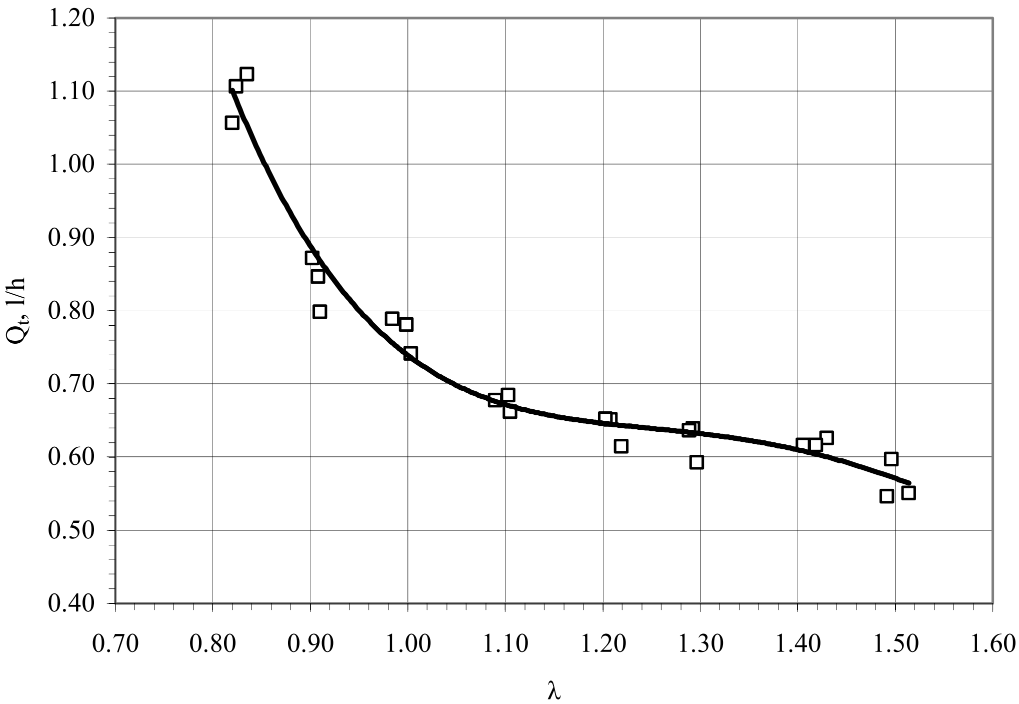


Fig. 2. **The change of consumption of fuel Q_t depending on the fuel-to-air ratio λ**

As it is seen in Figure 2 with less fuel-to-air ratio values the consumption of fuel is the highest. The bigger the fuel-to-air ratio, the less the fuel consumption. The consumption of fuel with rich fuel-air mixture ($\lambda = 1.51$) is by 48% higher that testifies of essential influence of the regulation of the fuel system on the amount of the consumed fuel. The minimal consumption of fuel for the motor $Q_t = 0.57$ l/h. Nevertheless, the motor is working more stable with the fuel-to-air ratio $\lambda = 1.30$ when the obtained consumption of fuel $Q_t = 0.64$ l/h.

Further we will analyze the changes of waste gas composition depending on the fuel-to-air ratio λ (Fig. 3.). The change of consumption of carbon oxide CO and dioxide CO_2 as well as of carbon hydrate CH, oxygen O_2 and fuel depending on the regulation of the fuel system Q_t is shown in Figure 3. Investigating the correlation between the fuel-to-air ratio and carbon oxide we can observe that the richer the fuel-air mixture is, the higher is CO. Regulating leaner fuel-air mixture we can get decrease of CO up to 0.1%. The amount of carbon oxide can be reduced by 98% comparing the measurements with rich and lean fuel-air mixture. CO_2 reaches its maximum in this graph at $\lambda = 1.10$ and further with the value of λ increasing the amount of carbon dioxide reduces.

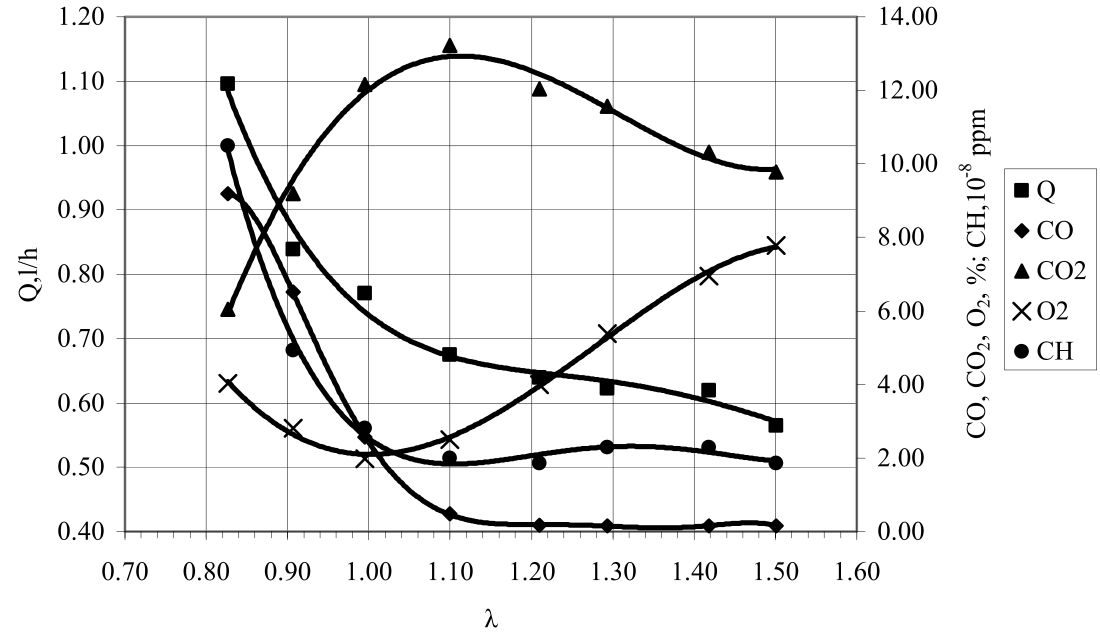


Fig. 3. **Dependence of the consumption of fuel and waste gas components on the fuel-to-air ratio**

Considering that CO_2 characterizes the quality of combustion it is optimal if the value of the fuel-to-air ratio is 1.10. Operation of the engine at this regulation is the best.

The values of carbon hydrates CH fastly decrease when the fuel-to-air ratio is in the range from 0.8 to 1.05, but in the range from 1.05 to 1.5 the values varied from 180 – 260 ppm. In the experiment an essential increase of CH component has not been achieved at lean fuel-air mixture that corresponds to the theory of change of this component.

At the fuel-to-air ratio value 1.35 – 1.5 the operation of the engine becomes unstable as O_2 is supplied too much and a qualitative combustion process does not take place. The change of the motor from the acceleration process to medium revolution goes on slower.

The most optimal regime of motor operation according to the consumption of waste gases is in the range of λ values 1.05 to 1.15 as then CO has its minimal values. Also CH values decrease and the value of CO_2 is the highest. In turn, from the point of view of the consumption of fuel the optimal range is from 1.25 to 1.35 as the consumption of fuel is less than in the range of 1.05 – 1.15, but CO_2 is decreased in the composition of waste gases by 15% that essentially influenced the operation of the engine. This regulation is optimal from the point of view of consumption of fuel as well as from the point of view of waste gas toxicity.

Conclusions

1. With every year the number of automobiles increases, so the consumption of fuel also increases the same as pollution of the surrounding environment. Doing the right regulation of the motor in idle speed gives a possibility to reduce the consumption of fuel by 40%.
2. The optimal setting of the fuel-to-air ratio from the point of view of the toxicity of waste gases is in the range from 1.05 – 1.15.
3. The optimal fuel-to-air ratio regulation from the point of view of consumption of fuel is in the range from 1.25 to 1.35.
4. The obtained characteristic curves of waste gas toxicity CO; CO_2; C_nH_m and corresponding to O_2 components in the classical theory correspond to the character of the discussed curves.
5. It is possible to reduce the content of CO by 98% in the range of the air-to-fuel ratio used in the experiment.
6. The most stable evaluation of the operation of Renault motor at $\lambda = 1.10$ as CO_2, it reaches the maximal value 13.2%.
7. The consumption of fuel in idle speed is essentially influenced by the regulation of the dosing systems; in idle speed it is possible to save up to 0.5 l of fuel per hour. This is essential in the city traffic, especially in rush hours.

Bibliography

1. Granta D., Birziņa R. Transports un vide. – Rīga, 1998., www.lu.lv (12.04.2005.)
2. BEA emission analyser. www.bosch.de/prueftechnik (02.05.2005.)
3. Pommers J., Liberts G. Automobiļa teorija. – Rīga: Zvaigzne, 1985. – 247 lpp.
4. Šneps-Šneppe V., Kreicbergs J., Danenbergs V., Zalcmanis G. Kā regulēt karburatoru. – Rīga: RTU, 1993. – 62 lpp.
5. Berjoza D. Analysis of methods of experimental research in power vehicle fuel consumption // International Scientific Conference “Advanced technologies for energy producing and effective utilization” proceedings. – Jelgava, 2004. – P. 192-196.