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BIOETHANOL GASOLINE FUEL BLENDS EFFECT ON STANDARD SPARK-IGNITION ENGINE OPERATING PARAMETERS

BIOETANOLIO – BENZINO MIŠINIŲ ĮTAKA STANDARTINIO KIBIRKŠTINIO UŽDEGIMO VARIKLIO DARBO RODIKLIAMS

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To improve the situation in the biofuels usage sphere, in June 2009 the Cabinet of Ministers of Latvia accepted modifications to the “Regulations on petrol and diesel fuel conformity assessment” that stated that from the 1st of October 2009 the 95th gasoline can be distributed only with the 4.5 to 5% mixture of bioethanol. Such amount of ethanol admixture does not adversely affect engine performance and also does not require any specific adjustments to the engine. This investigation examines how the admixture of bioethanol, which is higher than 5%, will affect spark ignition engine performance. Unadapted car VW Passat with a 1.8 l petrol engine will be operated with ethanol-gasoline fuel mixtures, where the ethanol content reaches up to 85% of the total volume. The impact of different mixtures on the engine power and torque characteristics as well as on the exhaust gas temperature will be examined. Finally, the fuel consumption and exhaust composition changes will be analyzed.
Bioethanol, fuel consumption, power, exhaust emission.

Introduction

Biofuels as alternative energy source are one of most urgent topics nowadays. Bioethanol is one of alternative fuel form which can be used in motor vehicles apropos fossil gasoline and partially diesel. Widely usage of bioethanol has achieved straight in spark ignition motor vehicles. In such engines bioethanol can be utilized in straight way as, for example, in Brazil, where clear undehydrate bioethanol is used, or in mixtures with fossil gasoline. One of most used mixtures of bioethanol-gasoline is E85, which consist 85% of bioethanol and 15% of gasoline. Such mixture fuels widely are used in USA and Sweden as well in Europe countries in especially for this purpose projected and modified motor vehicles (FFV). In many European countries, int. al., in Latvia, mixture fuel E5 is used, which consist of 5% admixture to fossil gasoline. As often as not mark of this fuel is not specially marked out, but fuel is marked as conventional fossil petrol. In Latvia since October 2009 is passed a law which predicts compulsory demand for all A95 gasoline fuels in market to spice with 4.5-5% bioethanol. In several countries and regions mixtures with other relation of bioethanol-gasoline are met, which is provided to utilize in more or less especially modified spark ignition engines.

As mentioned in F.Yüksel & B.Yüksel investigations, gasoline-ethanol mixtures, which contain up to 20% ethanol by volume, can be safely used without causing any damage to the engine [1]. In spite of wide possibilities of use of bioethanol, there are a line of unclear questions, which not at all makes better situation in sphere of utilization of bioethanol. Simple way how to exploit bioethanol-gasoline mixture in motor vehicles is to utilize it in standard unmodified motor vehicles. There arises a line of questions, which are connected with impact of used fuel on engine and elements of power system, changes of fuel consumption and exhaust gases operating on one or other kind of fuel as well as impact of used fuel on engine power and torque. In the same way arises question: what is maximum possible admixture of bioethanol in fuel mixture, which is possible to use in standard unmodified motor vehicle?

In order to establish known clarity in these questions, there is performed experimental study of standard spark ignition motor vehicle VW Passat, when as fuel mixtures of bioethanol-gasoline (A95 or E0 … E85) are used.

Literature analysis

A number of researches connected with exploitation of mixture of bioethanol-gasoline in spark ignition engines are performed in stationary conditions on motor power stands. In these experiments specific fuel consumption, composition of exhaust gases and other parameters at constant motor speed are established. Regimes of experiments not always can describe real condition of exploitation of motor vehicle in field. Acquired results in several researches are different.

Exploitation of ethanol-gasoline fuel mixture in spark ignition engines was studied by M.Al-Hasan, where such parameters as specific fuel consumption, engine torque, CO, CO_2 and HC emissions and other parameters for fuel mixtures from E0 till E25 were determined [2]. In these research were induce that the best results for engine power and exhaust emissions are when engine is operating on fuel mixture with 20% of ethanol admixture.

Experiments on one-cylinder spark ignition engine operating on fuel mixtures E0, E25, E50, E75 and E100 were performed by M.Bahattin Celtik [3]. In this research engine power, specific fuel consumption, composition of exhaust gases (CO, CO_2, HC, NO_x) at several compression ratios (6/1-10/1) and other parameters were analyzed. Results show that fuel E0 knocks at compression ratio 8/1, but E50 knocks not even at compression ratio 10/1.

From the experimental results, it was determined that the engine power increased by about 29% when it is operating on E50 fuel at high compression ratio compared to the operating on E0 fuel. At the same time, the specific fuel consumption, CO, CO_2, HC and NO_x emissions were reduced by about 3%, 53%, 10%, 12% and 19% respectively.

Purpose of the research and objectives

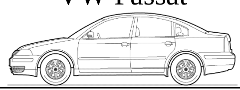
The aim of this paper is to analyze operation peculiarity of standard motor vehicle operating on bioethanol-gasoline fuel mixtures. Mine tasks to perform are as following:

- to determine changes of engine power and torque operating on bioethanol-gasoline fuel mixtures;
- to determine changes of fuel consumption operating on bioethanol-gasoline fuel mixtures;
- to determine changes of emissions of exhaust gases operating on bioethanol-gasoline fuel mixtures;
- to determine temperature of exhaust gases operating on bioethanol-gasoline fuel mixtures;

Object and methods

Automobile VW Passat with spark ignition engine with capacity of 1.8l was exploited in experiments. Sensitive characterization of automobile in table 1 is given.

Table 1. Technical characterization of experimental automobile.
1 lentelė. Tirto automobilio techninės charakteristikos.

Vehicle	VW Passat 
Year of manufacture	1997
Engine characteristics	Spark ignition, capacity – 1781cc, 20 valves, output power – 92 *kW* at 5800 *rpm,* equipped with catalytic exhaust gas converter
Fuel & ignition system	Standard fuel system (Bosch Motronic M3.8.2.), lambda – closed loop control
Gearbox	5-gear manual

Research was performed in Scientific Laboratory of Alternative Fuels of Latvia University of Agriculture on chassis dynamometer Mustang MD-1750 where following parameters were established: power and torque on leading wheels, fuel consumption, composition and temperature of exhaust gases. To determine all these parameters following tests were performed: power test, idle running test, constant speed tests (50kmh^{-1}, 90kmh^{-1} and 110kmh^{-1}), cycle IM-240 and especially worked cycle ”Jelgava”. Technical characteristic of cycle ”Jelgava” and peculiarities of elaboration are described in publication [4,5]. Technical characterization of laboratory equipment in table 2 is given. Switching scheme of laboratory equipment and automobile in Fig.1 is given.

Table 2. Technical characterization of laboratory equipment.
2 lentelė. Laboratorinės įrangos techninės charakteristikos.

Measuring unit	Technical characteristic
Chassis dynamometer Mustang *MD-1750*	Maximum measuring capability – 1287kW; peak absorption – 294*kW*; maximum measurement speed – 362kmh^{-1}; controls – Pentium-based PC; maximum axle weight – 4536*kg*.
Fuel consumption measurement system *AVL KMA Mobile*	Measuring range – 0.35–150lh^{-1}; fuel density range – 0.5–2g/cm^3; measuring error – 0.1*%*.
Multicomponent exhaust gas measurement system *AVL SESAM FTIR*	Measurable gas components: up to 25 pre-calibrated measurement gases (CO_2, CO, H_2O, SO_2, NO, NO_2, N_2O,NH_3, CH_4, C_2H_4 etc.); response time – 1*s*; sample gas flow – 10$lmin^{-1}$.

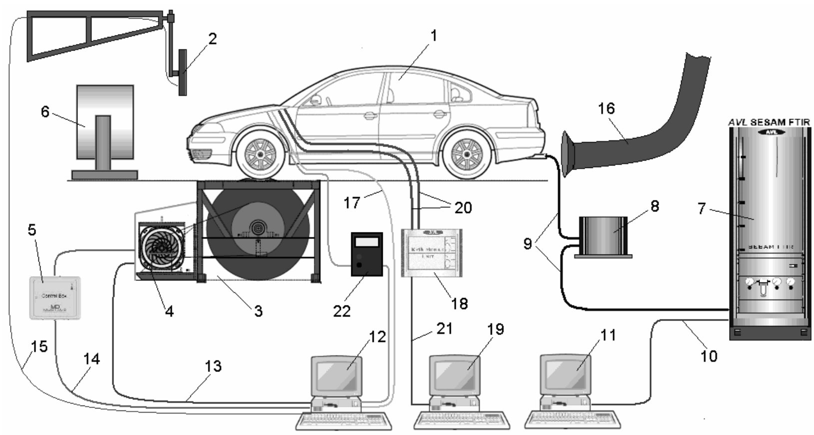


Fig. 1. Experiments measuring equipment attachment scheme: 1 – experimental car, 2 – test cycle simulation screen, 3 - chassis dynamometer Mustang MD-1750, 4 – power absorber unit (PAU), 5 – dynamometer control box, 6 – air blower, 7 – multicomponent exhaust gas measurement system AVL SESAM FTIR, 8 – heated filter, 9 – heated gas line, 10 – AVL date communication cable, 11 – PC with special software AVL, 12 – Mustang chassis dyno control module & data recording, 13 – Mustang dyno date communication cable, 14 – dyno control circuit, 15 – screen communication cable, 16 – exhaust extraction pipe, 17 – EGT sensor cable, 18 – fuel consumption measurement system AVL KMA Mobile, 19 - PC with special software AVL KMA Mobile, 20 – fuel lines, 21 - AVL KMA Mobile data communication cable, 22 - digital air/fuel ratio meter LM-1.
1 pav. Bandymų įrangos jungimo schema

Fuels used in experiments: E0 (A95), E10, E20, E30, E40, E50 and E85. These fuels were achieved by mixing fossil gasoline Statoil A95 with bioethanol produced by Ltd. ”Jaunpagasts Plus”.

The sequence of experiments, the number of repetitions and other issues related to measurements are taken from the methodology developed and approbated in previous tests [5, 6].

Results and discussions

In this paper with each mixture of fuel series of experiments were performed which consists of determination of automobile power, fuel consumption, exhaust gases and other parameters characterizing operation of engine. Each series was performed at least three times and from them achieved average data in figures below are given. Let’s discuss results for each of broached tasks.

Automobile power and torque. Automobile power was determined on driving wheels and that is why it is different from effective power given in technical documentation. After data in Fig. 2 it is seen that power changes operating on different bioethanol-gasoline mixtures are comparatively small. Constitutive changes are in case when in standard automobile fuel mixture with high content of bioethanol is used and at low engine speed it is observed essential drop of power, but at middle and high motor speeds power is greater than operating on fossil fuel. In spite of that specific heat of bioethanol is lower than for fossil gasoline, automatically enlargement of fuel portion allow engine to reach the same power as operating on A95 gasoline.

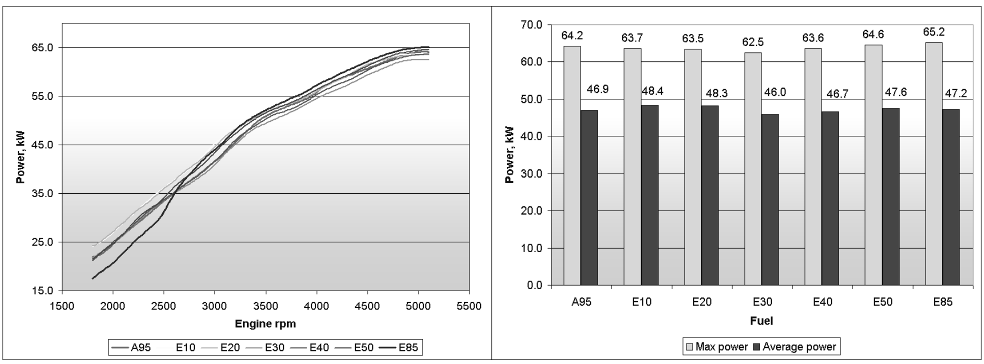


Fig. 2. Vehicle power changes: a – power curves, b – max and average power
2 pav. Automobilio galios pokyčiai: a –galios kreivės, b – maksimali ir vidutinė galia

Similar changes are observed for torque characteristics (Fig. 3). Constitutive drop of torque at low engine speed is operating on E85 fuel whereas, higher ratios at low engine speed are operating on E10 and E20 fuels.

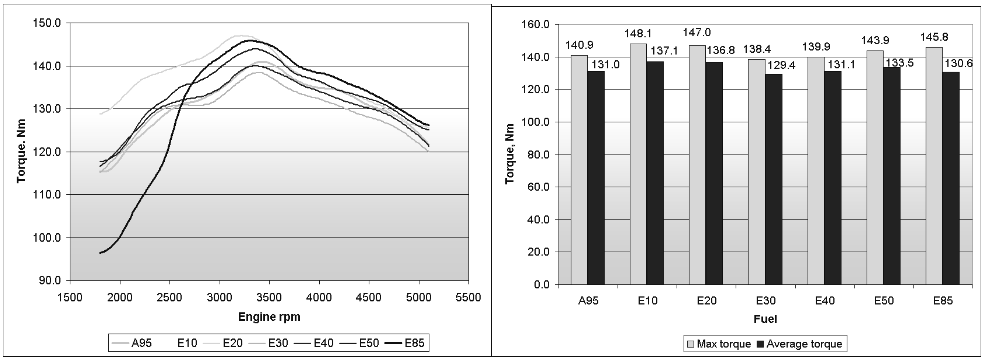


Fig. 3. Vehicle torque changes: a – torque curves, b – max and average torque
3 pav. Sukimo momento polytis: a – sukimo momento kreivės, b – maksimalus ir vidutinis sukimo momentas

Exhaust gas temperature (EGT). The highest EGT is achieved at load regime at high engine speed. That is why temperature changes are fixed during power test. Main attention is turned to maximum achieved temperature at the end of the test. EGT was controlled in intersection point of bores of exhaust port (~ 25 cm from exhaust valves). Average EGT during all power tests at the beginning achieved 444 ± 18 ˚C. For its part, maximum EGT at the end of tests for each fuel in Fig.4 is given.

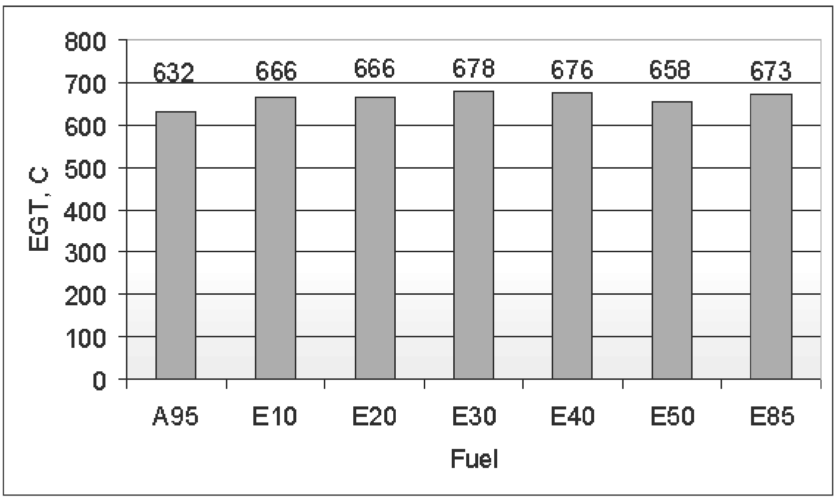


Fig. 4. Max exhaust gas temperature
4 pav. Maksimali deginių temperatūra

After data given in Fig.4 it is seen, that EGT, operating on bioethanol-gasoline mixture for standard unmodified automobile handful increases in comparison with case of operating with A95 gasoline, but this increase in unsubstantial. Insignificant increase of EGT unaffected negative in no shape temperature of active parts of engine. Biochemical quality of bioethanol and automatically increase of fuel portion provides that temperature of fuel mixture burning for standard unfitted automobile is so negligible.

Fuel consumption. In Fig. 5 it is shown changes of fuel consumption at several driving regimes in dependence of content of bioethanol in mixture of bioethanol-gasoline fuel. Character of increase of fuel consumption is similar in all driving regimes. The greater content of bioethanol in fuel mixture, the air-fuel mixture becomes leaner and oxygen sensor gives corresponding signal to electronically control block. Engine control block make richer air-fuel mixture in dependence of incoming signal. In standard automobile air-fuel mixture is enriched correspondingly to fossil gasoline air/fuel relation (AFR), id est., 14.7:1, despite in case of E85 EFR has to be 9.7:1.

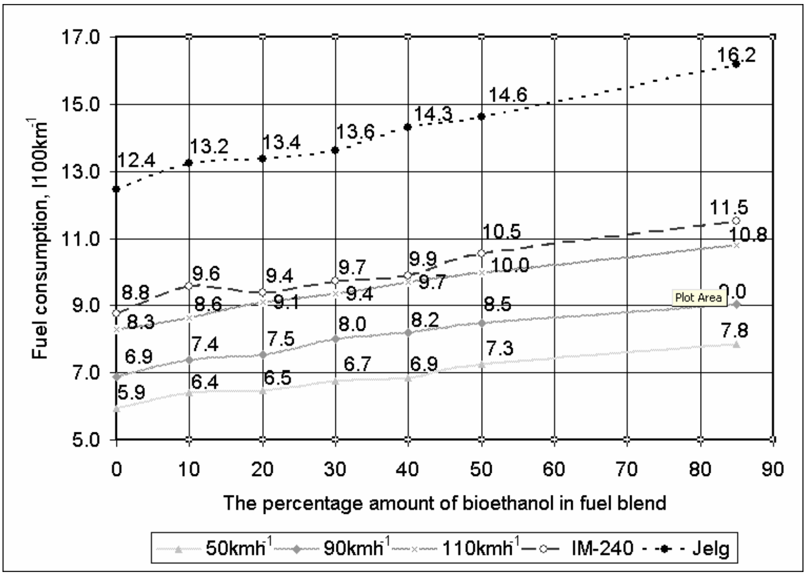


Fig. 5. Fuel consumption changes
5 pav. Degalų sąnaudų pokyčiai

In order to show graphically fuel consumption changes operating on bioethanol-gasoline mixtures, let us look at data achieved during all regimes of tests and state average percentage fuel consumption increase in comparison with case of operating on fossil fuel A95 (see Fig. 6).

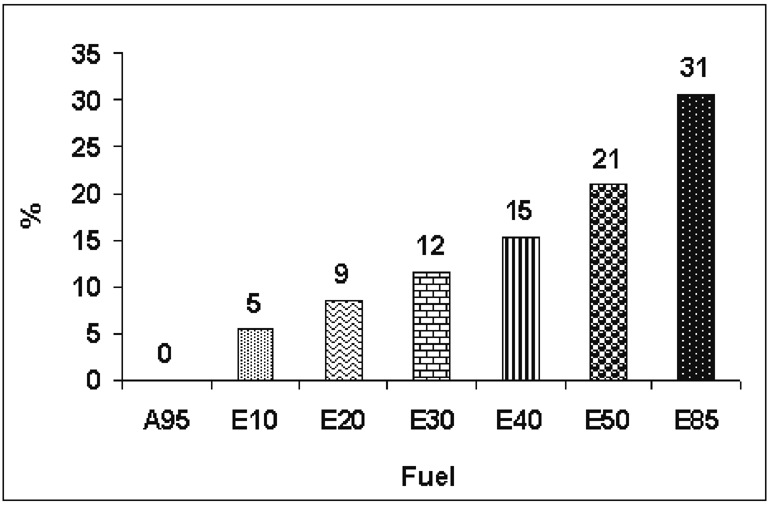


Fig. 6. Percentage increment of fuel consumption
6 pav. Procentinis degalų sąnaudų padidėjimas

Looking at changes of motor power, EGT and fuel consumption it is possible to infer that fuel and control systems of standard automobile VW Passat is able to reach AFR. Enriching of AFR is sufficient to make no danger on engine operation, overheating and damage of piston group parts. Nonetheless all experiments were performed at optimum operation temperature of engine. At such temperature it is possible to operate on bioethanol-gasoline mixture fuels when content of bioethanol is greater than 5%, 10% and up to 85%. Situation substantially becomes worse at low engine temperatures (at cold engine start). Operating on bioethanol-gasoline mixture fuel with high content of bioethanol (for example E85), it is practically impossible to start cold engine. In the same way in this research weren't observed chemical impact of bioethanol-gasoline mixture fuels on components of feeding system of engine.

Content of exhaust gas emissions. During experiments ~ 25 components of exhaust gases were determined, nonetheless content of many components of exhaust gases is near to zero or practically they are not in exhaust gases. In Fig. 7 it is shown components of exhaust gases which make greaten part of common exhaust gas amount.

Summarizing exhaust gas data it is seen, that, with increase of bioethanol content in AFR in greater part of chosen driving regimes decreases content of NH_3 (ammonia) CO_2 (carbon dioxide) and CO (carbon monoxide), whereas NO_x (total nitrogen oxides) quantity increases. Common change of hydrocarbons HGC (total hydrocarbon gasoline) quantity change is unsubstantial. In several driving regimes its' content increases, but in several decreases.

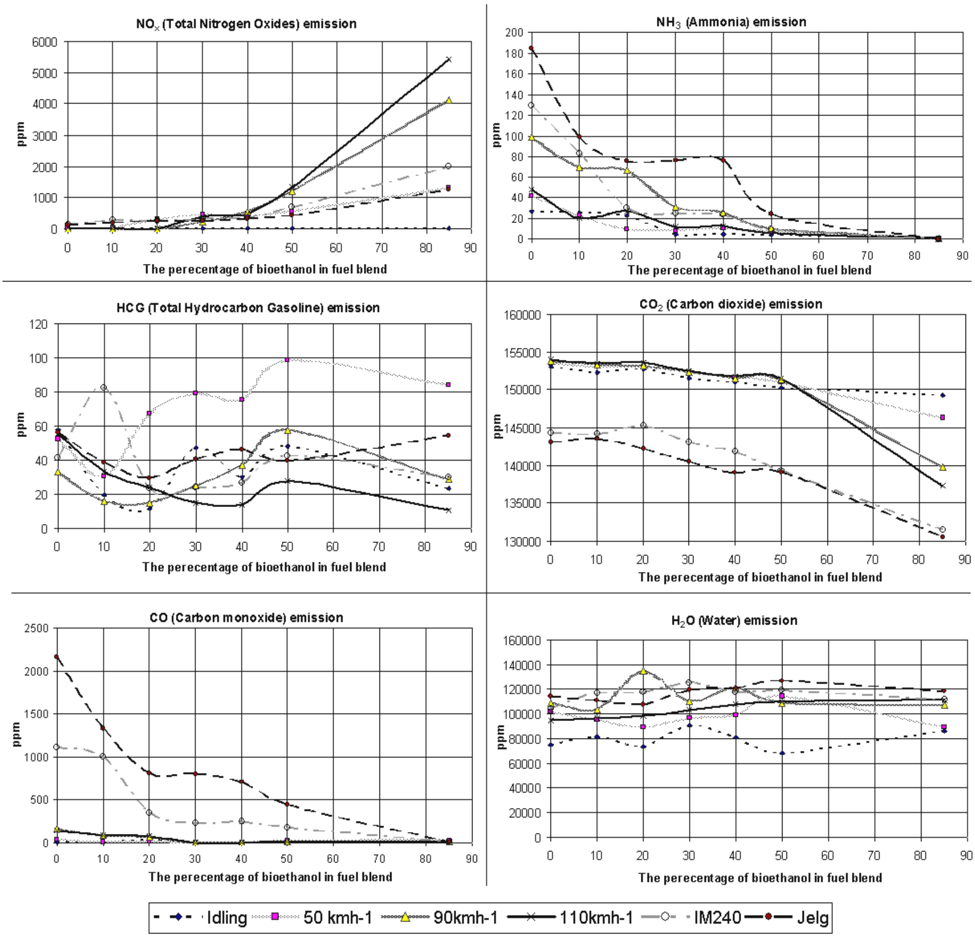


Fig. 7. Exhaust emission
7 pav. Deginių emisija

Conclusions

1. The maximum ethanol content of the fuel mixture which can be used in the non-modified automobile differs from the automobiles model. Mostly it depends on the type of fuel system and its control peculiarities, as well on the fuel pump and nozzle productivity.
2. While standard fuel and control systems are able to enrich air-fuel mixture, changes of power and torque are minimal. Greater changes of power and torque are operating on mixtures with high content of bioethanol. Operating on E85 fuel power and torque decreases at low but increases at high engine speeds in comparison with E0 fuel.

3. Changes of exhaust gas temperature operating on bioethanol-gasoline mixtures with several concentrations give evidence about normal burning process of fuel-air mixture which makes no danger on engine operation.
4. Enriching of air-fuel mixture in standard engine operating on bioethanol-gasoline mixture fuels happens due to closed loop engine control system. Oxygen sensor reacts to increased oxygen content in exhaust gases and forms corresponding signal to electronically control system which enrich air-fuel mixture.
5. Standard type of fuel system and electronically control system uncovers necessary enriching of air-fuel mixture at cold start of engine operating on bioethanol-gasoline mixture with high content of bioethanol (for example E85).
6. The fuel consumption test results show, that until the 100% of the nozzle load is not reached, increasing the ethanol content of the fuel mixture by 10%, fuel consumption increases by 3–6%.
7. Exhaust gas tests shows that increasing concentration of bioethanol in fuel mixtures, components of CO_2, CO, NH_3 decreases but NO_x component increases.

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Reziumė

Norint pagerinti situaciją biodegalų naudojimo srityje, 2009 m. birželį Latvijos Ministrų kabinetas priėmė nutarimą, kad nuo 2009 metų spalio 1 d. parduodamo benzino sudėtyje turi būti 4,5 – 5 % bioetanolio. Tokio etanolio kiekio įmaišymas neturi neigiamos įtakos variklio veikimui, todėl nereikalingas specialus variklio priderinimas. Šio darbo tikslas buvo ištirti, kokią įtaką kibirkštinio uždegimo variklio darbo rodikliams turės didesnio kaip 5 % bioetanolio kiekio įmaišymas į benziną. Neadaptuotas VW Passat automobilio 1,8 l darbinio tūrio benzininis variklis veikė etanolio-benzino mišiniais, kuriuose etanolio kiekis siekė nuo 0 iki 85 % degalų tūrio. Buvo tiriama įvairių mišinių įtaka variklio galios ir sukimo momento charakteristikoms, o taip pat deginių temperatūrai. Taip pat buvo stebimi degalų sąnaudų ir deginių sudėties pokyčiai.

Tyrimais nustatyta, kad didėjant etanolio kiekiui benzine, variklio galia ir sukimo momentas kinta nedaug. Didesni pokyčiai gauti varikliui veikiant degalais su dideliu etanolio kiekiu. Veikiant E85 degalais galia ir sukimo momentas mažėja esant mažam variklio sukimosi greičiui ir didėja esant dideliam sukimosi greičiui, lyginant su atitinkamais režimais varikliui veikiant benzinu. Padidėjus etanolio kiekiui benzine 10 %, degalų sąnaudos padidėja 3-6 %. Didėjant etanolio kiekiui benzine CO_2, CO, NH_3 koncentracija deginiuose mažėja, o NO_x – didėja.

Bioetanolis, degalų sąnaudos, galia, deginių emisija.

Вилнис Пирс, В. Малниченко

ВЛИЯНИЕ СМЕСЕЙ БИОЭТАНОЛА – БЕНЗИНА НА ПОКАЗАТЕЛИ РАБОТЫ СТАНДАРТНОГО ДВИГАТЕЛЯ С ИСКРОВЫМ ЗАЖИГАНИЕМ

Резюме

С целью улучшения ситуации в области использования биотоплива, кабинет Министров Латвии принял решение, что с 1 октября 2009 г. в составе продаваемого бензина должно быть 4,5 – 5% биоэтанола. Добавка такого количества этанола не имеет негативного влияния на работу двигателя, поэтому не нужна специальная подготовка двигателя. Цель этой работы – исследование влияния добавки в бензин большего 5% количества биоэтанола на показатели работы двигателя с искровым зажиганием. Неадаптированный 1,8 л. рабочего объема двигатель автомобиля VW Passat работал на смесях этанола – бензина с содержанием этанола от 0 до 85% по объему.

Исследовалось влияние различных смесей на мощность и крутящий момент двигателя, расход топлива, а также на состав и температуру выхлопных газов.

В результате исследований установлено, что при увеличении количества этанола в бензине мощность и крутящий момент двигателя изменяются незначительною. Значительные изменения получены при работе двигателя на топливе с большим содержанием этанола. При работе на топливе E85 мощность и крутящий момент при малой частоте вращения снижаются, а при большой частоте вращения – увеличиваются, по сравнению с соответствующими режимами при работе на бензине. При увеличении содержания этанола в бензине на 10%, расход топлива увеличивается на 3-6%. При увеличении количества этанола в бензине содержание CO_2, CO, NH_3 в выхлопных газах снижается, а NO_x – возрастает.

Биоэтанол, расход топлива, мощность, эмиссия выхлопных газов.