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Detection of Biodiesel Physical – Chemical Parameters in Diesel Engine

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Biodiesel is quickly becoming one of the most popular altemative fuels to replace or supplement petroleum-based diesel. Biodiesel is environment friendly fuel for diesel engines. It is often used as a mixture with diesel, but can also be used in its pure form.

Biodiesel is obtained from vegetable oils such as soy, flax, sunflower, mustard, canola and rapeseed. More and more countries lacking their own oil resources are developing this kind of altemative energy and admit that biodiesel is equivalent to and even better than fossil diesel.

Geographical location of the country predicts the kind of vegetable oil. In Latvia rapeseed oil is the most suitable vegetable oil used not only for food, but also for technical needs. Rapeseed oil is used in biodiesel production in Europe.

Rapeseed oil methylesters (RME), produced by SIA "Delta Riga" in Naukšēni, and rapeseed oil ethylesters (REE) prepared at RTU Faculty of Material Science and Applied Chemistry, as well as mixtures of these esters with fossil diesel have been investigated. Rapeseed oil methylesters (RME) is product of transesterification of rapeseed oil with methanol, but REE are produced by using ethanol as reagent. Crude glycerol is a by-product of the reaction, and it can be used both in chemical industry and for production of pure glycerol.

The aim of our work was evaluation of the influence of these fuels on engine dynamical (power, torque moment) parameters, economical (fuel consumption, fuel specific consumption) parameters and ecological (CO, NO_X, SO_2) parameters.

The comparative experimental method, including full experimental cycle for each kind of fuel, was used in the work. Results of the investigation confirm that different kinds of biodiesel can be effectively used. The use of biodiesel instead of fossil fuel considerably improves ecological situation. Biodiesel fuel is environment friendly fuel for diesel engines.

Biodiesel parameters: dynamical, economical, ecological.

Introduction

Invention of new kinds of energy sources requires both examination and analysis of their quality characteristics, as well as test of their energetic efficiency and conformity with environmental requirements. Consequently this is not only a scientific achievement, but also a practical application in real life.

Energy resources, e.g., mineral oil have been slowly disappearing, but demand for it rises due to increase of the number of vehicles (Wisniewski et al., 1997a; Shay, 1993; Scharmer et al., 1993; Mittelbach et al., 1995; Zhang et al., 1998). Therefore alternative solutions must be found to get the product which is not only effective, but also ecologically pure and environment friendly (Peterson et al., 1992; Thompson et al., 1996; Cvengrošova et al., 1997; Freedman et al., 1984; Karaosmanoglu et al., 1997; Gomez, 1996; Sharmer et al., 1994; Lago et al., 1985; Stage, 1988; Wimmer, 1991).

Scientists have to work on this issue as new technologies have been created and factories have already started to work in many countries around the world (Fig.1.) - Germany, Czech Republic (Komers et al., 1994; Andel, 1999; Pokorny et al., 2001), ASV, France (Delmas et al., 1996), Poland (Wisniewski et al., 1997b), Finland (Aksela et al., 1995), Austria e.g. (Biodiesel und..., 2001; Gudriniece et al., 2001; Strēle et al., 1999). In 1999 total production of biodiesel was 860 thou. tons and it is rapidly increasing. For example, Germany produced 130 thou. tons of biodiesel, in 2000 – 250 thou. tons, but this year it is planned to produce 500 thou. tons of biodiesel (Vornorm DIN V 51606, 1994; Gulbis et al., 2003).

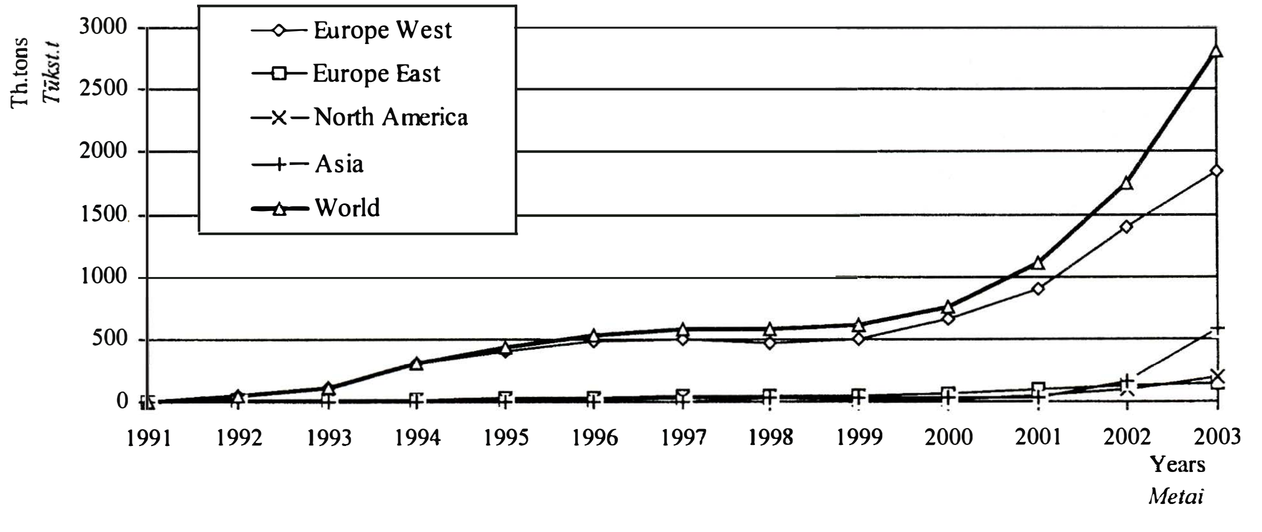

Fig.1. World production of biodiesel fuel in thou. tons
1 pav. Biodyzelino gamyba pasaulyje tūkst.t

According to the EU Green Paper "Towards the Strategy for the Security of Energy Supply" the growth of biodiesel fuels has to be 0.75 % per year; in year 2010 the consumption of biodiesel fuels should reach 5.75 % of the total consumption of vehicular fuels (Prankl, 2002; EC Green Paper, 2001; EC. Communication from ..., 2001; Alternatīvā enerģija, 2000).

Since 1995 experiments to get biodiesel or rapeseed oil ethyl esters (REE) have been done in Latvia - at Riga Technical University, Faculty of Material Science and Applied Chemistry.

The first biodiesel or rapeseed oil methyl esters (RME) plant in Latvia as well as in Baltic states was built in Naukšēni in Valmiera district by private company "Delta Riga Ltd". The plant started to work at the end of 2001 with a planned output of 2,500 tons of RME per year; it is about 1% of the total consumption of biodiesel fuel in Latvia per year. This year production capacity of plant has been doubled.

The role of local energy sources is very important in the energy balance of Latvia as Latvia does not have its own fossil fuel resources.

The National Biodiesel Fuel Program envisages 146,000 ha of agricultural land for cultivation of raw materials for biodiesel production. Such area of agricultural land should increase the annual production of bioethanol up to 42,3 thou. tons or 53,3 mill. l and the production of biodiesel or rapeseed ethyl esters (REE) – 60,7 thou. tons or 69,0 mill. l in the year 2010 (LR Nacionālās programmas projekts, 2003).

REE biodiesel and its mixtures with fossil diesel were used in our research. The objective of our research was to evaluate the influence of the biodiesel and its mixtures on dynamical, economical and ecological parameters of an engine in various modes of operation.

Objects and methods

Fresh biodiesel and its mixtures were tested under laboratory conditions in compression ignition engines at the Motor Testing Laboratory of Latvia University of Agriculture.

The modernized testing stand *VEM–100*, powered by *Ford Sierra 2.3L* diesel engine, was used for our experiments.

Power of braking Pb (kGf), crankshaft rotation frequency n (min^{-1}), fuel consumption (g) and time (s) were determined at the fixed level of the accelerator regulator in the state of maximum supply and at the following engine speed modes of operation: 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, min^{-1}, which had been set up by the braking system of the stand. Exhaust gases of the engine (CO, NO_x, SO_2) were measured by portable gas analyser Kane May 9106.

The diesel engine was started and heated up to the normal operation temperature, i.e., when the water temperature in the cooling system reached 85-90 °C. With the help of the stand the engine was loaded at maximum fuel injection rate. Stable value of engine speed was obtained by means of slowing down the engine speed till the minimum. Loading of the engine was continued and, simultaneously, rotation frequency of the crankshaft was decreased till the minimum stable value.

The engine was allowed to work for a while and, simultaneously, the data of the measuring instruments: load, engine torque, fuel consumption, time of fuel consumption was read. Then the engine was unloaded in order to decrease the rotation frequency to the predetermined value. After that the engine was allowed to work for a little while and data of the measuring instruments was read.

The measured data was used in calculation of dynamical (effective power, engine torque), economical (fuel consumption, specific fuel consumption) and ecological (CO, NO_x, SO_2) parameters of the obtained values.

The following fuels and biodiesel mixtures with fossil diesel were used:

- DD (fossil diesel);
- REE (rapeseed oil ethyl esters);
- RME (rapeseed oil methyl esters);
- 35REE (35 % rapeseed oil ethyl esters);
- 35RME (35 %rapeseed oil methyl esters).

Results and discussion

The research results provide various characteristic for every parameter at the definite mode of operation of the engine, which reflect the influence of the biodiesel and its mixture on the operation of the engine.

One of the major advantages is the fact that biodiesel and its mixtures can be used in existing engines and fuel injection equipment (no modification required) without negative impacts on operating performance.

Comparison of biodiesel and its mixtures with fossil diesel shows decrease in the effective power (Pe) by 0.8...16.1 % (Fig.2).

Biodiesel and its mixtures with fossil diesel decrease the engine torque (Me) by 2.0... 15.9 % (Fig. 3); it depends on the concentration of biodiesel in the fuel used and the load operation regime of the engine, i.e., the bigger the load is, the less the effective power and the torque are.

The fuel consumption (Bd) of biodiesel and its mixtures increased in comparison with fossil diesel by 1.6...20.1% (Fig.4).

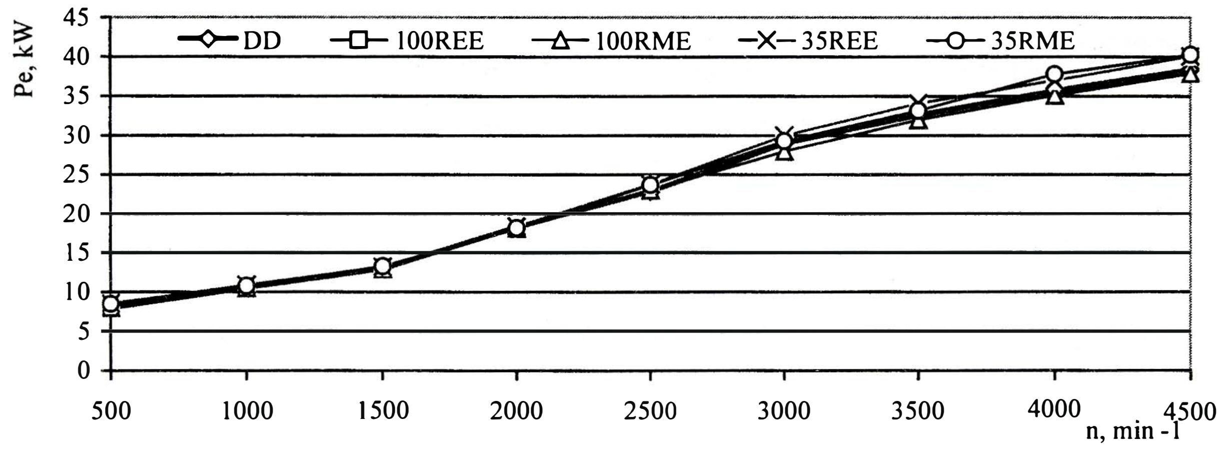

Fig. 2. The change of the effective power of biodiesel and its mixtures at various modes of operation of the engine *FORD SIERRA 2.3L*
2 pav. *Efektyviosios galios pokyčiai varikliui FORD SIERRA 2.3L dirbant įvairiu režimu ir degalais naudojant biodzeliną bei jo mišinius su mineraliniu dyzelinu*

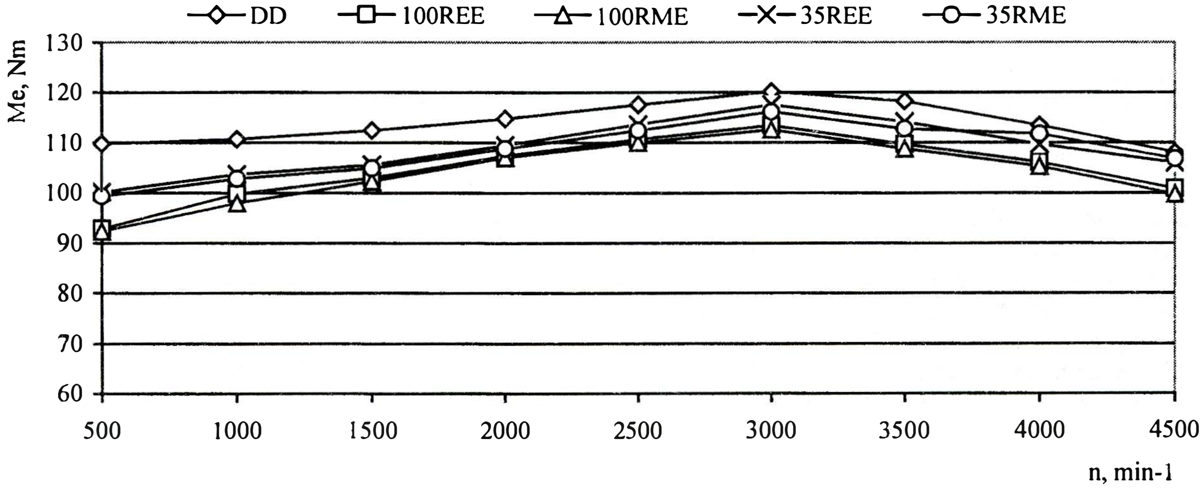

Fig. 3. The change of the engine torque of biodiesel and its mixtures at various modes of operation of the engine *FORD SIERRA 2.3L*
3 pav. *Sūkių dažnio pokyčiai varikliui FORD SIERRA 2.3L dirbant įvairiu režimu ir degalais naudojant biodyzeliną bei jo mišinius su mineraliniu dyzelinu*

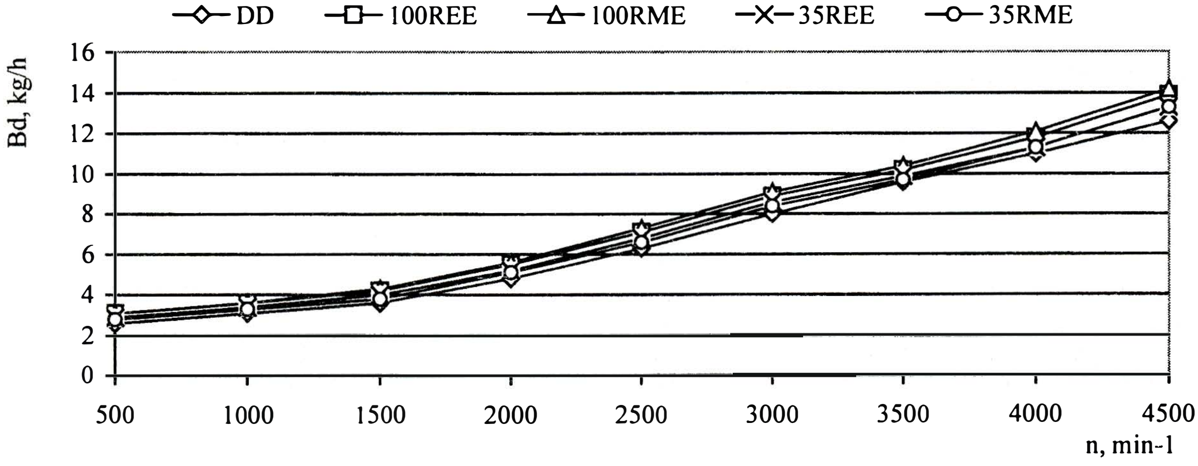

Fig. 4. The change of the fuel consumption of biodiesel and its mixtures at various modes of operation of the engine *FORD SIERRA 2.3L*
4 pav. *Degalų sąnaudų pokyčiai varikliui FORD SIERRA 2.3L dirbant įvairiu režimu ir degalais naudojant biodyzeliną bei jo mišinius su mineraliniu dyzelinu*

The fuel consumption at low engine rotation frequency was nearly the same as in case of the fossil diesel.

The increase was even more significant - 5.5…70.1 % - for specific fuel consumption (be) (Fig.5). The specific fuel consumption for rapeseed oil ethyl esters (REE) was lower than the one for rapeseed oil methyl esters (RME).

Increasing rotation frequency led to substantial increase of fuel consumption. The specific fuel consumption of biodiesel and its mixtures was higher than the one of fossil diesel.

The differences in fuel consumption and specific fuel consumption reflect the differences in heat of combustion and density of the fuels.

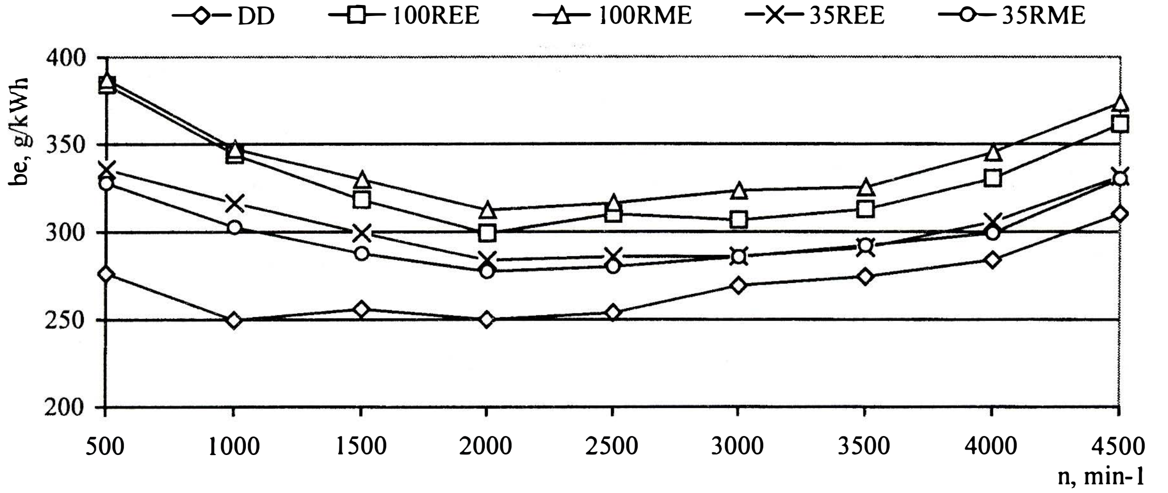

Fig. 5. The change of the specific fuel consumption of biodiesel and its mixtures at various modes of operation of the engine *FORD SIERRA 2.3L*
5 pav. *Specifinių degalų sąnaudų pokyčiai varikliui FORD SIERRA 2.3L dirbant įvairiu režimu ir degalais naudojant biodyzeliną bei jo mišinius su mineraliniu dyzelinu*

During the experimental research an increase of the amount of carbon monoxide (CO) in exhaust gases at the engine speed of ≈2000 min^{-1} was observed (in comparison with fossil diesel) (Fig.6.). The exhaust emissions of carbon monoxide (CO) from rapeseed oil ethyl ester (REE) were on average by 46 % lower than carbon monoxide (CO) emissions from rapeseed oil methyl ester (RME).

The amount of nitrogen oxides (NO_x) in exhaust gases at various operation speeds of the engine considerably decreased (in comparison with fossil diesel) (Fig.7.). The exhaust emissions of nitrogen oxides (NO_x) from REE were on average by 13 % lower than emissions of nitrogen oxides (NO_x) from RME.

The literature analysis shows that the NO_x content in exhaust gases varies significantly by the type of engine and the type of biodiesel fuel used. Age of the engine also affects NO_x content. Older diesel engines may have higher emissions of NO_x than the new ones. The newest diesel engines typically produce at least 1.4 grams of NO_x emissions less than many gasoline engines do (Zalcmanis, 1995). Decreasing NOx emissions in exhaust gases in the case of use of biodiesel in comparison with fossil diesel is explained by the fact that biodiesel chemically contains oxygen, which is absent in fossil diesel.

NO_x emissions depend on combustion temperature and on the local concentration of oxygen during the diffusion combustion phase on the weak side of the reaction zone inside the combustion chamber. As biodiesel contains more oxygen than fossil diesel, the concentration of oxygen is higher that leads to the reduction in NO_x. Decreasing the production of NO_x requires that combustion temperatures are lowered or that the availability of oxygen in the flame front be decreased (Combs, 1981).

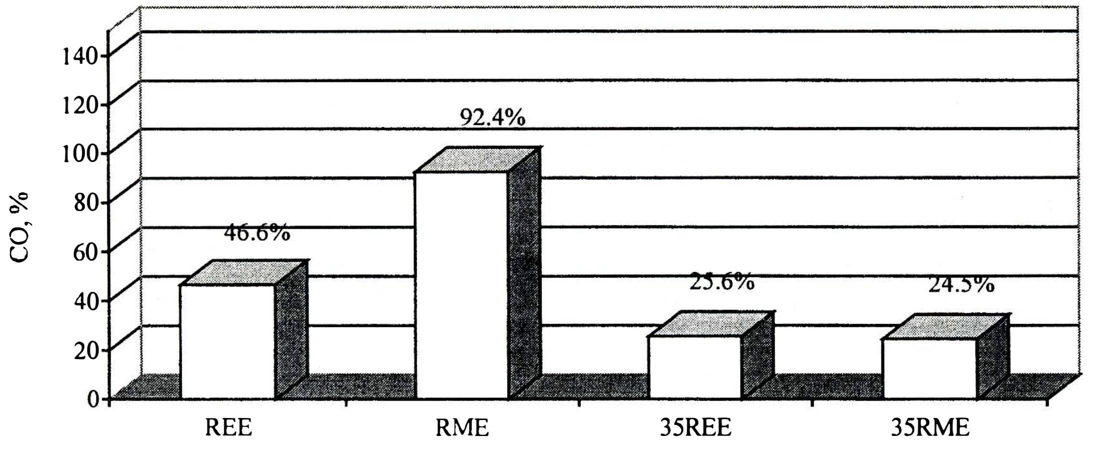

Fig. 6. The change in the quantity of carbon monoxide for biodiesel and its mixtures at a definite mode of operation of the engine (≈2000 min^{-1}) in comparison with fossil diesel
6 pav. *Anglies monoksido kiekio pokyčiai varikliui dirbant ≈2000 min⁻¹ sūkių dažniu ir degalais naudojant biodyzeliną bei jo mišinius su mineraliniu dyzelinu palyginti su grynu mineraliniu dyzelinu*

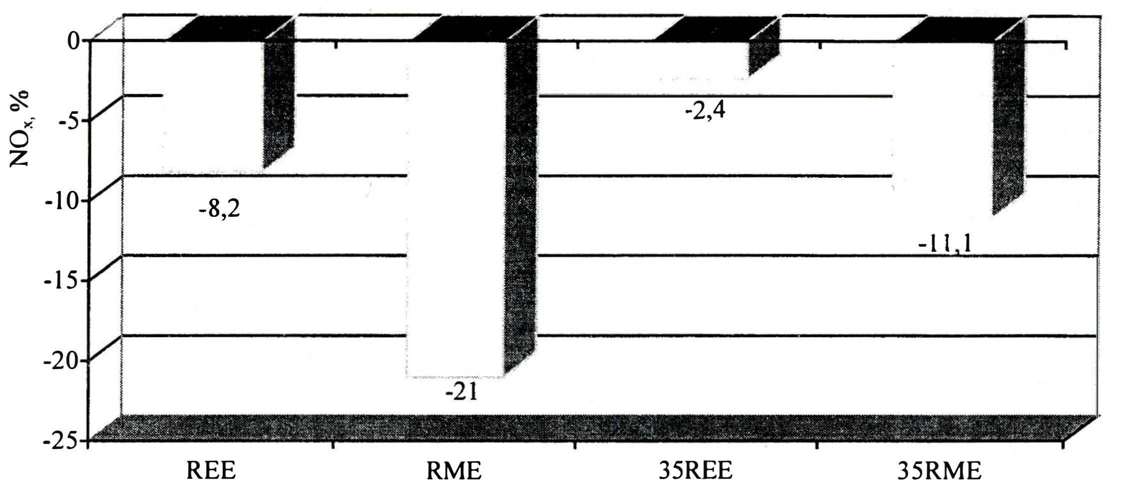

Fig. 7. The change in the quantity of nitrogen oxides for biodiesel and its mixtures at a definite mode of operation of the engine (≈2000 min^{-1}) in comparison with fossil diesel

7 pav. *Azoto oksidų kiekio pokyčiai varikliui dirbant ≈2000 min^{-1} sūkių dažniu ir degalais naudojant biodyzeliną bei jo mišinius su mineraliniu dyzelinu palyginti su grynu mineraliniu dyzelinu*

Conclusions

1. Biodiesel and its mixtures decrease the effective power of engine by 1.4...11.6 % (35REE), 0.8...12.1 % (35RME), 1.9...16.1 % (REE), 5.2...12.1 % (RME) in comparison with fossil diesel.
2. Use of biodiesel and its mixtures decreases rotation frequency by 2.0...8.9 % (35REE), 1.1...9.5 % (35RME), 5.6...15.4 % (REE), 6.3...15.9 % (RME).
3. Biodiesel and its mixtures increase the fuel consumption by 1.6...7.7 % (35REE), 1.6...7.7 % (35RME), 6.6...17.1 % (REE), 9.1...20.1 % (RME) in comparison with fossil diesel.
4. Biodiesel and its mixtures increase the specific fuel consumption by 6.0...26.7 % (35REE), 5.3...21.2 % (35RME), 13.8...39.0 % (REE), 18.7...40.1 % (RME) in comparison with fossil diesel.
5. During the engine stand experiments at 50% load (≈2000 rpm) of the engine an increase in CO was observed in comparison with fossil diesel.
6. During the engine stand research at 50% load (≈2000 rpm) of the engine a decrease in NO_x was observed in comparison with fossil diesel.
7. The exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel were essentially eliminated compared to sulfur oxides and sulfates from diesel.
8. Biodiesel in Latvia can be produced from rapeseed oil and can be used in the existing engines as 100% biodiesel or as 35% admixture to traditional diesel without major engine modification.
9. The importance of these biofuels lies in reducing of over-dependence on oil based fuels, which is the cause for concern as regards both the environment and security of supply.

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Biodyzelino fizikinių ir cheminių rodiklių nustatymas dyzeliniame variklyje

Santrauka

Biodyzelinas tampa populiariais alternatyviais degalais, kuriais galima visiškai ar iš dalies pakeisti mineralinį dyzeliną. Biodyzelinas yra aplinkai nekenksmingi degalai dyzeliniams varikliams. Jis dažnai vartojamas mišiniuose su mineraliniu dyzelinu, gali būti vartojamas ir grynas.

Biodyzelinas gaminamas iš augalinio aliejaus: sojų, saulėgrąžų, linų sėmenų, garstyčių, rapsų ir rapsiukų. Vis daugiau šalių, siekiančių apsirūpinti savais energijos ištekliais, plėtoja šios rūšies alternatyvios energijos išteklių vartojimą. Manoma, kad biodyzelinas yra lygiavertis ar net geresnis nei mineralinis dyzelinas.

Tai, iš kokios aliejaus rūšies gaminti biodyzeliną, priklauso nuo geografinės šalies padėties. Latvijoje tiek maistui, tiek techniniams tikslams dažniausiai naudojamas rapsų aliejus. Jis dažniausiai naudojamas biodyzelino gamybai ir Europoje.

Mes tyrimams naudojome rapsų aliejaus metilesterius (RME), pagamintus SIA „Delta Riga" " (Naukšēni) ir rapsų aliejaus etilesterius (REE), pagamintus Rygos technikos universiteto Medžiagotyros ir taikomosios chemijos fakultete. Šiame fakultete buvo pagaminti ir biodyzelino mišiniai su mineraliniu dyzelinu. Rapsų aliejaus metilesteriai (RME) yra rapsų aliejaus peresterinimo metanoliu produktas, tačiau rapsų aliejaus etilesteriai gaunami kaip reagentą naudojant etanolį. Reakcijos šalutinis produktas yra žalias glicerolis, kuris chemijos pramonėje gali būti naudojamas gryno glicerolio gamybai.

Darbo tikslas buvo įvertinti minėtų degalų poveikį variklio dinaminiams (galia, sūkio momentas), ekonominiams rodikliams (degalų sąnaudos, specifinės degalų sąnaudos) ir ekologiniams (CO, NO_X, SO_2 kiekiui išmetamosiose dujose) rodikliams.

Taikytas eksperimentinis metodas, numatantis visą kiekvienos rūšies degalų tyrimų ciklą. Tyrimų rezultatai patvirtino, kad gali būti efektyviai naudojamos atskiros degalų rūšys. Vartojant biodyzeliną vietoje mineralinio dyzelino, labai pagerėja ekologinė būklė.

Biodyzelino rodikliai: dinaminiai, ekonominiai, ekologiniai.

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