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# Alternative fuels for combustion engines. New ways to power vehicles

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The paper presents results of search and analysis. The ongoing difficulties with fuel and energy are the reason for continuous search for new energy carriers and trials to limit the energy consumption, which will result in reduction of harmful impact on the environment. It presents some ways to find new kinds of fuels and some technical methods to arrange this process.

## 1. Introduction

Continuous increase in the number of motor vehicles moving on public roads creates specific hazards for the environment that surrounds us. Generally, in the majority of considerations it is assumed that – as far as the harmful impact on the environment is concerned – the engine is the most adverse unit of a vehicle

Tempestuous development of motorisation has caused the necessity to limit its harmful impact on the environment. This is related to stricter and stricter requirements as to the protection of the natural environment. The necessity has arisen to apply solutions that have not been taken into consideration so far or have been ignored and astonishingly good results have been obtained through their application. The ongoing difficulties with fuel and energy are the reason for continuous search for new energy carriers and trials to limit the energy consumption, which will result in reduction of harmful impact on the environment.

The requirements imposed on the modern engines are very often opposing, which can be clearly seen when taking into account the continuously growing number of vehicles and difficulties in traffic related thereto, and – on the other hand – there is the necessity to reduce the quantity of consumed fuel and harmful components of toxic exhaust gases exhausted into the environment [4, 6]. As far as the engines driving both the cars and the lorries are concerned, this comes down to taking into account three, the most essential factors:

- low fuel consumption (cost-effectiveness of operation),
- low toxicity of exhaust gases,
- high engine response (good dynamic properties).

This problem was noticed at earliest in relation to the engines of lorries of high carrying capacities, where the cost-effectiveness of transport is of fundamental importance.

In order to solve the problem of the cost-effectiveness improvement and in order to reduce the toxicity in case of these engines, it was also necessary to apply a new approach, different from the traditional solutions. As far as the lorry engines are concerned, they have been more susceptible to meeting the stricter requirements for years, and there has been significant progress achieved in their construction forced by restrictive regulation on the one hand, and the necessity to reduce costs related to the fuel consumption on the other hand.

Simply speaking, the lower value of the fuel engine consumption by, the lower value of global quantity of toxic components emitted by an engine into the atmosphere. In this way, the key problem allowing for meeting these two first demands is to reduce the fuel consumption by the engine.

According to these demands, Scania and Volvo companies try to reduce the fuel consumption in the next versions of engines launched to the market. The factor that unambiguously allows for assessment of cost-effectiveness of the engine operation is the specific fuel consumption.

## 2. Fuels of rape origin

These fuels in the form of rape oil or methyl ester of fatty acid of rape oil were creating hopes for significant improvement of certain parameters of the engine operation with their simultaneous availability (numerous fallow lands in the West Pomeranian Province waiting for reclaiming) despite the fact that the rape is a capricious plant. Combustion of pure rape oil has turned out to be a complex issue and required changes in the construction of engines. One has focused on esters despite the fact that bringing their physical and chemical parameters close to those of the diesel oil required additional treatments. The psychological and economic aspects have been omitted in this paper. From the technical point of view, the products of rape fuels combustion are less toxic as these fuels do not contain sulphur, and additional oxygen bonds allow for significant reduction of the exhaust gases smokiness, the proof of which are the executed tests on the STAR 350 [1, 6, 7] diesel engine, which has been presented in Fig. 1.

The same situation in the form of the time density characteristic has been presented in Fig. 2.

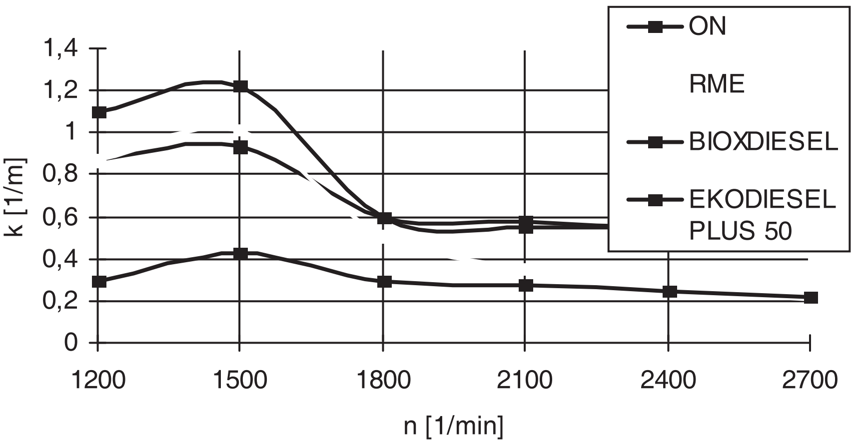


Fig. 1. Characteristic of the 359 engine smoking at powering with different fuels: ON - diesel oil, RME - methyl ester of fatty acid of rape oil, BIOXDIESEL - diesel oil with ester admixture, EKODIESEL PLUS 50 - diesel oil with ester admixture.
Rys. 1. Charakterystyka dymienia silnika 359 przy zasilaniu różnymi paliwami: ON - olej napędowy, RME - ester metylowy kwasu tłuszczowego oleju rzepakowego, BIOXDIESEL - olej napędowy z domieszką estru, EKODIESEL PLUS 50 - olej napędowy z domieszką estru.

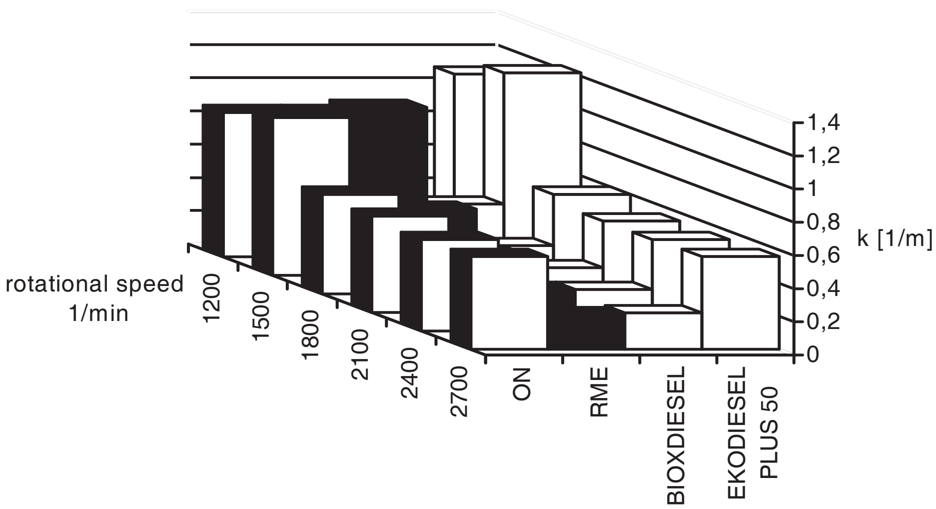


Fig. 2. Characteristic of time density of exhaust gases smokiness of the 359 engine.
Rys. 2. Charakterystyka gęstości czasowej zadymienia spalin silnika 359.

In order to enable comparison of smokiness in the Bosch scale (jB) and in the presently used units of exhaust gases opacity 1/m, their comparison has been presented in Fig. 3 [6].

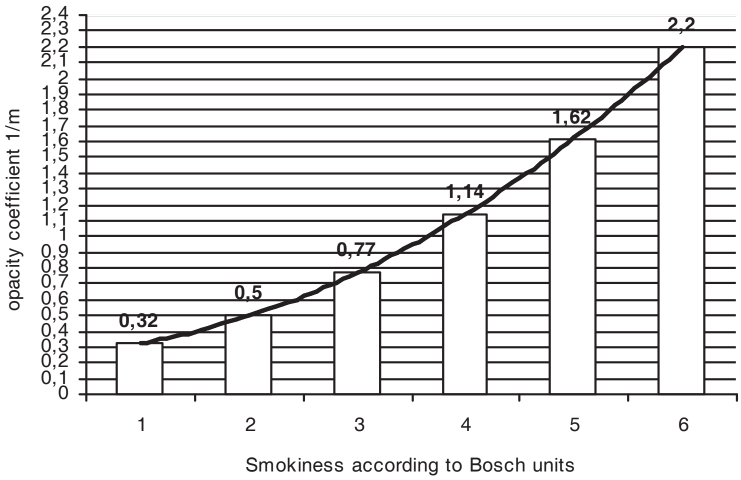


Fig. 3. Comparison of units of exhaust gases smokiness.
Rys. 3. Porównanie jednostek zadymienia spalin.

### 2.1. Starting the engine powered with plant fuels

Research carried out in the country on the operation of diesel engines powered with oils of vegetable origin and mixtures of diesel oil and oils of vegetable origin has shown that the operational parameters of the engine supplied in such a way are subject to improvement in relation to the engine powered with pure diesel oil or pure rape oil [4].

The density of both fuels is similar and they mix well in different proportions. With the specified proportion of rape oil to the diesel oil, such a state is obtained that the newly formed fuel has still got a relatively high calorific value, close to the calorific value of the diesel oil, and at the same time contains oxygen bonded in hydroxyl groups of the rape oil. Thus, this fuel is combusted more completely than pure diesel oil, and the quantity of heat produced in this process exceeds the quantity of heat produced during combustion of pure diesel oil. This causes that the total quantity of combusted fuel is lower, therefore the fuel consumption is reduced, and indirectly – also the emission of toxic compounds.

Therefore a question suggests itself, whether the engine maintains such positive properties also in the conditions of its starting at low ambient temperatures. At the same time it is known that in supercharged engines, even at powering with diesel oil, there are difficulties occurring during starting at low ambient temperatures.

Influence of addition of diesel oil to the fuel of vegetable origin on the limit temperature of starting of a diesel engine with direct injection has been presented in Fig. 4.

One can clearly see that the addition of the diesel oil amounting to 70% of the whole volume of fuel improves the starting properties of the engine at a relatively low cost [7]. Whereas the problems with starting with the ecological fuel available in our country do not encourage to its use, the normal operation of the engine, including also a supercharged engine, does not pose difficulties as this fuel evaporates better at high temperatures, which is advantageous for forming of homogenous fuel blend with air, similarly as in the case of the diesel oil.

In 1995, instructions of proceeding during starting of a tractor engine powered with mixtures of diesel oil and acid esters of rape oil were prepared at the Academy of Agriculture in Szczecin [4].

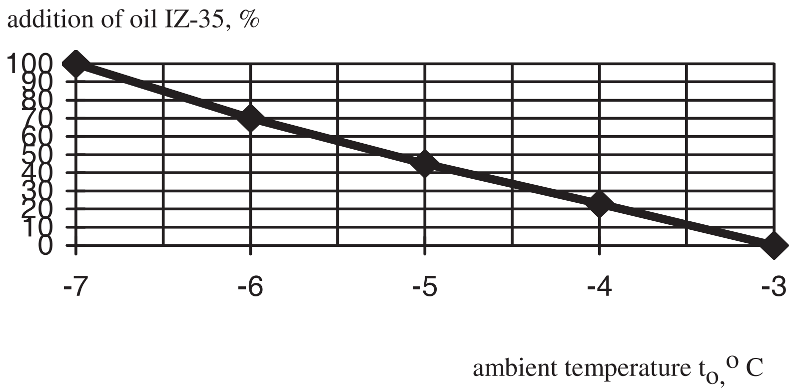


Fig. 4. Influence of addition of diesel oil on starting properties of the engine supplied with the fuel of vegetable origin [4].

Rys. 4. Wpływ dodatku oleju napędowego na właściwości rozruchowe silnika zasilanego paliwem pochodzenia rzepakowego [4].

### 3. Diesel engine powered with ethanol

Scania, in search for ecological engines using for buses, has applied a diesel engine powered with light fuel with the octane number of 95. This fuel, with the commercial denotation of E95 manufactured by SvenskEtanolkemiAB and the following composition:

- ethanol 95% – 92.2% m/m (93.3% v/v);
- ignition activator – 5% m/m;
- ether MTBE – 2.3% m/m;
- isobutano l – 5 % m/m;
- corrosion inhibitor – 90 ppm m/m;

is designed for powering of the Scania DS19 01 engine with the cubic capacity of $V_s = 8.7\ dm^3$ and the rated power of $N_e$ = 169 kW ( 230KM) at 1800÷2000 rpm, being a variation of the DSC9 11 engine. In the engine designed to be powered with ethanol, the compression ratio ε has been increased from 18 into 24, and also the controlling of the fuel dosing has been changed, the fuel pump output has been increased, the diameters of the openings of the spraying nozzles have been enlarged, gaskets, filters and cooler of the supercharging air have been changed. One of the buses with such an engine is already in operation in the town of Słupsk, and another one will be used in Warsaw as from September this year.

## 4. Engine supercharging

Supercharging is the commonly used method aiming at improvement of the operational parameters of an engine and at reduction of its harmful impact on the environment. In the most modern generation of high-speed diesel engines that meet all the very strict requirements, turbo-charged direct injection engines with cooling of the supercharging air (TDI) are used. Application of direct injection enables meeting the two demands as this is the most economical method of combustion, which results in the fact that the engine emits the lowest quantity of exhaust gases per unit of produced power, and thus the engine emits lower quantity of harmful compounds emitted into the atmosphere. Turbo-charging through increase of the mass of air supplied to the engine with its significant turbulence allows for better preparation of combustible air-fuel mixture and thus for better combustion process. Additional cooling of the supercharging air improves filling of the cylinder and thus creates better conditions for preparation of the fuel mixture.

### 4.1. Dynamical, mechanical and Comprex supercharging

Application of supercharging without compressor (dynamic supercharging) does not cause any results within the range of rotational speeds corresponding to the engine starting as the inlet system is adapted to causing wave phenomena at the rotational speeds within the area of torque to the rated power. During starting, the engine behaves the same as normal unsupercharged engine. At present, this is commonly used in the spark ignition engines with petrol injection as well as in the diesel engines of cars and lorries as combined supercharging in conjunction with turbo-charging. Mechanical turbo-charging also does not cause significant changes in the engine operation at starting speeds and does not cause undesired results.

The compressor supplies, however, a slightly greater quantity of air to the engine but this can be compensated by greater dose of fuel and starting will take place faster.

Thanks to that, the negative effects of starting consisting in increased emission of toxic compounds into the atmosphere can be reduced. It is similar with supercharging of the Comprex type that combines the features of these both discussed methods of supercharging.

### 4.2. Turbo-charging

The most common method of supercharging is turbo-charging. In this solution, the useless energy of escaping exhaust gases is used for powering of a turbine connected by means of shaft with a compressor. Despite significant technical maturity of engines and turbochargers, this supercharging is characterised by deterioration of starting parameters of the engine as the result of increase in the air flow resistance in the inlet system. Such resistance is increased due to the fact that the inflowing air must flow through the rotor of the compressor, unmoving as the engine so far does not produce exhaust gases powering the turbine. At the same time, reduction of the compression ratio in the turbo-charged engines, essential for these engines to obtain high efficiency within the area of medium and high loads influences the deterioration of the starting properties of the engine that one must be aware of. Improvement of such situation can be obtained through application of the above mentioned combined supercharging.

### 4.3. Results of application of dynamic supercharging

Its influence on the ecological parameters can be presented on the basis of testing of the SW 680 engine manufactured by the earlier mentioned Mielec-Diesel factory. The results of tests of the smokiness of exhaust gases of this engine have been presented in Fig. 5.

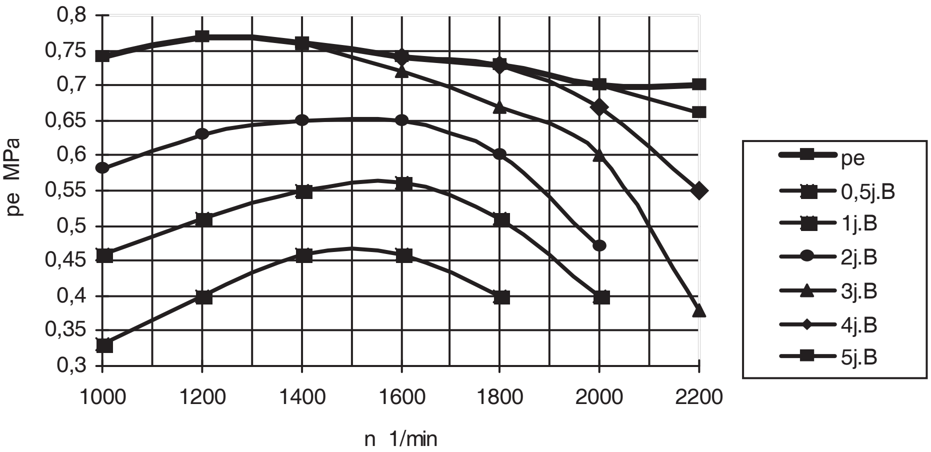


Fig. 5. Universal characteristic of smoking of the SW 680 engine in unsupercharged version.
Rys. 5. Uniwersalna charakterystyka dymienia silnika SW 680 w wersji wolno-ssącej.

It results from the data presented in the graphic form in Fig. 6 that the degree of smokiness of exhaust gases of the tested SW 680 engine in an unsupercharged version is different depending on the speed and loads but generally speaking, it is quite high. It ranges from 0.5 up to 5 in the Bosch scale, whereas the permissible smokiness for this type of engine should not exceed the value of 2.7 up to 3 in the Bosch scale (jB). The next figure presents the characteristic of time density of smokiness for the situation presented in Fig. 6.

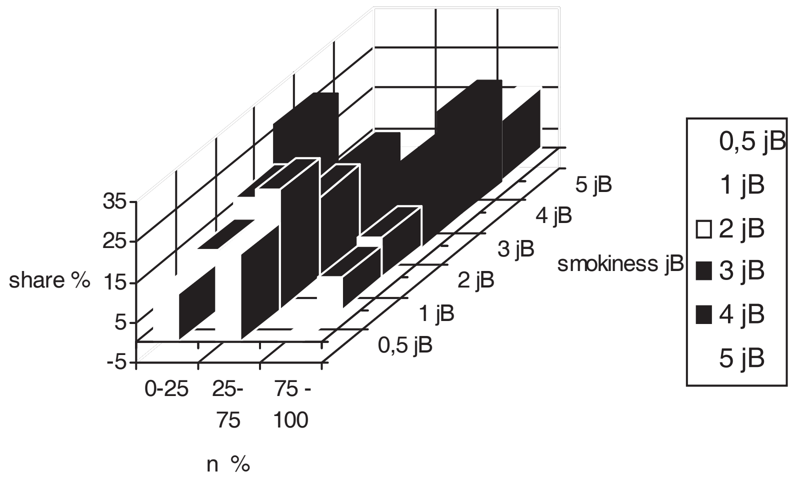


Fig. 6. Time density characteristic of the SW 680 engine without supercharging.
Rys. 6. Charakterystyka gęstości czasowej silnika SW 680 bez doładowania.

This figure shows the percentage share of particular values of smokiness in the whole area of operation and shows under what parameters the engine should operate to obtain the lowest harmful impact on the environment.

The next figure presents the universal characteristic of the smokiness of the exhaust gases of the SW 680 dynamically supercharged engine. When compared to the characteristic presented in Fig. 6, one can clearly see the difference to the advantage of the supercharged engine, hence e.g. the tendency to supercharge the majority of the currently used diesel engines.

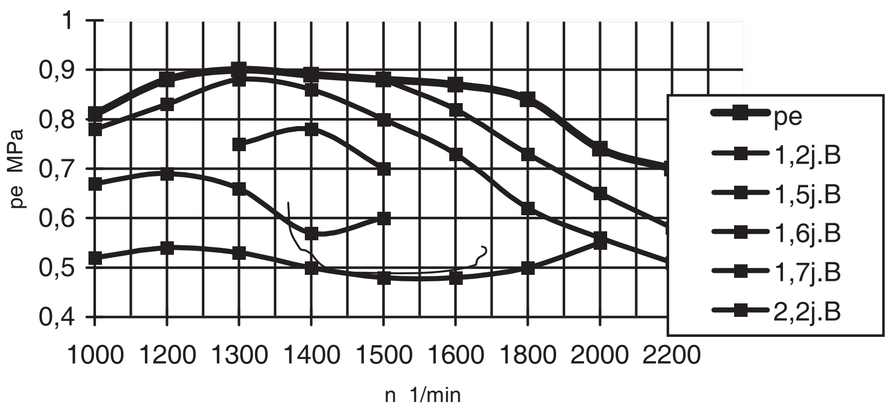


Fig. 7. Universal characteristic of the smokiness of the exhaust gases of the SW 680 dynamically supercharged engine.
Rys. 7. Uniwersalna charakterystyka dymienia silnika SW 680 doładowanego dynamicznie.

The Fig. 7 presents the universal characteristic of the smokiness of the exhaust gases of the SW 680 dynamically supercharged engine. When compared to the characteristic presented in Fig. 6, one can clearly see the difference to the advantage of the supercharged engine, hence e.g. the tendency to supercharge the majority of the currently used diesel engines

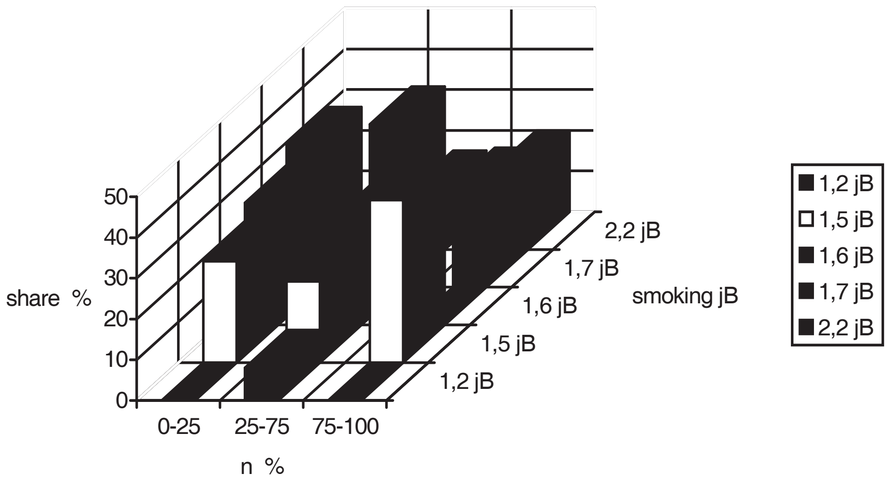


Fig. 8. Time density characteristic of the SW 680 engine with supercharging.
Rys. 8. Charakterystyka gęstości czasowej silnika SW 680 doładowanego dynamicznie.

The values of the exhaust gases smokiness for the dynamically supercharged engine are definitely lower as they range from 1.2 jB up to 2.2. jB (Bosch units), and the area of the characteristic of relatively low smokiness is significant for particular ranges of speeds. The highest percentage values of the exhaust gases smokiness took place at 1.5 jB and 1.7 jB (Bosch units) – look Fig 8.

## Literature

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## Alternatywne paliwa dla silników wysokoprężnych. Nowe metody doładowania samochodów

Summary

Artykuł prezentuje wyniki badań i analiz. Trwające trudności paliwowo-energetyczne powodują stałe poszukiwania nowych nośników energii oraz próby ograniczenia jej zużycia, co będzie skutkowało zmniejszeniem szkodliwego oddziaływania na otoczenie. W artykule przedstawiono drogi poszukiwań nowych paliw i niektóre aspekty techniczne organizacji procesu spalania.