Waste substances for the electricity production. Cheap power off the power industry

mgr inż. Piotr Kardasz

Department of Motor Vehicles and Combustion Engines, Faculty of Mechanical Engineering, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, POLAND, E-mail: piotr.kardasz@pwr.wroc.pl;

Abstract – The following article present the research on using an alternative fuel in diesel engines. The tested fuel is made from waste oil. The research conducted that use of this fuel helps to reduce the amount of pollutants emitted during the combustion and decreases the energy consumption. The use of the tested fuel also contributes to solve the waste disposal problem and increases the energy efficiency of the process.

Key words – alternative fuel, diesel, rapeseed oil, exhaust, fuel consumption

I. Introduction

The use of waste substances to generate electricity must be examined in two aspects. One of them is cheaper and more environmentally friendly electricity production, the second is more efficient waste management and removal of them from the environment. Additional aspect is to increase the availability of liquid fuels not derived from petroleum products. The need to seek additional sources of such fuels is caused by increasing demand for liquid fuels and large fluctuations in the global oil market [1]. Attempts are being made to increase the amount of additives in liquid fuels, which are agricultural products. However, increasing the content of these additives is limited by engine builders because of accelerated wear of the engines powered by fuels with higher content of bio-components[2]. One of the methods to increase the availability of liquid fuels is to research on the use of waste generated or low cost substances which are flammable, and their adaptation for an internal combustion as fuel.

Among the many ideas for unconventional fuels produced of waste, this article present the research on alternative fuel based on waste oil arising as a by-product of the spirits industry. Nowadays it is usually burned in power plants.

This paper presents an opportunity to use a new alternative fuel in the stationary engine. The use of diesel engine powered by it is a big opportunity. The engine can drive the generator or other devices in factories. As for the heat machine is quite efficient, using about 40 % of chemical energy of fuel, and the rest is released around, mainly in the form of heat. Cooling systems in car engines usually have a task only to allow the engine to work by heat removal, while the stationary engine the system can be an additional source of heat. For this purpose, systems around the engine should be developed. This will allow the utilization of the warmth from the engine cooling system to heat domestic water and space or as heat for the technological processes which do not require very high temperatures. In addition to energy savings, this way of heating creates less threat of overheating than electrical or combustion heating. In a similar way, you can recover some of the heat exhaust. These assumptions were verified experimentally.

II. The research

Research was conducted at an engine test stand with a 3-cylinder Perkins UR AD3.152 engine of 2502 cm^3 displacement, generating power 35.8 kW (48 hp). The aim of this study was to analyze the fuel consumption and exhaust emissions for the proposed unconventional fuel, and to compare to the reference fuel, which was typical diesel fuel with a density of 0.84 g/cm^3. Tested fuel is a mixture of rapeseed oil and waste oil.

Raw waste oil was prepared for the combustion by dehydrating it and mixing with rapeseed oil in a ratio of 2:3, so that a density was similar to diesel oil at 70°C. The mixture is delaminated, therefore emulsifier was added to avoid that. To ensure the homogeneity of the mixture, before its input to the engine, it was mixed again. The energy value of it was 39 MJ/kg, comparing to 42 MJ/kg of diesel oil. The rapeseed oil was fresh, not a waste from other production processes.

Engine was started using diesel oil, and then after heating the mixture to 70°C and the engine to 90°C, the fuel was changed to the analyzed mixture. The mixture was heated, first in a tank to 50°C, then in a heat exchanger located before the injection pump to 70°C (in a tube surrounded by a heating jacket, where flows the liquid, heated to 90°C). This temperature was determined on previous areometric studies on the use of rapeseed oil in diesel engines. These studies have confirmed the possibility that a pure rapeseed oil at 70°C can be used in the diesel engines instead of diesel oil. Also used a mixture subjected such tests, which results are shown in the following table.

TABLE 1

DENSITY OF TESTED SUBSTANCES [G/CM^3]

Temperature	Diesel Oil	Rapeseed Oil	Waste Oil	Alternative fuel mixture
20°C	0,84	0,87	0,89	0,88
70°C	0,84	0,84	—	0,84

A series of tests of fuel consumption and exhaust emissions was conducted for the tested mixture and diesel oil at an engine speed of 900, 1100 and 1400 rev./min., and loads 10, 20, 30, 40 and 50 Nm. After the trial, the fuel was changed to diesel oil, the engine run to a complete removal of the mixture from power supply system and the motor was switched off. Tests of fuel consumption were carried out by measuring the time in which the engine uses 50 ml of fuel at given speed and load. Then the amounts were converted to common units of fuel consumption and results were illustrated on the following graphs.

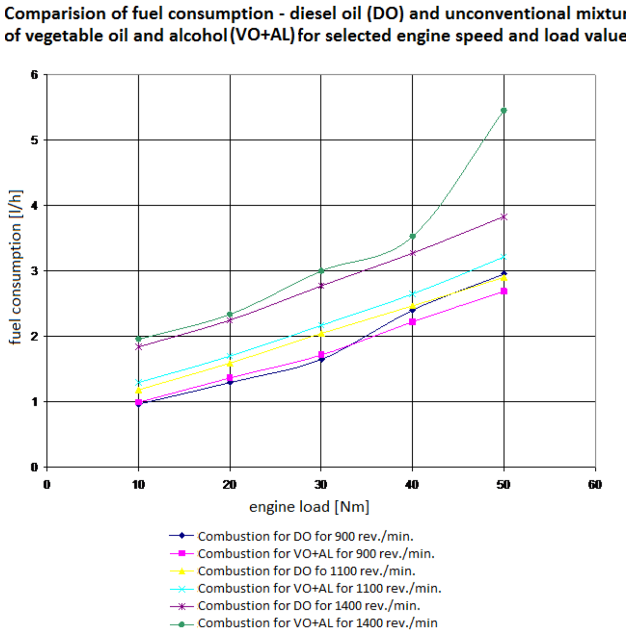

Fig. 1. Consumption of diesel oil and tested mixture for the selected engine speed and engine load

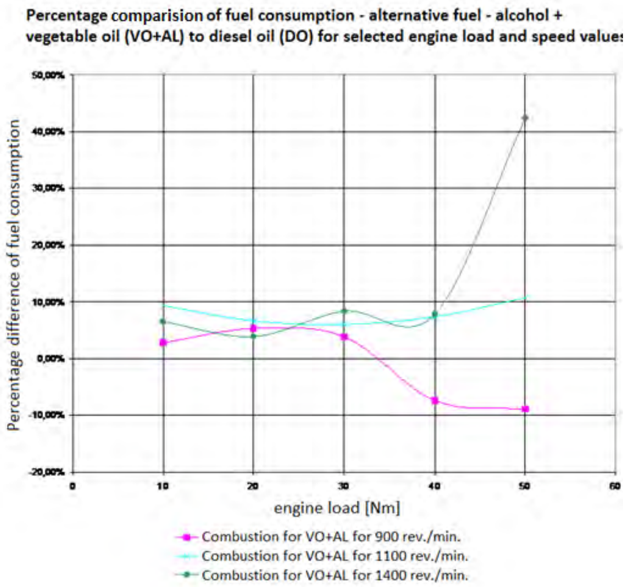

Fig. 2. The percentage difference between tested mixture and reference fuel consumption

The charts show:

- for 900 rev./min. the consumption of the tested fuel is slightly higher than the oil for load 10, 20, and 30 Nm, while for 40 and 50 Nm is below oil consumption,
- for 1100 rev./min. the consumption of the tested fuel for all of the load is slightly higher than the fuel oil, and from 10 to 30 Nm it decreases, and then increases. Only for a load of 50 Nm it is more than 10 % of it,
- for 1400 rev./min. the consumption of the tested fuel for load between 10 and 40 Nm is also slightly higher than the diesel oil – in the range of 10 to 20 Nm decreases, from 20 to 30 Nm increases, from 30 to 40 decreases slightly again . After exceeding 40 Nm grows quite rapidly and at 50 Nm is more than 40 % higher than for diesel oil,
- at speed of 900 rev./min., the tested fuel is considered the most economically through the entire range of test loads. For loads of 40 and 50 Nm consumption is even slightly smaller than the consumption of diesel oil. Only load of 20 Nm at 1400 rev./min., the percentage difference between alternative fuel and diesel oil is slightly bigger than 900 rev./min. Thetested mixture has an energy value lower by 7.14 % from diesel oil , and its use does not exceed 10 %, except a load of 50 Nm at engine speed of 1400 rev./min. As the results show, the engine powered by tested alternative fuel works best at the speed of 900 rev./min. and load 30 ÷ 50 Nm. For the load range 10 ÷ 30 Nm it works quite economical for all speeds of the tests, only for the speed of 1400 rev./min. and 50 Nm load is clearly uneconomical. Further studies should be carried out tests for speed close to 900 rev./min. in order to determine which speed is optimum.

To cooperate with the engine, a gear can be installed to match the optimum engine speed to the rated speed generator.

In addition to the fuel consumption, it is also an important to analyze the components of exhaust emitted during the combustion, which illustrated further.

- CO emission

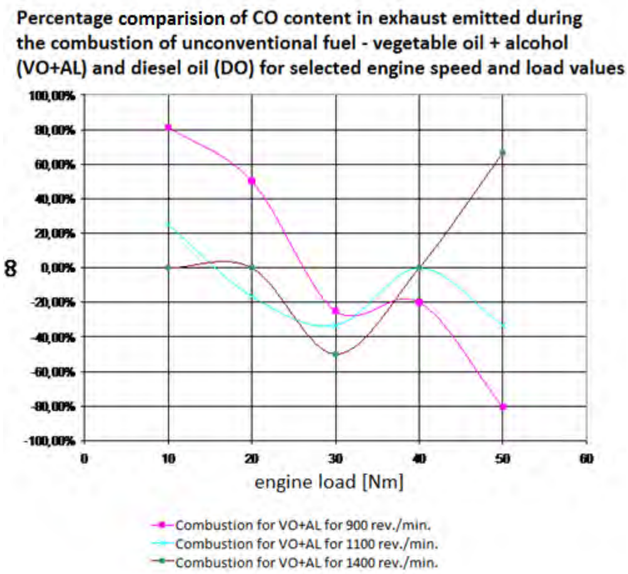

Fig. 3. CO emission

at the speed of 900 rev./min. and load of 10 Nm is higher by 80 % and for 20 Nm – about 50 % higher, comparing to diesel oil. For larger load it decreases and further for the 30 and 40 Nm is about 20 % less, at 50 Nm up to 80 % lower than for diesel oil,

at the speed of 1100 rev./min. and load of 10 Nm is 20 % bigger than diesel oil, to 20 and 30 Nm is respectively 19 and 26 % less, up to 40 Nm is identical and for 50 Nm is about 27 % lower

at the speed of 1400 rev./min. and loads of 10 and 20 Nm is the same as for diesel, for a load of 30 Nm is 50 % lower in relation to it, for 40 Nm is again identical, for 50 Nm is over 60 % of the emissions of diesel fuel,

- CO_2 emission

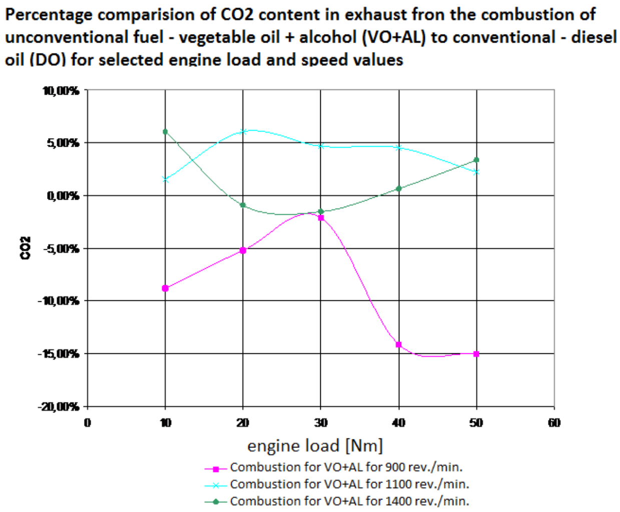

Fig. 4. CO_2 emission

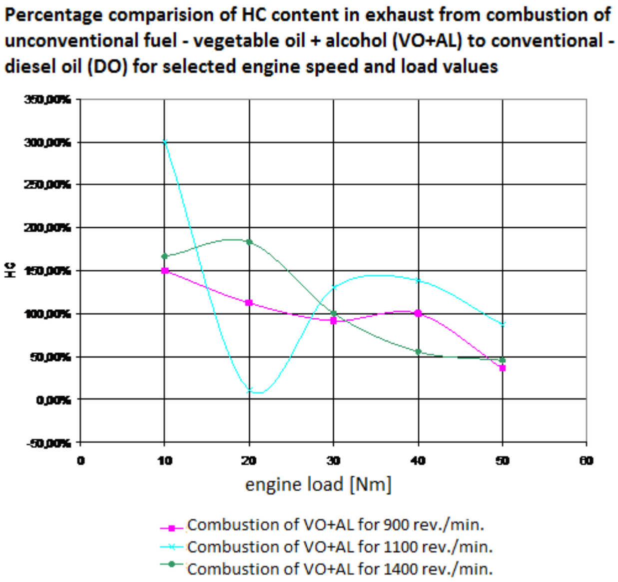

Fig. 5. HC emission

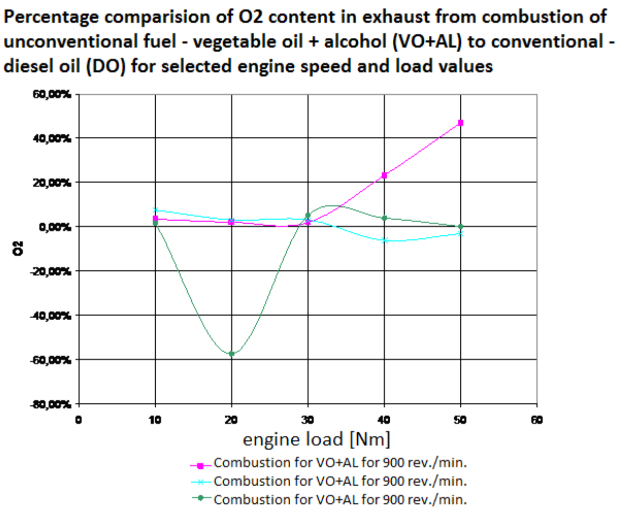

Fig 6. O_2 emission

For 900 rev./min. it varies from -9 % for load 10 Nm, -5 % and -2 % for loads of 20 and 30 Nm, then decreases to -14 % and -15 % for the 40 and 50 Nm. For 1100 rev./min. it oscillates from 6 to 1.5 % rev./min., and for 1400 rev./min. it varies from 6 % to 1.5 %,

- HC emission

For 900 rev./min, in the range of 10 ÷ 30 Nm it decreases from 150 to 91 %, in the range of 30 ÷ 40 Nm it increases to 100 %, in the range of 40 ÷ 50 Nm it decreases 36 %,

For 1100 rev./min., for load from 10 to 20 Nm it decreases from 30 to 11 %, in the range of 20 ÷ 40 Nm it increases to 138 %, and at the end of 50 Nm decreases to 88 %

- O_2 emission

For 900 rev./min. in range of 10 ÷ 30 Nm, it decreases from 3.34 to 1.87 %, then increases for 40 Nm to 23 % and for 50 Nm – 47 %, for speed of 1100 rev./min. it decreases from 7.5 % (for 10 Nm) to -6.2 % (for 40 Nm) and -3.2 % (for 50 Nm),

- NO emission

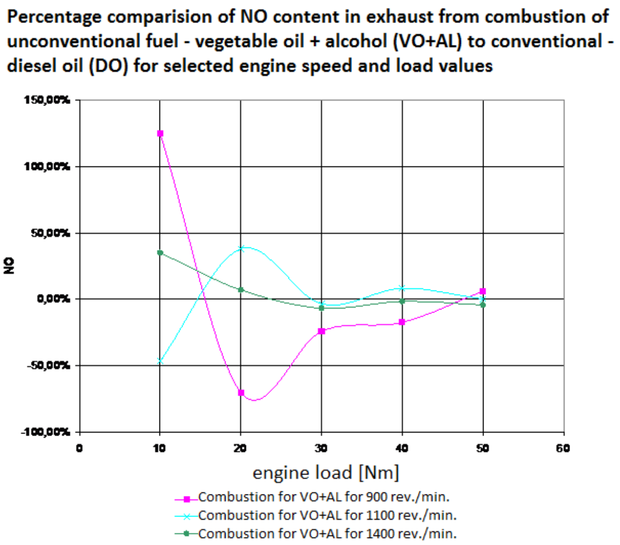

Fig. 7. NO emission

For speed of 900 rev./min. and load of 10 Nm it is 125 %, for 20 Nm it drops to 70 %, then increases: 30 Nm – 24 %, 40 Nm – 17.6 %, 50 Nm – 6 %; for 1100 rev./min. and load of 10 Nm it is 47 %, for 20 Nm – increases to 38 %, for 30 Nm decreases to -3.6 %, for 40 Nm – increases to 8 % and 50 Nm – decreases to 0 %, for speed of 1400 rev./min. and load of 10 Nm – 35 %, for 20 Nm – 6 %, and in the range of 30 ÷ 50 % it varies from -6.8 to -1.6 %.

Conclusion

The result of the study encourages to implement the solution. The implementation may not cost a lot. It can start with the use of existing power generators, which are currently used during interruptions in the supply of electricity. Because of the possibility of using this unconventional fuel without changing the engine settings, spirit factories can be convinced to start testing the fuel during normal production. These tests cost little money and effort. In the first stage, the test only requires an expansion of the fuel system with special installation for adding an emulsifier to prevent delamination, mixing and heating the mixture. In addition, the energy security rises because of the constant control of working conditions of the power generator.

The probability of a breakdown in the moment of interruption in the power supply in this case is minimal. The condition of power generator which is used only in an emergency situation, is not monitored regularly, and running during a power outage may fail due to corrosion, moisture, pollution, the overheating of connections not used for a long time, and precipitation of paraffin of the fuel stored for months or years in tank, etc..

If the tests proves that the cost and effort is disproportionate to the results achieved, the power generator can be returned to the state before the trial, which is the use of the unit only in emergency situations. The costs incurred for the development of the fuel system are not lost completely, because of the possibility of using both kinds of fuel – the conventional diesel oil and unconventional fuel based on rapeseed oil.

After a successful attempt of using the power generator for continuous electricity production, its use should be optimized.

As was mentioned, the combustion engine converts only about 40 % of the fuel energy into mechanical work processes, and the rest mainly to heat. Stationary engine can be used for heating the fuel.

The next step should be to use this heat for heating water and buildings, or for technological processes. For example, in the spirits industry it can be used to preheat the product before distillation. In the next steps, the heat and energy of exhaust can be used.

Implementation of the local power production also reduces the risk of electrical overload. This solution gives more time to upgrade the system due to contemporary requirements.

Due to the continuous reception, it is possible to reduce the size of the waste oil tank. Therefore, the cost of construction, repair and maintenance of the tank is lower. In addition, it increases fire and environmental safety, due to lower amount of combustible waste accumulated, which may pollute the environment in case of emergency.

The use of waste oil as fuel in the very location of its production will save on transportation to the place of disposal. In addition, it will reduce the congestion on roads and the amount of heavy vehicles transporting hazardous materials. Local production of power will help to avoid the power losses during the long road transfer to the recipient with the need to transition several times and eventually straightening – if the production processes at the plant require the use of direct current. It is possible to use a direct current generator as required.

Stationary engine runs is in stable condition. It provides the ability to optimize fuel composition and work parameters and catalysts to maximize energy efficiency and minimize emissions of pollutants. Experimental work may be easier because the speed is constant and appropriate for a given power generator. Due to the fact that the generator must be driven at a speed of 3000 rev./min., it is required to apply a transmitter between the motor and the generator, corresponding to the optimum speed of the engine.

The research will contribute to increase the efficiency of bio-components implementation for motor fuels and to meet higher and higher the EU requirements (according to the guidelines of the European Union by 2020 there should be 10 % of organic component in the composition of motor fuels)[3]. Lower Silesia is now the leader in the production of fuels from renewable sources by producing ~120000 Mg per year. The information obtained allow to conclude that this area of renewable fuels is very promising and should be developed in the near future.

References

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[3] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.