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Research Article

THE POTENTIAL USE OF WASTE OIL

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ABSTRACT
The purpose of this article is to present an effective use of the mixture consisting of waste oil and rapeseed oil. The results of laboratory tests for fuel consumption and exhaust emission prove significant similarity of the mixture to diesel oil. This paper describes the use of the mixture as: alternative fuel to an internal combustion engine, the source of electricity and heat; as well as its other positive aspects.

Keywords: waste oil, waste incineration, diesel, alternative fuel, electricity and heat.

INTRODUCTION

In many factories, waste oil is produced as a by-product. It is collected in special containers and transported to heat and power stations to be combusted. This article describes the way of using waste oil which was produced as a by-product in the distilling industry.

Waste oil can be used for the production of alternative fuel that propels combustion engines. The process of searching for new sources of liquid fuels is motivated by increased demand for this type of fuel, as well as the exploitation of poor sources of crude oil, which is used for fuel production nowadays (petrol, diesel oil) [1 – 6].

Diesel engines are quite efficient as heat engines. They use about 40% of fuel chemical energy. The remaining 60% is dispersed mainly in a form of heat. It can be used for water heating or in technological processes which do not demand quite as high temperatures (up to 200 °C using thermal energy of a combustion engine and up to 90 °C using energy of a cooling system).

ADJUSTMENT OF WASTE OIL

Before the combustion process, raw waste oil was dehydrated and mixed with rapeseed oil in a 3:2 ratio. To ensure homogeneity of the mixture everything was mixed again. The energy value of the mixture was 39 MJ/kg comparing to 42 MJ/kg of diesel oil. The rapeseed oil used in the process was fresh. It was not a by-product of any production processes.

Before the combustion process, the mixture was heated up to 70 °C in a special container and then it was put in a heat exchanger immediately in front of the injection pump (in a tube isolated with a heating jacket equipped with pipes with flowing liquid that was heated up to 90 °C).

The table below shows the density of each substance at a given temperature.

Table 1. The density (g/cm^3) of test substances

Temperature	ON	OR	OD	PA
20 °C	0.84	0.87	0.89	0.88
70 °C	0.84	0.84	–	0.87
90 °C	0.84	–	–	0.84

Comments: ON – diesel oil, OR – rapeseed oil, OD – waste oil PA – alternative fuel, a mixture that is the subject of research presented in this article.

TESTS OF THE MIXTURE

The tests of the mixture were carried out on the engine test stand at the Faculty of Mechanical Engineering, Wrocław University of Technology in the Division of Motor Vehicles and Internal Combustion Engines. The tests were focused on fuel consumption and exhaust emission for the mixture and standard fuel that is typical diesel oil withdensity of 0.84 g/cm^3. For the tests a three-cylinder Perkins UR AD3.152 engine of 2502 cm^3 capacity and generating the power of 35.8 kW (48 HP) was used.

The engine propelled with diesel oil was heated to a temperature of 90°C, and then the source of power was changed for the heated mixture. After the first set of tests the source of power was changed for diesel oil. The engine worked until the mixture was completely removed from the power system and then the engine was turned off. Measurement of fuel consumption and exhaust emission for the test mixture and diesel oil were taken for the following engine speeds: 900, 1100 and 1400 rpm and loads: 10, 20, 30, 40 and 50 Nm. The tests for fuel consumption were based on time measurement during which the engine consumed 50 ml of fuel for a given speed and load. Then, the time measurements were converted to common units of fuel consumption. The results were illustrated in the graphs (Figures 1 – 3).

The graph (Figure 1) shows that the combustion time of 50 ml of the test mixture is shorter than for diesel oil. The combustion time for the test mixture is longer than the time required to combust 50 ml of diesel oil only for the speed of 900 rpm and the load higher than 30 Nm.

The graphs (Figures 2 and 3) prove that:

- For the speed of 900 rpm and the loads of 10, 20 and 30 Nm, the consumption of the mixture is slightly higher than for diesel oil, while for 40 and 50 Nm the values are lower.
- For the speed of 1100 rpm and all of the test loads the consumption of the mixture is slightly higher than for diesel oil. In the range of

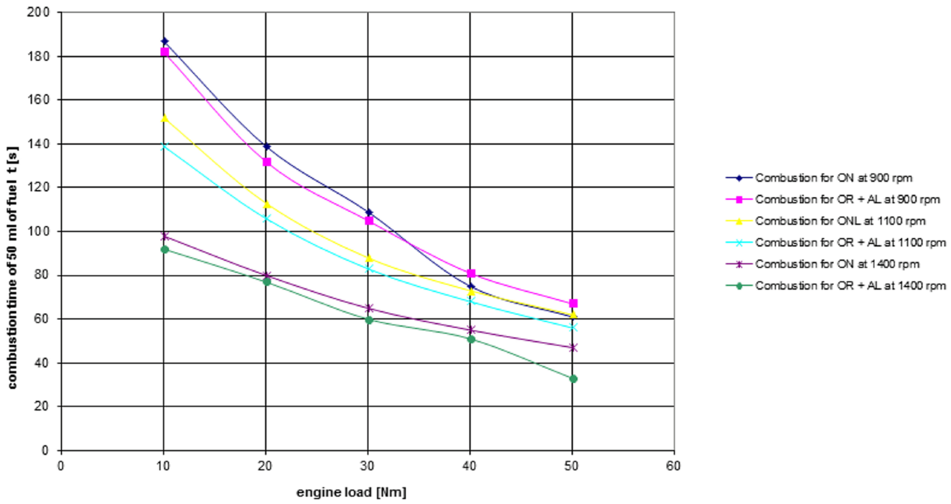

Fig. 1. Comparison of the fuel consumption for diesel oil and unconventional fuel: waste alcohol + vegetable oil (OR + AL), for particular engine speeds and loads

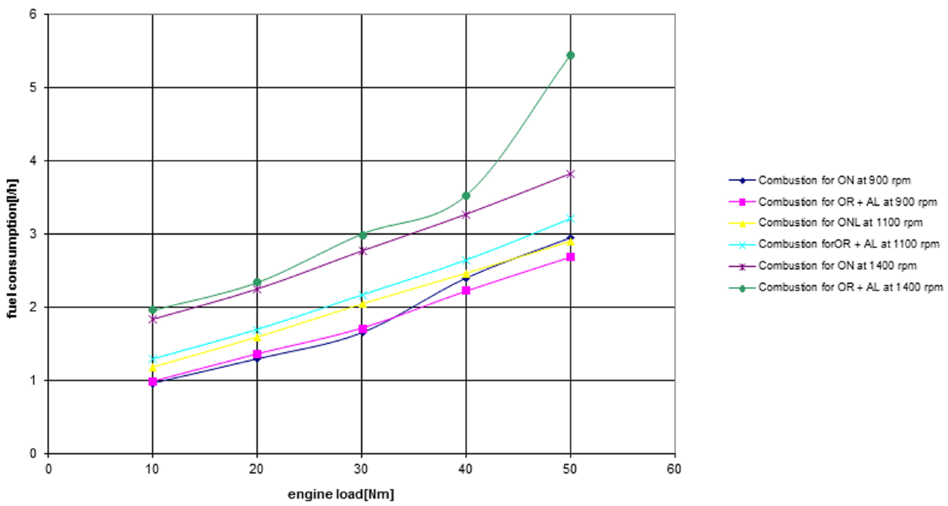

Fig. 2. Comparison of the fuel consumption for diesel oil and unconventional fuel: waste alcohol vegetable oil (OR + AL), for particular engine speeds and loads

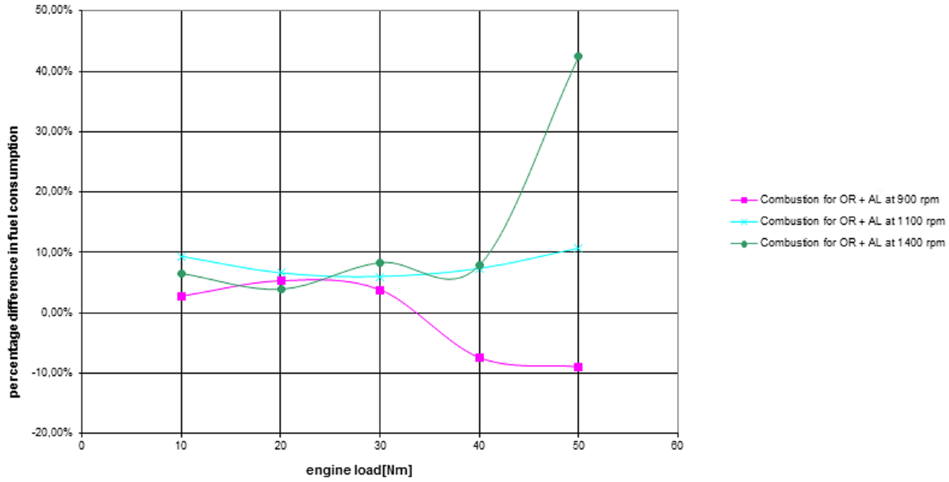

Fig. 3. Percentage comparison of the fuel consumption for unconventional fuel: waste alcohol + vegetable oil(OR + AL), to the consumption of diesel oil (ON) for particular engine speeds and loads

10 to 30 Nm the consumption decreases and then increases; only for the load of 50 Nm it is higher than 10%.

- For the speed of 1400 rpm and the loads between 10 to 40 Nm the consumption is also slightly higher than for diesel oil – in the range of 10 to 20 Nm it decreases, between 20 to 30 Nm it increases and between 30 to 40 it slightly decreases again. Above 40 Nm it grows quite rapidly and for 50 Nm the consumption is about 40% higher than for diesel oil.
- For the speed of 900 rpm work of the engine propelled with the mixture is most economical for all the test loads. For the loads of 40 and 50 Nm the consumption of the mixture is even slightly lower than for diesel oil; only for the load of 20 Nm and the speed of 1400 rpm the percentage difference in consumption of the alternative fuel and diesel oil is slightly higher than for the speed of 900 rpm. The energy value of the test fuel is lower by 7.14% than for diesel oil, and its energy consumption for all test combinations of speed and load does not exceed 10%, except for the load of 50 Nm and the speed of 1400 rpm. The above tests proved that the engine propelled with the alternative fuel works most efficient for the speed of 900 rpm and the load of 30–50 Nm.
- For the load between 10–30 Nm the engine works quite economical for all the test speeds. Only for the speed of 1400 rpm and the load of 50 Nm its work is uneconomical. Further tests are focused on the speed close to 900 rpm in order to determine accurate optimal speed.

To the construction of the engine a gear was added to match the optimum engine speed to the nominal speed generator.

During the tests particular components of exhaust gas were examined, which is illustrated with the following graphs (Figures 4 – 8):

- CO emission:
  For the speed of 900 rpm and the load of 10 and 20 Nm the emission is higher than for diesel oil by 0.065 and 0.02 respectively. For higher loads it decreases and for 30 and 40 Nm it is lower by 0.01 and for 50 Nm by 0.21 than for diesel oil.
  For the speed of 1100 rpm and the load of 10 Nm the emission is higher by 0.01 than for diesel oil; for 20, 30 and 50 Nm it is lower by 0.01, and for 40 Nm the value is the same and amounts to 0.02.
  For the speed of 1400 rpm and the load of 10, 20, 40 Nm the emission is the same as for diesel oil (0.02), for the load of 30 Nm it decreases to the value lower by 0.01 than for diesel oil, and for 50 Nm it is higher by 0.02 than for diesel oil.
- CO_2 emission:
  For the speed of 900 rpm the emission is lower than for diesel oil by 0.38 for the load of 10 Nm, by 0.3 for 20 Nm, by 0.15 for 30 Nm, by 1.4 for 40 Nm and by 1.75 for 50 Nm.
  For the speed of 1100 rpm the emission is higher than for diesel oil for all test loads: by 0.06 for 10 Nm, by 0.3 for 20 and 30 Nm, by 0.35 for 40 Nm and for 50 Nm by 0.2.
  For the speed of 1400 rpm and for the load of 10 Nm the emission is higher by 0.24 than for diesel oil, for 20 and 30 Nm the value is lower by 0.05 and 0.1 respectively, then it increases again and for the load of 40 Nm it is higher by about 0.05, and for 50 Nm by 0.3.

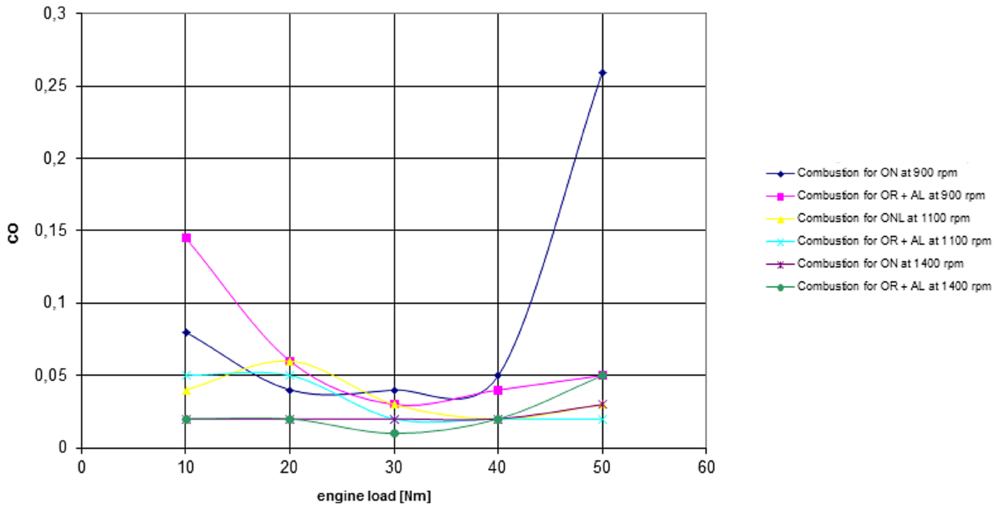

Fig. 4. Comparison of CO content in exhaust gases during the combustion process of unconventional fuel: waste alcohol + vegetable oil (OR+AL), and diesel oil (ON) for particular engine speeds and loads

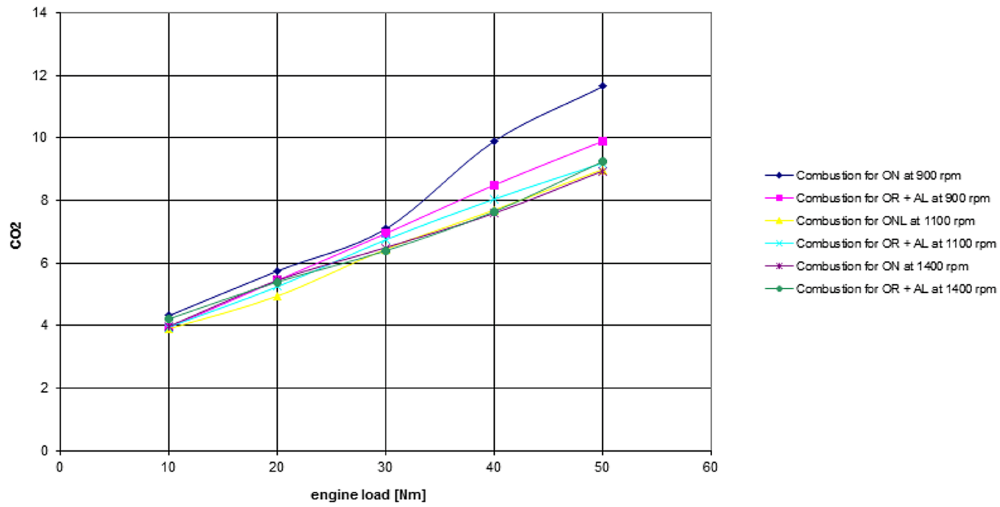

Fig. 5. Comparison of CO2 content in exhaust gases during the combustion process of unconventional fuel: waste alcohol + vegetable oil (OR+AL), and diesel oil (ON) for particular engine speeds and loads

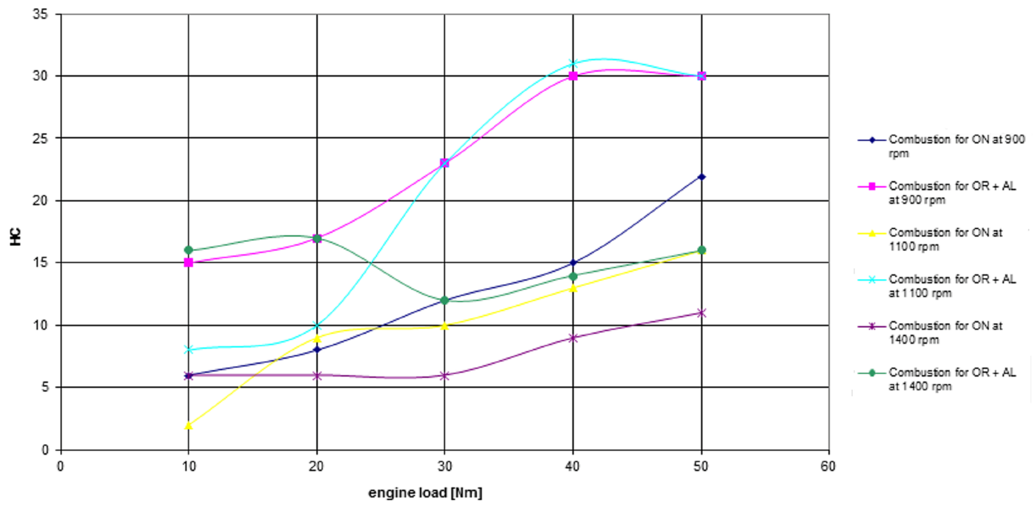

Fig. 6. Comparison of HC content in exhaust gases during the combustion process of unconventional fuel: waste alcohol + vegetable oil (OR+AL), and diesel oil (ON) for particular engine speeds and loads

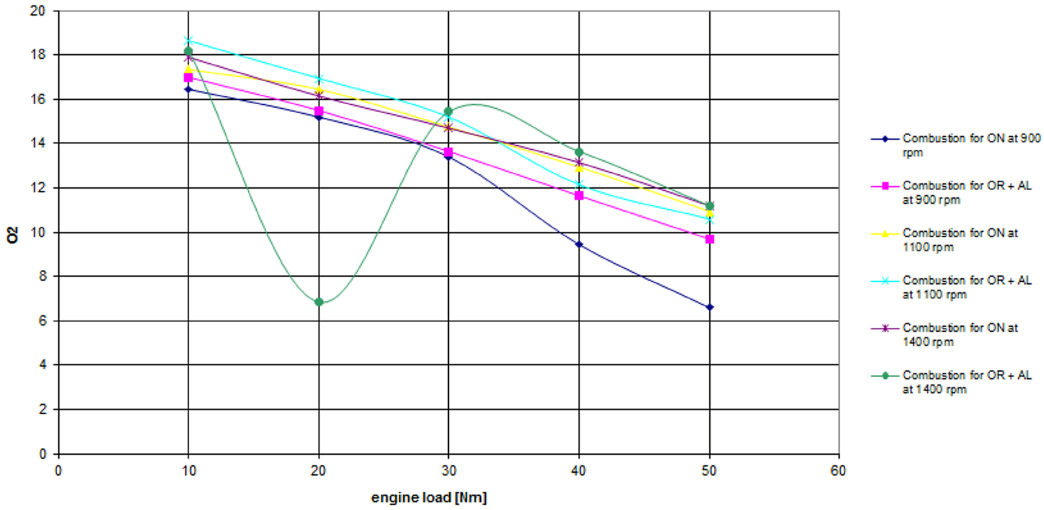

Fig. 7. Comparison of O2 content in exhaust gases during the combustion process of unconventional fuel: waste alcohol + vegetable oil (OR+AL), and diesel oil (ON) for particular engine speeds and loads

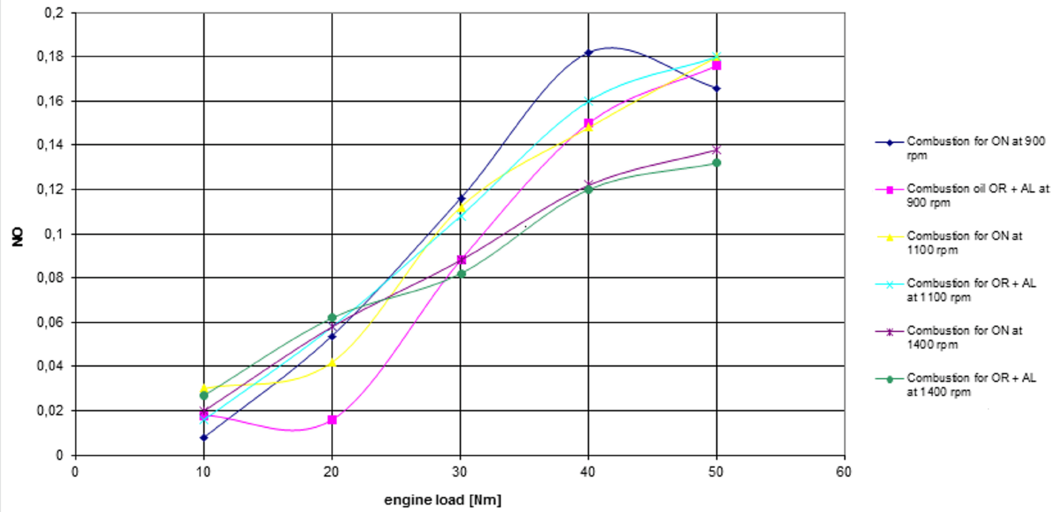

Fig. 8. Comparison of NO content in exhaust gases during the combustion process of unconventional fuel: waste alcohol + vegetable oil (OR + AL), and diesel oil (ON) for particular engine speeds and loads

- HC emission:
  For this component the emission is higher for the test mixture than for diesel oil for each test speed and load.
  For the speed of 900 rpm the emission is higher by 9 for 10 and 20 Nm, by 11 for 30 Nm, by 15 for 40 Nm and by 8 for 50 Nm.
  For the speed of 1100 rpm and for the load of 10 Nm it is higher by 6, for 20 Nm it is higher by only 1, then the value increases and for the loads of 30, 40 and 50 Nm it is higher by 13, 18 and 14 respectively. For the speed of 1400 rpm the emission is greater for the test loads by 10, 11, 6, 5 and 5 respectively.
- O_2 emission:
  For the speed of 900 rpm the emission is higher than for diesel oil. First, the difference is small and is equal to 0.55 for 10 Nm, 0.3 for 20 Nm, 0.25 for 30 Nm, then it increases to 2.2 for 40 Nm and 3.1 for 50 Nm.
  For the speed of 1100 rpm and for the load between 10 ÷ 30 Nm the emission is higher for the mixture by 1.3, 0.5 and 0.45, respectively, then it decreases to the value lower by 0.8 for 40 Nm than for diesel oil and by 0.35 for 50 nm.
  For the speed of 1400 rpm and for the load of 10 Nm it is slightly higher than for diesel oil (0.3), then it decreases to the value lower by 9 and it increases again to obtain the difference equal to 0.75 for 30 Nm and 0.5 for 40 Nm. For 50 Nm it reaches the same value (11.2).
- NO emission:
  For the speed of 900 rpm the emission is higher by 0.01 than for diesel oil only for 2 loads:

10 and 50 Nm. For other loads the value is lower, and the difference is 0.038 for 20 Nm, 0.028 for 30 Nm and 0.032 for 40 Nm.

For the speed of 1100 rpm the emission is higher for the load of 20 and 40 Nm respectively by 0.016 and 0.012. For the loads of 10 and 30 Nm it is lower by 0.014 for 10 Nm and by 0.004 for 30 Nm. For the load of 50 Nm the value is the same and amounts to 0.18.

For the speed of 1400 rpm it is higher only for loads of 10 and 20 Nm by 0.007 and 0.004 respectively, then it decreases to the value lower by 0.006 for 30 and 50 Nm, and by 0.002 for 40 Nm.

Further tests of the mixture will contribute to accurate analysis of the exhaust gases emitted during the combustion process. They will also allow for the systematization of catalysts.

WASTE OIL AS FUEL

As it was already mentioned, the waste oil can be used for the production of alternative fuel. It was proved in this paper by the tests' results.

The replacement of diesel oil with the analyzed mixture does not demand any changes in the internal combustion engine structure. It is necessary only to expand the fuel system with a special installation for mixing and heating the unconventional fuel. For this reason, it is recommended to use a stationary diesel engine which will be propelled with the test mixture at an early stage of tests carrying out outside the laboratory. Undoubtedly, the adjustment process of proper installations to the system will not be complex.

The use of the mixture by a power generator located in the company which produces the waste oil as a by-product seems to be a good solution. This allows for cheap and effective use of the oil at its source.

There is also an additional advantage of using such generator for tests – it is continuous maintenance of its technical condition. The generator works only when there are power cuts. Due to such long inactivity periods its individual components can be affected by corrosion or moisture.

Processing of waste oil at its source can help to limit spendings on transportation of waste to a disposal site. This will also reduce traffic load with heavy vehicles and the transportation of hazardous materials.

CONCLUSION

Poland, as a member of the European Union, must meet the requirements imposed by EU. One of them is a proper waste management system, which is specified in Directive 2008/98/EC on waste (Framework Directive) [3]. This document defines all levels of waste disposal and recycling. It also introduces a hierarchy of waste management (i.e., prevention, different recycling processes). One of the recycling processes is the incineration of waste for energy or heat production. The use of waste oil for alternative fuel production meets the waste management requirements defined in the Directive. It is also highly prospective method of energy and heat production for manufacturing companies. The use of the waste oil in power generators allows for cheap and more ecological electricity production. Such a local electricity production will help to avoid power losses resulting from long distances of electric power transmission to the recipient. During the process there is a need for transformation or conversion of alternating current (AC) to direct current (DC) if it is necessary for the production processes of a company. Additionally, special methods for the use of the heat generated in a diesel engine during the waste oil combustion process can be developed. They could be used in distilling industry to preheat the products before distillation process.

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