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MODIFICATION OF VEGETABLE OIL FOR HEATING PURPOSES

Key words

Heating fuel, furnace oil, modification of oil properties.

Abstract

The use of vegetable oil as a heating fuel requires the use of additives for improving the physicochemical properties of the oil. In order to use a composition based on vegetable oil without making any structural changes in the furnace, such as the reconstruction of the burner, it is necessary to decrease the viscosity of the fuel. For this purpose *foreshot*, which is a waste from the production of alcohols and has a low viscosity, was used. Compositions with different content of foreshot in vegetable oil were prepared and key parameters that allow the use oil as a heating fuel was examined. Composition on the base of vegetable oil was established. It meets the safety requirements and allows for proper atomization of fuel and force through the installation.

Introduction

The combustion of furnace oils takes place in boilers, steams, industrial furnaces, and technological processes. The primary liquid fuels used in heat engineering are furnace oils derived from crude oil processing. In the composition of furnace oils, the following chemical groups are present:

paraffins and ceresines, olefins, petroleum resins, asphaltenes, sulphur, and heavy metals. The components of furnace oils can be divided into primary, present in all furnace oils and determining their calorific value, and ingredients that do not originate from working processes and are usually undesirable. The latter include mechanical impurities and water.

Each fuel with specific properties may be burned in boilers and other devices only if the construction of burners and combustion chambers are adapted to the specific fuel, not only because of the quality of combustion, but because of the feeding burners' method or combustion chambers. Not only a construction of burners, which provide entrance of fuel into a combustion chamber, but also the installation supplying fuel to burners is significant [1–3].

The disadvantage of vegetable oils compared to petroleum oils is less calorific value, higher production costs, and low thermo-oxidation, hydrolytic and microbial resistance, which may complicate their storage. Important combustion properties of vegetable oils and fatty acid methyl esters are as follows [4–6]:

- Calorific value min. 35 MJ/kg,
- Chemical composition,
- Viscosity (kinematic viscosity of vegetable oils is up to 38 mm²/s at 40°C, methyl esters is up to 8 mm²/s at 20°C, light furnace oils is up to 6 mm²/s at 20°C),
- Density 0.85–0.93 g/cm^3,
- Fractional composition,
- Ignition temperature (vegetable oils is about 350°C, fatty acid methyl esters above 120°C), and
- Water content (max 200 mg/kg for light furnace oils).

Physical and chemical properties of vegetable oils (ignition temperature, kinematic viscosity, and fractional composition) differ significantly from the requirements specified in the standards for light furnace oils. The change of atomizers or reconstruction of other elements used in furnaces is uneconomical. Therefore, in order to use vegetable oil as fuel, reducing the viscosity of the vegetable oil is more profitable than the reconstruction of furnaces.

Liquid heating fuels, especially heavy furnace oils, biofuels and fuels based on waste products, are modified with special additives or by composing them with different liquids in order to improve the combustion process and satisfy the requirements of the manufacturers of burners and furnaces. Additives are added in small amounts. They are usually solutions or mixtures of various chemical compounds. The selection of additives requires extensive experience and complex research. Additives must not have a negative impact on other parameters or create oil deposits. Additives should form in basic products, non-ideal solutions or be stable to sedimentation micro-aggregation. Additives should not be washed out by water.

Additives can be applied directly in refineries or individually by the user. In the process of production and use, there are many types of modifiers [2, 3, 7–9]:

- Depressants added to liquid fuels in order to keep them in the liquid state at a temperature lower than 0°C;
- Corrosion inhibitor that prevent corrosion caused by the presence of water;
- Anti-aging additives (antioxidant, metals deactivator), which are useful for extended storage of furnace oils (oils aging causes precipitation of deposits which interfere in the combustion process);
- Demulsifiers, which prevent the formation of stable emulsions;
- Antifoaming agents, which prevent foaming during injection into the burner;
- Biocides (biocidal additives), which prevent the growth of microorganisms during storage of oils (the growth of microorganisms causes inter alia the formation of deposits, emulsions, turbidity, and stimulates aging processes);
- Detergents, which allow reducing or eliminating the formation of carbon deposits and deposits at the ends of burner nozzles.

The aim of this study was to investigate the possibility of adapting the properties of vegetable oil based fuel for use as a liquid heating fuel in typical heating oil boilers without any structural changes in the furnace. Non-modified vegetable oil could cause problems with pumping components or the failure of fuel atomizers.

Table 1. Physicochemical properties of the foreshot

Properties	Values
Density in 20° C [g/cm^3]	0.840-0.880
Distillation (95% vol.) [°C]	70-155
Kinematic viscosity in 40° C [mm^2/s	2,277
Sulphur content [% mass]	0,00
Water content [% mass]	≤ 2,0
Ignition temperature [°C]	≥20
Solidification temperature [°C]	<–30
Residue after incineration [% mass]	≤ 0.002
Acid value [mg KOH/g]	≤ 0.5
Coking capacity [% mass]	0.003
Heat of combustion [MJ/kg]	37.5

As indicated in the data in Table 1, the kinematic viscosity of foreshot at 20°C is very small and, therefore, it was selected as a vegetable oil diluent. It is also important that the mixture does not contain sulphur in its composition.

Research of the ignition temperature of the fuel compositions was performed using a Pensky-Marten's closed-cup flash tester. The ignition

temperature measurement involves heating the test product at a constant rate and approaching the flame test every 1°C to the filled with fuel cap. The ignition temperature of the test product should be regarded as the lowest temperature at which application of the test flame causes the vapour to ignite.

Determination of the kinematic viscosity of the fuel composition involves measuring the time of free movement of the test liquid between marked points on capillary tube at a given temperature.

1. Experimental results of the composition based on vegetable oil

Compositions based on the vegetable oil containing properly 5%, 10%, 15%, 20% and 25% of foreshot were prepared. Research of the kinematic viscosity of the all compositions and the pure oil was conducted. Kinematic viscosity test results are shown in Figure 1.

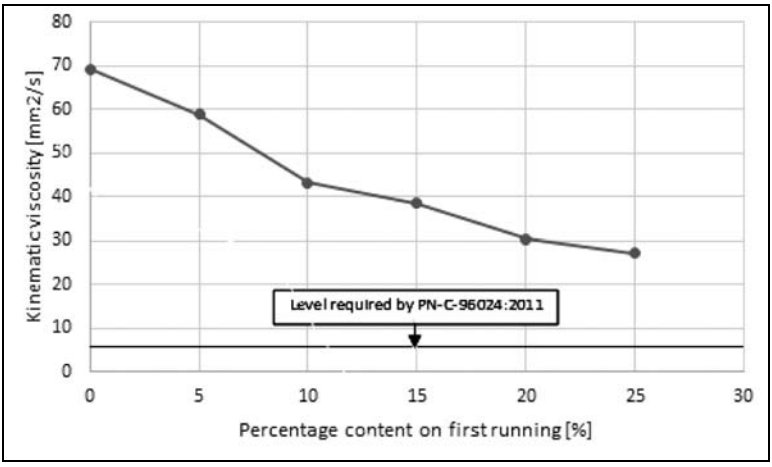

Fig. 1. Effect of the foreshot in vegetable oil content to viscosity at 20°C

According to data from Figure 1, the introduction of a 25% foreshot does not result in sufficient reduction of the kinematic viscosity of the composition to the level required by PN-C-96024:2011.Viscosity is a parameter that is critical for proper atomization of fuel, which determines the quality of the combustion process. If the oil viscosity is too high, the pump of the burner will experience premature wear or even failure due to flow resistance and higher pressure. The viscosity of the fuel during spraying should be in the range of 3–30 mm^2/s. Certain types of nozzles may spray oils having a viscosity of 45 mm^2/s [10]. It means that, despite not meeting the standard PN-C 96024:2011, the composition of vegetable oil containing 20% and 25% foreshot can be used as heating fuel, but using appropriate burners.

Another parameter important for safety reasons is the temperature of ignition. Too low ignition temperature indicates an admixture of light and volatile fractions. The use of that product can cause an explosion. The results of the ignition temperature of the composition containing different amounts of foreshot in vegetable oil are shown in Figure 2.

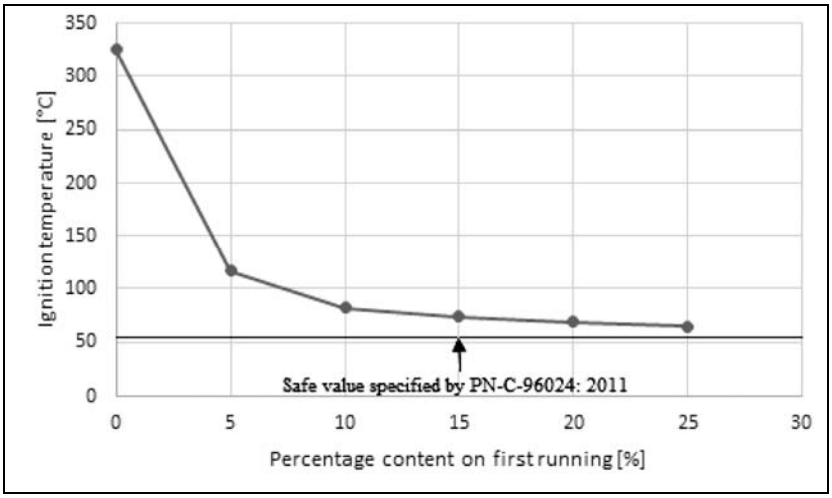

Fig. 2. Effect of the foreshot in vegetable oil content to ignition temperature

On the basis data in Figure 2, it was found that the introduction of more than 10% of foreshot would not significantly reduce the ignition temperature of the composition based on vegetable oil. Adding a 5% mixture to vegetable oil was enough to reduce the ignition temperature below 200°C. The addition of 25% of the mixture did not result in exceeding the specified PN-C-96024:2011 minimum safe value of 56°C.

According to data in Figure 1 and Figure 2, the foreshot modifies the physicochemical properties of vegetable oil. The viscosity of the compositions containing 20% and 25% of the foreshot is in the range of 3–30 mm^2/s, which is suitable for proper work of the atomizer, and the flow system. Despite the addition of such a large amount of the additive with a very low ignition temperature (about 20°C), it does not exceed the limit of safety. Based on the survey, it can be concluded that it is possible to use the composition of vegetable oil with foreshot as a heating fuel, but with appropriate burners.

Summary

Liquid heating fuels based on vegetable oils can be modified by using properly selected additives. Properties of compositions based on vegetable oils

should be close to the properties of light furnace oil. As a modifier used to improve the physicochemical properties, foreshot was used. It significantly reduced the viscosity of vegetable oil, which improves fuel atomization and the flow in the furnace. Adding foreshot resulted in a significant decrease in the ignition temperature, but even adding 25% of the modifier did not result in exceeding the safety limit values specified in PN-C-96024:2011. Thus, the obtained fuel can be considered safe. Foreshot's irritating odour can be an obstacle in the application for residential space heating. Methanol, which may be included in foreshot, is toxic and its vapours are explosive. The need to keep particular safety rules, including avoiding breathing vapours, the fuel should be stored in closed containers.

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References

1. Grint A., Veal C. J.: Effect of fuel oil source on the preparation of coal – oil dispersions, Fuel, 1985, 64, 8, pp. 1079–1084.
2. Dmytryshyn S.L., Dalai A.K., Chaudhari S.T., Mishra H.K., Reaney M.J.: Synthesis and characterization of vegetable oil derived esters: evaluation for their diesel additive properties Bioresource Technology, 2004, 92, 1, pp. 55–64.
3. Kerschbaum S., Rinke G.: Measurement of the temperature dependent viscosity of biodiesel fuels, Fuel, 2004, 83, 3, pp. 287–291.
4. Podniało A.: Paliwa, oleje i smary w ekologicznej eksploatacji, Wyd. Naukowo-Techniczne, Warszawa 2002.
5. Jakóbiec J., Bocheńska A., Ambroziak A.: Modyfikacja właściwości fizyko-chemicznych i użytkowych paliwa rzepakowego, Inżynieria Rolnicza, 2011, 4, 129, pp. 85–92.
6. Jóźwiak D., Szlęk A.: Ocena oleju rzepakowego jako paliwa kotłowego, Energetyka i Ekologia, 2006, pp. 449–451.
7. Allen C.A.W., Watts K.C., Ackman R.G., Pegg M.J.: Predicting the viscosity of biodiesel fuels from their fatty acid ester composition, Fuel, 1999, 78, pp. 1319–1326.
8. Furtak L., Łuksa A., Stępień A.: Ocena wpływu modyfikacji właściwości biopaliw ciepłowniczych na bazie olejów roślinnych na skład spalin i rozkład temperatury w komorze spalania. X Forum Ciepłowników Polskich, Międzyzdroje, 17–20 IX 2006.

9. Rosiński M., Furtak L., Stępień A.: Wpływ składu kompozycji na bazie estrów metylowych oleju rzepakowego na jakość procesu spalania w urządzeniach ogrzewczych małej mocy. XII International Conference Air Conditioning Protection & District Heating, Szklarska Poręba 26–29VI 2008.
10. Szymański M.: Spalanie i wymiana ciepła w kotłach niskotemperaturowych, Ciepłownictwo Ogrzewnictwo Wentylacja, 2013, 2, 17.

Modyfikacja właściwości oleju rzepakowego do celów ciepłowniczych

Słowa kluczowe

Paliwo ciepłownicze, olej opałowy, modyfikacja właściwości oleju.

Streszczenie

Wykorzystanie oleju roślinnego jako paliwa ciepłowniczego wymaga zastosowania dodatków uszlachetniających poprawiających właściwości fizykochemicznych oleju. Aby możliwe było wykorzystanie kompozycji na bazie oleju roślinnego bez wprowadzania zmian konstrukcyjnych w piecu, takich jak np. przebudowa palnika, konieczne jest obniżenie lepkości kinematycznej paliwa. Do tego celu zastosowano przedgon alkoholowy, który jest odpadem m.in. w produkcji alkoholi, a charakteryzuje się niską lepkością. Wytworzono kompozycje o różnej zawartości przedgonu w oleju rzepakowym i zbadano kluczowe parametry pozwalające zastosować olej jako paliwo ciepłownicze.