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LUBRICATING AND PHYSICOCHEMICAL PROPERTIES OF VEGETABLE OIL BASES FOR HYDRAULIC FLUIDS

Keywords

Vegetable oils, hydraulic fluids, oil bases, lubricating properties, physicochemical properties.

Abstract

The tests results of vegetable oil bases with viscosity grade VG 46, based on rapeseed oil were presented. The viscosity of vegetable oil has been modified through the addition of castor oil or synthetic viscosity improvers. The lubricating and physicochemical properties of base oils were investigated. The obtained results were compared with the requirements of Polish standard PN-C-96057-6: "Petroleum products - Hydraulic oils for hydrostatic systems - Hydraulic oils L-HV."

It was stated that vegetable bases exhibit excellent antiscuffing properties. They fulfil the requirements of the standard in the scope of rheological properties, corrosive properties, air release properties, and filtering rate. The elaborated oils have a high flash point. The mixture of rapeseed oil and castor oil has, additionally, high shear resistance and good demulsibility. For these reasons, this mixture was indicated as base oil for the L-HV class of hydraulic oil for agricultural machinery.

Introduction

The operating conditions of agricultural machinery are extremely hard [1]. The reliability of machines depends, among other factors, on the proper operation of hydraulic systems. The main factors are pressure and temperature [2]. The proper pressure of hydraulic fluid for internal systems is in the range of 1.0-17.5 MPa, and for external systems is from 8.0 to 25 MPa. The working pressure of hydraulic systems of combine-harvesters it is from 5.0 to 40 MPa. During operation, the temperature of hydraulic systems increases from 60 to 160°C, and sometimes reaches 200-300°C [3].

To ensure the reliable operation of hydraulic systems, hydraulic fluids have to fulfil strict requirements: physicochemical as well as resistance and strength characteristics [4, 5]. In agricultural machinery, L-HV class hydraulic fluids are usually employed. They exhibit high antiwear properties and a high viscosity index. These fluids are usually mineral based oils. It is well known that mineral bases are not environmentally friendly [6, 7]. Taking that into consideration, it is justified to use biodegradable oils in agricultural machinery. The biodegradable oils are not harmful to the environment. The main candidate for these oils is vegetable based oils [8-10].

This paper assesses the lubricating and physicochemical properties of vegetable oil bases intended for use as base oil for hydraulic fluids in agricultural machinery.

1. Experimental procedure

The subjects of these investigations were vegetable bases with a VG 46 viscosity grade, manufactured from refined rapeseed oil. To achieve the correct viscosity of rapeseed oil, 15% of castor oil (base I) or 2.5% of synthetic viscosity improver (base II) was added.

The lubricating and physicochemical properties of manufactured oil bases were studied. The results were compared with the requirements of Polish standard PN-C-96057-6: "Petroleum products - Hydraulic oils for hydrostatic systems - Hydraulic oils L-HV" as well as with commercial hydraulic oil for agricultural machinery of VG 46 grade. The parameters not included in the standard were compared to values obtained for commercially available oil. The tests were conducted according to methods indicated in standards concerning hydraulic oil L-HV. Additionally, the lubricating properties of oils were tested using methods developed in the Institute for Sustainable Technologies – National Research Institute [11].

The test balls were chrome alloy bearing steel, with a diameter of 12.7 mm, surface roughness Ra = 0.032 μm and hardness 60-65 HRC.

The wear scar was measured at a constant load 392.1 N and a rotational speed 1450 rpm, with test duration of 1 hr. The weld point was measured according to Polish Standard PN-76/C-04147 (Test for lubricating properties of oils and greases). The scuffing load (P_t) and limiting pressure of seizure (p_{oz}) were measured using a T-02 Four-Ball Apparatus [11]. The scuffing load is determined at a continuously increasing load and determines the load at which the lubricating film collapses and a sudden rise in the friction occurs. The higher the scuffing load value and limiting pressure of seizure, the better the resistance to scuffing.

The tests were repeated three times. To discard any outlying result, Dixon's test was performed (at 5% significance level). The results were calculated as an arithmetic average.

2. Results and discussion

The tests performed using four-ball apparatus, denoted as T-02, showed the diversity of lubricating properties of vegetable bases in comparison to standard requirements and to commercial product (Fig. 1). The investigated base oils did not fulfil the standard requirements for lubricating properties measured by four-ball apparatus (Fig. 1a). The measured wear scar diameters were 25% larger than indicated in the standard for L-HV class hydraulic fluids and achieved for commercial oil. These bases did not exhibit satisfactory antiwear prevention against wear of friction joints. The antiscuffing properties of the oils were tested using several constant loads – load stages. All investigated oils, both vegetable bases and commercial product, exhibited the same weld load. All oils lost their antiscuffing properties under the load of 1962 N. These oils have similar antiscuffing properties (Fig. 1b).

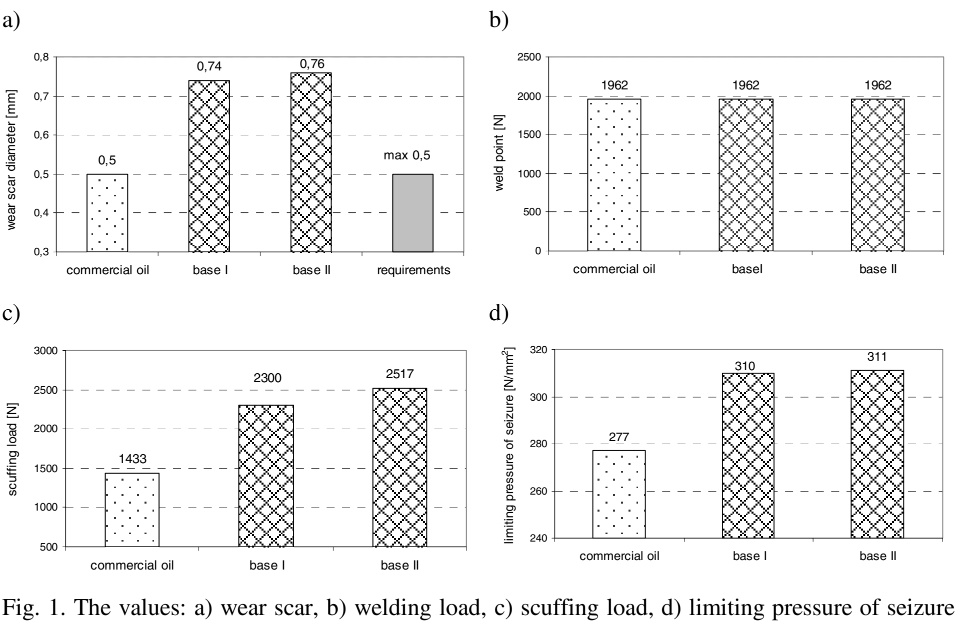

Fig. 1. The values: a) wear scar, b) welding load, c) scuffing load, d) limiting pressure of seizure for elaborated oil bases and the commercial product

The tests performed using the T-02 testing machine showed more effective antiscuffing action of vegetable base oils than that obtained for the commercial product (Fig. 1c and d). The values of scuffing load (P_t) and limiting pressure of scuffing (p_{oz}) for both elaborated oil bases were higher than that obtained for L-HV class hydraulic oil intended for agricultural machinery. The value of P_t parameter for base I was about 60% higher, and for base II about 80% higher than measured for the commercial oil. The investigated vegetable bases exhibited higher load-carrying capacity than the commercial oil. Among both tested oils better characteristics were achieved for base II. This base was a mixture of rapeseed oil and viscosity improver (Fig. 1c).

It was stated that there are no significant differences in scuffing behaviour. The limiting pressure of seizure of elaborated vegetable base oils is similar. The achieved limiting value of p_{oz} parameters was about 15% higher than the obtained for commercial hydraulic base oil. The four-ball tribosystem lubricated with base oil exhibited higher resistance to scuffing than that lubricated with commercial product (Fig. 1d).

The results of the physicochemical tests of oil bases were summarised in Fig. 2 and in Table 1. They revealed the diversification of measured parameters, especially these required by standard for L-HV class hydraulic oils. The vegetable bases have very good temperature-viscosity characteristics. The measured viscosity index for the mixture of vegetable oils was about 30% higher than required by the standard, and for the mixture of rapeseed oil and viscosity improver about 50% higher (Fig. 2a). This indicates the low susceptibility of viscosity of these base oils to temperature changes. The elaborated bases have a high flash point, for base I about 30% higher than required by the standard, and for base II about 60% higher than minimum standard requirements (Fig. 2b). The investigation of flow temperature indicated that, for vegetable bases, the maximum range stated by the standard was achieved. The commercial product has a flash point about 20% lower than that obtained for oils bases (Fig. 2c).

The shear resistance tests showed that the high resistance for destruction by mechanical shear forces of oil base I (mixture of vegetable oils). The decrease in oil viscosity for base I was sevenfold lower then required by the standard. The base II did not fulfil the standard requirements. For rapeseed oil with the viscosity improver a twofold decrease in viscosity than required by the standard was achieved (Fig. 2d).

The vegetable bases exhibited satisfactory anticorrosive properties (Table 1). All vegetable bases fulfilled the requirements of Polish PN-C-96057-6 standard for L-HV class hydraulic oils in the corrosive action with copper and steel, both in normal conditions, applied for petroleum products, and under extreme conditions of high temperature, and longer exposure of oil contact with metal -

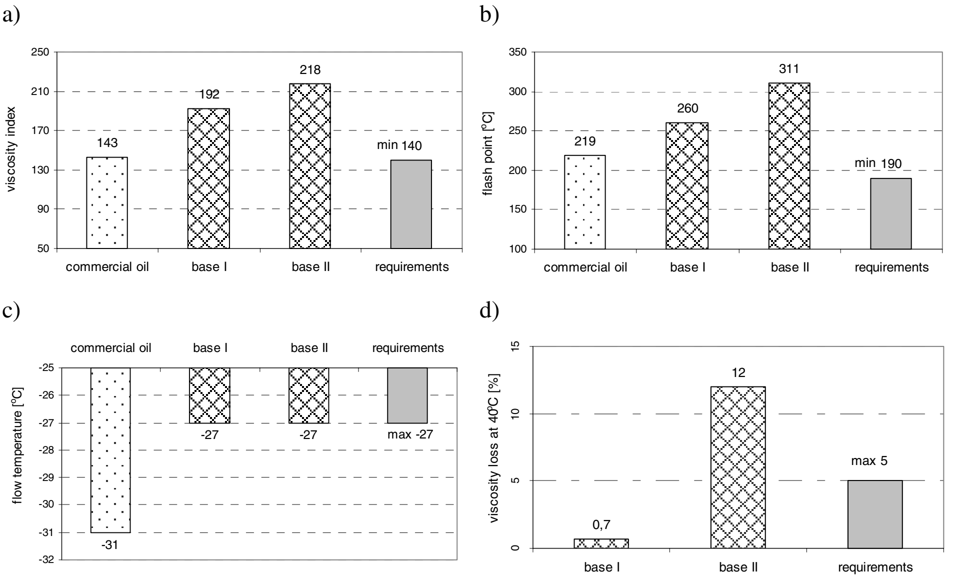

Fig. 2. The values: a) viscosity index, b) flash point, c) flow temperature, d) shear resistance for elaborated oil bases and the commercial product

Table 1. Physicochemical properties of elaborated oil bases and the commercial product

Property	Commercial oil	Base I	Base II	Standard PN-C-96057-6
Kinematic viscosity, 40°C, mm^2/s	47.52	45.35	46.49	41.4÷50.6
Corrosiveness to copper, 120°C, 3 hrs	1	1	1	≤ 1
Rusting characteristics in salt solution	no corrosion	no corrosion	no corrosion	No corrosion
Thermal stability in presence of copper, 135°C, 96 hrs, degree of corrosion	1	2	2	≤ 2
Air Release Properties, 50°C, min	-*	1,0	1,0	≤ 7
Filtering rate, s - oil without water - oil with 2% water (v/v),	-*	 270 280	 270 270	≤ 600 ≤ twofold oil flow time without water
Foam resistance, - foam volume, 25°C/95°C/25°C, cm^3 - foam stability, cm^3	 0/0/0 0/0/0/	 70/10/120 0/0/0	 0/0/0 0/0/0	 ≤ 100/100/100 ≤ 10/10/10
Demulsibility, 54°C, min	30	25	> 60	< 60

* not tested.

thermal stability in the presence of copper. The elaborated oil bases exhibited high air release properties. The time for air release from oil for both investigated bases was sevenfold shorter than stated in the standard. Both oil bases ensured sufficient protection of metal surfaces against wear by cavitation by air bubbles. The cavities or bubbles will collapse when they pass into the higher regions of pressure, causing noise, vibration, and damage to many of the components. The investigation of antifoam properties for base II, being the mixture of rapeseed oil and viscosity improver, did not indicate the tendency to create foam (in conditions indicated by the standard for L-HV class hydraulic oil). However, the mixture of the vegetable oils lathered under the flow of air and the standard limit was exceeded in temperatures of 25°C and 95°C.

Both oil bases fulfilled the standard requirement for the filtering rate (Table 1). The flow time through the drain was two times shorter than required by the standard. The filtering resistance during tests indicates that it is possible to effectively remove impurities from vegetable oils (especially solid particles) and ensure the purity of the final product.

The investigation of demulsibility indicated that only base I fulfils the standard requirements. The time necessary for complete separation of the emulsion of vegetable oils and water was two times longer than required by the standard. However the emulsion made with rapeseed oil and viscosity improver separated in the time required by the standard.

Conclusions

Base on the performed research one can state that vegetable oils, both mixtures of rapeseed oil and castor oil, as well as rapeseed oil containing the synthetic viscosity improver, can be used as base oil for L-HV class hydraulic fluids. Both bases fulfilled the standard requirements in the scope of crucial lubricating and physicochemical parameters. They exhibited high antiscuffing properties in scuffing conditions. They exhibited very good temperature-viscosity characteristics and high flash points. The corrosive action for copper and steel of these oils was not detected. A high value of viscosity index and effective antirust action are required especially for machines operating in fresh air, such as agricultural machines. The high filtering rate and high air release properties of both oil bases is beneficial for operating. These features facilitate filtering of solid contamination and water and through the prevention of wear of hydraulic systems. The mixture of rapeseed base oil and castor oil exhibited high resistance for destruction under mechanical shear forces and high demulsibility. However, rapeseed oil with viscosity improver did not show the tendency to create foam.

The application of vegetable base oils for manufacturing L-HV class hydraulic oil requires the modification of their antiwear and antiscuffing properties measured under increasing constant load of friction joint and low-temperature properties. In the case of the mixture of rapeseed oil and castor oil, it is necessary to lower the tendency for foam creation, and for rapeseed oil with viscosity improver it is necessary to improve the shear resistance and demulsibility. Keeping in consideration the chemical structure, it is necessary to modify the action of oxygen and exposure to high temperature for both oils.

The detailed analysis of the properties of vegetable base oils with regard to the standard requirements for L-HV class hydraulic oils and measured values of the additional parameters indicated that, for manufacturing hydraulic oils for agriculture machinery, it is more beneficial to use the mixture of rapeseed and castor oils. This mixture is better than the mixture of rapeseed oil and synthetic viscosity improver in respect to their shear resistance and demulsibility.

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Właściwości smarne i fizykochemiczne roślinnej bazy olejowej dla płynów hydraulicznych

Słowa kluczowe

Oleje roślinne, oleje hydrauliczne, bazy olejowe, właściwości smarne, właściwości fizykochemiczne.

Streszczenie

Przedstawiono wyniki badań roślinnych baz olejowych o klasie lepkości VG 46, wytworzonych z rafinowanego oleju rzepakowego. Lepkość oleju rzepakowego modyfikowano poprzez wprowadzenie oleju rycynowego lub syntetycznego wiskozatora. Oceniono właściwości smarne i fizykochemiczne olejów bazowych. Uzyskane wyniki badań odniesiono do wymagań normy PN-C-96057-6: „Oleje hydrauliczne do hydrostatycznych układów hydraulicznych. Oleje hydrauliczne L-HV”.

Stwierdzono, że roślinne bazy olejowe wykazywały wysokie właściwości przeciwzatarciowe w warunkach zacierania. Spełniały wymagania normy w zakresie właściwości reologicznych, przeciwkorozyjnych, zdolności do wydzielania powietrza i szybkości filtrowania. Cechowały się wysoką wartością temperatury zapłonu. Mieszanina oleju rzepakowego i rycynowego wykazywała dodatkowo wysoką odporność na ścinanie i korzystne właściwości deemulgujące. Z tego względu zaproponowano ją jako bazę dla olejów hydraulicznych rodzaju L-HV do maszyn rolniczych.