INFLUENCE OF PLANT OIL USE FOR FUEL SUPPLY AND HYDRAULIC SYSTEMS OF TRACTOR ENGINE

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Abstract. Plant oils were tested instead of the mineral ones to minimize the quantity of the imported oils and nature pollution. The oils for hydraulic systems were produced from *Žet-net* variety rape seeds by cold pressing with the screw press. The rapeseed oil was thermally processed (in the temperature reaching 260±5 ºC, processing duration – 1 hour) and catalysts were added – 25 % of cupric oxide. The rapeseed oil was stabilized by adding local plant admixtures. The viscosity of rapeseed oil used in hydraulic systems of agricultural machinery was 0.917 $g \cdot cm^{-3}$, the relative viscosity at 50 °C was 3.3 E_r, the alkaline number was 0.6 mg $KOH \cdot g^{-1}$, and the quantity of sulphur was 0.002 %. The test duration was 180 hours. The oil characteristics during the test practically remained unchanged, the hydraulic system maintained stability and worked without jerking. No oil foaming was noticed. The pressure in the hydraulic system during the tests was 12.0-12.8 MPa, oil temperature at the nominal loading did not exceed 43 ºC. The influence of rapeseed and linseed oil on high pressure hoses and polyethylene tubes used in the hydraulic system in relation to oil temperature was tested. This test lasted for 3500 hours. The largest change in the diameter of the rubber hoses was noticed when they were kept in rapeseed oil at the temperature of 75 ºC – it amounted to 18.6 % (in linseed oil – 11.8 %), the surface hardness decreased by 36.4 % (in linseed oil – 44.6 %). Neither kind of oil, nor the temperature had any influence on the PVC tubes.

Key words: plant oil, hydraulic system, mineral oil.

Introduction

Plant oils made from rapeseed, sunflower, linseed and other oilseed crops can successfully replace the mineral oils used in agricultural and forestry machinery. Their use for lubrication in chain machinery and use for filling hydraulic systems of tractors is gaining larger importance in practice [1-3]. Relatively frequent fluid leak or rupture in hydraulic systems of tractors results in the contamination of the ground by petroleum products and causes large material losses. Therefore, the use of plant oils in tractor hydraulic systems is very important for farm machinery.

The studies conducted by German researches showed that during a three week period only 30 % of mineral oil from the ground surface has been decomposed, when over the same period of time about 95 % of rapeseed oil has been decomposed [4]. It shows that the use of plant oil for hydraulic systems under our natural conditions is a viable subject. The literature sources indicate that hydraulic lubricants often work in extreme conditions; the oil temperature in hydraulic systems can reach the temperatures of 100 ºC and above [5]. Special requirements for lubricants of hydraulic systems are important: viscosity, oxidation, impurities, tar quantity etc. These requirements were taken into account in the feasibility studies of plant oil use for hydraulic systems carried out at Aleksandras Stulginskis University.

The goal of this paper is to evaluate the possibility of plant oil (rapeseed and linseed) use for hydraulic systems as well as to determine the potential adverse effects for rubber and plastic parts of hydraulic systems.

Materials and methods

The object of the investigation – rapeseed oil variety *Žet-net* and linseed oil, both obtained by the cold pressing method. The extracted oil was thermally treated at 260 ±5 ºC temperature adding 0.25 % of copper oxide, which acted as the catalyst. After heat treatment the oil was filtered. The resulting soap and tar were removed using 1 % silica gel and 2 % clay mixture while intensively stirring for 40 minutes at 90 ±1 ºC temperature. As a result, rapeseed oil with 0.917 $g \cdot cm^{-3}$ density, relative viscosity of 3.3 E_t (at 50 ºC temperature) and 0.002 % sulphur was obtained.

One of the main factors limiting the use of rapeseed oil in hydraulic systems is rapid oxidation. The oxidation process can be eased by using antioxidants. Many antioxidants have anti-corrosive properties as well [6]. The anti-oxidants and anti-corrosion additives used in mineral lubricants contain sulphur, nitrogen, phosphorus, and therefore, using them in plant oils is not appropriate. The use of antioxidants, which are common in the food industry is not profitable, therefore, natural extracts were used in the experiments, which accounted for 1 % of the total oil content. The oil corrosive properties mainly depend on the sulphur content in the oil, which is determined by the seed moisture content, seed varieties and oil pressure temperature [7].

The prepared plant oils have been tested in the hydraulic system of tractor MTZ-82. During the tests the oil temperature in the tank of the hydraulic system was measured using the thermometer TL-5, the accuracy of which was ±1 ºC, viscosity was measured using the "Engler" viscometer and density – using a hydrometer. The test duration was 180 h, and the total residence time of oil in the hydraulic system was 1100 hours.

The influence of rapeseed and linseed oil on the rubber and plastic components of the hydraulic system was analyzed in laboratory conditions. A high-pressure hose of tractor MTZ-82 hydraulic system and plastic (PVC) pipes were used in the tests. The specimen length was 50 mm, the outer diameter – correspondingly 22.0±0.2 mm and 10.5±0.15 mm. The samples were placed in glass 0.5 dm^3 volume containers, filled with rape and linseed oils. Before starting the tests, the oil viscosity and density at 20 ºC temperature was measured. The glass containers with the samples were stowed into a metal container with dimensions of 300 × 300 × 120 mm. In order to obtain the same heating of the samples the metal containers were filled with rapeseed oil. The metal containers were heated using an electric 0.4 kW power heater. The preset lubricant temperatures of 75, 55 and 35 ºC with ±2 ºC absolute error were maintained using the auto transformer AOSN-2-220. The temperature of oil was measured twice a day with a thermometer TS-4M, which has an absolute measurement error of 1 ºC. The test duration was 3500 hours.

At the end of the test the samples were removed from the glass tanks and dewatered at ambient temperature. The dimensions of the tested details were measured by a caliper with 0.1 mm accuracy. Hardness of the specimen surface was measured in accordance to the standard. After the tests the change of the oil viscosity and density was determined.

Results and discussion

The research data of use of natural antioxidants for rapeseed oil stability showed that the maximum effect was obtained when using the garlic and sage extract (Table 1). Accordingly, the obtained numbers of peroxide 1.21 and 2.10 show that this is equivalent to expensive antioxidant BGT used in the food industry, the peroxide number of which is 1.35.

Table 1

Stabilization of rapeseed oil by natural antioxidants

Extracts	Unit	Peroxide number
0.02 % BGT	$mekv \cdot kg^{-1}$	1.35
Sage	$mekv \cdot kg^{-1}$	2.10
Thyme	$mekv \cdot kg^{-1}$	2.40
Garlic	$mekv \cdot kg^{-1}$	1.21
Control	$mekv \cdot kg^{-1}$	4.51

Our studies have shown that the costs of antioxidants can be reduced by increasing the concentration of the active ingredients as well as mixing them with other antioxidants. This technique is promising in the preparation of biologically clean oil mixture.

Currently in Lithuania a variety *Star* of rapeseed with a low sulphur content in oil – 1-3 $mg \cdot kg^{-1}$ is most commonly grown. This variety of rapeseed is mainly used in food industry, but its seed yield is less than 2 $t \cdot ha^{-1}$. Varieties of winter rapeseed, such as *Žet-net*, are appropriate for technical use. These varieties are well adapted to the local conditions of the country. Their yield is 3-4 $t \cdot ha^{-1}$ of rapeseed, but the content of sulphur reaches 40 $mg \cdot kg^{-1}$ and more. The influence of the pressing temperature and the initial moisture content of rapeseed on the sulphur content in oil are shown in Figures 1 and 2.

The research data show that when increasing the moisture content of pressed seeds, the sulphur content in the oil increases as well. Noticeable increase of the sulphur content is observed when increasing the pressing temperature up to 80 ºC, but the influence of further pressing temperature growth results in a slight decline of the sulphur content. This is explained by the fact that during temperature increasing up to 80 ºC, the process of fermentative hydrolysis is accelerating, but it slows down when the pressing temperature continues to increase.

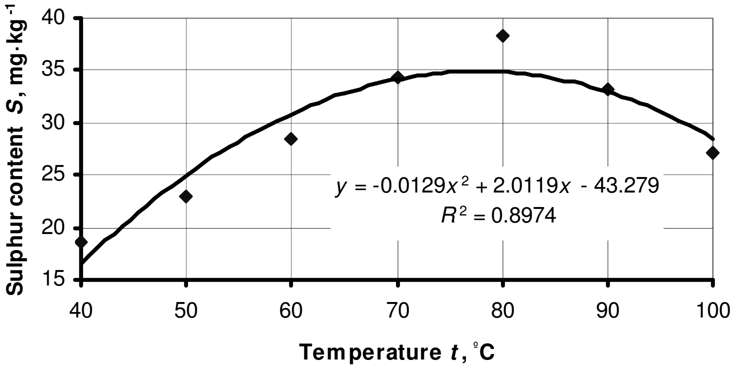

Fig. 1. **Influence of pressing temperature *t* on sulphur content *S***

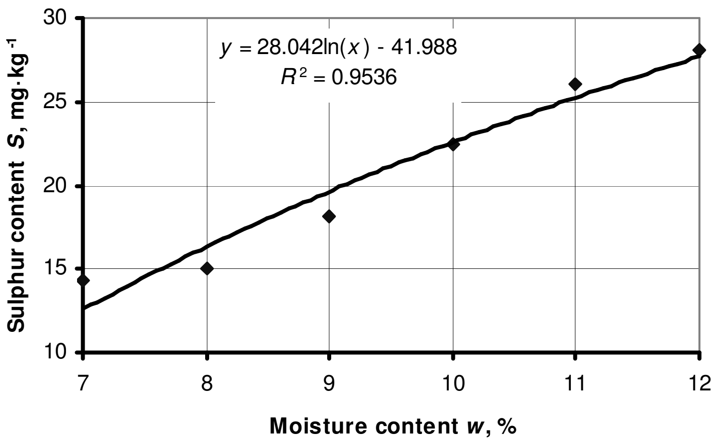

Fig. 2. **Influence of moisture content *w* of pressing rapeseed on sulphur content *S* when pressing temperature *t* was 50 ºC**

It should be noted that under extreme conditions when the pressing temperature was 80 ºC and seed moisture content 11 %, the sulphur content in the rapeseed oil did not exceed 0.004 %, which is about 20 times lower when compared to the amount of the sulphur content in the mineral oil type MG-22-A [8].

The testing of rapeseed oil in the hydraulic system of tractor MTZ – 82 showed that all components of the system worked steadily, the oil temperature was below the critical value – 125 ºC, the working pressure of the hydraulic system was 12.0 to 12.7 MPa. The characteristics of rapeseed oil before and after the tests are shown in Table 2.

Table 2

Characteristics of rapeseed oil

Indicators	**Units**	**Value of indicator**	
		before test	**after test**
Density	$G \cdot cm^{-3}$	0.917	0.914
Relative viscosity	E_t (t = 50 ºC)	3.3	4.1
Tar content	%	0	0
Acidity	mg $KON \cdot g^{-1}$	0.60	0.62
Pollution	%	0	0
Copper deposits	–	–	undetermined
Operating temperature:	ºC	–	–
unloaded	–	–	24.5
loaded	–	–	43.0

The table data show, that after 180 hours testing the density of rapeseed oil fell by 1 %, and the relative viscosity increased by 12.4 %. When the oil temperature was 43 ºC, it did not foam in the tank of the hydro system. The changes of the diameter of the rubber high pressure hose during testing are shown in Figure 3.

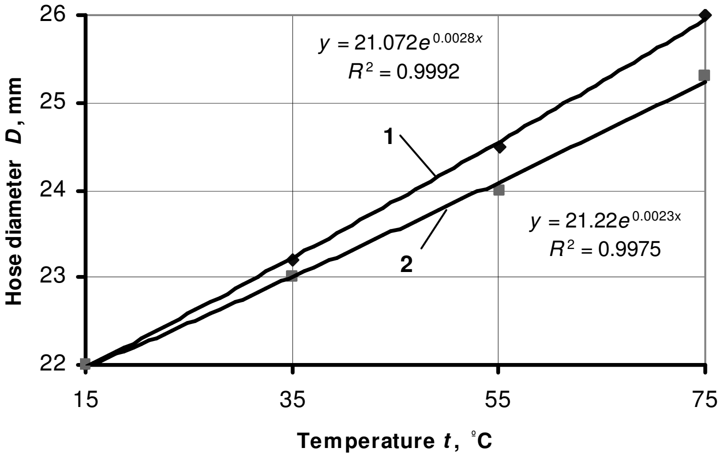

Fig. 3. **Changes of rubber hose diameter in oil of:** 1 – rapeseed; 2 – linseed

The data of tests showed that the rubber hose diameter increased by 18.6 % after being kept in rapeseed oil at the temperature of 75 ºC for 3500 hours, while keeping it in linseed oil – an average of 11.8 %. Neither the type of oil, nor its temperature affected the diameter of the plastic pipes. The dynamics of the strength of the rubber hoses is shown in Figure 4.

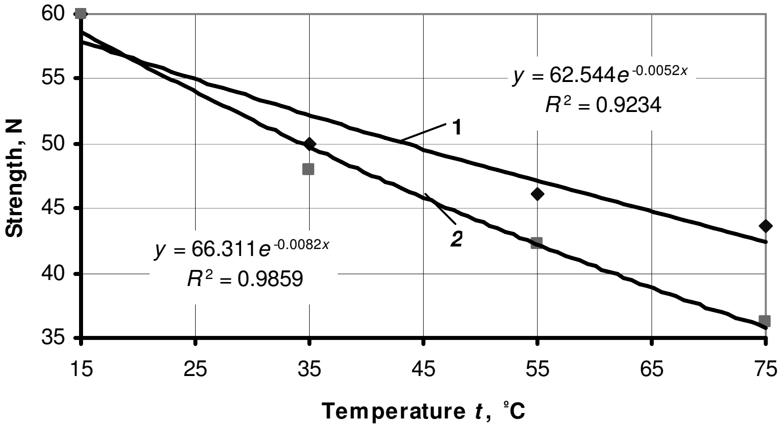

Fig. 4. **Change of rubber hose surface strength in oil of:** 1 – rapeseed; 2 – linseed

The test results showed that both rapeseed and linseed oil have a negative impact on the surface strength of the rubber hoses. It should be noted, that linseed is more aggressive than rapeseed oil, especially when the oil temperature rises above 35 ºC. The change of the surface strength of the plastic pipes when rapeseed oil was used has not been established, but the use of linseed oil at 75 ºC temperature influenced the decrease of the strength by 10.5 %. The changes of some physical features of rapeseed oil depending on temperature are shown in Table 3.

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The data in Table 3 show that rapeseed oil is sensitive to the long-term (3500 h) temperature effect. At 75 ºC temperature the viscosity has changed 3.7 times and the color changed from yellowish to dark (black). This is due to the process of oxidation and polymerization of natural oils.

We can summarize that increasing the oil temperature increases the negative impact on the rubber high-pressure hoses. On plastic tubes this effect is not significant. The results correlate well with the German scientists who have studied the RME (rapeseed methyl ester) influence on the rubber parts of the power system [9]. Therefore, the rubber parts of the tractor hydraulic and fuel supply systems, using plant oils or their mixtures, need to be replaced by parts made of polyamide.

Table 3

Influence of temperature change on some physical properties of rapeseed oil

Indicators	Units	Control	Temperature, ºC		
			35	55	75
Relative viscosity	E_t	3.7	5.7	8.7	13.9
Density	$g \cdot cm^{-3}$	0.915	0.922	0.933	0.938
Coloring	–	Yellowish	Greenish	Light Brown	Dark (Black)

Conclusions

1. During cold pressing of rape seed variety *Žet-net*, oil with the density of 0.917 $g \cdot cm^{-3}$, the relative viscosity at 50 ºC temperature of 3.3 E_t, acidity of 0.6 mg $KON \cdot g^{-1}$, sulphur content of 0.002 % and without tar was obtained.
2. Using natural garlic, sage and thyme extracts as natural antioxidants in quantities up to 1 % of oil total weight allows stabilizing the oxidation process.
3. Rapeseed oil negatively affects the rubber hoses of the hydro system of tractor MTZ-82. At the 75 ºC oil temperature and 3500 h of exposure the diameter of the rubber hoses increased by 18.6 % and the hardness of the surface decreased by 36.4 %. Plastic hoses were not affected by these conditions.
4. The hydro system of tractor MTZ-82 that used rapeseed oil worked stable. The pressure in the system ranged from 12.0 to 12.7 MPa, at nominal load the oil temperature did not exceeded 43 ºC, oil foaming was not noticed.

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