IOP Conf. Series: Materials Science and Engineering **177** (2017) 012108 doi:10.1088/1757-899X/177/1/012108

Tribological properties of hydraulic fluids modified by peat-based additives

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Abstract. The paper presents physicochemical investigations of the structure and properties of a nano-modifier synthesized from peat, the local raw material subjected to pyrolysis in air-free conditions. This nano-modifying additive is a combination of various forms of nanocarbon and polar and non-polar adsorbing materials such as silica (SiO_2), calcium carbonate ($CaCO_3$) and carbon (C). Different nanocarbon forms (nanotubes, fullerenes, nanodiamonds, nanofiber, nanodispersed carbon) used in different proportions with micro and macro peat components give multifunctional properties to the synthesized nano-modifier and the ability to positively change tribological properties of hydraulic fluids and oil lubricants. Test results of type TMT-600 show that its different percentage is required to modify tribological properties of the steel tribocouple under different loading conditions. At 0.5 wt.% content of this nano-modifier, stabilization of the friction ratio and an increase of seizure load are observed.

1. Introduction

Currently, nanomodifiers are being widely used in different fields of science, technology, and production [1-6]. However, in spite of their high efficiency, the use of nanomodifiers is often restricted by synthesis and expensiveness. Therefore, today the nanomodifier synthesis methods are not only the relevant but also important and significant problem of practical and theoretical interest, which should satisfy the criteria for technological availability and efficiency, energy and resource saving, ecological safety, natural balance, biocompatibility, and economic feasibility[7-9].

In-situ resources of the Siberian region allow the researchers to develop peat-based modifiers for the property control of dry mix mortars and other composite materials. The stock of this partially renewable resource available in Tomsk region achieves 29.3 billion tons per year per 40% humidity. In terms of this factor, Tomsk region ranks second after Tyumen region.

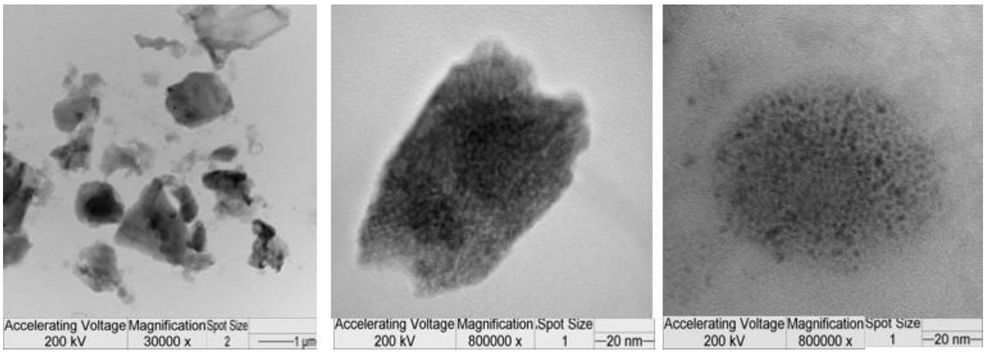
During the thermal treatment of peat, the larger amount of organic substances is subjected to destruction. The modifiers obtained due to the thermal treatment are divided into four types depending on the treatment temperature. These types are organic modifiers (200ºC); organomineral (400ºC) with prevailing organic substances; mineral-organic (600ºC) with prevailing mineral substances; and mineral (800ºC and higher) with a low amount of organic substances [10-11].

2. Materials and methods

The synthesized TMT-600 additive is used in construction industry to control the properties of cement systems. The comprehensive analysis provides the information on the structure and properties of this additive. Pyrolized peat in the amount of 100 mg was put into a container with 5 ml of 96% ethanol and then dispersed in ultrasonic bath ST-400D at 60 W. The obtained suspension was settled for 5 min. During this period, the coarse particles precipitated on the bottom of the container, while the suspension divided into two visible layers. Two or three drops of the suspended matter were pipetted from each of the three layers (including the lowest sediment layer) and then put onto the clear surface of the specimen glass. After drying of the suspended matter, the carbon film was sprayed onto the specimen glass and then torn from it by gelatins. The obtained specimens were investigated on the transmission electron microscope (TEM) 'JEM-2100' at 200 kV of accelerating voltage and in different magnification ranges.

3. TEM investigations

TEM investigations show that the particle size varies from tenths of a micrometer to several micrometers (Figure 1).



(a) (b) (c)

Figure 1. TEM images of particle formation: *a* – in sediment; *b, c* – clusters of fine particles.

Along with the formation of coarse particles, we observed the clusters of fine particles with the size of less than 5 nm (Figure 2 b, c) and elongated particles or nanofibers having the size of 200 nm and larger at their cross-section of 20 nm and less (Figure 2).

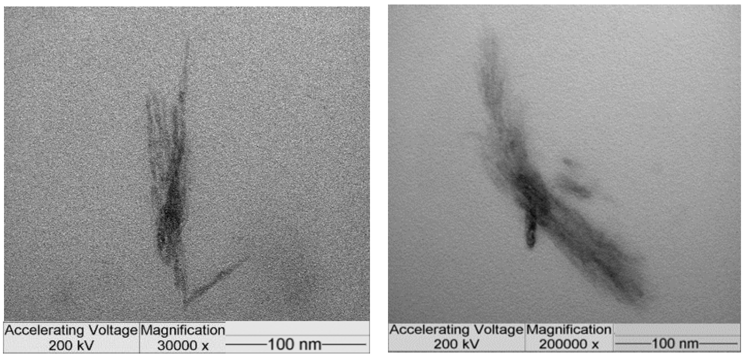
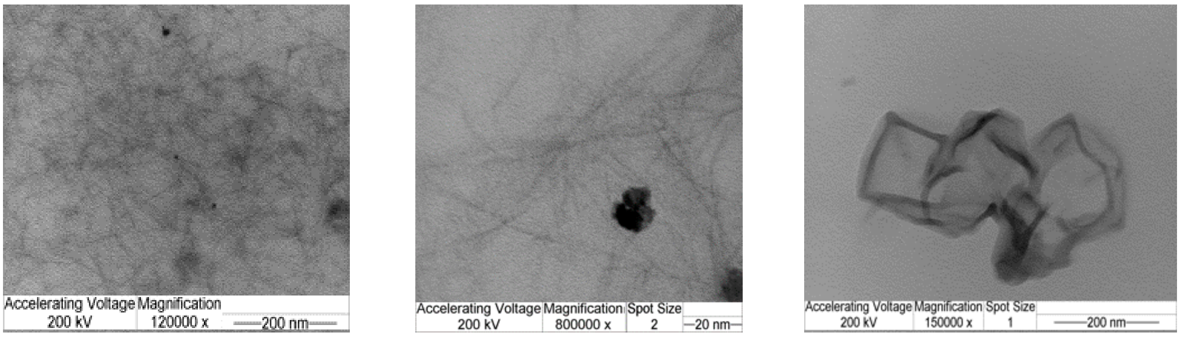


Figure 2. TEM images of nanofibers.

Isolated particles are formed in the central and upper layers of the suspension similar to those presented in Figure 1. Moreover, nanofibers 200 nm long having 2-4 nm in diameter are present in this suspension. Also, there are 10-20 nm particles with an irregular shape which adhere to these nanofibers (Figure 3).



(a) (b) (c)

Figure 3. TEM images of nanofibers: *a*, *b* – nanoparticles; *c* – particles with an irregular shape.

In all suspension layers, the observed particles possess the clearly visible periodic structure (Figure 4) represented by nanotubes. The size of the periodic structure ranges from 1.0–1.2 nm to 4.7–4.8 nm.

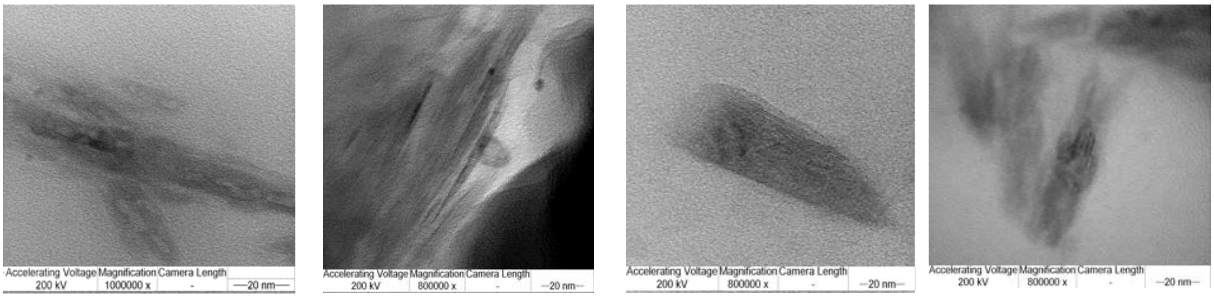


Figure 4. TEM images of nanoparticles with the periodic structure.

According to physicochemical investigations of the TMT-600 additive, it is the efficient mixture of different forms of nanocarbon including micro and macro peat components. The quantitative content of this additive is given in Table 1.

Table 1. Quantitative content of the TMT-600 modifier

Composition	**Size (nm)**	**Content (%)**
SiO_2	>400	43.81
$CaCO_3$	180	47.99
C (graphite)	15	7.77
$CaAl_2Si_2O_8$	100	0.31
C60	10-20	0.12

Carbon-based nanomodifiers have already found their use in engineering industry. As it is known, one of the dominant requirements for machining fluids is their lubricating capacity which prevents mechanisms from increased wear and frictional seizure in tribocoupling [12-13].

Nanostructure materials are characterized by the ability to modify the tribological properties of lubricants. Of great interest is the research carried out into the service properties of hydraulic oils modified by nanostructure materials.

Lubricants are estimated by such parameters as a frictional ratio, a loading capacity (at which frictional seizure of specimens occurs), and wear resistance.

The miltifactorial experiment includes the rotating roller–stationary shoe tribocoupling with immersion in oil.

The I-20-type hydraulic oil was the original material subjected to friction and wear tests. New shoes were produced for each experiment for the roller–shoe friction pair. The roller was cut from BelAZ 7540 wrist-pin made of the 15X steel type, while the shoe material was the 20 steel type. The rollers were made of 15X steel type having 60 Rockwell hardness and 0.63 surface finish. The contour area of contact was 0.55 cm^2. The experimental matrix is given in Table 2.

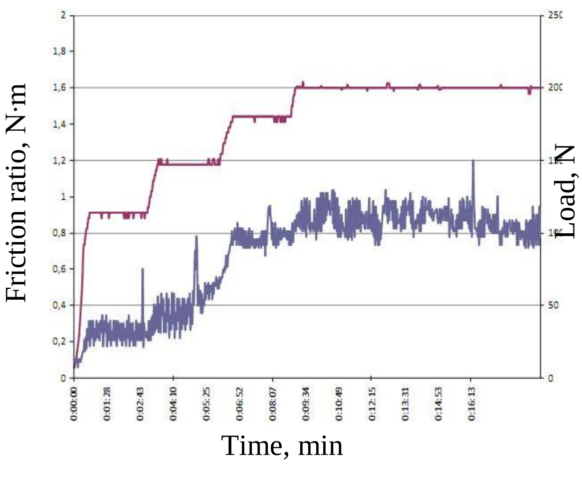
Table 2. Experimental matrix.

No.	Hydraulic oil	Friction pair	Test type	TMT-600 concentration in base oil (%)
1	I-20	Steel 15X – Steel 20	Antifrictionality, score resistance	
2	I-20+ TMT-600	Steel 15X – Steel 20	Antifrictionality, score resistance	0.01; 0.1; 0.5 1.0; 5.0

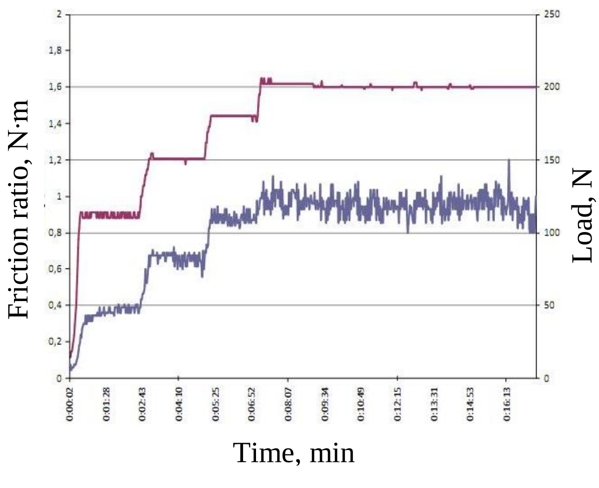
The antifriction tests were conducted under the dead load and the following conditions:

– 2.5 m/s sliding speed in I-20 and I-20+TMT hydraulic oils;
– 200 N normal load on each specimen for I-20 hydraulic oil;
– 60 min test duration for I-20 and I-20+TMT hydraulic oils.

Tribological tests were conducted on the original test bench ‘TK-2’ produced in the research laboratory of Tomsk State University of Architecture and Building. Wear resistance, antifriction properties, and loading capacity of oil additives were estimated by the wear-in of specimens in pure and modified oil compositions until the friction ratio achieved its stationary value. The wear-in process was carried out at a step load not exceeding 0.75 N. The scuffing load capacity of hydraulic oils was detected under the step loading of specimens up to their frictional seizure.



(a)



(b)

Figure 5. The friction ratio and load dependences for: *a* – pure reference hydraulic oil; *b* – modified oil at 0.5% TMT-600 content.

Some of the experimental findings, obtained in accordance with Table 2, are presented in Figure 5 and Table 3 in the real-time mode.

Table 3. Ultimate loads for investigated lubricants

TMT-600 content (%)	Load ratio (%)
0.01	No change
0.1	No change
0.5	+36
1.0	+53
5.0	-41

The studies of tribological properties of hydraulic oils modified by the TMT-600 additive will be further explained in our future works.

3. Conclusion

The experiments showed that the peat-based modifier improved the efficiency of hydraulic fluid lubricity. The modification of tribological properties of hydraulic fluids is of great theoretical and practical interest, since the peat dust has a negative effect on the friction and wear processes. Since the size of the modifier particles lies within the nanoscale level and that of the peat dust – within the micro and millimeter range, the nanodisperse state plays the important part in the reduction of friction and wear energy in machine parts and units.

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