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EVALUATION OF LUBRICATING PROPERTIES OF TITAN TRUCK PLUS 15W40 OIL USED IN MARINE DIESEL ENGINES

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Abstract

The paper presents the results of lubricating properties tests of Titan Truck Plus 15W40 motor oil. Tested oil was used in Caterpillar 3512B high-speed engines, which propelled the tug boat. The lubricating properties parameters were determined for fresh oil and used oil samples. Builder of Caterpillar 3512B engine recommends lubricating oil change after every 1000 hours of operation. Lubricating oil samples were taken from engine oil system after 342 hours of service and after 1024 hours of service, it means just before lubricating oil change.

The test results were collected by means of a four-ball extreme pressure tester T-02 according to Polish Norm PN-76/C-04147. The following lubricating properties parameters were determined: weld load P_z, maximum non-seizure load P_n, seizure load P_t and load wear index I_h. Investigations showed that for used oil samples maximum non-seizure load and seizure load increase but weld load and load wear index decrease. These results indicate that used oil has higher boundary layer resistance (better antiwear properties) but worse antiseizure properties, which are determined in hard working conditions of the sliding node elements.

In author's opinion, worsening of the antiseizure properties results of solid impurities presence, which come from lubricating oil deterioration process. To verify that thesis the detail analysis of the tested oils chemical content has been made. Spectrol Q100 spectrometer, which can specify content of 24 chemical elements in the lubricating oils was used for this purpose.

***Keywords**: marine diesel engine, lubricating oil, lubricating properties, oil deterioration*

1. Introduction

Diesel engine lubricating oil is affected by high temperature, pressure, oxygen from air and also is contaminated by friction nodes wearing particles, water, fuel, fuel combustion products and contaminants from ambient atmosphere (for example dust, sand). As a result of these impacts the complex, multistage chemical and physical process of lubricating oil alteration, known as oil deterioration, takes place. That process has disadvantageous influence on lubricating oil quality and its functions performed in diesel engine. Level of oil deterioration is characterized by values of lubricating oil properties like: viscosity, concentration of impurities, ability to neutralize acid combustion products and impurities dispersion [1, 4-6]. On the other hand, a certain kind of impurities formed in oxidation process it means organic fouling like: organic acids, tars, asphaltenes are surface active, asymmetrical chemical compounds so called electric dipoles. These compounds create on the metal surface the boundary layer thus improving used oils lubricating ability.

Lubricating ability as a definition appeared in technical literature at the end of 19th century, but so far, it was not clearly determined and has not unit of measure. Lubricating ability is determined on the basis of lubricating parameters. There is Polish Norm PN-76/C-04147, which describes methods of testing lubricating properties parameters of oils and greases by means of a four-ball extreme pressure tester. According to this norm the following lubricating properties parameters are determined: weld load P_z, maximum non-seizure load P_n, seizure load P_t and load wear index I_h.

The paper presents the results of lubricating properties tests of Titan Truck Plus 15W40 motor oil used in trunk piston marine diesel engine Caterpillar 3512B. The test results were collected with a four-ball extreme pressure tester T-02 according to Polish Norm PN-76/C-04147.

2. Test stand and research method

The test results were collected by means of a four-ball extreme pressure tester T-02 which was provided with computer-aided control and measurement systems. This apparatus was designed and manufactured at ITeE in Radom for the purpose of measuring motion resistance, wear and anti-seizure abilities in the presence of lubricant. The methodology of the tests is compatible with the Polish Norm (PN-76/C-04147), and it was described in [7-10].

The tribosystem, presented below on the Fig. 1, consists of four chrome alloy bearing steel balls (100 Cr6) with diameter 12.7 mm (0.5 in.), surface roughness R_a = 0.032 μm and Rockwell hardness 60 HRC. Three stationary lower balls (2) are fixed in the ball pot (4) and pressed at the required load *P* against the top ball (1). The top ball is fixed in the ball chuck (3), and it rotates at the defined speed *n*. In this way, pure sliding appears between the balls. Rotational of the top ball causes frictional torque, which produces a scar on the three lower balls. The contact zone of the balls was immersed in the tested lubricant. A very important feature of T-02 tester is the possibility of continuous increase of load *P* during a run. Also rotational speed *n* can be changed within a wide range.

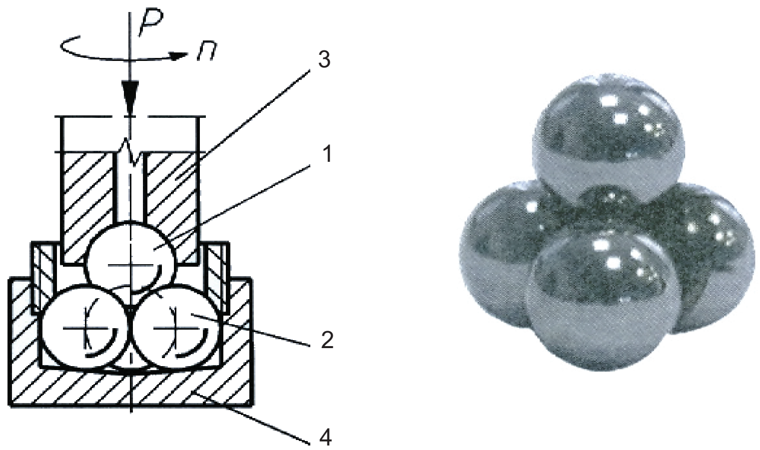

Fig. 1. Friction node of four-ball tester: 1 – top ball, 2 – lower balls, 3 - top ball chuck, 4 – lower balls pot [10]

Research was executed for Titan Truck Plus 15W40 a long term, all season engine oil for diesel and gasoline engines. It has been developed specially for highly loaded diesel engines. This oil has a significantly higher additive ratio than conventional high-performance engine oils. Oils of this type are designed as SHPD (Super High Performance Diesel Oil). Especially in supercharged diesel engines, SHPD oils provide significant advantages with regard to piston cleanliness, wear and greater power reserve. Characteristics of Titan Truck Plus 15W40 are presented in Tab.1.

Tab. 1. Physical properties of the Titan Truck Plus 15W40 engine oil

No.	Parameter	Value
1	Density at 15°C [g/ml]	0.887
2	Flash point [°C]	230
3	Pour point	-35°C
4	Viscosity index	138
5	Kinematic viscosity at 100°C [mm^2/s]	13.9
6	Kinematic viscosity at 40°C [mm^2/s]	104

Tested oil was used in Caterpillar 3512B high-speed engines, which propelled the tugboat. The lubricating properties parameters were determined for fresh oil and used oil samples. Builder of Caterpillar 3512B engine recommends lubricating oil change after every 1000 hours of operation. Lubricating oil samples were taken from engine oil system after 342 hours of service and after 1024 hours of service, it means just before lubricating oil change.

The following lubricating properties parameters were determined according to Polish Norm PN-76/C-04147: weld load P_z, maximum non-seizure load P_n, seizure load P_t and load wear index I_h.

In the first stage, the following parameters were assumed: maximum non-seizure load P_n, weld load P_z and load wear index I_h. The wear characteristic ($d = f(P)$), for the applied load was determined at room temperature, from 10-s runs of the set of four steel balls. The top ball rotated at 1450 rpm. The first test was performed under applied load F = 784.8 N. The load was stepped up (in accordance with the standard) in the next tests until the rotating ball became welded to the three fixed balls. New balls were used for each test, and all pieces and balls were first cleaned with solvent and then dried. In order to assess anti-wear properties of the tested lubricants, after each experiment the wear scar diameters of the balls were measured through a magnifying glass with an accuracy of 0.1 mm. On each of the three lower balls, two measurements of the wear spots were made: parallel and perpendicular to the motion and the average scar diameters were calculated. For each load, one run was performed, but when welding occurred, check runs were made.

In order to assess seizure load P_t, tests with linearly increasing load were performed. During the measurements, the load increased from 0 to about 7400 N with constant speed of 409 N/s. The rotational speed was also constant, equal to 500 rpm. The load increasing time was approximately 18 s – until the highest load was reached. It is assumed that the test finishes when seizure takes place, i.e. at the time of exceeding 10 Nm friction torque. If seizure is not detected, attaining of maximum load finishes the test. For each tested lubricant at least three runs were performed and the results were averaged.

3. Research results

Results of lubricating properties tests of Titan Truck Plus 15W40 diesel engine oil are given in Tab. 2 and Fig. 2-3.

The Fig. 2 presents comparison of the following lubricating properties parameters: maximum non-seizure load P_n, seizure loads P_t, load wear index I_h and weld load P_z. The maximum non-seizure load P_n and seizure load P_t characterize boundary layer resistance and serve to determine conditions in which destroying of these layer takes place and seizing begins. Weld load P_z and load wear index I_h show antiseizure properties of the lubricant. It is shown that:

- maximum non-seizure load P_n increases from 785 N to 981N at the end of oil service life - after 1024 hours of service,
- weld load P_z decreases (from 3090 N to 2452 N) for used oil samples,
- load wear index I_h also decreases (from 468 N to about 300 N) for used oil samples,
- seizure load P_t increases for used oil samples.

One can observe that for used oil samples parameters P_n, P_t increase and parameters P_z, I_h decrease. These results indicate that used oil has higher boundary layer resistance (better antiwear properties) but worse antiseizure properties, which are determined in hard working conditions of the sliding node elements. The load wear index is calculated according to Polish Norm PN-76/C-04147 and its lower value for used oils samples results from higher scar diameters measured on the balls. The wear scar diameters in load function for Titan Truck Plus 15W40 engine fresh oil sample and used oils samples (after 342 and 1024 hours of service) are presented in Fig. 3. It can be seen from Fig. 3 that for the lowest loads (785 and 981 N), the scar diameters on the balls are smaller for used oils samples but for higher loads (with effect from 1236 N) of the sliding node, the scar diameters are smaller for fresh oil sample. At the load 2452 N the scar diameters on balls were measured only when fresh oil was used. The average value of scar diameters was 3.58 mm.

Friction node elements lubricated by used oils were sized up.
Used oils antiseizure properties worsened (P_z and I_h parameters decreased). Probably as a results of solid impurities presence which come from lubricating oil deterioration process. Solid impurities influence can have different character depending on their kind (organic and inorganic impurities), size and place in friction node. Organic impurities not always increase wear of friction node elements in contradistinction to inorganic impurities. Size of solid impurities has essential influence on critical thickness of oil film and wear of friction surfaces [11].

Tab. 2. Lubricating properties of Titan Truck Plus 15W40 engine oil

Lubricating properties parameters	Titan Truck Plus 15W40	Titan Truck Plus 15W40 after 342 hours of service	Titan Truck Plus 15W40 after 1024 hours of service
P_n [N]	785	785	981
P_z [N]	3090	2452	2452
I_h [N]	468	293	305
P_t [N]	2200	2350	2733

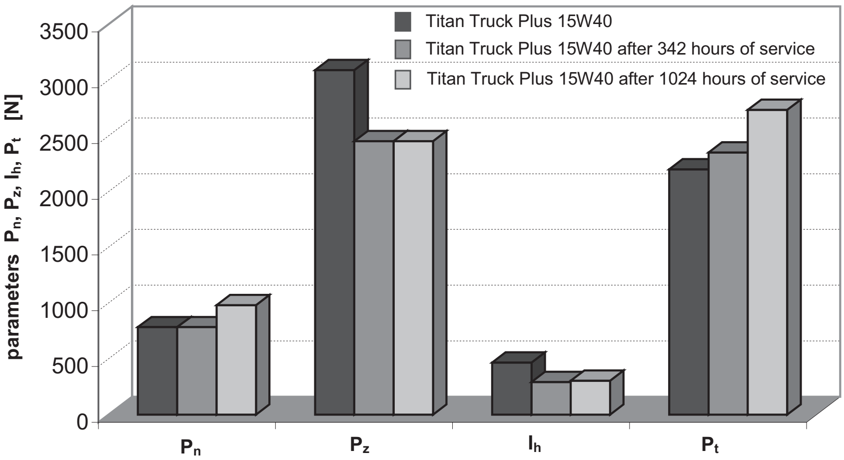

Fig. 2. Lubricating properties of Titan Truck Plus 15W40 engine oil

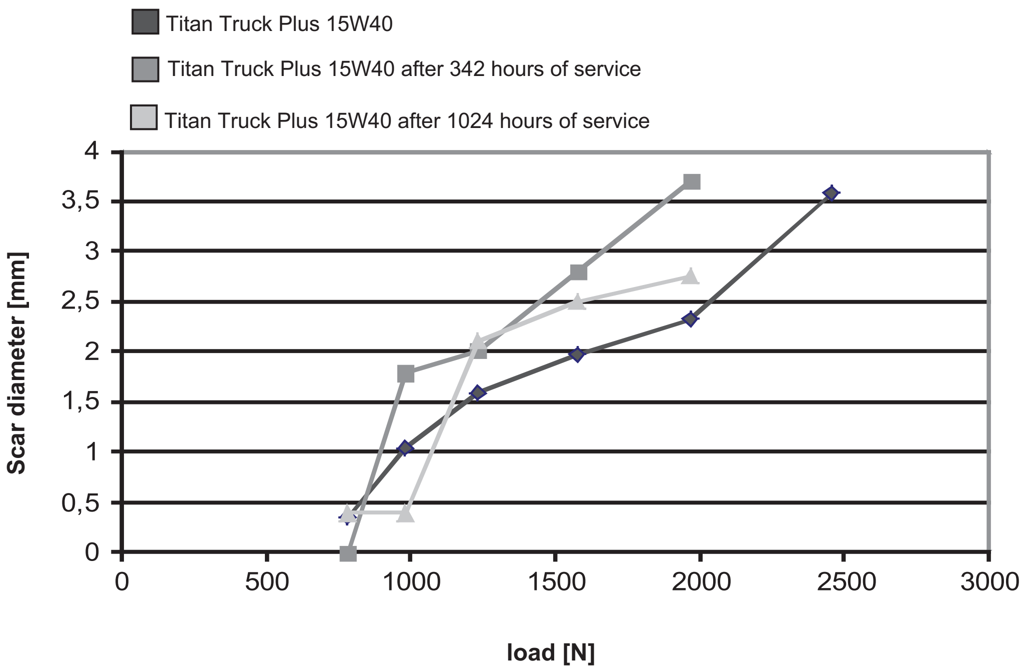

Fig. 3. Wear scar diameters in load function for tested lubricants

4. Analysis of the tested oils chemical content

To verify the thesis that lubricating oil antiseizure properties were worsened by solid impurities presence the detail analysis of the tested oils chemical content has been made. Spectrol Q100 spectrometer, which can specify content of 24 chemical elements in the examined oils, was used for this purpose. Research results are presented in Tab. 3.

Tab. 3. Chemical elements content in tested oils

Lub.oil service hours [h]	Chemical elements content [ppm]										
	Ag	Al	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg
0	0.061	0.778	29.104	0.114	185.25	0.526	0.314	0.00	0.00	0.477	0.735
342	0.055	3.556	3.169	0.552	2854.1	0.482	0.318	1.176	0.979	2.275	8.139
1024	0.042	3.536	3.281	0.532	2811.8	0.372	0.252	3.49	2.024	1.710	8.989

Lub.oil service hours [h]	Chemical elements content [ppm]										
	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Ti	V	Zn
0	0.403	2.569	1.115	0.230	485.65	0.33	0.411	0.00	0.034	1.743	140.13
342	1.203	3.986	54.055	0.228	1338.7	2.713	3.626	0.00	0.407	1.89	1485.0
1024	1.106	3.693	52.018	0.132	1401.4	2.718	2.936	0.00	0.726	1.451	1622.4

Chemical elements like Al, Cd, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, Ag, Sn, Ti, Zn, which are present in used oil, may indicate on wearing of engine's construction elements. Chemical elements like Na, V, Al, Si are impurities from fuel, but Mg, Ca, Na, P from water or coolant and Si from dust [11]. One can observe strong growth of Al, Ca, Cu, Fe, Mg, Na, P, Si and Zn chemical elements content in used oils samples (Tab. 3). In particular, the large increase of Na and P chemical element contents is puzzling. These results showed possibility of coolant leakages to lubricating oil system.

5. Summary

The results of lubricating properties tests of Titan Truck Plus 15W40 motor oil used in Caterpillar 3512B high speed engines which propelled the tug boat showed that for used oil samples parameters P_n, P_t increase and parameters P_z, I_h decrease. These results indicate that used oil has higher boundary layer resistance (better antiwear properties) but worse antiseizure properties, which are determined in hard working conditions of the sliding node elements. Lubricating oil antiseizure properties worsening (P_z and I_h parameters decrease) probably results from solid impurities presence, which comes from lubricating oil deterioration process. So as to verify this thesis the detail analysis of the tested oils chemical content has been made with Spectrol Q100 spectrometer. The strong growth of Al, Cu, Fe, Mg, Pb and Zn chemical elements content, which presence in used oil may indicate on wearing of engine's construction elements, was observed. The large increase of Na and P chemical element contents was also seen. These results showed possibility of coolant leakages to lubricating oil system.

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