Investigation of Engine Oil Wear by Nuclear Magnetic Resonance

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Using methods of optical metallography, nuclear magnetic resonance (NMR) and end friction of samples made of 45 steel at a load of 500 N for 0.5 and 3.0 hours, the mechanism of wear (triggering) of cleaning additives in mineral motor oil M-6Z/12G1 was studied. It is shown that with an increase in the time of end friction (engine operation) and an increase in the number of wear particles, a significant decrease in the time of spin-spin relaxation of protons and the enlargement of molecular complexes is observed in engine oil, due to the enveloping of wear particles with additives.

Keywords (from 3 to 5 max): friction, wear, nuclear magnetic resonance, mineral motor oil, additives

1. Introduction

It is known that the time for replacing engine oils is very short and, for example, for a passenger car is 6 ... 8 thousand km of mileage [1]. Detergents are additives that are added to the oil to ensure that the engine surfaces are clean during operation.

2. Methods

The kinetics of interaction of wear particles with oil additives was studied using optical metallography, nuclear magnetic resonance (NMR), and end friction of steel 45 in motor oil M6z/12G1 at a load of 500 N for 0.5 and 3.0 hours. A small-sized NMR tomograph [2] was equipped with a permanent magnet with a field of 0.127 Tl and a proton resonance frequency of 5.44 MHz

2.1. Results nuclear magnetic resonance.
To describe the drop in the amplitudes of NMR signals from the oil proton relaxation time, the time dependence A(t) was used (see Fig. 1(a, c, f)):

$$A(t) = Ca \times \exp(-t/T2a) + (1 - Ca) \times \exp(-t/T2b)$$

where, T2a, T2b, T2average, (in microsecond) - the spin-spin relaxation time of protons; Ca = 60% - characterizes the percentage of those molecular compounds that have shorter relaxation times (see table 1). In the table: 1o, 2o and 3o – oil samples in the initial state, after 0.5 and 3.0 hours of end friction, and then after 10 days of exposure to the formation of a sediment of wear particles; 1t, 2t and 3t – the same samples after shaking to dissolve the sediment.

Table 1: M6z/12G1 oil proton relaxation time

A sample of oil	**T_2 a, mcs**	**T_2 b, mcs**	**T_2 cp, mcs**	**C_a %**
1_o	0,80	0,85	0,44	60,06
1_t	0,90	1,70	0,50	59,80
2_o	0,60	0,80	0,40	59,20
2_t	-	-	0,30	-
3_o	0,35	0,70	0,25	58,86
3_t	-	-	0,11	-

2.2. Results of optical metallography.
As shown by the results of optical microscopy, Fig.1 (b, d, g), with an increase in the time of end friction, molecular complexes were enlarged, due to the enveloping of wear particles with additives.

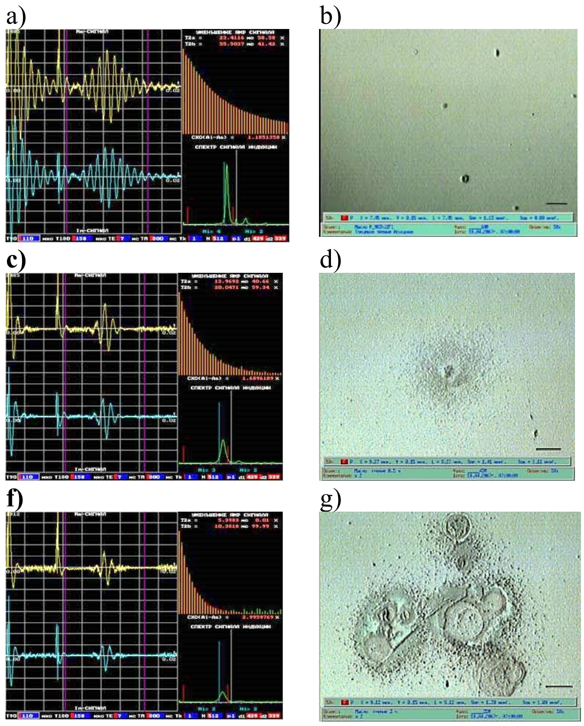

Figure 1: Monitoring the response of cleaning additives in engine oil during engine operation, by recording the time of spin-spin relaxation of oil protons by nuclear magnetic resonance (NMR), (a, c, f) and optical metallography (b, d, g) in the initial state (a, b), after mechanical friction in the oil for 0.5 h (c, d) and 3.0 h (f, g).

3. Discussion

As the end friction time increases and the number of wear particles increases, there is a significant decrease in spin-spin relaxation times for engine oil samples. The reason for the decrease in the content of cleaning additives in the oil is the surface interaction of oil molecules with ferromagnetic particles (wear products).

4. References

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