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PROPOSITION OF METHODOLOGY FOR ENGINE LUBRICANTS RHEOLOGICAL PROPERTIES ESTIMATION

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Abstract

The paper presents methodology of engine lubricants' rheological properties estimation, that is extended in comparison with SAE J 300 specification. Modifications implemented in proposed method allow for better assessment of depressants and viscosity improvers added to engine lubrication oils. This methodology can be applied both at the stage of new formulations as in case of extended assessment of engine lubricants offered on commercial market.

Key words: *engines, engine oils, lubricants, rheological properties, laboratory tests*

1. Introduction

Tribological properties of engine lubricants have been defined, both in the scope of test methods and requirements, in SAE J 300 viscosity classification [1].

Table. 1. SAE J 300 engine oils viscosity classification

SAE Visco-sity grade	Low temperature viscosity (starting), mPas, in temperature, ^{0}C	Low temperature viscosity (pumping), mPas, in temperature, ^{0}C	Kinematic viscosity in temperature 100^{0}C, mm^2/s		HT/HS viscosity in 150^{0}C temperature, mPas
	max.	min.	min.	max.	min.
0W	6200 w -35	60000 w -40	3.8	-	-
5W	6600 w -30	60000 w -35	3.8	-	-
10W	7000 w -25	60000 w -30	4.1	-	-
15W	7000 w -20	60000 w -25	5.6	-	-
20W	9500 w -15	60000 w -20	5.6	-	-
25W	13000 w -10	60000 w -15	9.3	-	-
20	-	-	5.6	<9.3	2.6

SAE Visco-sity grade	Low temperature viscosity (starting), mPas, in temperature, ^{0}C	Low temperature viscosity (pumping), mPas, in temperature, ^{0}C	Kinematic viscosity in temperature 100^{0}C, mm^2/s		HT/HS viscosity in 150^{0}C temperature, mPas
	max.	min.	min.	max.	min.
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	2.9 (for 0W-40, 5W-40 and 10W-40)
40	-	-	12.5	<16.3	3.7 (dla 15W-40, 20W-40, 25W-40 and 40)
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

2. Interpretation of SAE J 300 viscosity classification

Rheological properties test methods differ from one another in the scope of:

- test tempetrature,
- shear stress,
- cooling or heating time,
- viscosimeters construction.

Table 2. Selected parameters in test methods of engine oils reological properties

Parameter	Test method	Shear stress	Temperature of testing	Cooling/ heating time	Viscosity measure-ment
Low temperature viscosity (starting)	ASTM D 5293	high	-10, -15, -20, -25, -30 and –35^{0}C	240 s	pointwise
Low temperature viscosity (pumping)	ASTM D 4684	low	-15, -20, -25, -30, -35 and -40^{0}C	from 45 to 51 h	pointwise
Kinematic viscosity	ASTM D 445	low	100^{0}C	900 s	pointwise
HT/HS viscosity	ASTM D 4741 ASTM D 4683	high	150^{0}C	120 s	pointwise

The main advantage of SAE J 300 viscosity classification is that it reflects the operating conditions of lubricant in an engine:

- During start-up,
- Immidiately after start-up, during lubricant pumping into tribological system,
- In connecting-rod bearings.

The main advantages of SAE J 300 viscosity classification are:

- Pointwise measurements of viscosity,
- Not reflecting the process of engine lubricant mechanical degradation during normal operation.

The attempt has been made to implement to SAE J 300 viscosity classification a low temperature method, that to complete measurements of dynamic viscosity (pumping), based on continuous measurement of lubricant dynamic viscosity during long-term cooling. It is a Brookfield scanning test performed according to ASTM D 5133 standard.

In the scope of taking into consideration the process of lubricant viscosity decrease due to mechanical degradation of viscosity improvers, no requirements have been implemented. The only test method is testing the decrease of viscosity after 30 shear cycles in „pump-injector" rig, which was implemented in different specifications for engine oils.

3. Proposition of a method for estimation of engine lubricants rheological properties

Some percentage of engine lubricants offered on the market do not conform to requirements of SAE J 300 viscosity classification in the scope of rheological properties.

Table 3. Results of rheological properties tests of SAE 15W-40 engine lubricants (according to ASE J 300) offered on Polish market [2]

Parameter, unit of measurement	Requirement according to SAE J 300	Results of tests				
		Oil no. 1	Oil no. 2	Oil no. 3	Oil no. 4	Oil no. 5
Kinematic viscosity in 100^0C, mm^2/s	12,5-16,3	13.33	**11.96**	14.87	**16.54**	14.39
Kinematic viscosity in 40^0C, mm^2/s	-	97.23	89.34	104.5	154.5	118.7
CCS viscosity in -20^0C, mPa·s	max. 7000	6700	6500	6200	**9700**	**7200**
MRV viscosity in -25^0C, mPa·s	max. 60000	23800	22600	19400	56900	35600
HTHS viscosity in 150^0C, mPa·s	min. 3.7	3.7	**3.3**	4.1	4.7	3.7

Next problem is that engine lubricants, even conforming to requirements of SAE J 300 classification In scope of rheological properties, sometimes are a reason of engines failures.

So the authors of this paper propose the wider consideration of engine lubricants reological properties testing.

Proposed methodology of rheological properties testing extends requirements of SAE J 300 viscosity classification by the following elements:

- Drawing a trapezoid of viscosity decrease with talking into consideration decrease of engine lubricant dynamic viscosity decrease after 150 shear cycles In :pump-injector" rig for tests with both low and high shear stress (testing the resistance against mechanical degradation). This testing enables determination of hysteresis of lubricant viscosity change caused by mechanical degradation [3] [4] (trapezoid area),

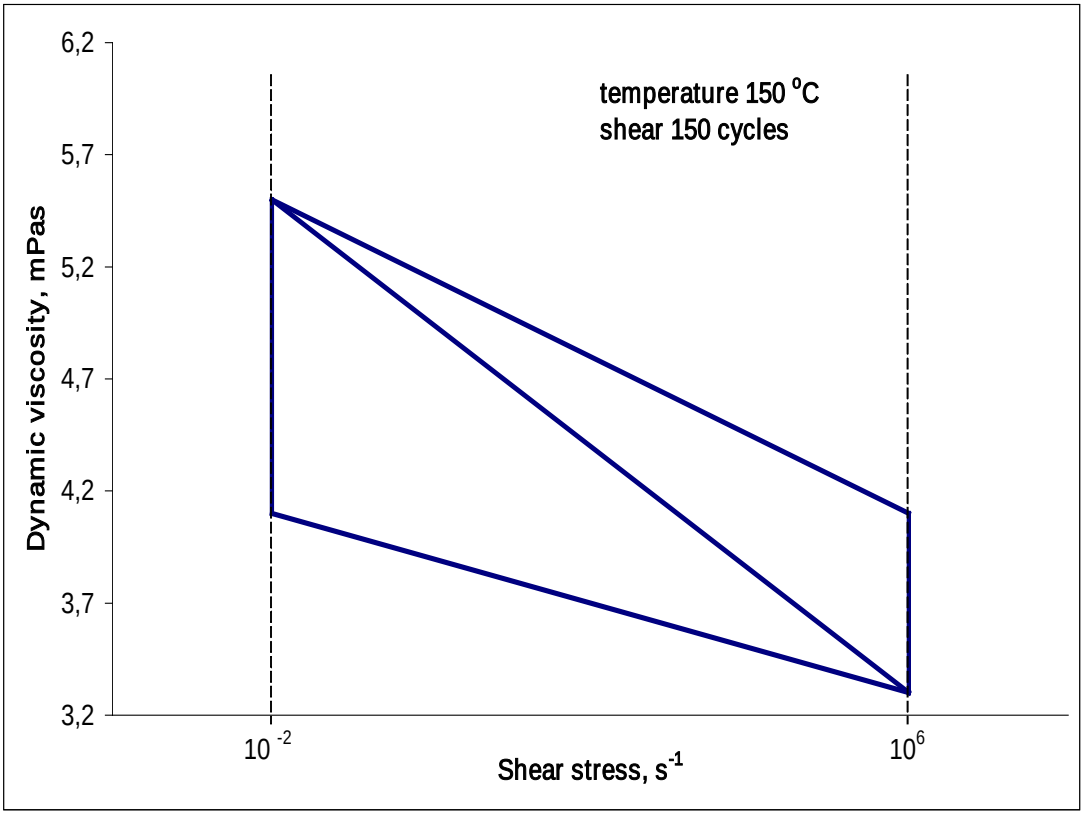

Fig. 1. Viscosity change trapezoid for SAE 20W-50 engine lubricant (low resistance against mechanical degradation)

- Drawing the curves of dynamic viscosity (pumping) change and dynamic viscosity (starting) for a few measurements performed for different testing temperatures, which enables determination of viscosity change during cooling (still not continuous but also not a pointwise) both for low and high shear stress,
- testing dynamic viscosity with Brookfield scanning viscosimeter (dynamic viscosity continous measurements during long-term cooling with low shear stress).

In the future, the next element of this methodology should be testing the influence of time on viscosity change (in this case its progressive increase) after mechanical degradation, due to polymer chains reconstruction in viscosity improvers.

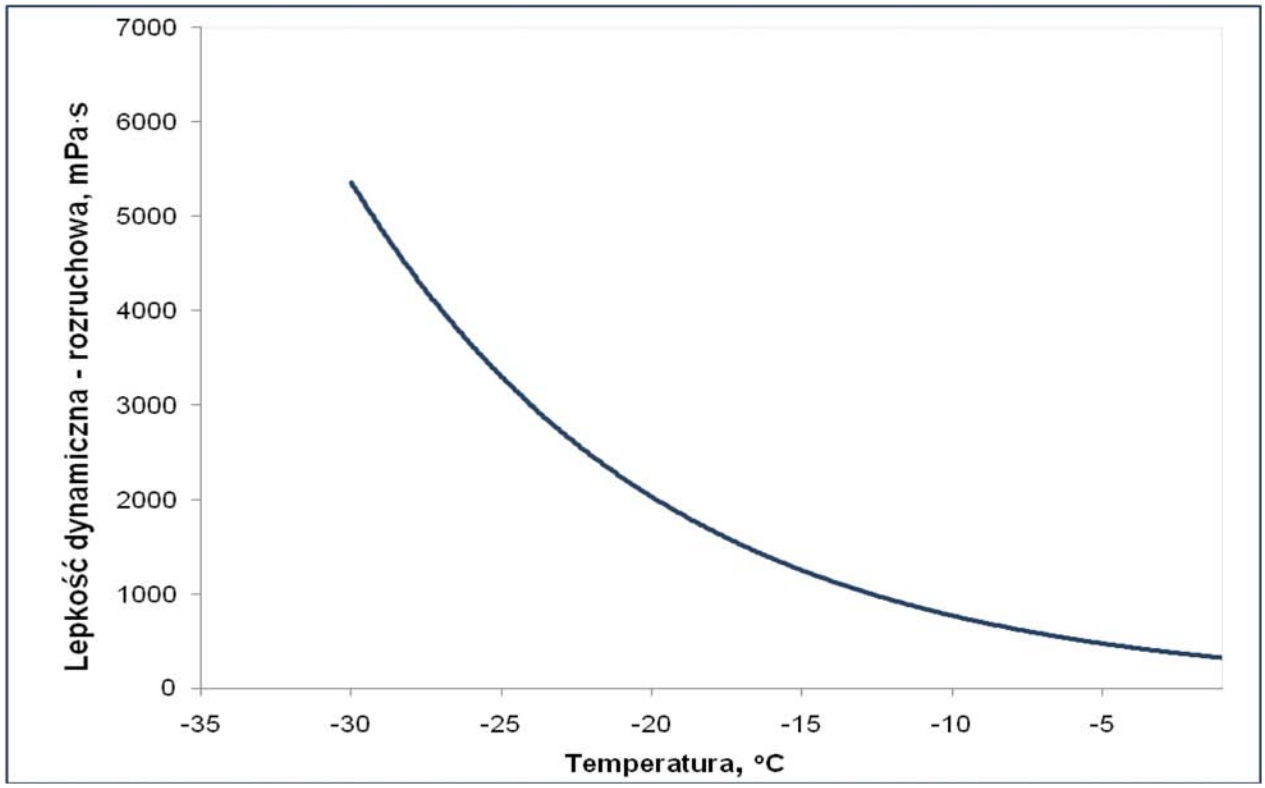

Fig. 2. Change of dynamic viscosity– starting for SAE 5W-40 lubricant

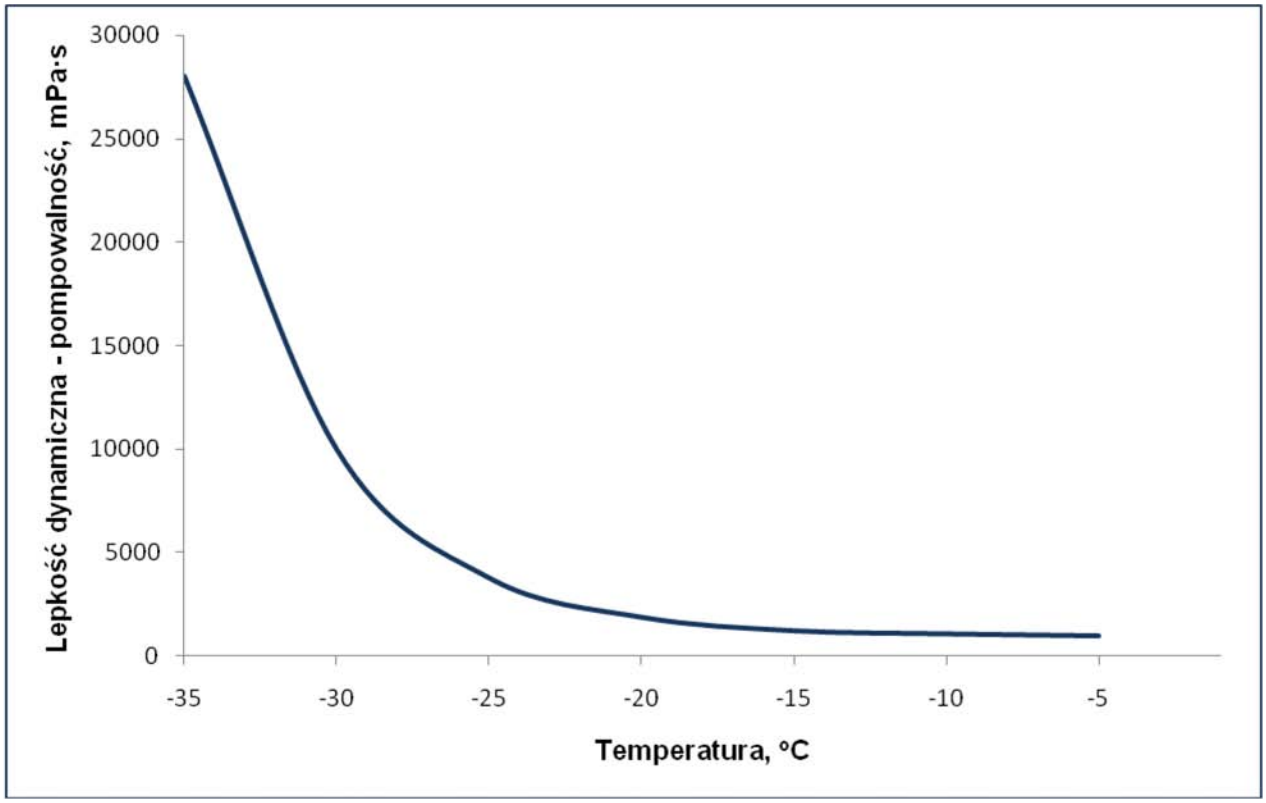

Fig. 3. Change of dynamic viscosity– pumping for SAE 5W-40 lubricant

4. Summary

Proposed methodology of engine lubricants rheological properties testing may be applied in:

- testing of engine lubricants offered commercially on the market i.e. to assess the reason of engine failure,
- creating new technolgies for engine lubricants production (viscosity and depressants quality assesment).

This may influence the quality improvement of commercially available engine lubricants in the future.

Literature

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