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LUBRICITY-BASED ESTIMATION OF THE CHANGES IN THE BRAKE FLUID QUALITY

Piotr Bzura

Gdansk University of Technology
Narutowicza 11/12, 80-950 Gdansk, Poland
tel.: +48 58 3472573
e-mail: pbzura@pg.gda.pl

Abstract

As wear of most of the vehicle assemblies threatens only with a breakdown, excessive wear of the breaking system components threatens with a disaster. The brake fluid is one of the most important elements of a breaking system, fulfilling many tasks. Additional work in the ABS, ASR or ESP systems requires it to keep proper lubricity in a wide range of temperatures.

The paper presents a possibility, based on the laboratory test results, of determining the value of lubricity combining the physical and chemical as well as rhelogical properties of fluids. Lubricity, determined for three brake fluids (designations reserved by the comparative test ordering company), allowed to select the best fluid, which will probably be used in the car braking systems.

In particularly, the Stribeck diagram, of the wear process, *example of the fluid lubricity change process, process of the mass wear changes of the T-02 tester balls in the tested brake fluids, process of the lubricity changes in the tested brake fluids are presented in the paper.*

***Keywords**: vehicle, brake fluid, break model, lubricity, boundary layer*

OCENA ZMIAN JAKOŚCI PŁYNU HAMULCOWEGO WEDŁUG SMARNOŚCI

Streszczenie

O ile zużycie większości zespołów pojazdu grozi jedynie awarią o tyle nadmierne zużycie części układu hamulcowego grozi katastrofą. Płyn hamulcowy jest jednym z najistotniejszych elementów układu hamulcowego spełniającym wiele zadań. Dodatkowa praca w układach ABS, ASR czy ESP wymaga by w szerokim zakresie temperatur zachował właściwą smarność.

W artykule została przedstawiona na podstawie wyników badań laboratoryjnych możliwość określenia wartości smarności łączącej własności fizykochemiczne i reologiczne płynów. Smarność, która została określona dla trzech płynów hamulcowych (oznaczenia zastrzeżone przez firmę zlecającą porównanie ich własności), umożliwiła wybór najlepszego, który pewnie zostanie zastosowany w układach hamulcowych samochodów. W szczególności wykres Stribecka, przykład procesu zużycia, przykład zmian procesu smarności płynów, przebieg procesu zmian zużycia masowego kulek aparatu T-02 badanych płynów hamulcowych, przebieg procesu zmian smarności badanych płynów hamulcowych so przedstawione w artykule.

***Słowa kluczowe**: pojazd, model hamulca, płyn hamulcowy, smarność, warstwa graniczna*

1. Introduction

An important characteristic of a brake fluid is its boiling point. The working temperature of a braking system in normal drive may be in the range of 300÷700°C. Hot brake discs transmit temperature to the brake shoes and those, through the whole brake calliper (and particularly the pistons), raise the brake fluid temperature significantly. The fluid, even in an extreme temperature, must not reach the boiling point as "vapour locks" will appear in the boiling fluid. A symptom of that condition is lack of resistance of the pressed brake pedal. A remedy may be pumping the brake but often it does not help much.

The changing working conditions of the brake fluid in operation (absorption of moisture and the ageing processes) make the periodical change necessary. All those phenomena cause the change of physical, chemical and rheological properties of the fluid but it is not sufficient to decide on that basis whether the fluid change is necessary. The only good solution is to carry out a wear experiment - fluid should be changed when its physical, chemical and rheological properties have deteriorated significantly. Such information may be obtained from the fluid lubricity measurements and forecasting its changes.

Analysis of the changes of lubricity of three tested brake fluids was carried out by interpretation of quasistatic wear during laboratory tests in the T-02 four-ball extreme pressure tester.

2. Model of the wear process

The boundary friction [1] (also called semi-dry friction) occurs when the layer of liquid (brake fluid) between surfaces of solid bodies (T-02 tester balls) is so thin that the liquid shows specific properties depending on the temperature. In low temperatures physical sorption occurs and when there is no fluid circulation (as in the braking system) then desorption takes place with the temperature increase - the boundary layer is liquidated. But in high temperatures apart from the physical sorption also chemical sorption occurs, i.e. polar particles form chemical compounds with the metal they contact. Then inhibition of desorption occurs, with positive effect. Practical experience shows that temperature of some 150°C almost entirely liquidates the physically sorbed boundary layer and in the case of substances easily reacting with metals the desorption temperature limit is raised to 300÷400°C. Therefore, in the boundary friction conditions the state, structure and temperature of the solid body surface should be taken into account as well as the friction factor dependent on the boundary layer thickness, as shown in Fig. 1.

The ability of a liquid to create boundary layer is called lubricity.

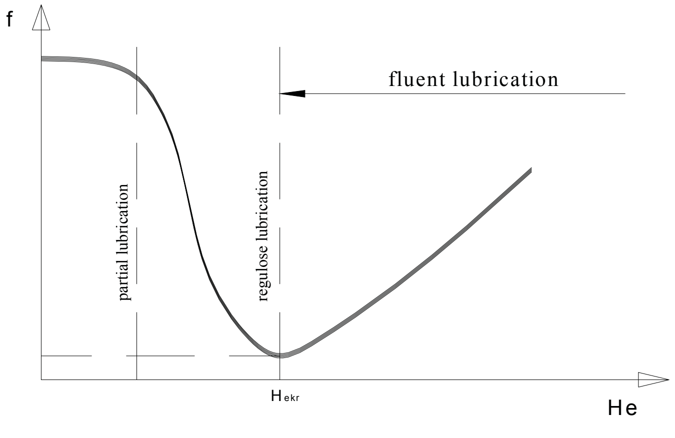

Fig. 1. Stribeck diagram [1, 4]
where: f - friction factor; H_e - Hersey number

All the above mentioned factors influencing the boundary friction process indicate that creation of the boundary layer is one of the most difficult physical chemistry processes. Additionally, it allows interpreting the rheological properties characterising the friction factor.

From the beginning of the boundary friction process one can observe mass decrement, clear permanent set in the form of scratches with mass decrement and grooves without mass decrement (i.e. quasistatic wear).

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In the most general case such a wear process is described by a model known as the Lorenz curve (Fig. 2), which may be divided into three characteristic phases: wearing-in, normal wear and break-down wear. The break-down phase may be excluded from further considerations.

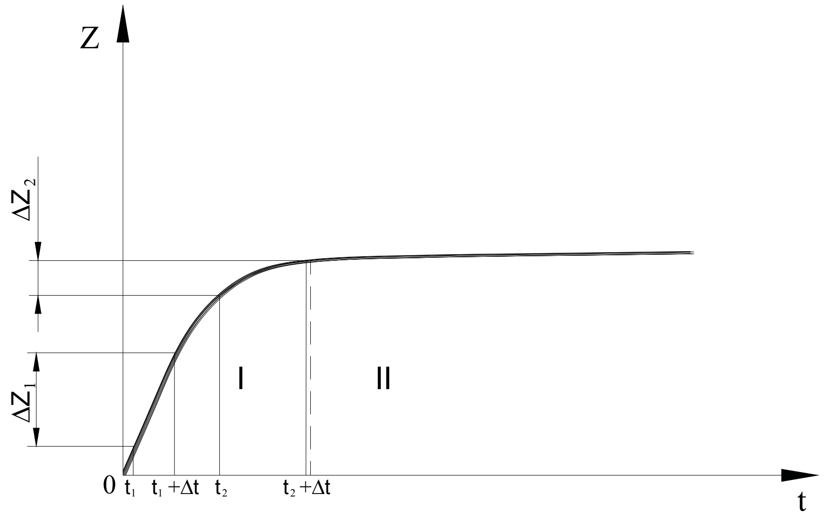

Fig. 2. Example of the wear process [3]
where: I - wearing-in; II - stabilized wear

In the wearing-in period the friction node is getting adapted to the existing working conditions. The wear rate decreases with time. A characteristic feature of that period is correlation of the wear increment and time

$$\Delta Z_1 > \Delta Z_2, where\ t_1 < t_2, \tag{1}$$

where:

ΔZ_1 - wear increment,

ΔZ_2 - wear increment,

$t_1+\Delta t$ – time interval of the wear.

The model 1 shown above was used for interpretation of the collaboration of a tribological system consisting of the T-02 tester balls and the tested brake fluid sample.

The indicator allowing comparing the physical, chemical and rheological properties of the brake fluids is lubricity G:

$$G = \frac{P}{d_{śr} \cdot \eta \cdot \upsilon}, \tag{2}$$

where:

P – seizing load,

$d_{śr}$ - mean value of a tested ball defect,

η - dynamic viscosity,

υ - speed of the relative movement of the T-02 tester ball surfaces.

Using the above presented analysis of the physical, chemical and rheological parameters, the Stribeck and Lorenz diagrams were combined into one curve (Fig. 3) - model 2 allowing interpreting the lubricity.

In the wearing-in period the fluid in the tribological system is getting adapted. The lubricity increment rate decreases with time. A characteristic feature of that period is increase of lubricity with time.

$$G_1 \approx G_2 > G_0, where\ t_2 > t_1 > t_0, \tag{3}$$

where:

G_0 - lubricity of pure brake fluid,

$G_1 \cong G_2$ - lubricity of the brake fluid after wearing-in.

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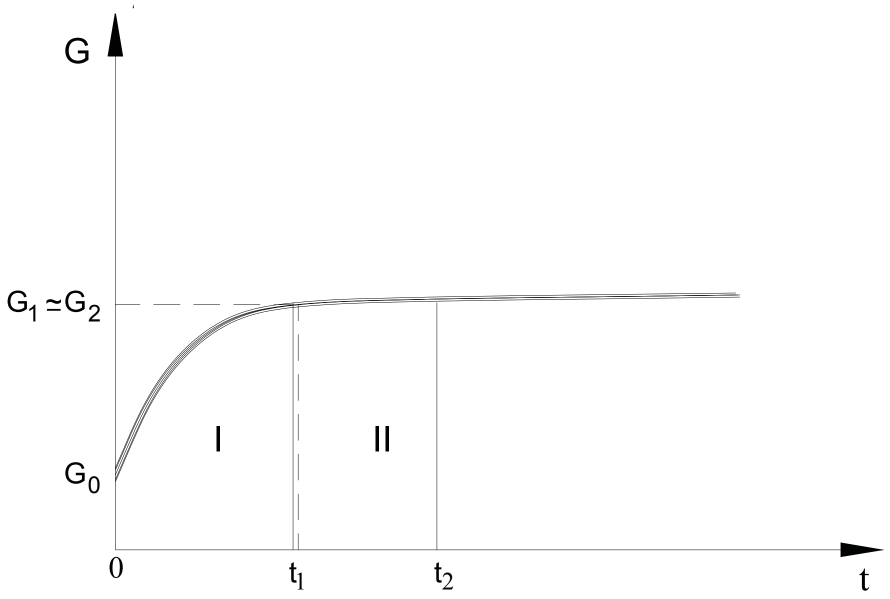

Fig. 3. Example of the fluid lubricity change process

3. Test results

Three brake fluids supplied by the test ordering company were subjected to investigations. The tests were carried out in two stages. In the first stage pure brake fluid samples were used and in the second stage samples of the same brake fluid but after a period of operation, i.e. after partial or full wearing-in time.

The laboratory tests were performed with an Anton Paar GmbH DV-1P viscosimeter and an ITeE Radom T-02 four-ball apparatus [2]. The whole testing procedure was in accordance with the respective company requirements.

The test elements for the brake fluid lubricity measurements were 12.7 mm nominal diameter bearing balls, made from the LH15 bearing steel in the accuracy class 16.

Additionally, the ignition temperature measurement in an open melting crucible was performed by the Cleveland method, of the SCHOTT-GERÄTE GmbH. All the samples showed the temperature of 125°C, which means that no moisture was absorbed into the working brake fluid.

Tab. 1. Laboratory test results for three samples of pure brake fluid

	d_{sr}[mm] mean defect diameter	Z_{sr} [mg] mean mass decrement	P[N] seizing load	η[mPas] dynamic viscosity at 20°C	G[-]
Sample A	2,229	4,33	4262,2	17,35	5,80E+08
Sample B	2,232	5,00	5169,4	15,95	7,64E+08
Sample C	2,234	5,00	4664,6	16,34	6,73E+08

Tab. 2. Laboratory test results for three samples of brake fluid after an operation period

	d_{sr}[mm] mean defect diameter	Z_{sr} [mg] mean mass decrement	P[N] seizing load	η[mPas] dynamic viscosity at 20°C	G[-]
Sample A	2,192	3,02	4074,72	16,9	7,04E+08
Sample B	1,712	0,78	7400	15,24	1,76E+09
Sample C	2,266	3,42	5390,4	15,64	9,47E+08

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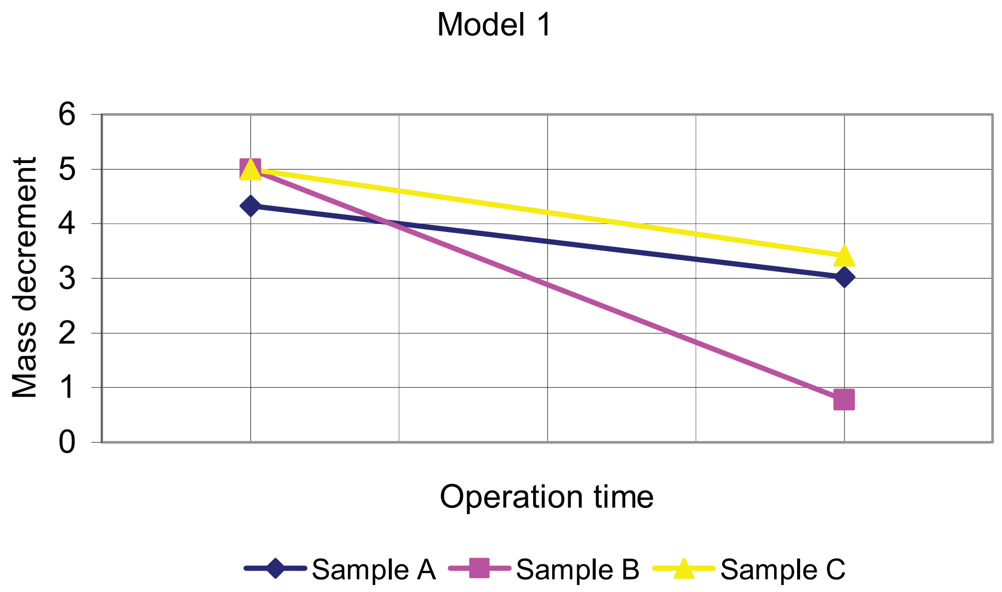

Fig. 4. Process of the mass wear changes of the T-02 tester balls in the tested brake fluids
Rys. 4. Przebieg procesu zmian zużycia masowego kulek aparatu T-02 badanych płynów hamulcowych

The presented test results and their interpretation show that the sample B brake fluid has the best physical, chemical and rheological properties.

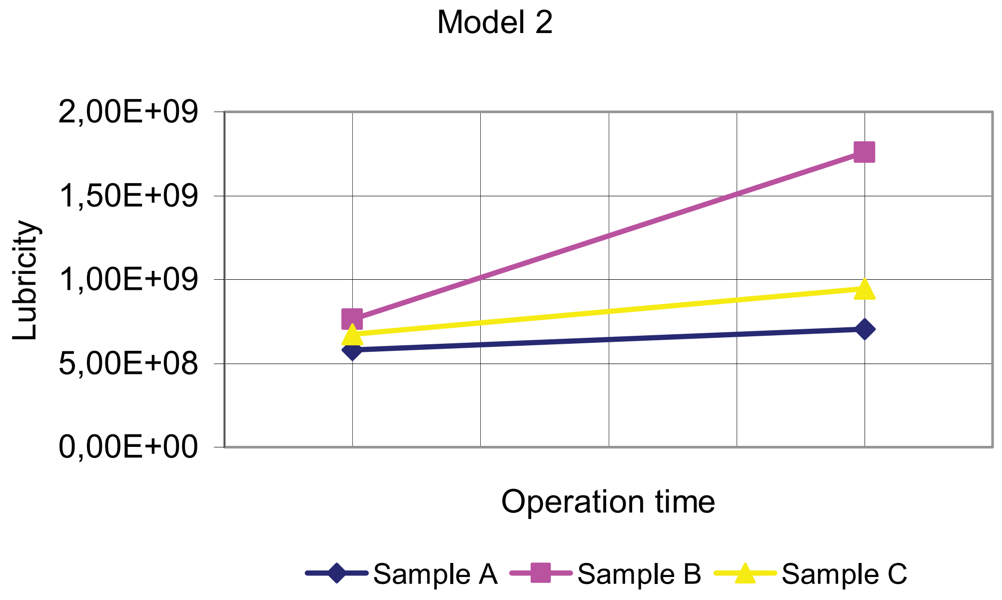

Fig. 5. Process of the lubricity changes in the tested brake fluids
Rys. 5. Przebieg procesu zmian smarności badanych płynów hamulcowych

5. Summary

A conception has been presented of taking lubricity into account in comparisons of the quality of tested brake fluids. The model 1 curve (Fig. 2 and 4) and the proposed model 2 curve (Fig. 3 and 5) have rightly interpreted the changes in the brake fluid quality.

Notably, this method of interpretation may be used also for testing other engine fluids (i.e. engine lubricant).

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As the selected brake fluid has not yet been introduced for normal use, insufficient data are available for the lubricity-based evaluation and forecasting of its maintaining the full operational quality.

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