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Research of Brake Fluids Viscosity Properties

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Abstract:

Four samples of the top SYNTOL HD 265 PLUS brake fluid with 0.2 %, 1.7 % , 3.6 % and 5.9 % by weight water content were prepared in the laboratory. Ubbelohde viscosimeter was used for the determination of the brake fluid kinematic viscosity. The results have proved that the change of brake fluid viscosity is affected not only by temperature but by water content, too.

Keywords:

Brake fluids, ethylene glycol, polyglycols, boiling point, viscosity, Ubbelohde viscosimeter

1. Introduction

At the present time, brake fluids on glycol basis (ethylene glykol (di-, tri-), polyglycols, polyglycolethers) are used for double circuit systems. These brake fluids have hydrophilic characteristics which cause an easy combination with water during driving. Figure 1 illustrates the hydrophilic characteristics of brake fluids. The O–H structures between ethylene glycol (diethylene glycol, triethylene glycol) and water form easily through hydrogen bonding and cause the moistened ethylene glycol (and other high glycols), which changes the characteristics of the material [1]. The dashed lines in Fig. 1 show the hydrogen bonds. The moistened brake fluid changes its physical and chemical characteristics.

There are various international, national and company standards which specify their physical-chemical properties. The following ones are most substantial: SAE J 1703/1704, ISO 4925 and FMVSS CRF 571.116. A considerable part of European producers of brake fluids applies the Volkswagen company technical

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standards (VW TL 766 in X, Y, and Z version). See the Table 1 for the limit values specified in these standards.

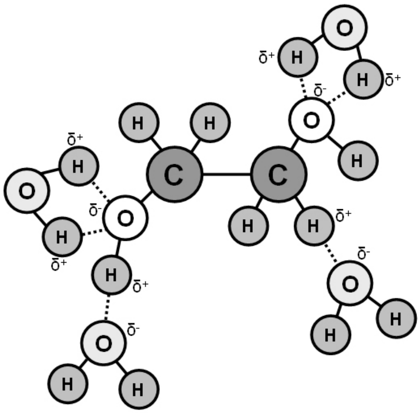

Fig. 1: Illustration of ethylene glycol molecule absorbing and polymerizing the hydromolecules (water) through hydrogen bonding [2].

The table shows that the brake fluid hygroscopic properties are considered in the boiling point (dry and wet boiling points are defined). The dry boiling point reflects the boiling point value of a new brake fluid with max. 0.2 % by weight water content. The wet boiling point reflects the boiling point of the brake fluid with approximately 3.5 % by weight water content. Being this value achieved the brake fluid must be renewed.

In relation to thermal-viscosity properties, the limit values of kinematic viscosity are specified for two temperature conditions in the above mentioned standards: for –40 °C and for +100 °C. The aforesaid values show that the brake fluid viscosity varies considerably with the change in temperature.

Table 1: Limit values for the boiling point and kinematic viscosity of brake fluids.

	Standard*								
	A	B, C	D, E	F	G	H	I	J, K	L
Dry boiling point [°C]	≥ 205	≥ 205	≥ 230	≥ 230	≥ 250	≥ 250	≥ 265	≥ 260	≥ 260
Wet boiling point [°C]	≥ 140	≥ 140	≥ 155	≥ 155	≥ 163	≥ 165	≥ 175	≥ 180	≥ 185
Kinematic viscosity at -40 °C [mm^2/s]	≤ 1800	≤ 1500	≤ 1800	≤ 1500	≤ 1100	≤ 750	≤ 700	≤ 900	≤ 800
Kinematic viscosity at + 100 °C [mm^2/s]	≥ 1.5	≥ 1.5	≥ 1.5	≥ 1.5	≥ 1.5	≥ 1.5	≥ 1.5	≥ 1.5	≥ 2.2

standard:** ***A *- SAE J 1703 (APR 2004),* ***B*** *- FMVSS CRF 571.116 DOT 3 (10-1-93),* ***C*** *– ISO 4925 Class 3 (2005-02-01),* ***D*** *- FMVSS CRF 571.116 DOT 4 (10-1-93),* ***E*** *- SAE J 1704 (July 2006),* ***F*** *- ISO 4925 Class 4 (2005-02-01),* ***G*** *- VW TL 766/X (May 2006),* ***H*** *- ISO 4925 Class 6*

*(2005-02-01), **I** - VW TL 766/Z (May 2006), **J** - FMV CRF 571.116 DOT 5.1 (10-1-93), **K** – ISO 4925 Class 5.1 (2005-02-01), **L** - VW TL 766/Y (May 2006),*

where*: **SAE** (Society of Automotive Engineers), **FMVSS** (Federal Motor Vehicle Safety Standard), **DOT** (Department of Transportation),* **ISO** *(International Organization for Standardization),* **VW** *(Volkswagen company standard).*

The kinematic viscosity values for these two temperature limits apply only to new brake fluids with water content up to 0.2 % by weight approximately. The effect of service hygroscopicity on viscosity properties of glycol brake fluids has not been specified. Nevertheless, poor viscosity properties of the brake fluid can result in multiple longer reaction time of the brake system in case of emergency. This fact can have far-reaching consequences as far as the operational safety of the vehicle is concerned. This is the reason the presented article is concerned with the effect of brake fluid hygroscopicity on viscosity properties of brake fluids.

2. Material and Methods

Four samples of the SYNTOL HD 265 PLUS brake fluid with water content of 0.2 % by weight, 1.7 % by weight, 3.6 % by weight and 5.9 % by weight were prepared in the lab. The water content in brake fluid samples was measured by the Karl Fischer method according to the company standard [3] in Velvana inc., Velvary.

Ubbelohde viscosimeter (Fig. 2) was used for the determination of the brake fluid kinematic viscosity. The measurement principle is based on the flow time of the fluid constant volume rate between two gauge marks A and B.

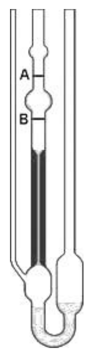

Fig. 2: Ubbelohde viscosimeter (A,B – marks).

The kinematic viscosity measurement of the aforementioned four SYNTOL HD 265 PLUS brake fluid samples was performed at –40 °C and +100 °C temperatures. Temperature treatment of the viscosimeter by means of the LAUDA type RL6 cryostat (Fig. 3) made possible the viscosity measurement at –40 °C.

The kinematic viscosity has been calculated from the following formula:

$$n = kt \tag{1}$$

where: k – constant of calibration (viscosimeter for 100 °C: $k = 0.01000 \times 10^{-6}$ m^2/s^2, viscosimeters for –40 °C: $k = 3.001 / 3.005 / 3.006 \times 10^{-6}$ m^2/s^2),

t – rate of flow time between the A and B gauge marks (Fig. 2).

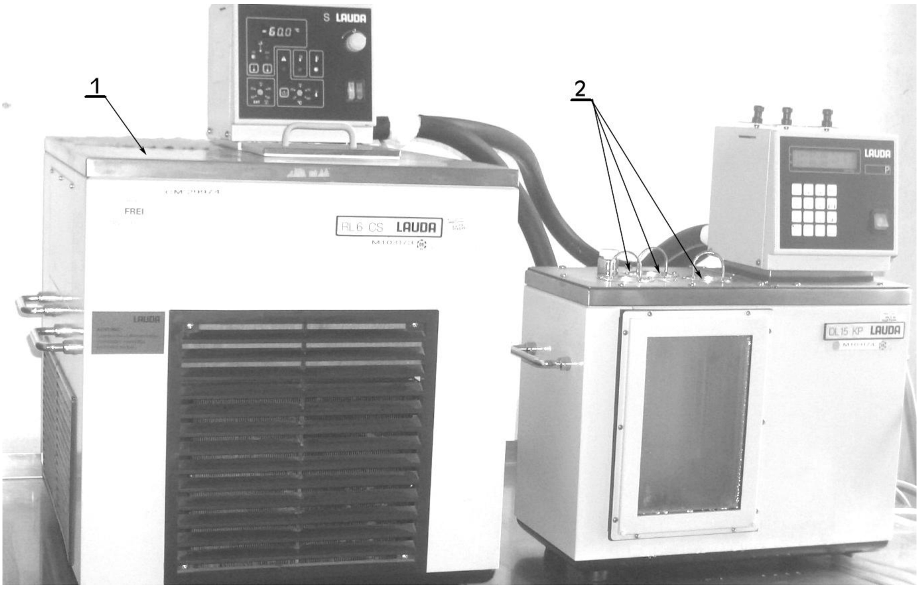

Fig. 3: LAUDA type RL6 cryostat in Velvana inc., Velvary
1 - cryostat, 2 - Ubbelohde viscosimeters

3. Results and Discussion

Summary results of the SYNTOL HD 265 PLUS brake fluid kinematic viscosity measured at –40 ^{o}C are plotted in Fig. 4 and at +100 ^{o}C are plotted in Fig. 5.

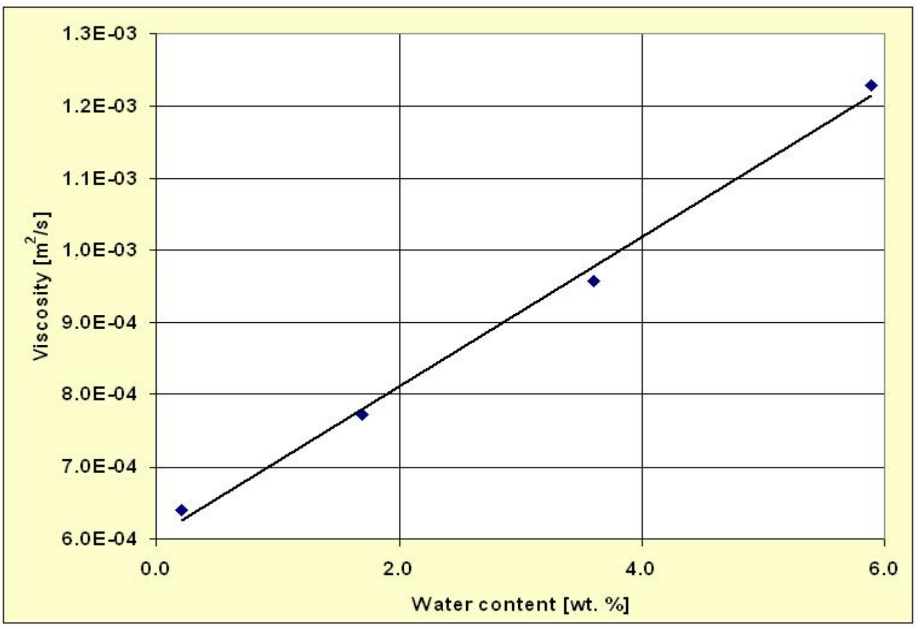

Fig. 4: SYNTOL HD 265 Plus brake fluid viscosity – water content relation for –40 °C.

The figures shows that the brake fluid viscosities vary not only with temperature (this fact has been known), but also with the change of water content (this fact has not been known).

The curve running through the values measured at –40 °C temperature (Fig. 4) shows that even low increase in water content (by about 5.9 % by weight) raised the value of the brake fluid viscosity from 6.45×10^{-4} m^2/s up to 1.24×10^{-3} m^2/s, i.e. by 97 %.

Such rise in viscosity is undesirable for the service because of hypothetical consideration that the rise can result in adverse multiple longer reaction time of the brake system. This fact can have far-reaching consequences as far as the operational safety of the vehicle is concerned especially in winter season, immediately after starting the vehicle. This regime is extreme; therefore the results measured should be regarded as extreme ones as well.

The curve running through the values measured at +100 °C temperature (Fig. 5) shows that with the rise in water content the brake fluid viscosity decreases.

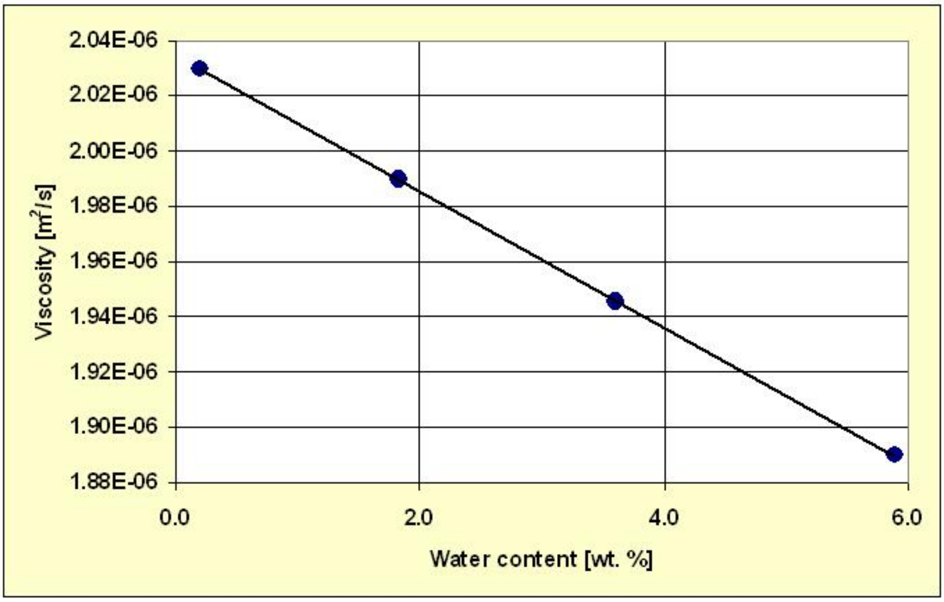

Fig. 5: SYNTOL HD 265 Plus brake fluid viscosity – water content relation for +100 °C.

The decrease in water content (by 5.9 % by weight approximately) reduced the brake fluid viscosity from 2.3×10^{-6} m^2/s to 1.9×10^{-6} m^2/s. This decrease in viscosity is also undesirable for the operation because of adverse effect on the transmission of effort from the brake pedal to control members, deterioration of lubrication function, etc. The braking regime, when brake fluid temperature of +100 °C is attained, can be rather normal in service. Far more extreme regime of vehicle braking, when the brake fluid temperature reaches 155 °C [4], can occur in practice (when driving down gradual decline, during abrupt intensive braking in high initial speed, etc.).

4. Conclusion

The present writers are concerned with the research of brake fluid viscosity properties. Four samples of SYNTOL HD 265 PLUS brake fluid with water content of 0.2 %, 1.7 %, 3.6 % and 5.9 % by weight were prepared in the laboratory. The measurement of water content in brake fluid samples was performed by the Karl Fischer method. Ubbelohde viscosimeter was used for the determination of the brake fluid kinematic viscosity. The kinematic viscosity measurement of the aforementioned samples was performed at –40 °C and +100 °C temperatures. The results have proved that not only the temperature, but also the water content can affect the alteration of the brake fluid viscosity. When the water content grows, brake fluid viscosity declines at positive temperatures and on the contrary brake fluid viscosity grows at negative temperatures. This fact has not been known up to now. Top quality brake fluid of the DOT 4 classification (SYNTOL HD 265 PLUS) was selected for the research. However, there are other brake fluids of the DOT 4 classification on the market with far poorer declared viscosity properties. The application of these brake fluids in the brake system can have unfavourable effect on the function of the brake system and thus far-reaching consequences as far as the safety of traffic operation is concerned.

Obviously it could be rewarding experience to be concerned with these problems including more close collaboration between brake fluid producers and vehicle producers and the incorporation of professionals. Therefore the authors recommend discussing the existing problems more widely. In the future it might be considered whether to make more effort in publicity and promotion of brake fluid quality importance and its dangerous nature when not adhering to the recommended principles for its application, to equip Technical Inspection Stations and service stations with external diagnostic instruments and whether to consider the possibility of dashboard diagnostic instrument installation for the measurement of brake fluid.

References

[1] Kao, M.-J., Tien, D.-C., Jwo, C.-S., and Tsung, T.-T. The Study of Hydrophilic Characteristics of Ethylene Glycol. *Journal of Physics: Conference Series* (7th International Symposium on Measurement Technology and Intelligent Instruments), 2005, Vol. 13, pp. 442-445.

[2] Kao, M.-J., Tien, D.-C., Ting C.-C. and Tsung, T.-T. Hydrophilic characterization of automotive brake fluid. *Journal of Testing and Evaluation*, 2006, Vol. 34, No. 5, pp. 400-404. ISSN 0090-3973.

[3] *Company standard for the determination of water content in brake fluids PP 45/41* (in Czech). Velvary : Velvana, a.s., 2005. 25 p.

[4] Čorňák, Š. et al. *Procedure of suitability evaluation of brake fluid boiling point measurement devices* (in Czech). Brno : University of Defence, 2007. 30 p. ISBN 80-8075-154-4.

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