THE INFLUENCE OF VEHICLE OPERATION ON THE BRAKE FLUID BOILING POINT

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Abstract: *The possibility to brake is the most important thing in the road transport safety. The effectiveness of the vehicle braking is influenced by brake fluid state – exactly the water volume share in the fluid. The brake fluid boiling point describes water volume in the fluid. By measuring the boiling point, this paper examines how a boiling point decline is influenced by the vehicle operation.*

Keywords: BRAKE FLUID BOILING POINT, VEHICLE OPERATION, MEASUREMENT

1. Introduction

Brakes are an important safety feature of vehicles. The quality of brake fluid is important for the operation of a hydraulic braking system. Quality characteristics of the brake fluid affect significantly the functionality of operated brakes and thus the safety of vehicle occupants and other road users.

2. Physical and Chemical Properties of Brake Fluid

Many international, national and corporate standards and specifications exist to describe physical and chemical properties of brake fluid produced based on glycol. They are derived mainly from standard SAE J 1703, e.g. FMVSS CFR571.116, ISO 4925, NF 12-640, RS 1305-68, and etc. These standards include not only basic physical and chemical properties of brake fluid but also the exact procedure for an evaluation of brake fluid before placing in the market (e.g. colour, boiling point, viscosity, evaporation, and etc.).

The boiling point should be as high as possible in order to prevent from the formation of air (steam) bubbles at high temperature during braking in a brake system. The viscosity should be the lowest in the cold state and the highest during heat (a high viscosity index is required). Corrosion protection of metal parts of a braking system is important because it significantly affects lifetime of brake fluid. The lubricating properties are also important because of the protection of brake system components which move against to each other. The compressibility should be minimal and it should be independent on temperature and pressure if possible. The brake fluid should not evaporate under no conditions, any temperature or other impacts that occur in a brake system. It should remain as stable as possible and to be miscible with other brake fluid. Operating temperature of brake fluid in brake systems of vehicles range from -50 °C to +200 °C and more, particularly for sports cars.[1, 2]

Table 1: *Classification of brake fluid. [4]*

Standard	FMVSS 116			ISO 4925	SAE J1703
	DOT 3	DOT 4	DOT5.1		
Dry boiling point [°C]	≥ 205	≥ 230	≥ 260	≥ 205	≥ 205
Wet boiling point [°C]	≥ 140	≥ 155	≥ 180	≥ 140	≥ 140
Viscosity at -40 [mm^2/s]	< 1500	< 1800	< 900	< 1500	< 1800
Viscosity at +100 [mm^2/s]	> 1,5	> 1,5	> 1,5	> 1,5	> 1,5

Dry boiling point is the boiling point of brake fluid which does not contain water (0 % of water i.e. immediately after opening the original packaging).

Wet boiling point is the critical value of boiling temperature of brake fluid and it corresponds to water content of approximately 3,5 percent by weight i.e. it rep-resents a certain allowable amount of water set by the standard for each kind of brake fluid.[5]

While braking, the friction releases considerable heat. Therefore, brake fluid must be design for the highest possible boiling point in order to withstand these high temperatures. However, brake fluid is hygroscopic, meaning that it naturally absorbs water. In any hydraulic brake system during operation, brake fluid gradually absorbs humidity from the air mainly through a cap of the brake reservoir as well as rubber hoses and seals. This humidity lowers the boiling point of brake fluid.[6]

For example, the boiling point of brake fluid SYNTOL HD 265 with the value of at least +260 °C reduces during operation as follows:

- 0 % of water: ≥ +260°C
- 0,18 % of water: +259°C
- 1,15 % of water: +229°C
- 3,13% of water: +175°C
- 4,01% of water: +157°C

In operation, this means that the difference between 0 – 4 % of the water content in brake fluid causes a temperature decline of the boiling point by 102 °C thus to the threshold of functionality and usability of the brake fluid.[7]

In normal operation, brake fluid absorbs the water in the range of 1 – 2 % of its weight per one year. The actual amount of absorbed water, however, depends on the state of components of a brake system especially rubber hoses.[8]

3. Own Measurement

The boiling temperature of brake fluid is monitored on vehicles with hydraulic brakes by using the measuring instrument for boiling temperature of brake fluid. A manual for using this instrument is used in the process of measuring. A probe is inserted into the fluid reservoir or a sample of the fluid is taken from that reservoir. Inspection also verifies whether there are mechanical impurities and debris in the fluid. If construction design of vehicles does not allow accessing to fluid reservoir and thus inserting a probe or sampling, the boiling temperature of brake fluid is not assessed.

Fig. 1 *BOSCH BFT100 with accessories.*

The tester of brake fluid BOSCH BFT100 (Fig. 1) is an instrument for measuring the boiling point of brake fluid in vehicles with hydraulic brakes. The principle of measurement is based on heating of brake fluid by using a heating probe which is directly

inserted into the fluid reservoir. Subsequently, the temperature of brake fluid is measured.

Practical Measurement of Changes in Boiling Point of Brake Fluid during the Vehicle Operation

The measurement was carried out on seven different vehicle brands: Fiat, Alfa Romeo, Volkswagen, Audi, Citroen and Kia. The vehicles were divided according to their predominant operation as follows:

1. The operation of a vehicle type „City" – Fiat Stilo 1.9JTD, Alfa Romeo GT, Volkswagen Passat 1.9TDI
2. The operation of a vehicle type „Outside City" – Audi A6 3.0TDI, Citroen Berlingo
3. The operation of a vehicle type „Garaged" – Kia Ceed 1.6, Citroen C6

The measurement was carried out in the localities of Bardejov, Zilina in the period from 10 November 2014 to 31 March 2015 at different time intervals. Based on the statistical data provided by Slovak Hydrometeorological Institute (SHMU), information about average air temperature and relative humidity were available for individual measurements carried out in mentioned localities.

No dependencies or calculations were further derived from the information provided by SHMÚ. The information was transferred into graphs to show development of temperature and humidity in mentioned localities during whole time period in which measurements were carried out. Each measurement of individual vehicles consisted of three consecutive measurements of the same collected or measured sample of brake fluid. The overall result was determined as the arithmetic average of the measured values. The role of the measurements was to also monitor the number of kilometers driven by the vehicle since the last carried measurement as well as the number of days since the last carried measurement. Two graphs were compiled for each vehicle:

- dependence of changes in boiling point of brake fluid on the number of days elapsed from the last carried measurement or refilling brake fluid,
- dependence of changes in boiling point of brake fluid on the number of driven kilometers together.

To determine long-term intensity of decline in boiling point of brake fluid as well as short-term intensity, we selected two vehicles (Fiat Stilo – operation "City" and Citroen Berlingo – operation "Outside City"). We bought new brake fluid DOT 3 and we refilled old brake fluid by this new one. Subsequently, we examined the intensity of increase and subsequent decline in boiling point of brake fluid during observed period.

4. Results and Discussion

Based on the results obtained from measurements, we were finally able to express decline in boiling point in relation to the number of days and kilometers driven in vehicle operation.

4.1 The Course of Average Daily Temperature and Relative Humidity

As previously mentioned, brake fluid is hygroscopic, meaning that it absorbs humidity from the air. Based on the information provided by SHMU, Fig. 2 depicts development of temperature and air humidity in localities Bardejov and Zilina.

We had to consider daily temperatures and especially air humidity in given localities during observed period because individual measurements were carried out during several months. This had to be taken into account so that we could conclude that decline in boiling point of brake fluid was caused by changes in temperature and air humidity in individual localities where the vehicles were operated.

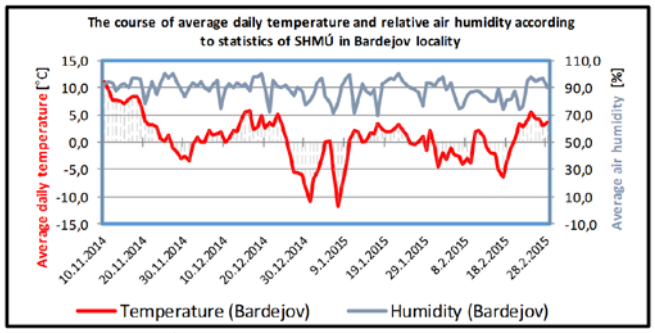

Fig. 2 *The course of average daily temperature and relative air humidity (Bardejov).*

4.2 The Course of Changes in Boiling Point of Brake Fluid during Vehicle Operation

The course of changes in boiling point is depicted in following graphs for each vehicle depending on kilometers driven and days of vehicle operation from the last measurement. The vehicles are divided according to type of operation.

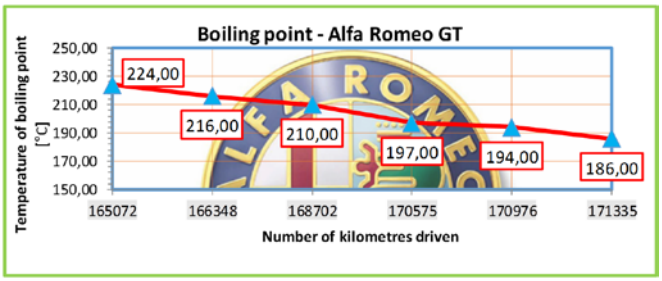

Fig. 3 *Decline in boiling point of brake fluid in terms of driving performance.*

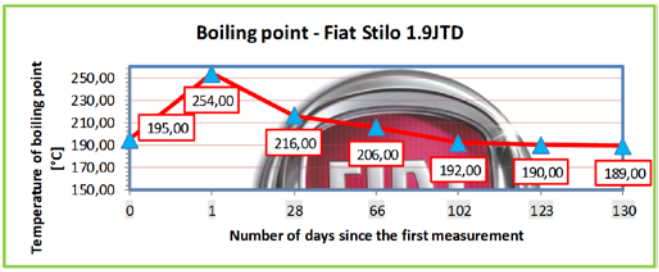

Fig. 4 *Decline in boiling point of brake fluid in terms of operation time (after refilling by new brake fluid).*

4.2 Comparison and Evaluation of the Average Rate of a Boiling Point Decline

Under calculating the average rate of a boiling point decline for each vehicle and each category, smaller differences of the decline can be observed in the recalculation for one day compared to the recalculation for 1000 kilometers. Therefore, it is necessary to exchange brake fluid with respect to the distance travelled and not in terms of time.

Tested vehicle - Fiat Stilo has a high value of the decline rate (marked in red in Tab. 2). This is due to the fact that the new brake fluid absorbs great percentage of humidity after refilling. However, an increasing proportion of water in brake fluid decreases the rate of further absorption. Therefore, if the test had lasted longer, the average rate of decline would have been lower (Fig. 4).

In the case of garaged vehicles with almost no operation (constant conditions), the decline was only minimal (almost none). This represented a reference sample.

Table 2: *The average rate of a boiling point decline of brake fluid. [4]*

Category	*Vehicle*	*Decline intensity of BPBF (°C/day)*	*Decline intensity of BPBF (cat.) (°C/day)*	*Decline intensity of BPBF (°C/1000km)*	*Decline intensity of BPBF (cat.) (°C/1000km)*
City	*Alfa Romeo GT*	*0,29*	*0,34*	*6,07*	*22,07*
	VW Passat	*0,24*		*20,46*	
	Fiat Stilo	*0,50*		*39,68*	
Outside City	*Audi A6*	*0,08*	*0,14*	*1,31*	*4,17*
	Citroën Berlingo	*0,19*		*7,03*	
Garage	*Citroën C6*	*0,03*	*0,03*	-	-
	Kia Ceed	*0,03*		-	

5. Conclusion

If we recalculated the average rate of a boiling point decline from one day to two years (i.e. recommended time interval for exchanging brake fluid) for the category of "City" and "Outside City" vehicle operation, the average decline of boiling point would be about 175 °C. This means the decline of boiling point to the threshold values brake fluid functionality. Therefore, it is recommended to exchange brake fluid at least once every two years. Besides the mentioned vehicle Fiat Stilo (see Tab. 2), it must be taken into account that the measurement was also influenced by the fact that it was carried out during the worst operating conditions – winter season of the middle continental climate zone. Lower absorption of fluid humidity in the summer operation (higher temperature and lower air humidity) would result in a lower decline rate of boiling point of brake fluid. Therefore, these results cannot be applied to year-round operation. Given the mentioned facts, long-term measurements should be carried out at least for one year.

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