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The effect of Kuwait climate on the Automotive brake fluids

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1. Abstract

Brake fluids are mainly used in the braking and clutch systems on automobiles, motorcycle and light trucks, it's used to transfer brake pedal force into pressure and send this pressure to the front and rear brakes to stop the vehicle. This paper study the change of a real life brake fluid boiling point and a percentage of water content for passenger cars. The test was taken on 35 cars used in the State of Kuwait. Kuwait climate is dry and low humidity [1]. The tested vehicles were varied in terms of manufactured year, which is from 2007 to 2023, mileage from 12,000 km to 337,000 km and the brake fluid type (DOT3 and DOT4) which had not been replaced for all the tested vehicles before. All results were recorded from special devices BF200 Moisture analyzer detector and BOSCH BFT 100 boiling point tester. The results showed a slight relative decrease in the boiling point of the brake fluid for all the selected cars, and that the boiling point did not exceed the minimum allowable level of temperature for the brake fluid. As well the percentage of the content of water in the brake fluid for the selected cars did not exceed the upper limit.

Keywords: Brake fluid, Boiling point of brake fluid, Water content in brake fluid.

2. Introduction

Automotive brake is one of the most important safety systems of a vehicle [2]. It's commonly designed in a way to stop/reduce the speed of the vehicle through a set of components by using friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat [3]. In vehicles, there are three types of brakes systems: mechanical brakes, air brakes and hydraulic brakes. For the purpose of this research only the hydraulic type will be considered as it is the more popular type and it's widely used in vehicles due to its great advantages. The hydraulic brake system works with the principle of Pascal's law, which states whenever pressure is applied on fluid it travels uniformly in all the directions [4]. Brakes operated by hydraulic fluid pressure, when the driver press the brake pedal, it depresses a piston in the master cylinder forces the brake fluid to increases in pressure. This pressure is transmitted in all lines pushes out the brake shoe (in drum brakes) or the brakes pads (in disc brake) causing to a friction between the brake shoe/pads and drums/discs, the wheels slow down or even stop.

During the braking process, the brake fluid builds up a force through the brake pedal via the brake booster, brake lines and hoses to the brake pads in the brake caliper. This can create a pressure of up to 1200 psi, causing the brake disc to reach a temperature of even more than 530°C [5]. The harder the driver push on the pedal, the more pressure is applied to brake discs lead to higher friction, causing brake fluid temperature to increase and reaches its boiling point. A brake fluid that reaches its boiling point will vaporize inside the line, causing the fluid to become compressible and provide inadequate hydraulic transfer of the braking force.

Brake fluid is designed to have a high boiling point, it is one of most important characteristics of brake fluid. The boiling point of brake fluid is measured in two different ways: The dry boiling point, which is the boiling of fresh brake fluid and the wet boiling point is its boiling point after absorbing some moisture.

Most brake fluids used today are glycol-ether based. Glycol-ether brake fluids are hygroscopic [6], which means they absorb moisture from the atmosphere and allow it to settle into the brake system where it will eventually cause corrosion problems, damage to costly ABS (anti-lock system) components [7] and it can also lead to decrease the brake fluid boiling point. As its absorbing moisture from the atmosphere, the excessive water content will decrease the boiling point of brake fluid and under hard braking conditions brake fluid can boil from the heat created by friction of the drums/rotors. Once water becomes steam, it's a gas and can be compressed. That causes a low spongy pedal and less braking force, which can lead to total hydraulic brake system failure.

The most popular classification of brake fluids is the US. DOT (Department of Transportation). It's classified to (DOT3, DOT4, DOT5.1 and DOT5). The first three are glycol-based fluids, which means they absorb water. DOT5 is silicon-based it doesn't absorb water [8]. (Table 1) shows their primary differences are their wet & dry boiling points and their composition.

Table 1: Classification of brake fluid Boiling point according to DOT [9].

Fluid type	Dry Boiling Point	Wet Boiling Point	Composition
DOT 3	205°C	140°C	Glycol Ether
DOT 4	230°C	155°C	Glycol Ether
DOT 4+	260°C	180°C	Glycol Ether
DOT 5	260°C	180°C	Silicone
DOT 5.1	260°C	180°C	Glycol Ether

For the purpose of this research, we will focus on the wet boiling point value and the percentage of water content of the brake fluid DOT3 and DOT4, for a selected group of 35 vehicles were taken from the State of Kuwait. The average temperature of Kuwait climate, fluctuated from 43°C during summer time to 15°C winter time with the average daily low falling to 23°C for summer and 5°C for winter [10]. The annual humidity ranges from approximately 30% to 36% [1,11].
DOT3 and DOT4 Brake fluids are hygroscopic, so it will tend to absorb water and moisture from the air [8]. The moisture content increases approximately 1% to 2% per year [12]. After many years of serves if the brake fluid excessive the water content average and reach 3.7% the fluid will boil at a lower temperature [13]. Vehicles manufacturers recommend replacing the brake fluid every 2 years or after approximately 40000 km [7]. From Table 1 DOT3 and DOT4 brake fluid has a wet boiling point of 140°C and 155°C. Therefor under hard braking conditions the fluid will heat up above the degree of 140°C and 155°C. If the brake fluid heated past its boiling point, some of the fluid vaporizes and creates bubbles within the brake lines. This is a very dangerous situation, this can lead to what is commonly known as vapour lock [14]. This occurs since the vapour is compressed, causes brake pressure fade and even cause the brake pedal to drop out. In extreme cases the driver can then push the brake pedal all the way to the floor without achieving the necessary braking power. For this reason, the recommendations from fluid manufacturers typically range from one to two years for performing a flush or replacement of the brake fluid, or when the brake fluid fails a test for boiling point and water content.

3. Research Methodology

This paper presents an experimental investigation on effect of the water level in brake fluid on the rate of decrease in temperature and the boiling point of brake fluid. A selected group of 35 vehicles were taken from the State of Kuwait, which has a mostly dry climate and low humidity. The vehicles produced in 2007- 2023 with different ages and different mileage. Brake fluid has never been replaced for the selected group of the vehicles before. The measurement of the brake fluid water content determination tests was carried out by using a moisture analyzer detector BF200 (Figure 1). The measurement of the brake fluid boiling point value was carried by BOSCH BFT 100 (Figure 2). The BOSCH BFT 100 tester was characterized by the precision of the determination of the boiling point of all types of fluids based on glycol used in vehicles. The measurement in both cases was made by immersing the probe in the vehicle's brake fluid reservoir tank.

Figure 1: BF200 Moisture analyzer detector

Figure 2: BOSCH BFT 100 Brake Fluid Tester

4. Testing new brake fluids:

Firstly, the BF200 Moisture analyzer detector and BOSCH BFT 100 boiling point tester are used to check a sample of five types of new brake fluids conditions and use the results before starting investigation the real-world brake fluid condition. This test can show how far the real-world brake fluid differ from the new condition fluid.

At this test, five types of brake fluid had been used (Table 2)

Table 2: Shows new Brake fluids types and results.

Brake fluid type	Brake fluid Brand	Moisture content	Boiling point
	Toyota DOT 3	1%	238 °C
	Motorcraft ford DOT 3	1.5%	259 °C
	Veedol DOT 3	1%	246 °C
	AcDelco DOT 4	1.5%	269 °C
	Mercedes Benz DOT 4 plus	0.5%	275 °C

The results of the new brake fluids show a higher boiling point than specified limes, which are (238 °C for Toyota DOT 3, 259 °C for Motorcraft ford DOT 3, 246 °C for Veedol DoT 3, 269 °C for AcDelco DOT 4 and 275 °C for Mercedes Benz DOT 4 plus.

The results shows that All the new brake fluids give a higher fluid specification than the specified limit, which was higher than specified limits for the highest number and higher than the fluid specification for the lowest results.

Although the new brake fluid was well sealed, the new brake fluids tests show a water content in the brake fluid same water contents with the brake fluid used in some vehicles which is 1.5% moisture content.

5. Research Results

5.1. Test 1. The percentage of water content in the brake fluid:

The first test was carried out by BF200 Moisture analyzer detector to determine the percentage of water content in the brake fluid.

Figure 3 shows, that the calibration curve for the relationship between brake fluid moisture content and vehicle mileages. 50% Passenger cars manufactured years from 2019 to 2023 has 1.5% and lower water contents comparing to 72% of Passenger cars manufactured from 2007 to 2017 that has above 2% to 3.5% of water contents. The highest moisture level on the brake fluid founded was 3.5% which was for 2013 manufactured year passenger cars followed by 3% for 2010, 2012 model's passenger car, and two 2019 model's passenger cars.

Although the highest moisture level on the brake fluid founded was 3.5% for 2013 model, but still did not reach the maximum permissible rate of 3.7%.

Once the fluid has reached 3.7% moisture, the boiling point expected to be fallen to Wet Boiling Point, 140°C.

All results for the brake fluid temperature value and the percentage of water content were recorded in one table for the selected group of 35 vehicles (Table 3).

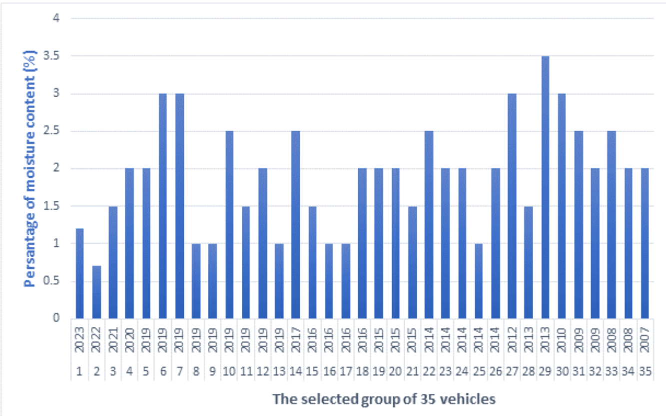

Figure 3: Calibration curve for the relationship between brake fluid moisture content and vehicles manufacture years.

5.2. Test 2. Brake fluid temperature:

The second test was carried out by BOSCH BFT 100 to record the test results and show the brake fluid temperature value. Figure 4 shows the change in the boiling point of the vehicles brake fluid depending on manufacture year.

The boiling point of 86% (19 cars from total of 23) vehicles from 2007 to 2017 drop to 195°C and lower to 178°C, while only 15% (2 cars from total of 13) of vehicles from 2019 to 2023 drop to 184°C and 194°C and both of these cars are 5 years old, which manufacture in 2019.

The collected date from the all tested cars does not shows any brake fluid boiling point that drop below the stander Wet Boiling Point.

Table 3 shows a comparisons of brake fluid boiling point and water content for the selected group of 35 vehicles.

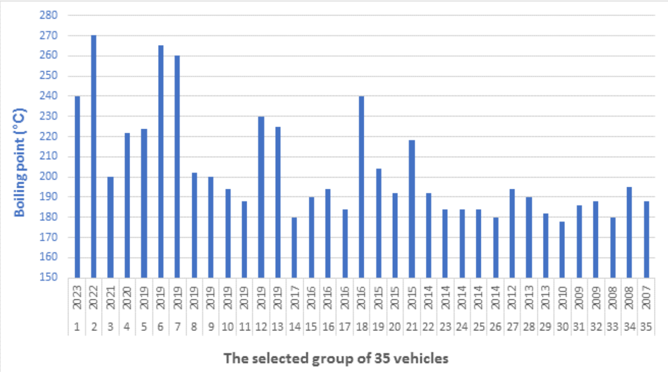

Figure 4: Calibration curve for the Brake fluid boiling point value depending on vehicle manufacture years.

Table 3: shows the result of brake fluid water content and boiling point for the selected group of 35 vehicles.

No	Vehicle Type	No of cyl	Model	Odometer (Km)	Fluid type	Water content test result (%)	Boiling point test result (°C)
1	Mazda CX-9	4	2023	12000	DOT3	1.2	240
2	Ford F150	8	2022	42000	DOT4	0.7	270
3	Toyota Prado	6	2021	37000	DOT3	1.5	200
4	Chevrolet Caprice	8	2020	95000	DOT4	2	222
5	MG 6	6	2019	48000	DOT4	2	224
6	Mercedes E200	4	2019	49000	DOT4+	3	218
7	Mercedes GLC 250	4	2019	50000	DOT4+	3	204
8	Cadillac Escalade	8	2019	65000	DOT3	1	202
9	Toyota Land Cruiser	8	2019	87000	DOT3	1	200
10	Chevrolet Blazer	6	2019	104000	DOT3	2.5	194
11	Toyota Camry	6	2019	110000	DOT3&4	1.5	188
12	Chevrolet Tahoe	8	2019	207000	DOT3	2	230
13	Ford F150	8	2019	51000	DOT4	1	225
14	Toyota Camry	4	2017	141000	DOT3&4	2.5	180
15	Nissan Altima	6	2016	91000	DOT3	1.5	190
16	Toyota Land Cruiser	8	2016	200000	DOT3	1	194
17	Toyota Aurion	6	2016	216000	DOT3	1	184
18	GMC Yukon	8	2016	260000	DOT3	2	240
19	BMW X5	6	2015	107000	DOT4	2	204
20	Jeep Grand Cherokee	6	2015	122000	DOT3	2	192
21	Nissan Patrol	8	2015	161000	DOT3	1.5	218
22	Nissan Maxima	6	2014	92000	DOT3	2.5	192
23	Chevrolet Tahoe	8	2014	165000	DOT3	2	184
24	Mitsubishi Pajero	6	2014	178000	DOT3	2	184
25	Nissan Patrol	8	2014	216000	DOT3	1	184
26	Toyota FJ Cruiser	6	2014	239000	DOT3	2	180
27	Dodge Durango	8	2013	147000	DOT4	3	190
28	BMW 320i	4	2013	192000	DOT4	1.5	182
29	Land Rover	6	2012	157000	DOT4	3.5	194
30	Ford Explorer	6	2010	234000	DOT3	3	178

No	Vehicle Type	No of cyl	Model	Odometer (Km)	Fluid type	Water content test result (%)	Boiling point test result (°C)
31	GMC Yukon	8	2009	214000	DOT3	2.5	186
32	Nissan Patrol	6	2009	337000	DOT3	2	188
33	GMC Acadia	6	2008	173000	DOT3	2.5	180
34	GMC Yukon	8	2008	264000	DOT3	2	195
35	Cadillac Escalade	8	2007	308000	DOT3	2	188

Table 4: Comparison between several cars of the selected group that use brake fluid DOT3

No	Vehicle Type	No of cyl	Model	Odometer (Km)	Fluid type	Water content test result (%)	Boiling point test result (°C)
1	Mazda	4	2023	12000	DOT3	1.2	240
2	Toyota Prado	6	2021	37000	DOT3	1.5	200
3	Cadillac Escalade	8	2019	65000	DOT3	1	202
4	Toyota Land Cruiser	8	2019	87000	DOT3	1	200
5	Chevrolet Blazer	6	2019	104000	DOT3	2.5	194
6	Toyota Camry	6	2019	110000	DOT3&4	1.5	188
7	Chevrolet Tahoe	8	2019	207000	DOT3	2	230
8	Toyota Camry	4	2017	141000	DOT3&4	2.5	180
9	Nissan Altima	6	2016	91000	DOT3	1.5	190
10	Toyota Land Cruiser	8	2016	200000	DOT3	1	194
11	Toyota Aurion	6	2016	216000	DOT3	1	184
12	GMC Yukon	8	2016	260000	DOT3	2	240
13	Jeep Grand Cherokee	6	2015	122000	DOT3	2	192
14	Nissan Patrol	8	2015	161000	DOT3	1.5	218
15	Nissan Maxima	6	2014	92000	DOT3	2.5	192
16	Chevrolet Tahoe	8	2014	165000	DOT3	2	184
17	Mitsubishi Pajero	6	2014	178000	DOT3	2	184
18	Nissan Patrol	8	2014	216000	DOT3	1	184
19	Toyota FJ Cruiser	6	2014	239000	DOT3	2	180
20	Ford Explorer	6	2010	234000	DOT3	3	178
21	GMC Yukon	8	2009	214000	DOT3	2.5	186
22	Nissan Patrol	6	2009	337000	DOT3	2	188
23	GMC Acadia	6	2008	173000	DOT3	2.5	180
24	GMC Yukon	8	2008	264000	DOT3	2	195
25	Cadillac Escalade	8	2007	308000	DOT3	2	188

Table 5: Comparison between several cars of the selected group that use brake fluid DOT4

No	Vehicle Type	No of cyl	Model	Odometer (Km)	Fluid type	Water content test result (%)	Boiling point test result (°C)
1	Ford F150	8	2022	42000	DOT4	0.7	270
2	Chevrolet Caprice	8	2020	95000	DOT4	2	222
3	MG 6	6	2019	48000	DOT4	2	224
4	Toyota Camry	6	2019	110000	DOT3&4	1.5	188
5	Ford F150	8	2019	51000	DOT4	1	225

6	Toyota Camry	4	2017	141000	DOT3&4	2.5	180
7	BMW X5	6	2015	107000	DOT4	2	204
8	Dodge Durango	8	2013	147000	DOT4	3	190
9	BMW 320i	4	2013	192000	DOT4	1.5	182
10	Land Rover	6	2012	157000	DOT4	3.5	194

By studying the Table 4&5 Dot 3 & 4 brake fluid type, the results does not shows significant relationship between the boiling point of brake fluid and water content with the car age, car mileages and type of brake fluid of the selected groups of 35 cars. Also, it is noted that there is inaccurate slight annual increase in the percentage of water content in the brake fluid, as well as a slight annual decrease in the boiling point value.
As for Dot 4 plus, 2 cars were tested, we don't have enough information data.

6. Conclusions

Automotive brake system is very crucial to control re-acceleration of a vehicle and to bring it to complete stop by dissipating kinetic energy via friction to heat. Vehicles that are used in dry climates with low humidity, the moisture absorption of brake fluid is slightly less than the average per year and much less than in areas saturated with moisture. The research shows that a boiling point of brake fluid for 5 years old car, can drop to 184°C and that can become more worst such cars moves in areas with highly humid climates. The highest water contents found was 3.5% for land rover 2012, which is only 0.2% to reach 3.7%. raising the water contents to such high level could dropping boiling point of the brake fluid below the Wet Boiling Point leading to brake failure and lead to accidents. Furthermore, the research shows that lower in boiling temperature of the used car during the last five years, shows the necessity to check regularly and find early any change could happened in boiling point or humidity or replace the brake fluid to avoid and sudden change in brake fluid specifications.
Besides that, the master cylinder, brake caliper, wheel cylinder assembly and brake system seals conditions should be taken in consideration when changing the brake fluid, that might cause brake fluid leak or luck in brake pressure drop due the system wear. Some industrialists recommendations to replace the brake fluid every 2 years or 40000 km, due to its saturation with excessive moisture that leads to a low boiling point are for areas saturated with high humidity and difficult driving conditions (continuous hard driving or mountain driving). However, the study does not shows relation between the change in the brake fluid specification and the car age or car mileage hence the change in brake fluid specification results due car movement not due to the distance the car achieved. Some other factors that may affect the brake fluid, such as changing the characteristics of the brake fluid due to wear of the system parts, which are not covered by this study, may be studied in other research.

7. References

[1] Bhat, N. R., Lekha, V. S., Suleiman, M. K., Thomas, B., Ali, S. I., George, P., & Al-Mulla, L. (2012). Estimation of water requirements for young date palms under arid climatic conditions of Kuwait. *World Journal of Agricultural Sciences*, *8*(5), 448-452.

[2] Caban, J., Vrábel, J., Šarkan, B., Kuranc, A., & Słowik, T. (2021). Operational tests of brake fluid in passenger cars. *Periodica Polytechnica Transportation Engineering*, *49*(2), 126-131.

[3] BĄKOWSKI, H., STANIK, Z., & KUBIK, A. (2017). BADANIE PROCESÓW ZUŻYCIOWYCH PŁYNU HAMULCOWEGO W ZŁOŻONYCH WARUNKACH WYMUSZEŃ. *KWARTALNIK TRIBOLOGIA, 273(3), 21-27.*

[4] Selvanathan, P. S., & Govindaraj, R. (2017). Enhanced Temperature Control in Disc Brakes. *Bonfring International Journal of Industrial Engineering and Management Science*, *7*(1), 05- 08.

[5] Lee, K. (1999). *Numerical prediction of brake fluid temperature rise during braking and heat soaking (No. 1999-01-0483). SAE Technical Paper.*

[6] Jakóbiec, J. A. N. U. S. Z. (2006). Badania stanowiskowe płynów hamulcowych. *Archiwum Motoryzacji, (1), 63-78.*

[7] Caban, J., Vrábel, J., Šarkan, B., Kuranc, A., & Słowik, T. (2021). Operational tests of brake fluid in passenger cars. *Periodica Polytechnica Transportation Engineering*, *49*(2), 126-131.

[8] Wójcik, M. (2018). Rheological properties of new and used brake fluids. *Acta Mecánica Slovaca, 22(4), 50-54.*

[9] Čorňák, Š., Balík, R., & Barták, J. (2006). THE SPECIFICS ASPECTS OF BRAKE FLUIDS EVALUATION IN OPERATION. *Perner's Contacts*, *1*(4), 1-6.

[10] Almedeij, J. (2012). Modeling pan evaporation for Kuwait by multiple linear regression. *The Scientific World Journal, 2012.*

[11] *Climate & Weather Averages in Kuwait City, Kuwait*. (n.d.). Www.timeanddate.com. Retrieved May10, 2023, from https://www.timeanddate.com/weather/kuwait/kuwait-city/climate

[12] Halderman, J. D., & Mitchell, C. D. (2004). *Automotive brake systems*. Pearson/Prentice Hall.

[13] Federal Motor Vehicle Safety Standards 116, U.S department of transportation, National Highway Traffic Safety Administration, 1991

[14] Sanders, P. J., & Barry, J. (1985). *Conversion of Hydraulic Brake Systems from Polyglycol to Silicone Brake Fluid: Residual Polyglycol Remaining After Conversion*. MATERIALS RESEARCH LABS ASCOT VALE (AUSTRALIA).