Articles

Analysis of the plastic point of brake fluid in L3 category vehicles at preset times.

Análisis del punto plástico de líquido de frenos en vehículos categoría L3 en tiempos preestablecidos

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ABSTRACT

Brake fluid is the element of the braking system with the lowest priority when performing maintenance; however, it is key to the safety offered by the system in emergency situations. Previous studies have analyzed brake fluid wear focused on M1 category vehicles; the present study focuses on the analysis of brake fluid in L3 category vehicles according to pre-established times and mileages, based on the analysis of two essential fluid properties: boiling point and humidity percentage. For the analysis, 6 samples of DOT 4 category fluid were taken from motorcycles of different origins included among the most commercialized brands in Ecuador, for which 3 measuring equipment were used, GD-F 8063, BOSCH BTF100 and Duoyi DY23B, based on ASTM D110 and FMVSS116 standards. For each sample, 3 measurements were performed for the two properties under analysis, obtaining a measurement average validated by ANOVA statistical analysis. It was determined that the brake fluid reaches its plastic point after 17000 km, where its boiling point is less than 155°C with a humidity percentage higher than 3%. It was

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established that fluid wear depends to a greater extent on the mileage traveled than on the age of the vehicle. In addition, increasing new brake fluid does not present a benefit since the properties of the fluid do not undergo a significant improvement that would help to extend its useful life.
Keywords: Plastic point, DOT4 brake fluid, hygroscopy, moisture percentage.

RESUMEN
El líquido de frenos se constituye como el elemento del sistema de frenado con menor prioridad al realizar mantenimientos, sin embargo, es clave en la seguridad que ofrece el sistema en situaciones de emergencia. Estudios previos han analizado el desgaste del líquido de frenos enfocados hacia vehículos de categoría M1, el presente estudio se centra en el análisis del líquido de frenos en vehículos categoría L3 de acuerdo a tiempos y kilometrajes preestablecidos, en función del análisis de dos propiedades del líquido esenciales, estas son el punto de ebullición y porcentaje de humedad. Para el análisis se tomaron 6 muestras de líquido categoría DOT 4 pertenecientes a motocicletas de distintas procedencias incluidas entre las marcas más comercializadas del Ecuador para las cuales se utilizó 3 equipos de medición, GD-F 8063, BOSCH BTF100 y Duoyi DY23B, basándose en las normativas ASTM D110 y FMVSS116. En cada muestra se realizaron 3 mediciones para las dos propiedades en análisis, obteniendo un promedio de medición validado por un análisis estadístico ANOVA. Se determinó que el líquido de frenos llega a su punto plástico superando los 17000 km, en donde su punto de ebullición es menor a 155°C con un porcentaje de humedad superior al 3%. Se estableció que el desgaste del líquido depende en mayor medida del kilometraje recorrido que de la antigüedad del vehículo. Además, el incrementar líquido de frenos nuevo no presenta un beneficio ya que las propiedades del líquido no sufren una mejora significativa que ayuden a alargar su vida útil.

Palbras claves: Punto plástico, líquido de frenos DOT4, higroscopia, porcentaje de humedad.

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INTRODUCTION

In a vehicle there are several systems that together provide safety and comfort to its occupants, one of the most important is the braking system, which has the purpose of stopping the vehicle according to the driver's requirements in an efficient manner. In turn, a fundamental component of the braking system, which is not given due attention, is the brake fluid. With the passage of time and mileage, the brake fluid loses its physicochemical properties and, due to its hygroscopic characteristics, absorbs moisture, lowering its boiling point until it reaches the plastic point, which compromises braking efficiency. The degree of wear in the fluid or alteration of its physicochemical properties, in turn, is influenced by the composition of the fluid as defined by each manufacturer. Although this characteristic has been previously studied, only category M1 vehicles have been taken into consideration, so this study focuses on category L3 vehicles, which in recent years have been increasing their market share, mainly due to the health crisis experienced worldwide since 2020 due to the appearance of COVID-19. The pandemic brought with it a higher unemployment rate and with it a strong economic crisis, so many people opted to change cars for motorcycles as a more economical means of transportation. This is reflected in the number of sales of motorcycles, which according to (Coba, 2020) for June 2020 increased by 25% compared to 2019, and this increase in sales is maintained since 130483 units were sold in 2020. (Baldeón et al., 2020) and in 2021 the figure rose to 165701 (Baldeón et al., 2021), showing an increase in sales of 27% (Baldeón et al., 2021). showing an increase in sales of 27%.

The present study focuses on the analysis of the condition of the brake fluid as a function of its boiling point, taking into account different models of motorcycles marketed in Ecuador, in which the brake fluid presents a degree of wear according to pre-established times. In addition, with an analysis of the amount of moisture absorbed by the brake fluid due to its use and contact with the environment, its relationship with respect to the decrease in the boiling point of the fluid is determined. With a comparison of these results, a relationship is established between the boiling point, the absorbed moisture and the condition of the brake fluid according to the mileage travelled and the time elapsed.

According to Evtiukov as cited in. (Podoprigora et al., 2018), one out of three traffic accidents has its origin in failures of the vehicle braking system. Currently, several instruments are used to measure the condition of the braking system in vehicle technical inspections, however, they are focused on controlling the condition of the friction elements such as brake discs, pads, and shoes, but not on a global evaluation of the entire system, leaving aside other system characteristics that change during vehicle operation, such as brake fluid (Podoprigora et al., 2018)..

As the safety requirements of vehicles increase, it is also necessary to use high performance fluids whose characteristics ensure the correct operation of the different systems. Basically, brake fluid is a solution of ethylene glycol and polyglycols, together

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with lubricants and corrosion inhibitors. Brake fluid commonly consists of 70 to 80% of base fluid, to which 20 to 30% of lubricants and 1 to 5% of additives that protect the metal from corrosion are added. (Wójcik, 2019).
Due to the passage of time and use, brake fluid changes its properties such as viscosity, lubricating and anticorrosive properties, and mainly its boiling point, which is affected due to its hygroscopic characteristic, i.e. the facility it has to absorb moisture (Skrucany et al., 2016).. This characteristic is manifested due to the main component of the brake fluid, i.e. ethylene glycol, which due to its molecular structure (O-H), is attracted to the moisture present in the environment (Mitchell et al., 2006).
This article focused on the analysis of the plastic point of different brake fluids used in various models of vehicles belonging to the L3 category, taking into consideration different origins. For this purpose, a sample of the fluid was obtained from each of the motorcycles under analysis in order to measure this physical characteristic according to the times established by the manufacturers in their maintenance plans for fluid replacement.
Safety in driving depends on different factors such as the human, the vehicle and the road; in this sense, active and passive safety refer to the vehicle and the safety systems it has (Rodriguez et al., 2022). (Rodriguez et al., 2022). Active safety is attributed to those mechanisms aimed at reducing risks during the driving of the vehicle where the driver intervenes directly on them, i.e. it focuses on accident prevention (Ferro, 2021)On the other hand, passive safety focuses on mechanisms aimed at reducing the effects of an accident on passengers, i.e. they act as soon as an accident has occurred. This group includes a series of devices that, although they are currently mandatory, have been implemented gradually (Rodriguez et al., 2022). In category L3 vehicles, active and passive safety systems have been adapted according to their requirements; thus, they share elements with automobiles and implement systems typical of motorcycles.
Brake fluid plays a fundamental role in vehicle safety as it transmits the power from the pedal to the piston or cylinders and in turn to the friction elements to activate the braking system in a smooth, fast and safe manner. (Bako et al., 2019). Like all fluids it is incompressible, so it transmits force instantaneously to the friction elements. The manufacturing norms and quality standards of brake fluids are given by the United States Department of Transportation (DOT), thus these have an identification according to their use and application given by this regulatory entity (Instituto Técnico de Capacitación y Productividad INTECAP, 2008).. Two main types of brake fluids are commercialized in motorcycles, DOT3 and DOT4, which have different physicochemical characteristics defined on the basis of internationally established standards such as FMVS116 or SAE J 1703.
One of the most important characteristics of brake fluid, which makes it possible to determine its condition, is its boiling point, from which the dry boiling point, which refers to the resistance index of the fluid to thermal stress, and the wet boiling point are differentiated, referring to the dry boiling point affected by the absorption of water by the liquid due to its hygroscopic characteristics derived from its constituent elements,

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such as ethylene glycol and polyglycols, which due to their molecular structure (O-H) facilitate the formation of hydrogen bonds with other molecules present in the environment (Mitchell et al., 2006). To measure the boiling point, variations in external factors such as atmospheric pressure must be taken into account, so the boiling point will vary according to the atmospheric characteristics of the place.

MATERIALS AND METHODS

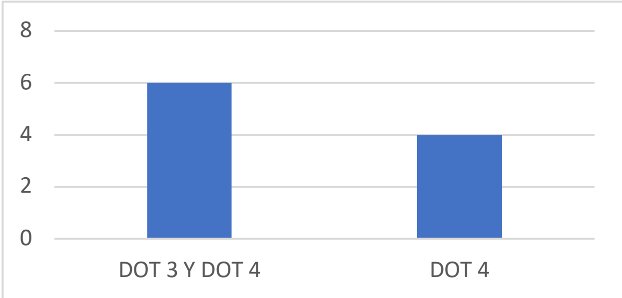
This research is based on a quantitative approach focused on the collection of structured data regarding the essential characteristics of brake fluid such as its boiling point and percentage of humidity with respect to the mileage traveled and time elapsed, which were validated through a statistical analysis based on the method of variance of one factor or One Way ANOVA. Regarding the type of study to be used, the interpretative descriptive study was used as a reference. This type of study is related to the investigation of brake fluid behavior based on the analysis of a specific category of brake fluid, so that the variables taken into consideration meet the same standard that allows determining the characteristics through uniform methods. (Guevara et al., 2020).. Thus, DOT4 has been taken as the reference liquid since it is currently the most used liquid according to various sources such as authorized services of Japanese, Indian and Chinese brands. Finally, the comparative tool was used to compare the results obtained. The approach is oriented to the sampling of brake fluid in different states of degradation according to established mileages, with which results were obtained that allowed establishing a comparison between the decrease in the boiling point and the increase in the percentage of humidity.

MATERIALS

Brake fluid

Currently, essentially four categories of brake fluids are marketed, such as DOT3, DOT4, DOT5 and DOT5.1, however, commercially the most common fluids according to (Wójcik, 2019) are DOT 3 and DOT 4 since DOT 5.1 brake fluid is mostly used in high performance or competition vehicles, and on the other hand DOT 5 has a synthetic base that makes it incompatible with other fluids, therefore, its use is uncommon. In order to determine the brake fluid to be used, a previous research was carried out in which the following data was obtained on the brake fluid used by 10 different L3 category vehicles of different brands marketed in the country.

Figure 1. Type of brake fluid used by motorcycles of different brands.



Source: Authors

Vehicle

In this study, L3 category vehicles from different origins belonging to the 15 most commercialized brands in the country have been taken into consideration in order to establish a comparison based on different motorcycles with a strong presence in the market. Table 4 shows the models and mileage of the motorcycles taken into consideration.

Table 1. *Vehicle models used for sample collection*

Vehicle	Year	Mileage
LX1	2022	4125 km
SCh2	2021	10573 km
BjP3	2020	16871 km
SzV4	2020	22168 km
YSZ5	2020	25531 km
TKCR6	2022	30687 km

Source: Authors

The mileages chosen are based on the manufacturers' indications, according to the brake fluid change period recommended by the manufacturers, i.e. every 2 years. Therefore, a fluid analysis was performed approximately every 5000 km of travel, taking into account that an average of about 15,000 km are traveled per year.

Regulations

To carry out the brake fluid tests, essentially two standards were used; on the one hand, ASTM D1120 was considered, which covers the determination of the equilibrium boiling point of engine coolants and brake fluids contemplated in the Ecuadorian standard NTE INEN 44; this boiling point refers to the temperature at which the sample changes state under equilibrium conditions at atmospheric pressure. (ASTM INTERNATIONAL, 2004). The second regulation taken into consideration is the FMVSS116 from which an

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extract was taken referring to the minimum conditions that brake fluid must comply with to be considered **safe** (Code of Federal Regulations, 2004).

Measuring equipment

Three devices were used to measure the different brake fluids, two of them for measuring the boiling point in °C of brake fluid GD-F 8063 Engine Coolants Boiling Point Tester and Bosch BFT100, and one for measuring the percentage of moisture present in Duoyi DY23B.

RESULTS

Measurement protocol

To take the samples, a total brake fluid change was carried out on all the motorcycles under study, extracting the brake fluid present in the front and rear reservoirs and brake pipes, obtaining fluid samples of between 60 and 90 ml depending on the size of the motorcycle reservoirs. Two methods were used to measure the boiling point. On the one hand, use was made of Bosch BFT 100 equipment in which 3 measurements were taken for each sample in order to establish reliable results. This is based on the concept of repeatability, which according to (Senar, 2001) is a statistical measure referring to the consistency of measurements of a certain characteristic in the same individual; to have a reliable repeatability result, at least 2 measurements must be performed in each individual or sample. The repeatability study is carried out through an analysis of variance of a single factor ANOVA, where the repeatability will have a value from 0 to 1 being an acceptable value for a study of 0.7. In turn, the boiling point was validated through the measurement of this characteristic in the QUALCO laboratory through the application of the ASTM D1120 standard using the GD-F 8063 equipment in one of the samples, corroborating the information obtained with the BOSCH BFT100 equipment, as indicated by (Mills, 1998) in his patent FLUID BOILING POINT ANALYZER, where he emphasizes that to verify the measurements obtained with the BFT100 equipment, a sample can be sent to the laboratory to measure the equilibrium boiling point. Subsequently, the moisture present in the liquid was measured using the same concept of repeatability with the objective of establishing a relationship between the decrease in boiling point and the increase in moisture absorption due to the hygroscopic characteristic of the liquid using the Duoyi DY23B equipment. Finally, an amount of 10 ml of new DOT 4 liquid was added to the samples that were found to be below the wet boiling point, and the same measurements were performed on these samples as on the original samples in order to establish whether or not there is an improvement in the properties of the liquid by carrying out this practice.

Boiling point measurement results

As previously mentioned, 3 boiling point tests were performed, from which an average of the temperature at which the brake fluid changes phase was obtained.

Table 2. *Results of boiling point measurement with BOSCH BFT 100 equipment*

Motorcycle	No. Test	Boiling point (°C)	Average boiling point (°C)
	1	194	
LX1	2	197	194
	3	190	
	1	165	
SCh2	2	165	166
	3	168	
	1	160	
BjP3	2	155	157
	3	157	
	1	142	
SzV4	2	142	140
	3	136	
	1	144	
YSZ5	2	140	138
	3	131	
	1	136	
TKCR6	2	132	131
	3	126	

***Source**:* Authors

The measurements made with the BOSCH BFT 100 were validated by means of the ANOVA statistical analysis presented below.

Table 3. *Analysis of Variance One Way ANOVA of boiling point.*

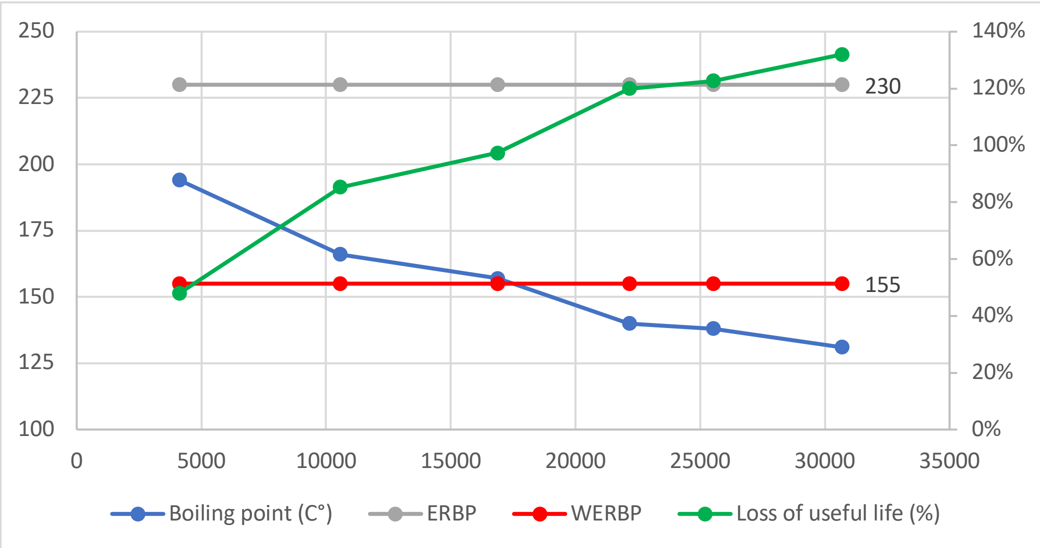
Origin of variations	Sum of squares	Degrees of freedom	Mean squares
Between groups	7485,962723	5	1497,192545
Within the groups	207,6803501	12	17,30669584

Source: Authors

Based on this analysis, the values obtained from the mean square average between groups and within groups are applied to obtain the value of the repeatability of the measurements according to the formula established by (Senar, 2001). Thus the degree of repeatability is 98%, with a measurement error of 2%. In addition to this statistical analysis, the results obtained through the measurement of the equilibrium boiling point in the QUALCO laboratory were confirmed through the validation of the sample belonging to the LX1 motorcycle, where a value of 183°C was obtained (Tutiven &

Moscoso, 2001). (Tutiven & Moscoso, 2022) presenting a variation of 5.6% with respect to the measurements made with the Bosch BFT 100 equipment, an acceptable value according to the precision granted by the equipment manufacturer, which indicates variations close to 5% for temperature measurement ranges higher than 180°C.
Figure 2 shows the graph of the results of the boiling point in the different brake fluid samples, these results are analyzed as a function of the mileage of the motorcycles, observing a decrease in the boiling point as the mileage increases in each of the samples.

Figure 2. *Boiling point measurement results*



Source: Authors

The measurements carried out show that the useful life of the DOT 4 brake fluid at only 4125 km was reduced by 48%, i.e. it has lost half of its useful life, while at the following mileages measured, i.e. at 10573 and 16871 km, the reduction of its useful life was 85% and 97%, at this point being considered unusable, since it is 3% away from reaching the plastic point at which the fluid definitively loses its properties and represents a risk to the safety of the braking system. Based on these results, it can be interpreted that the boiling point of the brake fluid, as indicated by the FMVSS116 standard, loses its minimum operating conditions after 17000 km traveled, i.e. its boiling point is at the limit point of the minimum acceptable temperature of 155°C. At 30,000 km traveled, the brake fluid represents a total risk for the driver since it has an extremely low boiling point of only 31°C above the boiling point of water .

Results of moisture percentage measurement

As for the degree of moisture absorbed by the different brake fluids under analysis, as with the boiling point measurement, 3 measurements were taken for each sample. The results obtained are shown below.

Table 4. *Results of moisture percentage measurement*

Motorcycle	No. Test	% Humidity	Average % humidity
	1	1,5	
LX1	2	1,9	1,7
	3	1,7	
	1	2,1	
SCh2	2	2,3	2,2
	3	2,1	
	1	2,6	
BjP3	2	2,6	2,6
	3	2,6	
	1	3,4	
SzV4	2	3	3,1
	3	3	
	1	3,4	
YSZ5	2	3	3,3
	3	3,6	
	1	4	
TKCR6	2	3,8	3,8
	3	3,6	

Source: Authors

Likewise, these measurements were validated through an ANOVA statistical analysis, verifying their reliability. The analysis is shown in Table 11.

Table 5. *Analysis of Variance One Way ANOVA of moisture percentage.*

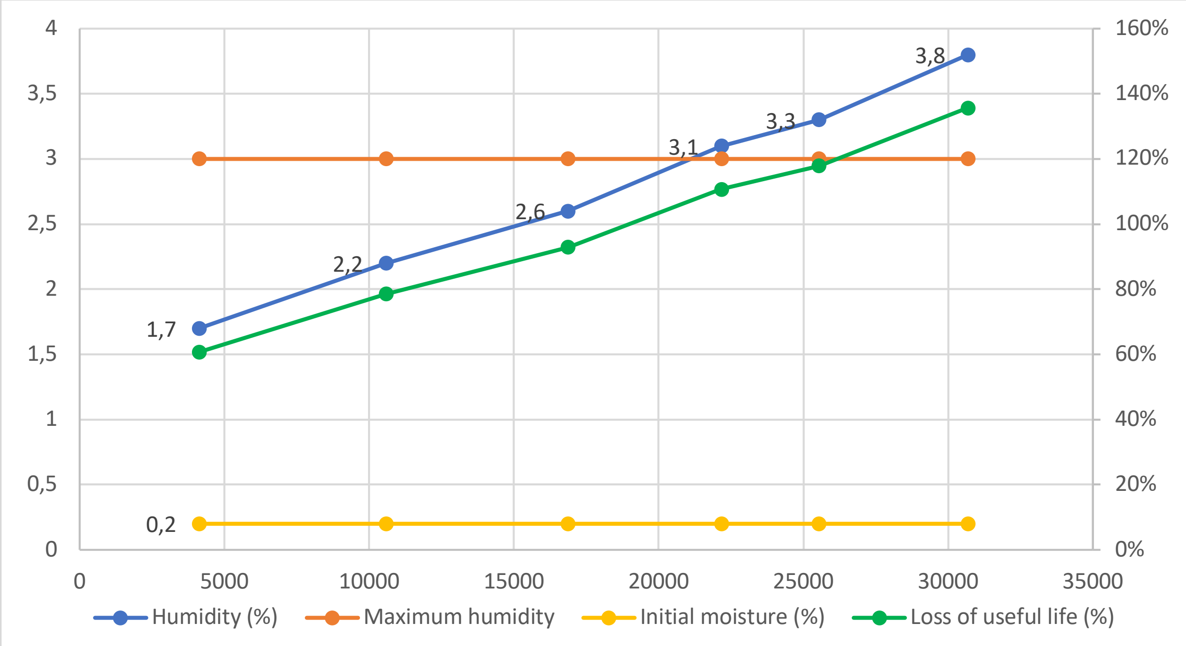
Origin of variations	Sum of squares	Degrees of freedom	Mean squares
Between groups	9,137777778	5	1,827555556
Within the groups	0,48	12	0,04

Source: Authors

Based on the data obtained from the average of squares between groups and within groups, the repeatability equation established by (Senar, 2001) determining that the degree of repeatability is 96% with a measurement error of 4%.

Figure 3 shows the results obtained in the form of a graph of the moisture measurement in each of the brake fluid samples, taking as a reference a maximum tolerable moisture value of 3% in the fluid, thus defining the point at which it is no longer useful.

Figure 3. *Results of moisture percentage measurement*



Source: Authors

According to the results obtained by measuring the condition of the brake fluid based on the moisture present in it, the useful life of the fluid decreases by 36% at 4125 km traveled and continues to decrease to 85% loss up to 17000 km; at this point the fluid is close to the maximum limit of moisture above which it is no longer useful, however, it still meets the minimum operating conditions. The critical point according to the analysis of the condition of the fluid by moisture measurement is near 22000 km, where the amount of water absorbed by the fluid represents a risk for the braking system. Brake fluid in optimum conditions contains 0.1% moisture and gradually loses its properties until it reaches a value of 3% moisture present, which indicates that after this mileage the brake fluid is no longer useful. It is evident that, despite the fact that the sample of 30687 km belonging to the TKCR6 motorcycle is 2 years more recent compared to the samples of other motorcycles except for sample LX1, it is the sample that has absorbed the greatest amount of water, this is due to the operating conditions of the vehicle, which has a high mileage compared to its age. Due to its hygroscopic characteristic, brake fluid is prone to absorb moisture, and the greater its exposure to the environment, the greater the absorption.

Boiling point and moisture percentage results for samples with new brake fluid increase

After measuring the boiling point of the brake fluid in the samples of the 6 motorcycles under study, it was determined that the brake fluid of 3 motorcycles had lost the minimum operating requirements, so 10 ml of new fluid of the same category, i.e. DOT 4, was added, obtaining the following results regarding boiling point

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Table 6. *Boiling point measurement results with increment of new brake fluid category DOT 4.*

Motorcycle	No. Test	Boiling point (°C)	Average boiling point (°C)
	1	141	
SzV4	2	142	142
	3	144	
	1	135	
YSZ5	2	139	139
	3	143	
	1	133	
TKCR6	2	130	132
	3	134	

Source: Authors

As in the measurement of the initial samples, the percentage of moisture present in these three samples after the increase of new brake fluid was measured, obtaining the results presented in Table 7.

Table 7. *Results of moisture percentage measurement with increment of new brake fluid category DOT 4.*

Motorcycle	No. Test	% Humidity	Average % humidity
	1	2,7	
SzV4	2	2,9	2,9
	3	3	
	1	3,4	
YSZ5	2	2,9	3,1
	3	2,9	
	1	3,8	
TKCR6	2	3,6	3,6
	3	3,4	

Source: Authors

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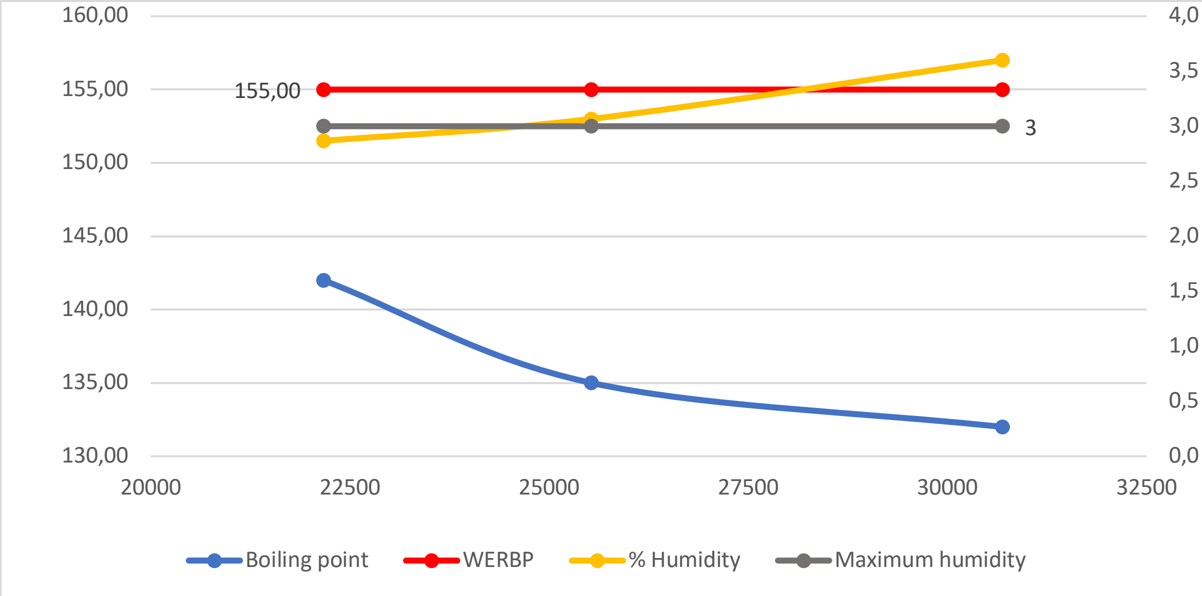
Figure 4 shows the results obtained in graphical form concerning the boiling point and percentage of moisture present in the brake fluid after it has been increased with 10 ml of new fluid.

Figure 4. *Boiling point and moisture percentage results for samples with new brake fluid increase.*



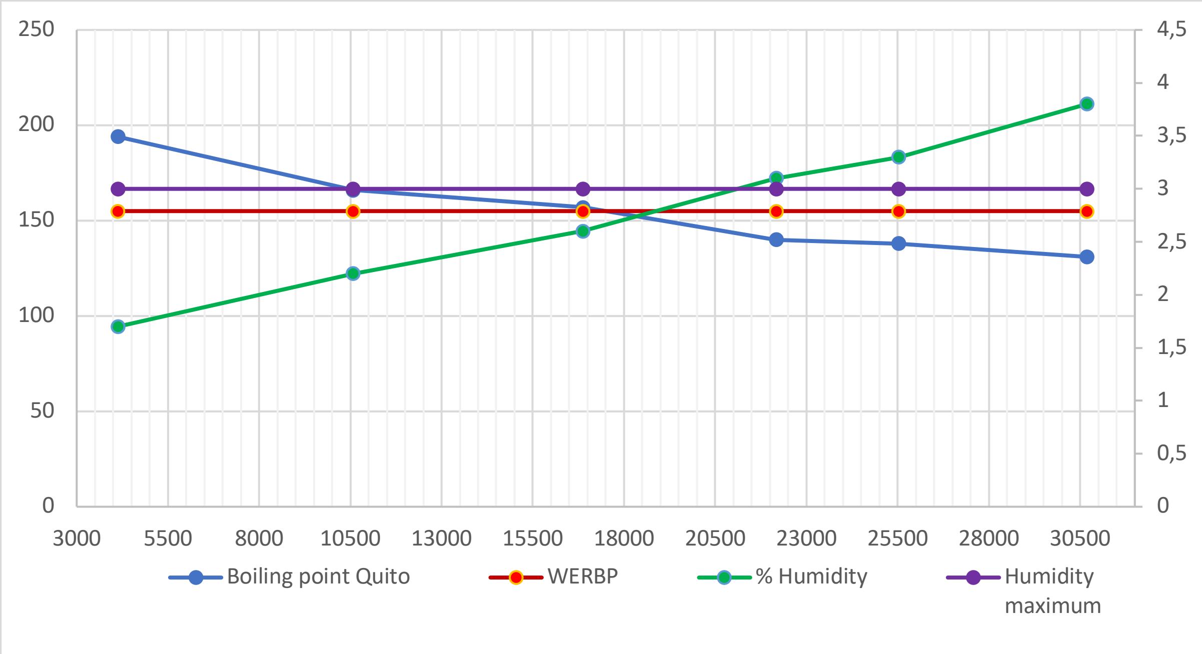
Source: Authors

On average, the brake fluid reservoir in L3 category vehicles has a volume of 30 ml. A common practice in our environment is to top up the brake fluid, however, in very few occasions the complete change of the brake fluid is carried out, so it was decided to simulate this situation in the samples whose boiling point was below the critical point by making an increase of 10 ml of new brake fluid for each sample. It is evident that despite the increase in fresh brake fluid, none of the samples under analysis were able to exceed the wet boiling point or significantly lower the moisture percentage below 3%. This reflects that this practice in this category of vehicles is not beneficial due to the small volume of fluid present in the motorcycle's hydraulic circuit.

Comparison of Results

Figure 5 shows the combination of the results obtained for both boiling point and percentage of moisture in the brake fluid samples of L3 category vehicles, establishing as critical point or limit the wet boiling point or WERBP which is reached at 155°C represented by the red line along the graph, thus identifying the mileage range from which the boiling point of the brake fluid begins to fall below the limit and at the same time its percentage of moisture exceeds the maximum allowed. According to the results obtained, the use of brake fluid that no longer has the physical and chemical characteristics for optimum performance can be prevented.

Figure 5. *Comparison of Results*

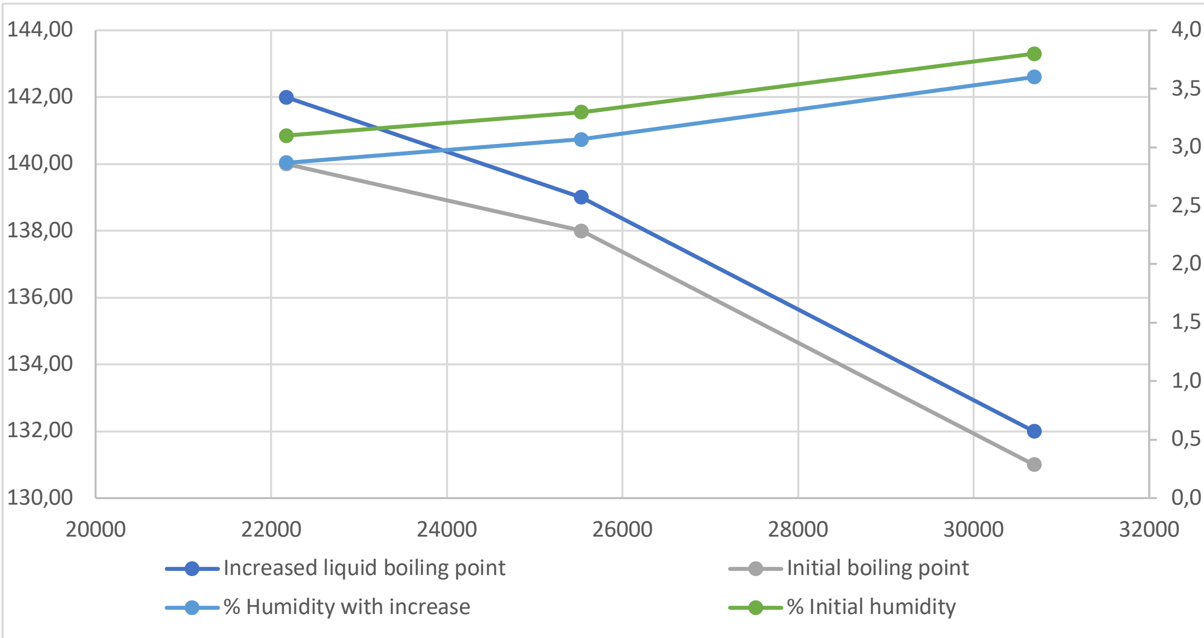


Source: Authors

The comparative results show that the greatest deterioration of the brake fluid occurs in the first 17000 km, where it is observed that with only 2.6% of humidity present in the fluid, the boiling point drop reaches 73°C, that is, 97% of the fluid's useful life is fulfilled within this mileage range, regardless of the motorcycle's age, since the first sample corresponds to vehicle LX1 year 2022, while the second sample corresponds to vehicle SCh2 year 2020, and the third sample corresponds to motorcycle BjP3 year 2020, establishing that the mileage has a greater impact on the fluid's condition than its age. After this mileage, the drop in boiling point is more stable, presenting a drop of 26°C over the next 13000 km. On the other hand, the increase in the percentage of humidity is more uniform throughout the useful life of the brake fluid, it being observed that when the fluid reaches a value close to 4% humidity, the fluid has a boiling point lower than 140°C. The graph shows that the point at which the boiling point and moisture percentage graphs converge is slightly higher at 18000 km with a temperature of 150°C and a moisture percentage slightly higher than 2.5%. This indicates that, although the method of verifying the condition of the brake fluid by measuring the boiling point is more accurate, a good alternative that does not differ greatly is verification by measuring the percentage of moisture, since both methods show similar results.

Figure 6 shows a comparison of the boiling point and moisture percentage results obtained with the initial samples and the samples affected by the increase of new brake fluids in them.

Figure 6. *Comparison of results between the initial samples and the samples affected by the increase of new brake fluid.*



Source: Authors

In the comparison of the results of the initial samples with the samples with an increase in new brake fluid, it is observed that the change in both the boiling point and the percentage of moisture in the samples is minimal. In the sample belonging to motorcycle SzV4 there is an increase of 2°C in the boiling point and a decrease in the moisture percentage of 0.2%; on the other hand, in the sample belonging to motorcycle YSZ5 there is an increase of 1°C and a decrease in moisture of 0.2%. Finally, the sample belonging to motorcycle TKCR6 showed an increase of 1°C and a decrease in humidity of 0.2%. This shows that, once the plastic point in the brake fluid has been reached, mixing with new fluid does not reflect a significant change in the fluid that would help to recover the minimum safety requirements established for the use of the fluid.

DISCUSSION

Due to its basic components such as ethylene glycol and polyglycols whose chemical composition is based on hydrogen and oxygen bonds, brake fluid is prone to absorb humidity from the environment, which directly affects its boiling point, a fundamental characteristic in the safety of the braking system. Due to the operation of the vehicle, this hygroscopic characteristic causes the fluid to lose its properties and in turn affects other elements of the braking system such as pipes and rubbers due to the corrosion generated in the system and the thermal stress to which they are subjected. A brake fluid that does not meet the minimum requirements established in the transport safety regulations is no longer a reliable safety element when driving, since it compromises the

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braking efficiency of the motorcycle as it is prone to generate vapor bubbles that affect the normal braking action of the hydraulic system, which may lead to traffic accidents.
After analyzing the results obtained regarding the boiling point of the brake fluid and the percentage of moisture present in it in L3 category vehicles, it was determined that after 17,000 km of travel, the brake fluid reaches the critical point where its boiling point is below the minimum limit established in safety regulations such as FMVSS 116, presenting values close to 155°C for the boiling point and 3% presence of moisture. After this mileage, the liquid has reached its plastic point and is no longer suitable for operation in the vehicle. These results are counteracted by the maintenance data specified by the manufacturers, who indicate that the brake fluid change should be performed every 2 years or 30,000 km, however, the change should be performed in advance of these recommended times. In addition, it is established that the factor with the greatest incidence on wear is the mileage traveled, imposing itself over the time elapsed; this is evidenced based on the years of manufacture of the motorcycles taken into consideration, where the motorcycle with the greatest wear in the fluid corresponds to the most recent of all those analyzed.
Within the boiling point and humidity percentage tests in the samples that exceeded the elastic point reaching the plastic point, i.e. in the SzV4, YSZ5 and TKCR6 motorcycles, in which 10 ml of new DOT 4 category brake fluid was increased, simulating the recurrent practice in the mechanic workshops of our environment consisting of refilling the missing fluid inside the reservoir, It was established that it does not represent a benefit in the safety of the same, since according to the analysis carried out on these samples, it was obtained that the changes were not significant, with a range of increase of the boiling point between 1 and 2 °C and with a decrease in the percentage of humidity of maximum 0.2% in relation to the total volume of the sample. Therefore, once the plastic point of the brake fluid has been reached, it is recommended that the brake fluid in the system be replaced in its entirety.

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