International Journal of Advancements in Mechanical and Aeronautical Engineering
Volume 3 : Issue 1 [ISSN 2372-4153]
Publication Date : 18 April, 2016

Braking Efficiency Estimation Of An Automobile Vehicle Based On Predictive Parameters

S. Sanz, E. Olmeda, A.M. Gómez, M.J. Boada, B. Boada, V. Díaz

***Abstract*— For the evaluation of the effectiveness of the brake system, most countries have a system of technical review. The test of brake inspection is done on a machine called brake tester. This checkpoint is uncomfortable for the user and it consumes some time of inspection that results in longer waiting time. To minimize this problem arises in this article a methodology to predict, in a large number of occasions, the result of the inspection of the braking system without having to resort to testing inspection by brake tester.**

The methodology is based on an exhaustive inspection data processing as well as validation of other checkpoints already exist in reviewing ITV consisting primarily of the visual inspection of the vehicle.This electronic document is a "live" template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document. *(Abstract)*

***Keywords*— braking force, automobile, itv, prediction**

I. Introduction *(Heading 1)*

The Vehicle Inspection (ITV) is perceived by citizens as a means of helping to maintain the safety of your vehicle, and therefore has an implicit social acceptance. There are studies that scientifically and objectively manifest that provides the ITV contribution to road safety

There are regulations covering the four phases of the life of the vehicle: the design, manufacture, service life and withdrawal from circulation. The specific type approval legislation defines the characteristics required of a vehicle design to be accepted. Once the vehicle is in circulation, it is necessary to ensure that, despite the degradation caused by time and use, the cars continue to maintain adequate technical features that allow safe use. The vehicle inspection is the most common method used by various countries ensures that vehicles on their roads meet adequate standards of conservation.

The technical inspection consists of two distinct parts; visual inspection and mechanical inspection. The visual inspection carried out by the technician, includes a large number of revised points, these points are supplemented by mechanical inspection, doing an exhaustive review of vehicle.

Sanz S., Gómez, A. M., Olmeda, E., Boada M.J., Boada B, Díaz V., San Román J.L.

Instituto de Seguridad de Vehículos Automóviles (ISVA)/ Universidad Carlos III de Madrid
Spain

There is evidence that technical failures vehicles contribute decisively to traffic accidents: the 6% of all automobile accidents should, representing 2,000 deaths annually and a much larger number of injured.[1]

Thirty tree percent of the rejections car [2] in technical inspections are produced by basic safety defects related to the brakes, tires or suspensions, according to a study by the Real Automóvil Club de España [3] and the concessionaire of ITV in Spain, Atisae. From a sample of 153,000 vehicles, 30,000 cars were rejected, representing 19 percent of all vehicles tested. The percentage of vehicles that fail the ITV on first inspection is 15 percent, while in the review of the ten years, the percentage is 24 percent. The main serious defects that lead to rejections in the ITV are exhaust and emissions systems, with 24 percent, defects in the lighting system, with 23 percent, axles, wheels, tires and suspension (22 percent) and poor brakes, accounts for 11 percent. Under this percentage of rejections third it is attributable to passenger cars, leaving the rest to commercial vehicles. Other studies show similar results and shows that, on average, each vehicle is rejected 1,59 detect defects that prevent their circulation due to violations related to safety or to the environment.

Since the passenger vehicles are involved in a greater percentage of injury accidents, in Spain it has analyzed the status of those involved in such accidents. It is observed in a study [4] the percentage due to deterioration of the braking system decreases over the years but very discreetly. In the study it is that traffic accidents are also attributable to other defects detected in ITV and the age of vehicles.

We must mention here that the brake test, along with the detection of gaps, is the most aggressive vehicle. However there is no reason to suggest that any vehicle system is deteriorating for this reason. But it is reasonable to conclude that, as a quasi-dynamic test, there are many physical variables involved in the process, being complex quantification braking efforts. Also a large extent it involved how to stop the driver.

The parameters obtained from the brake tester that may be cause for rejection of the brake system are the brake efficiency (EC.3) ovality (EC.2) and braking force imbalance between wheels on the same axle (Ec .1). These variables are calculated based:

$$D(\%) = \frac{F_{máx} - F_{min}}{F_{máx}} \cdot 100 \quad (1)$$

$$d(\%) = \frac{F_{máx} - F_{min}}{F_{máx}} \cdot 100 \quad (2)$$

$$E(\%) = \frac{F}{(MMA)\cdot g}\cdot 100 \quad (3)$$

II. Objetives

The aim of this article is to have a methodology to reliably predict the brake efficiency of a vehicle, without the use of brake tester, thereby saving time inspection without reducing the quality of the same. In addition, it saves the own vehicle to suffer unnecessary effort, both in the tire, as in the braking system itself, or direction.

It is assumed that the vehicle is well maintained by the user and that before the test brake tester (to be replaced by the methodology described here), has successfully overcome previous checkpoints on ITV, object inspection protocol faithfully follows the technical guidelines of the corresponding Public Administration. In one Conventional periodic inspection, it is inspected prior to the brake system; there are other points that indicate whether the vehicle is able to overcome this final test. Among them are possible leaks in the hydraulic circuit system, brake fluid, deficiencies in the tire, etc.

It should be clarified that the nomenclature of "vehicle inspection" is equivalent to "vehicular review."

III. Methodology

The methodology proposed in this article is based on the experience of the authors in the area of technical inspection ITV, based on the results of over 20 years of implementation of the ITV in Spain.

It is assumed that for a well-maintained by the user and once past a previous point in ITV vehicle inspection, you can anticipate the result of the test on brake tester, adhesion previously knowing it presents for each type of vehicle. Generally, the most important parameter involved in brake tester adhesion is the coefficient of adhesion which this presents against the mass of the vehicle itself. It must be seen in the expression above exposed of the braking efficiency, the mass of the vehicle is compared with full braking force, so it follows that there is a direct relationship between the brake efficiency and grip available, existing in the brake tester during such test.

We must distinguish between passenger cars and commercial vehicles. Each needs a kind of brake tester. Although it is increasingly common use of universal brake testers that allow inspect the brake system of both types. It is stressed here the validity of the methodology if the tyre (for example) is in good working order. Or the brake system disk or drums, actuated by hydraulic or pneumatic system, are also in perfect condition. Generally, these two cases are inspected visually.

To implant this methodology are compiled data from numerous inspections of vehicles. It information collected contains weight, measured braking force axis and efficiency calculated. Importantly, trying to determine the effectiveness of braking, not the efficiency of the brake system and you can follow without stopping the vehicle reach a minimum level of braking forces. Each Administration establishes minimum criteria from which the vehicle is rejected in the brake test. In all European countries it is common and set passenger vehicles for a minimum of 50% efficiency and 45% for heavy vehicles.[5]

Firstly break tester adhesion in question (EC.4) is determined by discriminating according to the vehicle mass. Thus, according to the mass and for the same brake tester, adhesions obtained may differ. To this end we start from a sample of 11,000 vehicles.

$$\mu = \frac{F_{frenado}}{peso}$$

Obviously, assuming brake tester roughness it is constant maintained for an estimated period of 6 months (time that matches the calibration equipment) adhesion will be the same for each braking test.

Known adhesion of brake tester and calculated for a given mass range vehicle, the methodology is to visual inspection the previous checkpoints mentioned above. If it is the favorable result, the vehicle mass is multiplied by the employee adherence obtained in the segment established weights, obtaining full braking force. Therefore it is decided whether the inspection is favorable or not

A. *Prediction Model Of Braking Effectiveness*

In addition to the parameters that affect the braking efficiency mentioned above, there are others that also affect the determination of this value. May be mentioned the tire inflation pressure (pressure below normal mean inflated tire greater resistance to friction so alter the outcome). This significantly increases the fuel consumption and makes the tire wears unevenly, shortening their lifespan. Excessive friction ends up generate safety risks as a potential blowout. The number of kilometers traveled by the vehicle (and seniority) and even the make and model also decisively affect the final result.

In line with this point it is worth quoting a report by the company Dekra in 2015 about the reliability of passenger cars [6]. Dekra is a German management services used Vehicles Company, and industrial inspection certification and has an international network of more than 35,000 stations ITV. In the report, Dekra analyzes a sample of 5,000,000 cars, grouped into more than 450 models of passenger cars, all-terrain vehicles and commercial vehicles. All of them have more than 4 years old and an average mileage of 100,000 km. A first conclusion of the report is that thinning statistical data can be used when deducting the future operation of an automotive vehicle correct or not, based on antiquity the make and model. Should this be a parameter to be added in the future to our study. In addition, a car that is of high cost is not synonymous with it the most reliable. For example, a Mazda 3 costs 25,000 euros and is more robust than a Porsche Cayenne.

This report concludes that what most affects the proper functioning of this system is the use of cars in urban circuit or its own weight. As an example, some data failure rates found in some vehicles are shown by make and model, Table 1.

TABLE I. FAILURE RATE RATIO DEPENDING ON MODEL

Modelo	% de averías
Mercedes Clase A (2013-/)	0,3
Mercedes Clase B (2012-/)	0,4
Nissan Juke (2010-/)	3,3
Chevrolet Orlando (2011-15)	3,3
Volkswagen Up! (2011-/)	3,4
Mini Countryman (2010-/)	3,5
Dacia Sandero (2012-/)	8,4
Alfa Romeo Giulietta (2010-/)	8,5

To develop the methodology, it is part of a population of real data on ITV, a total of 11,000 vehicles, passenger cars and industrial vehicles. Each of the following data is obtained:

- Mass at the time of the review (kg)
- Wheel braking forces (N) obtained in the brake tester.

The collected data were obtained on a line of universal inspection, so it serves both passenger cars and for trucks. As the line along which heavy vehicles are inspected often, data were obtained vehicles whose weights are between the stretch of 2,000 kg and 19,000 kg. This segment contains the segment heavier passenger cars (including vans) and the entire segment of heavy vehicles. It notes that there are few units in the sample of the heaviest vehicles (18 to 19 tons), as they are much less numerous. For treatment of the data has been divided into nine intervals range of 2,000 kg each, thus facilitating the study of the behavior of vehicles on brake tester according to their weight.

Although the starting knowledge weight of each vehicle axle, when brake tester to testing, inspection stations recorded the braking force and the total weight, but not the weight value of each necessary axle. To solve this we assume that the tire grip-set brake tester is similar to the front and rear axles. The weight distribution is calculated as follows (Ec.5 y Ec.6):

$$M_t = \frac{F_{tf} \cdot M_{Total}}{F_{df} + F_{tf}} \quad (5)$$

Where,

M_Total: total vehicle mass

M_t: gravitating mass on the rear axle

M_d: gravitating mass on the front axle

F_tf: braking force on the rear axle

F_df: braking force on the front axle

Also:

$$M_d = M_{Total} - M_t \quad (6)$$

To follow the methodology proposed here, it is now determined the adhesion utilized of each of the inspections carried out in each vehicle, dividing the braking force of each axis as the weight that weighs on him. Obviously it will be the same for each of the vehicle's axles. It should be noted here that the available unused adhesion between a tire and the road now responds to the ratio calculated. For a given contact rule is verified "greater weight to more grip and vice versa". In each of the sections of selected mass is calculated by the average value per tranche of the adhesion utilized, Fig. 3.

Fig. 3: Adherence to weight

The Fig. 3 represents the useful mass adhering section. Should be noted that, since the roughness characteristics of the universal brake tester used in the study are good, this remains practically constant over the entire range of vehicles checked. Only significant decreases for heavier way, because usually tend to go to ITV with little load, resulting ineffectiveness of your brake system.

To discriminate this situation an average value of adhesion is adopted useful sections of mass 2000 kg. So we have different values of this parameter.

The combination of vehicles the following values are obtained,

TABLE II. FORCES VALUES VEHICLE WEIGHT RANGES

Intervalo (·1000kg)	Peso (N)	Adherencia	Fuerza medida (N)	Fuerza Estimada (N)	Error (%) (Fe-Fm)/Fe
2-4	31039	0,706	21702	21905	0,93%
4-6	48844	0,676	33193	33019	0,52%
6-8	70968	0,662	47005	47003	0,00%
8-10	88612	0,682	60413	60447	0,06%
10-12	109716	0,721	78995	79097	0,13%
12-14	131024	0,659	86238	86364	0,15%
14-16	150247	0,600	90043	90124	0,09%
16-18	170260	0,561	95432	95454	0,02%
18-19	182300	0,563	102548	102635	0,08%

In Table 2 is established of the rows, the average vehicle weight of each mass range, the adhesion utilized calculated for each interval (shown in Fig. 3) and the mean total braking force of the vehicle wheels as in brake tester. Multiplying the weight of each vehicle by the useful adhesion and taking the average of all vehicles segment, the total braking force based on the estimated μ used by section is obtained. Finally, the last column shows the relative error between the measured forces on the brake tester and calculated according to this model. In Fig. 4 is shown in this graph. We calculated the correlation between the two functions, and its value of 0.99999. Therefore it can be seen that both curves are very similar. This means that the initial proposal on the objectives of this article will be successful.

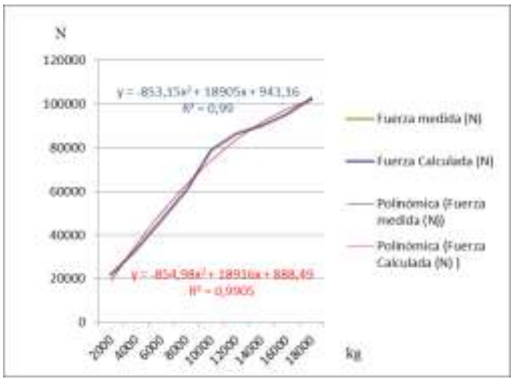

Fig. 4: Evolution force measured and calculated. The abscissa and ordinate mass braking forces as depicted and calculated

The idea of choosing sections, when calculating the useful adhesion is necessary because the technical review does not require taking the vehicle fully loaded. The variability of the load that each user has in his vehicle is very important. Especially in commercial vehicles, which usually come at half load or fully downloaded, for convenience of transporter. Therefore, more section is subdivided more accurate will be prediction model proposed here. To confirm this divisions below the first tranche of charge between 2000 and 4000 kg (Table 3 y Fig. 5). In all other sections the behavior is similar. The same goes for each of the axes.

TABLE III. INTERVAL VALUES OF FORCES VEHICLE WEIGHT ON FRONT AXLE (SECTION BETWEEN 2000 Y 4000 KG)

Intervalo 2000-4000	Peso Delantero (N)	Adherencia promedio eje delantero	Fuerza medida. Delantero (N)	Fuerza Estimada. Delantero (N)	Error (%) (Fe-Fm)/Fe
2000-2300	13236,0376	0,760877687	10036	10071	0,35%
2301-2600	15576,2160	0,76937029	11930	11984	0,45%
2601-2750	13881,2988	0,723753131	10067	10047	0,20%
2751-2900	15717,9351	0,713763395	11182	11219	0,33%
2901-3200	14652,8211	0,72208118	10492	10581	0,84%
3201-3280	19259,8052	0,730612227	13796	14071	1,96%
3281-3300	17783,3674	0,745350651	13246	13255	0,07%
3301-3500	17688,7864	0,707713522	12300	12519	1,75%
3101-3560	19558,4108	0,593659282	11558	11611	0,46%
3561-4000	19445,0223	0,622543682	11786	12105	2,64%

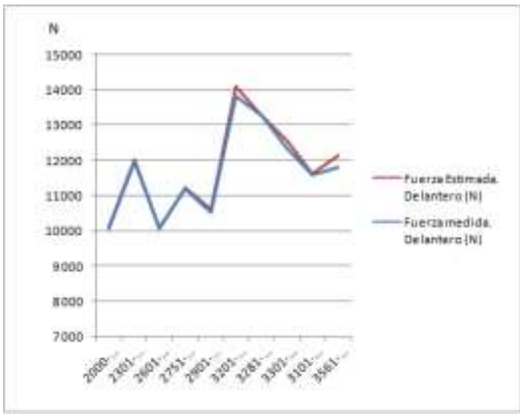

Fig. 1: Evolution force measured and calculated front axle (section between 2000 y 4000 kg).

The proposed methodology is finally this: once maintained and calibrated line revision ITV, is set for a six-month period the service brake tester adherence by sections 2000 kg mass of vehicles. When a particular car comes to ITV and once proven levels of brake circuit, this presents no leak and that the tires are in good condition, is what characterizes mass range is the said vehicle. Sheet of the masses of the front and rear axles are known. They are multiplied by the coefficient of adhesion medium used in that section in question, thereby calculating respective braking forces. The addition of all gives full braking force that should match a small mistake with that obtained directly brake tester.

IV. Conclusions

Analyzed above, it can be concluded that the hypothesis that it is possible to predict the braking force of a vehicle is shown. This prediction is based on a thorough knowledge of the state of the brake tester ITV. Therefore a system for predicting the braking efficiency of the inspection process ITV (Vehicle Revision) to replace real test with brake tester is proposed. This inspection times and unnecessary wear on the tire and the brake system of the vehicle itself are saved. Results of the testing of the methodology follows that drags a relatively small error.

V. Future works

Remains to be done in situ experimental tests that help refine the final result of the methodology presented. Of them should get experimentally know the goodness of the methodology. Given the characteristics of the vehicular review in which the vehicle is described as fit or unfit, we are in a statistically random and binomial case, because the end result is a 0 or a 1. Therefore it needs the Pearson χ^2 for statistical studies in depth. As is known, the Pearson's χ^2 test is a nonparametric test that measures the discrepancy between observed and theoretical distribution proposed by our methodology which shows the goodness of it.

$$\chi^2 = \sum_i \frac{(observed_i - theoretical_i)^2}{theoretical_i} \quad (7)$$

The higher the value of χ^2, less plausible is that the hypothesis is correct. The same way, the more it approaches zero the value of χ^2, are both tighter distributions.

References

[1] [1] J.L. San Román García, A. Gauchía Babé, y V. Díaz López, «Contribución de la Inspección Técnica de Vehículos (ITV) a la seguridad vial 2012», 2012.

[2] [2] «Autofácil», LUIKE, 18-nov-2008.

[3] [3] Real Automóvil Club de España y ATISAE, «El 33% de los rechazos en las ITV son por defectos básicos de seguridad en frenos, ruedas o suspensiones». [En línea]. Disponible en: http://www.europapress.es/motor/noticia-economia-motor-33-rechazos-itv-son-defectos-basicos-seguridad-frenos-ruedas-suspensiones-20081113113818.html. [Accedido: 14-jul-2015].

[4] [4] Contribución de la Inspección Técnica de Vehículos (ITV) a la Seguridad Vial. 2007.

[5] [5] Ministerio de Indutria, Energía y Turismo, «Manual de procedimiento estaciones ITV». ene-2012.

[6] [6] Luis Ramos Penabad, «Informe Dekra 2015: los coches más fiables del mercado», jun. 2015.

Susana Sanz, member of ISVA and Mecatran research group, received her Degree in Mechanical Engineering and Master's Degree in Mechanical Engineering and transportation from Carlos III University of Madrid in 2009 and 2012, respectively. She is currently a research assistant and Professor of The Mechanical Engineering Department at UC3M. Her research area includes vehicles and stability control form automobile vehicles.

Ana María Gómez, member of ISVA and Mecatran research group, received her Master's Degree in Industrial Engineering from Madrid Polytechnic University in 2002. She was working 10 years in Energy Engineering Companies us a project manager. She is currently a research assistant and Professor in Department of Mechanical Engineering at UC3M. Her research area includes control of vehicle lateral dynamics, vehicles and bus dynamics.

Ester Olmeda member of ISVA and Mecatran research group, received her Master's Degree in Mechanical Engineering from the Polytechnic University of Madrid in 2003 (main subject of Machines). After two years working in the Mechanical and Manufacturing Engineering Department at the Polytechnic University, she joined the Mechanical Engineering Department of the University Carlos III of Madrid. She has been working there as Research and Professor since then. In this University she obtained her PhD in Mechanical Engineering in 2008. Her research interests include machinery safety, tribology, vehicles and bus dynamics.

Maria Jesús López Boada, member of ISVA and Mecatran research group, received her Industrial Engineer and PhD degree from Carlos III University of Madrid in 1996 and 2002, respectively. She was research assistant in Department of Systems and Automation Engineering at UC3M between 1997 and 2002. She has worked in control architectures and development of learning skills in autonomous mobile robots. She is currently Professor of the Mechanical Engineering Department at UC3M. Her research area includes intelligent vehicles, both autonomous and motorized, and control of vehicle lateral dynamics

Beatriz López Boada, member of ISVA and Mecatran research group, received her Industrial Engineering and PhD degrees from Carlos III University of Madrid (UC3M) in 1996 and 2002, respectively. She was research assistant in the Department of Systems and Automation Engineering at UC3M from 1997 to 2002. She has worked in the localization and mapping problems in the robotic field. Currently, she is Professor of the Mechanical Engineering Department at UC3M. Her research field covers intelligent vehicles, both autonomous and motorized, and control of vehicle in vertical and lateral dynamics. He also researches in magnetorheological damper, modelling and estimation.

Vicente Díaz is Full Professor of the Mechanical Engineering Department of Carlos III University and leader of research group Mecatran. His area of expertise at UC3M is in the field of transports, vehicle dynamics engineering, end-of-life recycling and motor vehicle inspection. He has a great number of publications and papers indexed in JCR relative to vehicle dynamic modelling (including heavy vehicle), vehicle lateral control and tyre modelling. He has been leader of projects which have been developed for the automobile industry as well as leader in tyre research competitive government projects. In addition, he has supervised several PhD Thesis on bus structure dynamics, tyre modelling and Electronic Stability Control for automobile vehicles