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Performance of Mot Brake Testers with Varying: Tyre Pressures, Distance between Rollers and Roughness of Rollers

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***Abstract*— This research examines the differences in data measured by the force sensor from brake testers at Spanish Ministry of Transport (MOT) testing stations with varying parameters such as tyre pressure, distance between roller, and roller roughness. Experimental data from three ITVs, (Ministry of Transport tests), has been compared. This study will answer the following questions. What part of the braking torque applied to the wheel has been measured by the force sensor of the brake tester at the MOT stations? What affect does the variation of some parameters, such as; tyre pressure, distance between rollers, and roller roughness have on data measured by the force sensor of brake testers.**

***Index Terms*— Brake Force, Longitudinal Sliding, MOT Brake Tester, Performance, Tyre Pressure.**

I. INTRODUCTION

When we perform the vehicle inspection at Ministry of Transport test stations, one of the tests that is applied to our vehicle is the brake test. This test measures, amongst other parameters, the longitudinal brake and effectiveness (Citia, 1999)[1], (EC, 2002)[2], (Ministry of Industry, Tourism and Trade2006,2009)[3-4]. This study deals with the analysis of the performance of the force sensor used in the banks of rollers at an MOT station, see Figure 1. The performance analyzed is the relationship between the torque measured by the sensor and the brake torque applied on the wheel at the time of braking, and this evaluates the MOT tester as a system to measure.

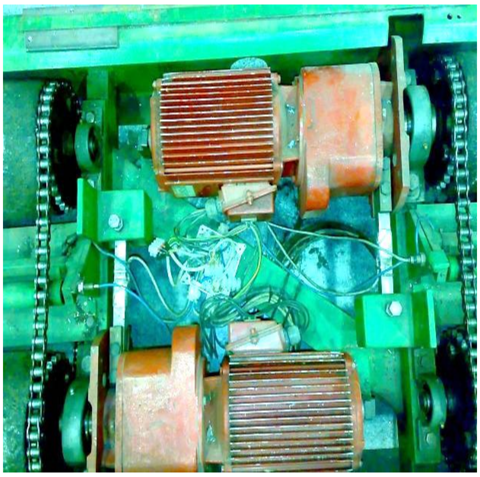

Fig 1. Brake Sensor at MOT390

We have analyzed which are the best conditions for transmitting brake torque. This performance analysis is measured by varying different parameters, such as; the tyre inflation pressure, the distance between rollers and roughness of the surface of the rollers. In the analysis of the influence of pressure on the brake, test pressures studied were: 1 bar, 1.5 bar, 2 bar, 2.5 bar and 3 bar. With these test pressures, it is clearly defined whether or not this parameter influence the brake measurements on MOT brake testers if the rest of the parameters remain constant; thus, any differences in the measurements are solely due to changes in inflation pressure. These same pressure variations in the same type of tyre, a ***Continental Contact***, were performed on three MOT stations. These stations had a different distance between rollers and roughness of rollers. The purpose of this study is to quantify the brake sensor performance of MOT brake varying parameters such as: tyre inflation pressure, distance between rollers and roller surface.

II. TEST METHOD

To carry out this study, we used a vehicle Renault 21 Nevada, 7-seater diesel, with independent front suspension. The vehicle was equipped with a front disc and sliding calipers brake system using a DOT 4 quality brake fluid and tandem brake pumps. On the rear wheels used drum brakes are fitted. We installed two encoders, the first was located in the right front wheel and the second on the roller, the pulses acquired by both encoders during both tests were converted to an analogical signal. Data from both encoders has been used to obtain slippage, according to equation 1. (F. Aparicio 2001, Dixson 1996) [5-7].

$$\text{Slippage} = 1 - \frac{\text{Wheel velocity}}{\text{Roller velocity}} \qquad (1)$$

A pressure sensor was installed in the brake circuit to obtain the brake force applied to the right front wheel. This sensor measured the pressure in the hydraulic circuit after pressing the brake pedal (Vera, 1995) [5]. Measurement of braking on the roller was obtained from the sensor installed in the MOT brake tester. The brake test was performed at a speed of 5km/h. Then, the wheel was stopped by braking. Pressure data on the hydraulic brake circuit and the brake torque data measured by the MOT sensor were recorded at the same time.

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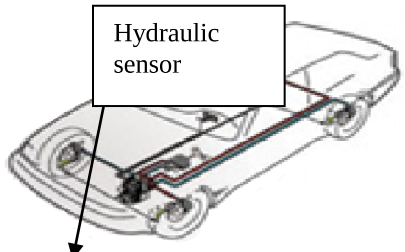

Fig 2. Location of the Pressure Sensor in the Front Right Wheel Brake Circuit

To sum up, the following criteria were measured:

1. Slip rate (i).
2. Inflation pressure of tyres (Pi).
3. Distance between rollers and roller surface roughness (Dr).
4. Roughness of the rollers differed at the three stations so that variable is discarded.

Measurement results of all tests were:

1. Maximum braking torque to the wheels (MF_{wheel}).
2. Maximum braking force measured by the roller bank (F_{MOT}).
3. Rotational speed of the rollers (Vr_{MOT}).
4. Rotational speed of the wheel (Vr_{wheel}).

Test guidelines to follow are:

• The test was carried out at a constant speed of 5 km/h and controlled with encoders to obtain slippage.

• The ambient temperature was not considered a parameter to study because after repeated trials in different seasons a difference of no more than 2% was obtained.

The average deviation of the measurements should not exceed 3%, in each series of results A lever was used to calibrate the force sensor of each roller bank, see figure 1. This same lever was used in the three MOT testers studied in order to know that there were no differences due to different calibration of the sensors. For the calibration, we applied a weight of 1kg, generating a torque of 9.8 Nm and then the voltage from the MOT sensor was measured.

Fig 3: Calibration of MOT450 Dynamometer

Our tests were carried on the three MOT stations: MOT390, MOT410 and MOT450. The number after the acronym MOT denotes the, in millimeters, between the axis of the rollers. Comparative analysis of the experimental data was centered on the value of braking at the moment of maximum slippage. The force applied to the roller at the moment of maximum slippage was compared with the torque applied to the wheel at the same point of maximum slippage.

The roughness of the rollers at MOT410 and MOT450 was the same, 40 microns; the roughness of the rollers at MOT390 was lower, 33 microns. The difference being due to the fact thousands of tests had been carried out during its lifetime in Alicante. Tests on the three MOTs were performed with the same ***Continental Contact*** tyre to ensure any that differences in the measurement were not due to this parameter.

III. MEASURING EFFECTIVENESS OF BRAKING

The braking test consists of measuring the effectiveness of 4-wheels and brake imbalance between the two wheels on each axle. According to the directive 96/96/CEE [3] of the Ministry of Industry, the MOT rejection threshold is 50% of effective braking; with the maximum allowable imbalance between the two wheels on each axle is 30%. The imbalance obtained with the vehicle used in the tests was practically zero. Effectiveness (E) is the ratio of the braking forces relative to the vehicle mass (m) [4]. According to the following formula:

$$E = \frac{F_{total}}{m * g} 100 \qquad (2)$$

Where:

E = % of efficacy.

F_{Total}= Sum of all braking forces in Newton (sum of the brake tester readings for all wheels of the vehicle).

m = Mass in kg. The vehicle Renault 21 Nevada 7-seater Turbo Diesel had a weight of 1185 kg + the driver weight of 60 kg= 1245kg.

g = acceleration of gravity (9.81 m / s^2)

To achieve a minimum efficiency of 50% strength in the right wheel should be measured at 1.8 kN. This data has been obtained with the following equation:

$$Fdd = \frac{50\% * 1245Kg * \frac{9.8\ m}{s^2}}{100} * \frac{60\%}{2} = 1830.15N$$

$$= 1.8\ kN \qquad (3)$$

The roll radius is 0.1 m so the torque to indicate the rejection threshold in graphics is 180 Nm. The authors did not analyze whether or not the data obtained by the vehicle would pass a brake test at different stations because it has previously been described in other papers, [8-9], published by them. In this paper we have studied whether or not such variation depends on a unique "capacity or performance brake" from each MOT tester, or, if instead, this performance is affected differently depending on different parameters.

IV. MOT SENSOR PERFORMANCE

The MOT "performance" is the percentage of torque applied on the wheel that is measured by the MOT brake sensor:

$$MOT\ performance = \frac{Torque\ applied\ on\ the\ wheel}{Torque\ measured\ by\ MOT\ sensor} \qquad (4)$$

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- Torque $_{\text{measured by the MOT sensor}}$ = Brake $_{\text{(kN) measured by MOT sensor roller axis}}$ * 0.1 meters roller radius.
- Torque $_{\text{applied to wheel}}$ = moment (bar obtained by the pressure sensor located in the brake circuit of the right front wheel) x (conversion factor).

When it is the same:

$$\eta = \text{MOTperformance} = \frac{\text{Braketorque}_{\text{applied on the wheel}}}{\text{MOT Brake torque}_{(\text{Kn in the roller axle} * 0.1\text{meters})}} \quad (5)$$

Here we compare the braking torque on the wheel and torque on the MOT sensor at MOT390 during the test. It can be seen from the starter that measurements do not match.

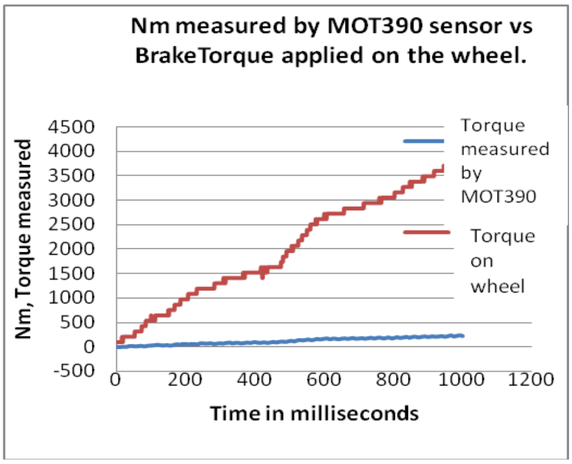

Fig 4. Ratio of Brake Torques Applied Wheel and Read by the Pressure Sensor On The Vehicle Circulating ITV390 Bank

Therefore, it can be concluded that the brake torque applied to the wheel is not entirely measured by the MOT 390 sensor. If we divide the braking torque applied to the wheel and the torque measured by the MOT sensor we can observe in figure 5 that there is linear relationship.

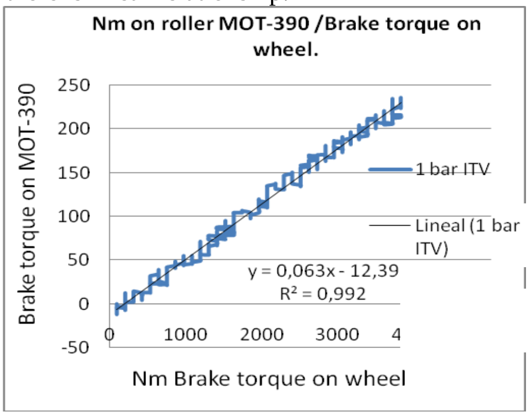

Fig 5. Relationship Between The Brake Torque Applied To The Wheel and That The Sensor Perceives The Dynamometer ITV-390, For A 185-Continental Contact Tire Wear, Inflated To 1 Bar.

As can be seen in the graphic, the performance torque applied to the wheel in comparison to torque measured by the sensor at the point of maximum slip, has the same value as the line tendency for which the value is 6.4% in the case studied. This linear relationship of the graph involves the performance measure affecting any point on the curve. So in the analysis we can compare only a performance point, this will be the maximum slip point.

V. RESULTS

A Performance at the MOT390

In the comparative study between the torque applied to wheel and read by the force sensor at MOT390, we see in the graphic below data differences between torque measured by the MOT sensor and applied on the wheel:

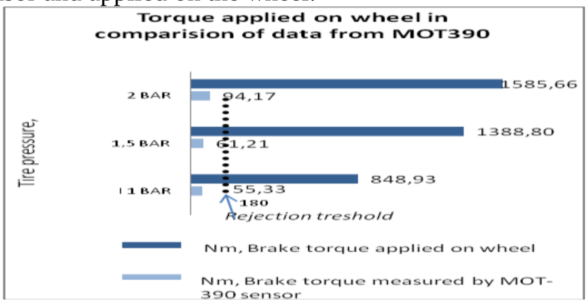

Fig 6. Torque Applied To Wheel and MOT-390 KN, With Continental Contact Tires.

As we can see in figure 6, pressure applied on the wheel differs significantly to torque measured by the MOT sensor. We analyzed the performance of the MOT390 bank, and as can be seen this is between 4 and 7%. It can be said that this value is really low, and as we have seen insufficient to pass the test of 50% of "efficiency", when the brake system is in good condition. With this experimental data it was decided not to continue testing with this bank because it has been demonstrated that this is not optimal for testing. The next study was to compare if the same ***Continental Contact*** tyres could pass the test for all tyre inflation pressures, from 1 to 3 bar, on MOT450 and MOT410.

B Performance on MOT-410.

The following graph shows the extent of braking torque received by the sensor relative to the ITV410 braking torque applied to the wheel at the time of 100% slip on testing.

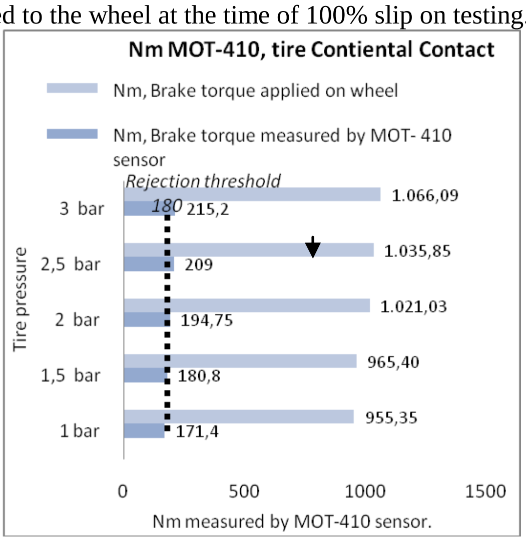

Fig 7. Torque Applied On the Wheel in Comparison With Data Measured By MOT410 Sensor

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As can be seen in figure 7, the brake performance of the same vehicle with the same tyre is now between 18% to 20%, with tyre pressures from 1 to 3 bar. As it is shown this performance does not match the MOT390.

C- Performance in the MOT450.

The following graph shows the braking torque measured by the sensor at MOT450 in comparison with the braking torque applied to the wheel at the point of 100% slip on testing.

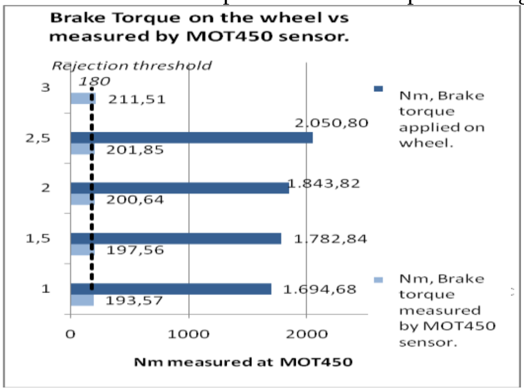


Fig 8. Brake Torque Applied On The Wheel in Comparison With Brake Torque Measured By The MOT450.

As can be seen in figure 8, the trend of the brake torque applied to the wheel increases as does the tyre pressure, this as happened with data measured by the torque sensor MOT450. As can be seen in the graph, the performance is between 11.4% and 10% of the torque applied to the wheel. This graph demonstrates that the performance of the same vehicle with the same tyre, does not match with that measured atMOT410 andMOT390. So, comparing the braking torque, at the point of maximum tyre slip, with a Tubules 185/65/R14 Continental Contact CT 21 tyre with tread depth of 3mm at the MOT390, MOT410 andMOT450, we conclude that the distance between the rollers, the roughness of the rollers and the tyre pressure are all critical values in the longitudinal brake behavior on the roller tester.

D Data comparison from MOT390, MOT410 and MOT450.

In the following graphic we have compared the results of brake data obtained by three MOT brake sensors:

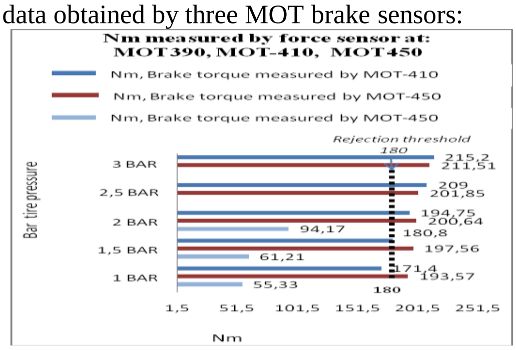


Fig 9. Brake Torque Measured By the MOT390 MOT410 MOT450.

As it can be seen in figure 9, the tyre pressure increase from 1 to 3 bar have different influences on brake torque measured by the MOT testers; in MOT390 the brake torque increases by 300%, at MOT410 by 125%, and at MOT450 by 109.5%. It can also be seen that the vehicle would not pass the brake test at MOT390 and at MOT410 with 1 bar of tyre pressure.

In the following graphic we have compared results of brake data applied to the wheel at three MOT testers:

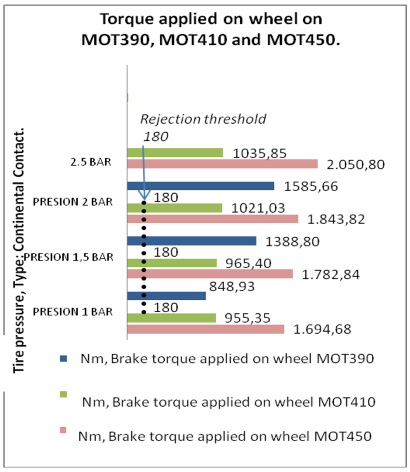
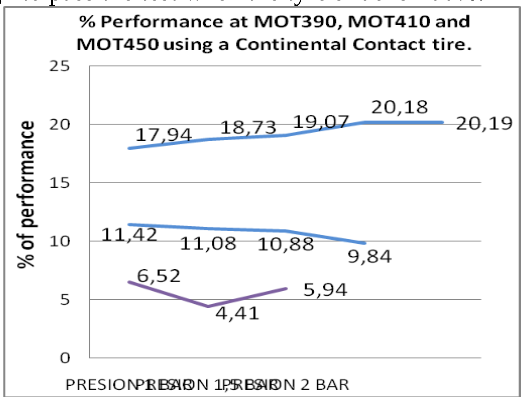


Fig 10. Brake Torque Applied to the Wheel at the Moment Of 100% Slip in the Brake Test at MOT390 MOT410 MOT450 Stations

On the other hand, in figure 10, it is clear that when tyre pressure increases from 1 to 3 bar a different percentage of torque applied to the wheel to obtain 100% of slippage can be seen: at MOT390 it increased by 125.6%, at MOT410 it increased by 111.6% and at MOT450 it increased by 121%. As can be seen in the three MOTS' the torque applied is enough to pass the test when the tyre slide is 100%.



1BAR 1.5BAR 2BAR 2.5BAR 3BAR

Fig 11. Performance of MOT Brake Tester at MOT390 MOT410 MOT450 Station.

As we can see in figure 11 performance at MOT390 is about 6%, at MOT410: 10-11% and at MOT450: 18-20%. So it is concluded that there is not a unique performance for MOT brake testers.

VI. CONCLUSIONS OF THE EXPERIMENTAL WORK

In summary, experimental data has been obtained by varying each parameter to study its influence on the results, the conclusions were as follows:

A - Influence of tyre inflation pressure:

As can be seen in figure 11, tyre pressure is the least influential factor studied in the performance. As can be seen,

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the variation in percentage of performance due to the increase of tyre pressure is lower than 2.5% which is lower than the 3% of dispersion of data considered in the measurements. In contrast, it has been demonstrated that tyre pressure variation measurements in the three banks of MOT have a significant influence on the results of the tests.

B.- Influence of the distance between rollers:

It has been shown that the distance between rollers affects the test results of ITV braking. The comparative study of the braking vehicle tyre has been done at the MOT 450 and 410, because both rollers have the same surface roughness, 49 µm. We have used the same ***Continental Contact*** tyre, keeping all other parameters constant and calibrated exactly the same way. Comparing the data between MOT450 and MOT410, differences were up by 11% in the measurements obtained by the sensor at each respective MOT station due to a reduced distance of 40mm between the rollers. The performance comparison between MOT410 and MOT450 was up by 10%.

C. Influence of the roughness of the rollers:

It has been shown that the roughness of the roller also affects brake action. A reduction in roughness from 49 µm (at MOT410) to 33 µm (at MOT390) can reduce the brake data measured by the MOT sensor by up to 35%. Performance variation between MOT390 and 410 can increase up to 4% and comparing the measurement to MOT450 performance increases by 14%. The main conclusion from this study is that the braking test performed on the MOT tester and measured by a force sensor measures between 4 and 20% of brake torque applied to the wheel, and the vehicle could not pass the test even when brake system is in perfect condition. This performance is not constant and it depends on variations in other parameters such as the distance between the rollers and the roughness of the roller surface varying results by up to 11%. In contrast, it has been demonstrated that tyre pressure does not affect this performance by more than 3%. Finally, it has been demonstrated that the MOT brake tester is not a suitable tool to check vehicle brake systems because of the variability of results. The vehicle can or can't pass the test threshold depending on variables such as tyre pressure, distance between rollers and roughness of the roller surface even when the vehicle braking systems are in good condition.

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Carolina Senabre, received in 1998 the Engineer degree from the Polytechnic University of Valencia.
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Emilio Velasco Sanchez received in 1992 the Industrial Engineer degree from the Polytechnic University of Madrid (Spain).And received the PhD degree on Industrial Engineering at 1997. From 1993 to 1998, he was a Professor in the Mechanical engineering division at "Carlos III University" in Madrid. And he was also a member of the research staff at the Automobile Research Institute (INSIA), where he worked in the fields of passive safety of vehicles, structural design and accidentology, and he was involved in numerous national and international projects. In 1998, he became a Professor at the Miguel Hernández University of Elche, where recently he has been appointed Director of Engineering studies. He is teaching mechanical technology, and transport security in Industrial Engineering. He has authored numerous publications and contribution to congresses

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