Comparative study on the lateral run-out of friction surfaces measurement of brake discs using a brake roller tester and a dial gauge

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Abstract. Brake system diagnosis is one of the most common and necessary technical operations applied to the car, regardless of its type and operating phases. Measuring the diagnostic parameters on a roller brake tester is a fast operation with no disassembly necessary. Measuring the run-out of friction surfaces of brake discs with a dial gauge is an action that requires more extensive preparatory operations but it offers a high accuracy of the results. The paper aims to analyze the correlation between the dial gauge measured values and the diagnostic obtained using the brake roller tester.

1 Introduction

The continuous improvement of vehicles performances and the growth of traffic intensity make the vehicle braking system one of the most important safety elements in the road traffic. The braking system must fulfil its specific functions throughout the entire vehicle life. Considerable effort is spent in the design and testing of disk brakes of modern passenger cars [1]. Diagnosing technical condition of this system is one of the most common and necessary technical operations applied to the car, regardless of its type and stage of use and therefore special attention is given to it [2].

National and international regulations on braking performances has been improved in time, changing in correlation with the evolution in the conception of new cars. Regulations on testing and diagnostic parameters of the braking system are set out in Regulations 13 and 78 UNECE and European Community Council Directive no. 71/320 / EEC. In Romania, the standard STAS 11960-84 was conceived according to UNECE Regulation 13. Also technical regulations on road safety are approved by RNTR [3].

The most used method to check the brake system is using a roller brake tester. Usually, roller testers measure the braking force at each wheel of the car, the force applied on the brake pedal and the weight of the car. Based on these measurements, the following parameters are calculated:

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Ovality – relative difference between minimum and maximum brake force, measured on the same wheel:

$$O = \frac{Max(F_{br}) - Min(F_{br})}{Max(F_{br})} \cdot 100 [\%]. \tag{1}$$

Relative imbalance between the braking forces on the same axle:

$$D = \frac{|F_{br.l} - F_{br.r}|}{Max(F_{br.l}, F_{br.r})} \cdot 100 [\%]. \tag{2}$$

The effectiveness of the braking system:

$$E = \frac{\sum_{i=1}^n (F_{br})_{max.i}}{G} \cdot 100 [\%], \tag{3}$$

where $\sum_{i=1}^n (F_{br})_{max.i}$ is the sum of maximum braking forces from all the wheels, and G is the vehicle weight during the test; $Max(F_{br})$ – maximum brake force; $Min(F_{br})$ – minimum brake force; $F_{br.l}$ – braking force at the left wheel; $F_{br.r}$ – braking force at the right wheel; $Max(F_{br.l}, F_{br.r})$ – the maximum value between $F_{br.l}$ and $F_{br.r}$, G – the car weight.

The caliper housing may not fully retract after the brake is released. The remnant contact between the pad and the disc affects the fuel efficiency and the life of the pad friction lining and increases the temperature and wear of disc and pads. This off-brake calliper drag is greatly affected by the lateral run-out, which is defined as the side-to-side motion of the disc as it turns on the hub [4].

„Regulation No 90 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of replacement brake lining assemblies, drum brake linings and discs and drums for power-driven vehicles and their trailers” limits the values for lateral run-out friction surface of the disc brake to 0.05 mm [5]. Limit values set by the manufacturer for this parameter depend on constructive peculiarities of the system that contains the brake discs and on the user’s exigency. Run-out limit values imposed by some manufacturers are shown in Table 1 [6, 12]:

Table 1. Lateral run-out limit values [6, 12].

Vehicle	Fiat Tipo 1.4 L/16V	Chrysler 300-3.0L V6 24V V.V.T.	Lancia Grand Voyager 2.8L TD	Jeep Cherokee 1.4 16V	Opel Astra H
Value [mm]	0.05	0.035	0.05	0.04	0.05
Vehicle	Jeep Grand Cherokee 3.0 V6 TD	Jeep Wrangler 2.8L 4cyl	Jeep Renegade 1.4 L	VW cars	Škoda Octavia
Value [mm]	0.05	0.025	0.02	0.05	0.05

Table 1 shows that the specified limits are lower or equal to the limits in accordance with European legislation [5].

Determination of lateral run-out is done using a dial gauge and following the procedure indicated in the maintenance and repair manuals.

When a roller brake tester is used, the lateral run-out is estimated considering that the variation of the braking force at one wheel (the so-called „Ovality”) is proportional to the run-out of the brake disc of the respective wheel. Thus, a value expressed as a percentage, is computed according to the relation (1).

The ovality limit measured on the roller brake tester is not regulated by legislation, but it may be specified by the manufacturer of the tester; e.g. BOSCH indicates a maximum acceptable value of 25% for its BSA 43XX tester [7].

A braking system which has good effectiveness and good relative imbalance is considered in good condition according RNTR1, no matter the value of ovality.

2 Preparing and conducting experimental research

The study presents the results of the lateral run-out of friction surfaces measurement of brake discs using a brake roller tester and a dial gauge. The use of the brake roller tester is a fast operation, part of the braking system diagnostic program. This measurement represents an indirect estimation of the run-out. The use of a dial gauge is an action that requires more extensive preparatory operations but it provides accurate results.

Both methods have been used in order to show if it is possible to establish a correlation between the values measured by these two methods.

Experimental research has been conducted using three cars: Opel Astra, VW Passat, Škoda Octavia. Some of their technical data are listed in Table 2.

Table 2. Specifications of tested vehicles.

No.	Vehicle	Curb weight [kg]	Kilometres	Year of manufacture
1	Opel Astra	1395	171158	2007
2	VW Passat	1579	96850	2007
3	Škoda Octavia	1385	174637	2008

2.1 Lateral run-out measurement of brake discs using a brake roller tester

In the first stage, tests were conducted on Bosch BSA 43XX roller tester located in University Politehnica of Bucharest, Faculty of Transports, Automotive Engineering Department.

Before starting, the vehicle has to be driven 5 km on an urban route, followed by intense heating of the brakes on the roller tester. Tire pressure was adjusted at nominal value. Each car has been tested three times successively.

During the test, the pressure on the brake pedal rises gradually. When the braking force at the wheel reaches a reference value memorized by the computer of the roller tester, a message appears on the tester's display which indicates that the operator must keep constant the pressure on the brake pedal for a few seconds, until the message disappears. The roller tester computes the ovality during this period and displays it in percent.

2.2 Lateral run-out measurement of brake discs using a dial gauge

In the second phase of the experimental research, the test consisted in measuring the brake discs lateral run-out using a dial gauge. The procedure indicated in the maintenance and repair manuals for ovality measuring was followed. It was similar for all the three tested cars.

After removing the wheels from the vehicle, the wheel brake assembly components were blown with compressed air to remove dust particles. Each disc brake was tight with its studs using the helpful parts (struts) as suggested in Figure 1.

The dial gauge was fitted with a magnetic base on the shock absorber (Figure 1). The spindle of the dial gauge was positioned 10 mm towards the interior from the edge of the disc, as recommended in [12].

For the wheels of the front axle, measurements were made on both surfaces of the brake disk. No correspondence has been established between the measured values on the two surfaces but only the maximum measured values were retained. For the wheels of the rear axle, the lateral run-out was only measured on the outer surface of the disc.

Fig. 1. Mounting the dial gauge on the front brake assembly.

3 Experimental results

In the case of the lateral run-out measurement using a brake roller tester, the braking forces developed at each wheel have been measured and used to calculate the relative imbalance, the effectiveness and the ovality. The rolling resistance when the brakes were not applied was also measured.

In the case of the periodically testing of the car’s technical condition, the regulations only specify acceptable limits for effectiveness, relative imbalance and rolling resistance when brakes are not applied. Taking into consideration the effectiveness and the relative imbalance, for which all values did not exceed the limits, it results that the three tested cars were in good operation condition. In the case of the rolling resistance, only few the tests revealed higher values than normal for two of the tested cars, the arithmetic means of the three values being under limits. Therefore, the cars operation condition may also be considered acceptable from this criterion point of view.

If all three cars are considered in good or acceptable condition for effectiveness, relative imbalance and rolling resistance criteria, the ovality shows that one vehicle is in good condition, one is at the limit and the other is defective.

The operator did not notice improper behaviour of the braking system during preparatory operations (heating brakes) nor during the tests themselves for VW and Opel cars. But while driving Škoda there were excessive vibrations and pulses in the brake pedal during braking. This behaviour is confirmed also by the roller tester measured values.

For Škoda and Opel it has to be specified that during the last year they have run on short distances followed by long periods of immobilization which can cause deposits on the brake discs (areas heavily oxidized, uneven brake pistons sliding) that affect the reproducibility of results (due to rapid and permanent evolution of the surfaces quality during measurements).

The lateral run-out values obtained using the dial gauge are listed in Table 3.

Table 3. The lateral run-out [mm] values obtained using the dial gauge.

Vehicle	Front Right Wheel			Front Left Wheel			Rear Right Wheel			Rear Left Wheel		
	Int.	Ext.	D.T.	Int.	Ext.	D.T.	Int.	Ext.	D.T.	Int.	Ext.	D.T.
Opel Astra	0.03	0.028	25	0.04	0.05	24.7	*	0.03	9.6	*	0.07	9.6
VW Passat	0.015	0.03	24.2	0.01	0.028	24.8	*	0.04	12.4	*	0.05	12.6
Škoda Octavia	0.11	0.09	19.4	0.67	0.19	19.9	*	0.025	9.1	*	0.04	9.4

where: Int. = interior surface of the brake disc; Ext. = exterior surface of the brake disc; D.T. = brake disc thickness.

Comparative results concerning the ovality measurement on the roller tester (rectangles) and lateral run-out measurement using dial gauge (circles) are shown in Figure 2.

Analyzing the results, it is observed that it cannot be establish a correlation between the ovality value obtained by using the roller tester and the lateral run-out measured using a dial gauge. This is because of differences between the influences acting in these two methods. Measuring the ovality using roller tester is an indirect method based on the braking forces measurement, while measuring the lateral run-out using the dial gauge is a direct, high precision action.

Fig. 2. Comparative results of lateral run-out using roller tester and dial gauge.

Disc replacement imposed by an inadequate value of the lateral run-out is decided by using a dial gauge. Most of the times, the roller tester measurement grabs attention and suggests the direct measurement using dial gauge. Identification by the driver of an inappropriate behaviour of the car is a subjective action and depends on the readiness and understanding of phenomena that occur in the braking process of the wheel.

4 Conclusions

Analyzing the results, it is observed that it cannot be establish a correlation between the ovality value obtained by using the roller tester and the lateral run-out measured using a dial gauge. The variations of the braking force noticed during the test on a roller stand (which defines the value of ovality) may be produced not only by the run-out of the brake disc, but also by other causes that can modify the friction coefficient, such as damaged friction surfaces, hesitation in caliper movement, seizing of piston in the wheel braking-cylinder, etc.

These influences are more important when the car is operated with large periods of immobilization which can cause deposits on the brake discs (areas heavily oxidized, uneven sliding pistons brake).

However, if the acceptable limit of ovality is overpassed, a direct check of the brake disc run-out must be complete using the dial gauge and the final decision of replacing the brake disc may be only taken on the basis of this test.

References

1. T. Jearsiripongkul, P. Hagedorn, KKKU Engineering Journal, **31**, 299 (2004)
2. C. Andreescu, M. Oprean, Gr. Danciu, G. Anghelache, *Automobile Diagnosis - Practical Activities*, (PRINTECH Publishing House, 2002)
3. *** Order of the Romanian Transport Ministry No. 2133/2005– RNTR 1
4. S.H. Masood, L. Singh, *5th Australasian Congress on Applied Mechanics*, (2007)
5. *** Regulation No. 90 of the Economic Commission for Europe of the United Nations (UN/ECE)
6. ***Technical Specifications: Fiat Tipo, Jeep Cherokee, Grand Cherokee, Wrangler, Renegade, Lancia Grand Voyager, VW Passat
7. *** Technical Specifications of BOSCH Brake Stand, Model BSA/SDL43XX
8. M. Stratulat, C. Andreescu, *Automobile Diagnosis*, (Societatea Știință și Tehnică S.A., 1998)
9. *** Vehicle registration certificate of VW Passat, 2007
10. *** Vehicle registration certificate of Škoda Octavia 2008
11. *** Vehicle registration certificate of Opel Astra 2007
12. *** Maintenance and repair manuals of Opel Astra, Škoda Octavia, VW Passat 2007