THE QUALITY OF THE BRAKE COMPONENTS AND ITS IMPACT ON THE BASIC PARAMETERS OF BRAKING

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Abstract: *One of the most important characteristics of the vehicle, which characterizes the behaviour of the vehicle while driving, is the ability to reduce vehicle´s speed to stop point. Brake system requirements are set by statute ECE 13 and each EU Member State is obligated to implement them into their legislation. The brake system consists of a set of parts that serve to gradually reduce the speed of the vehicle to stop it and the system must keep it stationary if it has already been stopped. The quality of the brake discs and brake pads is decisive during braking as well as in removing heat from the brake area. This article discusses about the basic parameters compared during braking in changing the quality of brake components which impact road safety and the safety of passengers in vehicles.*

Keywords: breaking, stopping distance, safety

1. Introduction

Distance, which is necessary for the complete halt of the vehicle, consists of several parts. There is the same composition for the time required to stop the vehicle. These times are theoretically shown in Figure 1. From the figure, it is clear that the vehicle has zero braking ratio during the reaction and thus the speed of the vehicle is the same as it was before the reaction time.

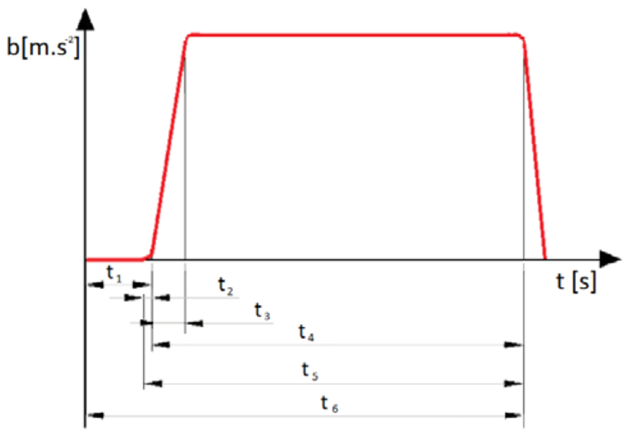

Fig. 1 *Theoretical course of braking deceleration in time from the moment of the impulse for braking the vehicle Source: authors*

t1 - driver response time [s]

t2 - delay time of brakes [s]

t3 - increased time of braking deceleration [s]

t4 - time of effective braking

t5 - total braking time

t6 - the time needed to stop the vehicle

2. Action forces between the tire and the road

Force application and transfer of tangential and radial forces are between the tire and the road. Three force components, which are involved in the transmission of forces, can be considered during braking the vehicle:

- Adhesive force - creates shear stresses between the surfaces, and its size depends on surface cleanliness and pressure, which the individual surfaces are pressed together

- Deformation force – is created, when the surface roughness is pushing into the surface of the tire.

- Abrasion force - this is the result of the work necessary for uprooting of particles in the tread. This force is the most apparent during heavy braking especially if the vehicle is not equipped with ABS. In terms of tires, it is preferable when this force is as low as possible.

Fig. 1 shows the course of braking deceleration. During the effective braking it is possible to consider the value of the mean fully developed deceleration.

The mean fully developed deceleration (MFDD) shall be calculated as the deceleration averaged with respect to distance over the interval v_b to v_e, according to the following formula:

$$MFDD = \frac{v_b^2 - v_e^2}{25{,}92 \cdot (S_e - S_b)} \quad [m \cdot s^{-2}]$$

where: v_0 – initial vehicle speed in $km \cdot h^{-1}$,

v_b – vehicle speed at 0.8 v_0 in $km \cdot h^{-1}$,

v_e – vehicle speed at 0.1 v_0 in $km \cdot h^{-1}$,

S_b – distance travelled between v_0 and v_e in meters,

S_e – distance travelled between v_0 and v_e in meters.

This article was created on the basis of measurements carried out in closed airport Rosina. Decelerometer XL Meter^{TM} Pro was used for recording during braking deceleration.

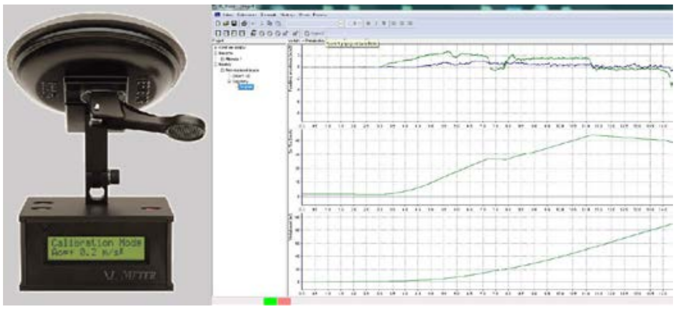

Fig. 2 *Decelerometer XL MeterTM Pro Source: [2]*

This device, shown in Fig. 2, allows to evaluate and analyze the acceleration or vehicle dynamics. This feature is able to evaluate the acceleration of the vehicle at different time intervals. This allows to quickly and objectively compare different kinds of vehicles.

The results displayed from the device of MeterTM XL Pro are:

- v [$km \cdot h^{-1}$] – current speed when the measurement was stopped
- s [m] – distance from the beginning to the end of the measurement
- t [s] – time from the beginning to the end of the measurement.

3. Measurement methodology, used vehicle and brake components

Measurements were carried out on the vehicle of Skoda Octavia. The vehicle had the disconnected brakes on the rear axle. It follows that the measurements examined a braking distance only with the involvement of the front axle. Rear axle brakes were sealed at the end of the hole of brake pipe. Thanks to this, there was no leakage of brake fluid from the pipeline, see Figure 3.

Fig. 3 *Seal at the end of the brake pipe. The rear axle of the vehicle - Skoda Octavia. Source: Authors*

Used brake linings were assessed on the basis of bid price in the market. Table 1 compares the parameters and the price of the brake discs and brake linings companies of STARLINE and BREMBO.

Table 1: *Comparison of parameters and prices of components on the front axle used for measurements*

Parameter of the brake disc	STARLINE	BREMBO
diameter [mm]	288	288
inner diameter [mm]	136	136
thickness [mm]	25	25
Price without VAT [€ / piece]	24.19	68.19
Parameter of brake lining	**STARLINE**	**BREMBO**
thickness [mm]	19.70	20.6
breadth [mm]	156.28	156.4
Price without VAT [€ / piece]	25.29	56.49

Source: Authors

During the measurements of the stopping distance, it was necessary to replace the original brake components with components of Starline in service workshop. Then, the measurements were made at the prescribed speed. Subsequently, it was necessary to replace STARLINE components with the components of BREMBO in the service workshop.

Measurements were made at the speed of about 50 km·h^{-1} and 90 km·h^{-1}. At any speed, 50 repetitions were carried out. After achieving the required speed, a driver depressed the brake pedal. And at the same time he tried to brake with the maximum possible braking deceleration. The following variables were investigated for measurements:

- stopping time [s]
- stopping distance [m]
- MFDD [m·s^{-2}].

4. Evaluation and outputs of the measured data

About 10 measurements, which reached a maximum speed approaching 50 km·h^{-1} or 90 km·h^{-1}, were selected from each group of measurements. Subsequently, the individual measurements were compared to each other. Results at a speed of 50 km·h^{-1} can be seen in Fig. 4

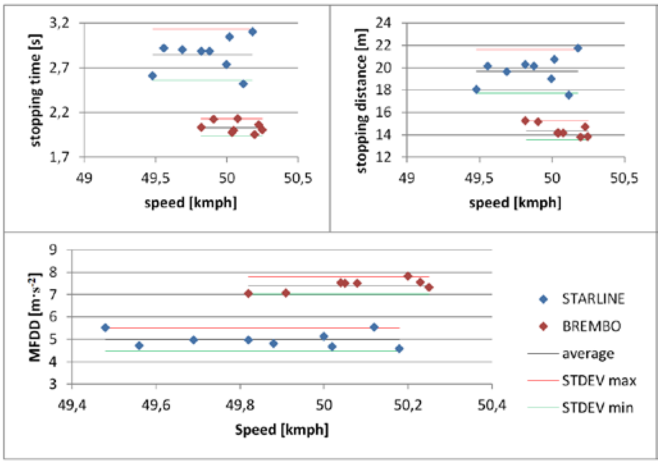

Fig.4 Compared data from measurements at a speed of 50 km·h^{-1} for brake components of BREMBO and STARLINE. Source: Authors.

It may be seen from Fig. 4 that by using less expensive components from STARLINE, the average stopping time and stopping distance are greater than the values observed with the use of brake components from BREMBO. The average values of monitored parameters are shown in Table 2.

Table 2: *Comparison of average measured values of monitored parameters at 50 km•h-1.*

Speed	Components	Stopping time [s]	Stopping distance [m]	MFDD [m·s^{-2}]
50 km·h^{-1}	STARLINE	2.843	19.689	4.992
	BREMBO	2.032	14.387	7.418

Source: Authors

As well as in the previous case, because of the speed limit outside the village 90 km·h^{-1} were carried out comparative measurements in the meeting of approximations that speed. Comparison between the components, which were purchased at a higher or lower price are shown in Fig. 5

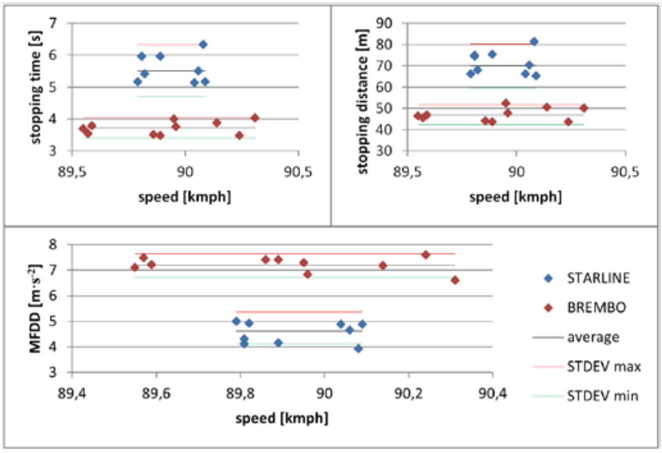

Fig.5 Comparison of the data for measurements of the speed of approximately 90 km·h^{-1} for brake components from STARLINE and BREMBO Source: Authors

As well as in the previous case, the values were measured in achieving the speed of 90 km•h-1 and the average values of the observed variables were worse with the components from STARLINE compared to the values obtained by using the brake linings and brake discs from BREMBO. Accepted mean for the measurements are shown in Table 3.

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Table 3: *The average values of monitored parameters at a speed of about 90 km•h-1*

Speed	Components	Stopping time [s]	Stopping distance [m]	MFDD [$m \cdot s^{-2}$]
90 $km \cdot h^{-1}$	STARLINE	5.512	69.872	4.619
	BREMBO	3.716	47.019	7.191

Source: Authors

Conclusion

During measuring the stopping distance, it was found thanks to the calibrated equipment - XL MeterTM, that during braking with using brake components from STARLINE, the stopping distance at 50 km•h-1 was by an average of 5,302 meters longer compared to using the BREMBO brake components. This is related to the length of time required to stop the vehicle. This was on average greater by 0.811 seconds. The average value of MFDD was lower by 2.426 $m \cdot s^{-2}$ by STARLINE components.

The similar results were achieved by measurements at the speed of 90 $km \cdot h^{-1}$. Stopping distance by using the brake components from STARLINE was greater by about 22.853 metres compared to the average values measured with components of BREMBO. Time needed for braking the vehicle was longer in average by 1.796 seconds. The average value of the MFDD was lower when using cheaper components about 2.572 $m \cdot s^{-2}$.

When using the mentioned components, the difference in price of brake linings and brake discs on the front axle is € 150.4 without VAT in favor of STARLINE. However, taking into account the road safety, the components from BREMBO can be considered as preferable based on measured data.

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