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BRAKING EFFICIENCY DETERMINED USING AN ACCELEROMETER IN THE ASPECT OF TECHNICAL CONDITION OF SHOCK ABSORBER

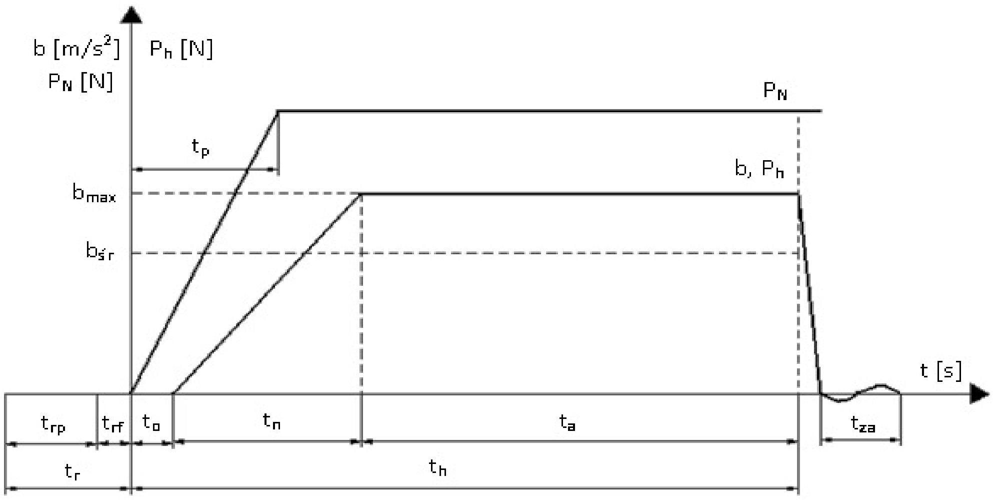
Summary. This article presents results of tests of the effect exerted by technical condition of shock absorbers on the braking efficiency of an automotive vehicle. The tests were conducted using Fiat Seicento featuring front shock absorbers which enabled shock-absorbing fluid-level adjustment. The tests comprised measurements conducted on the shock absorbers in four states, i.e. the nominal state with the fluid level at 100%, with shock-absorbing fluid levels of 25%, 50% and 75% as well as with the fluid tank completely empty (0%). Road tests of braking efficiency were conducted on cobbled pavement by means of a decelerometer.

1. INTRODUCTION

Inspection of road vehicle is very necessary to control, technically maintain and keep in a safe and environmentally acceptable condition during their use. Each country has its own directive, which should be followed during the inspection and they also specified the standards to be followed. EU for the periodic inspection of the vehicles follows the directive 2014/45/EC. Vehicles with the malfunctioning technical system have an impact on road safety and may contribute to road accidents. Improving the roadworthiness testing system can reduce this impact. During the inspection of any vehicle, the most important parameter are the braking parameters. For measuring the braking parameters, the deceleration of the vehicle can be used. The instruments which are used to measure these braking parameters are called as the decelerometer [3, 4, 18-21].

The processes which take place when an automotive vehicle is braking are of crucial importance from the perspective of safe use of roads. The considerable kinetic energy generated during the car braking process is transformed into heat (caused by friction forces acting in brake discs and in tyres on the pavement). It is prerequisite that a braking vehicle be affected by external forces (tangential reactions on wheels). Fig. 1 provides a schematic diagram of the car braking process. Throughout the entire braking process, one may distinguish between individual times related not only to the operation of brakes, but also those needed for the driver's response and pressing of the brake pedal. The vehicle driver is in fact a crucial factor in terms of the road traffic safety system. Intentional reactions are made while braking when objects enter the clear vision area (perception time), when they are captured (capture time) and processed in logical terms (information processing time). Next, as a consequence of impulses, one engages muscles to perform a subconscious technical process (adapting time). Subconscious (pre-programmed) responses may be developed by training, thus reducing their time and improving efficiency. The perception and capture times, on the other hand, are roughly identical in most people [1, 6, 7].

When a vehicle is undergoing technical inspection, the diagnostics only takes the braking system's technical condition into consideration, and therefore braking time is measured starting from the moment when the brake pedal is pressed until the vehicle comes to a stop.



PN—force of pressure on the brake pedal [N], P_h—braking force [N], b—braking deceleration [m/s^2], t—time [s], t_p—time for which the force of pressure on the brake pedal is increasing (<0.4 s) [s], t_r—driver response time (0.4–0.6 s), sum of psychic response time t_{rp} and physical response time t_{rt} [s], t_o—time lag to brake actuation (0.2–0.6 s) [s], t_n—time of braking deceleration increasing (0.1–0.5 s) [s], t_a—time of the effect of full braking force [s], t_{za}—time of braking deceleration decay [s]

Fig. 1. Car braking graph [1]

The degree of wear of shock absorbers depends on many factors including driving style, road conditions and the technical condition of the rest components of the suspension. It is estimated that in moving cars on our roads, durability expressed in vehicle mileage is about 60–80 0000 km. Manufacturers recommend their control at 20,000 km. Defective shock absorbers reduce driving safety as a result of detachment of the wheel from the road vehicle braking distance that increases and also results in faster wear of the suspension connectors that may cause a malfunction of the system ABS, ASR and ESP.

These systems need to work properly to ensure optimum contact with the road wheels. Bad condition of the shock absorber results in an increase in braking distance of the vehicle both for vehicles without electronic systems (ABS and ESP) and for vehicles with these systems. Figs. 3 and 4 show the results of research (Prof. Rompe, TÜV Rheinland/Berlin-Brandenburg [22]) and the stopping distance when braking from a speed of 80 km/h. The experiment was carried out for efficient shock absorbers and dampers reduced the effectiveness of 50% (decrease the damping force—which may account for partially fluid leak). Research has shown that when reduced to 50% effective damping, braking from a speed of 80 km/h to a standstill average car without ABS increased by 4.3%, while vehicles with ABS increase to as much as 14.1% (Fig. 2). Also, in the case of a vehicle that equipped the Electronic Stability Program (ESP) with shock absorbers, damping reduced the effectiveness of the braking distance that is extended by 20% (Fig. 3).

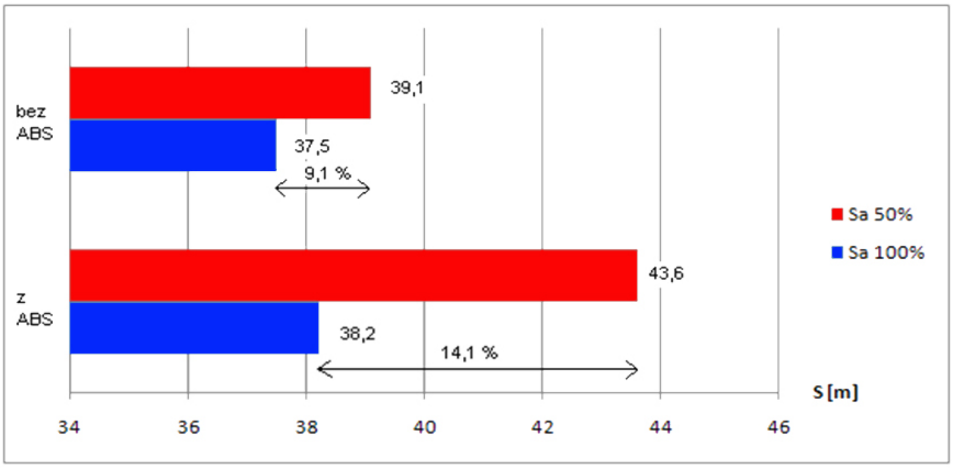


Fig. 2. Graph presents the braking distance for different dumping efficiency of shock absorber with and without system ABS from 80 km/h velocity: Sa—damping efficiency [%], S—braking distance [m]

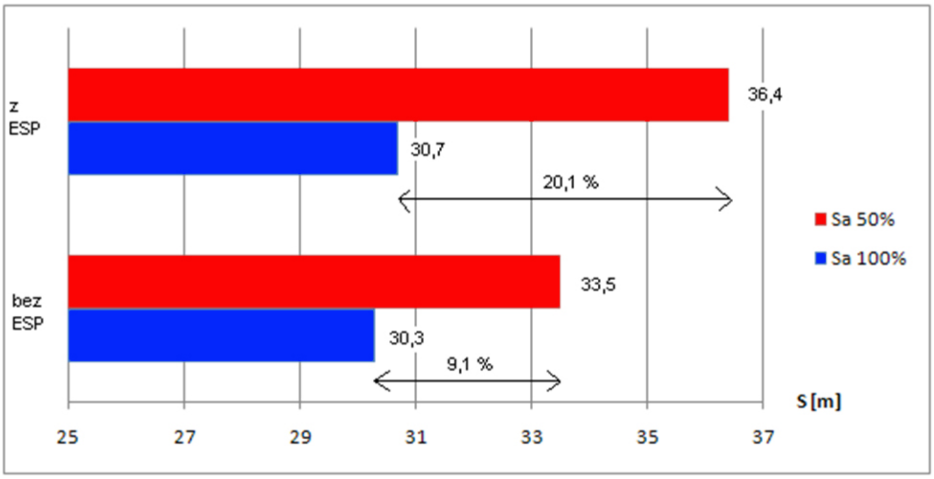


Fig. 3. Graph presents the braking distance for different dumping efficiency of shock absorber with and without system ESP from 80 km/h velocity on the corner: Sa—damping efficiency [%], S—braking distance [m]

2. TECHNICAL INSPECTIONS OF BRAKING SYSTEMS

The procedures conducted at vehicle inspection stations make extensive use of the following methods [2, 10, 12]:

- Quasi-static method.
- Dynamic method.

The braking deceleration measurement method requires using special instrumentation. The devices contemporarily in use are electronic decelerometers which enable recording of the force of pressure on the brake pedal. The results obtained from measurements of the maximum and the average braking deceleration are compared with the values defined in applicable regulations.

A decelerometer is a mandatory piece of equipment one will find at each vehicle inspection station. The device is ITS (Z/15/086/06) certified. The OP-1-type decelerometer (Fig. 4) is a microprocessor-based device intended for verification of the effectiveness of vehicle brakes. Its advanced built-in measuring algorithm compensates for what is referred to as the *dive effect* [20].

Technical specifications of the OP-1-type decelerometer are as follows:

- Acceleration measuring range: 10 m/s^2
  - Resolution: 0.1 m/s^2
  - Permissible error: 0.1 m/s^2

- Brake pedal pressure measuring range: 1,000 N
  - Resolution 10 N
  - Permissible error 10 N
- Memory storage: 10 measurements
- RTC clock
- Three measurement initiation modes (manual/pressure-induced/acceleration-induced)
- USB port to communicate with a PC
- Computer software

Fig. 4. OP-1 decelerometer

3. TEST PROCEDURE

Fiat Seicento's front and rear suspension system features pressureless twin-tube hydraulic shock absorbers. The shock absorbers examined in the tests are typically used in the MacPherson strut shown in Fig. 5. These shock absorbers have been redesigned to enable complete shock absorber dismantling, and they feature a hole which makes it possible to change the shock-absorbing fluid level [14-17]. The tests comprised measurements conducted on the shock absorbers in four states, i.e. the nominal state with the fluid level at 100%, with shock-absorbing fluid levels of 25%, 50% and 75% as well as with the fluid tank completely empty (0%).

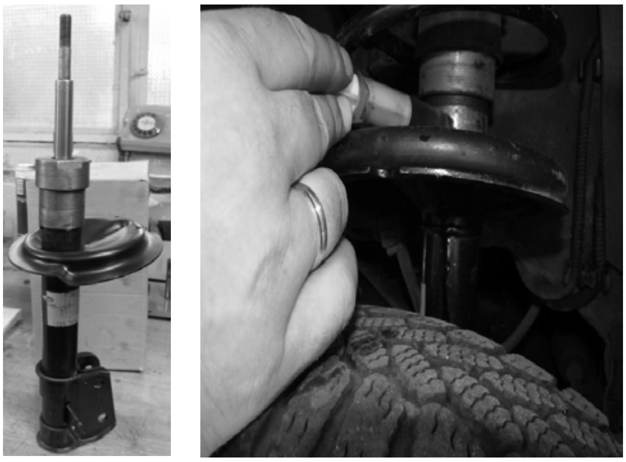


Fig. 5. Dismountable front shock absorber and filling it with shock-absorbing fluid

The decelerometer installed on board of the test car and used for measurements has been depicted in Fig. 6, whereas a section of the cobbled pavement road where the measurements were conducted has been shown in Fig. 7.

Fig. 6. OP-1 decelerometer and brake pedal pressure sensor used in the tests

Fig. 7. Cobbled pavement road where measurements were conducted

The results obtained from the measurements of braking deceleration and brake pedal pressure force for successive shock-absorbing fluid levels have been illustrated in Figs. 8–12. The results obtained in three other tests for the successive shock-absorbing fluid levels have been provided in electronic format on a disc attached to the paper.

The tests were conducted on cobbled pavement in order to increase the share of the dynamic impact exerted by the road profile and to induce vertical vibrations during braking. Having analysed the braking deceleration time curves recorded, one should stress that during braking with the shock absorbers having ca. 50% or less of the shock-absorbing fluid, there are considerable changes to the instantaneous values of deceleration, while the change curve profile is more classical with the fluid level of 50% and lower, and it comprises deceleration increase, phase of braking with a preset deceleration value and deceleration drop to zero. The foregoing may result from various factors, including the design of the measuring instrument itself, as it is lying freely on the vehicle floor during the tests and is by no means isolated from vibrations. Bearing the conditions under which the experiment was conducted, namely the cobbled pavement, one could observe considerable variations to the braking deceleration value, especially with the shock absorbers in poor technical condition. Consequently, the sole information on the maximum value of the recorded braking deceleration does not suffice alone to assess the effectiveness of braking. The mean value of the braking deceleration was determined based on registered diagrams (Fig. 13).

The obtained braking deceleration diagrams determine the braking time (from the moment of the increase of the pressure on the brake pedal to the moment of stopping the vehicle) - Fig 14.

The mean value of the braking deceleration was also calculated, assuming that the braking was carried out from a speed of 30 km/h (corresponding to 8.33 m/s) - Fig.15. The adopted speed corresponds to the assumptions contained in the OP-1 instrument manual.

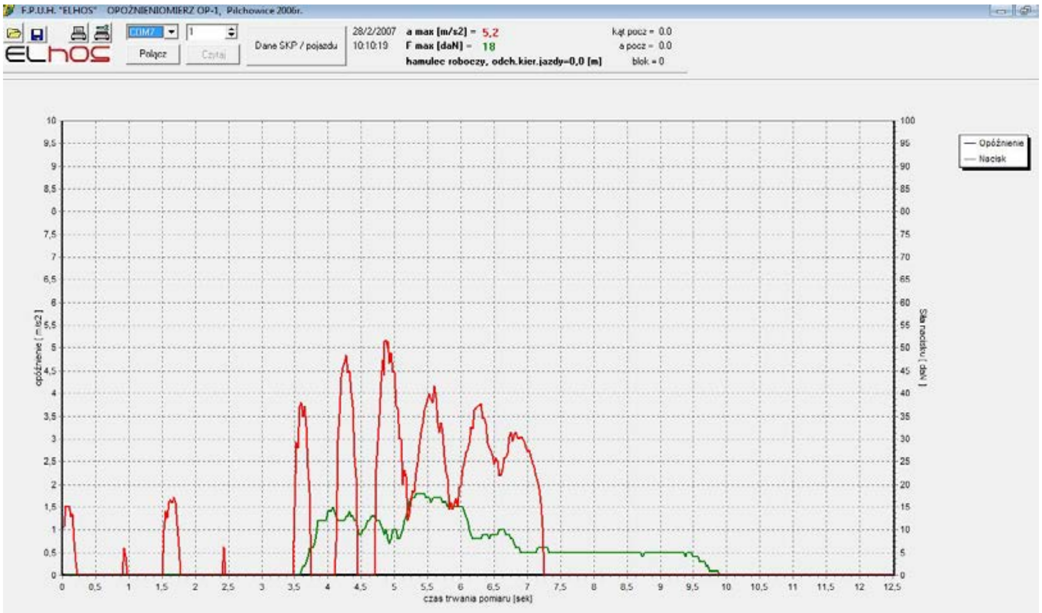


Fig. 8. Shock absorber graph—shock-absorbing fluid level of 0%

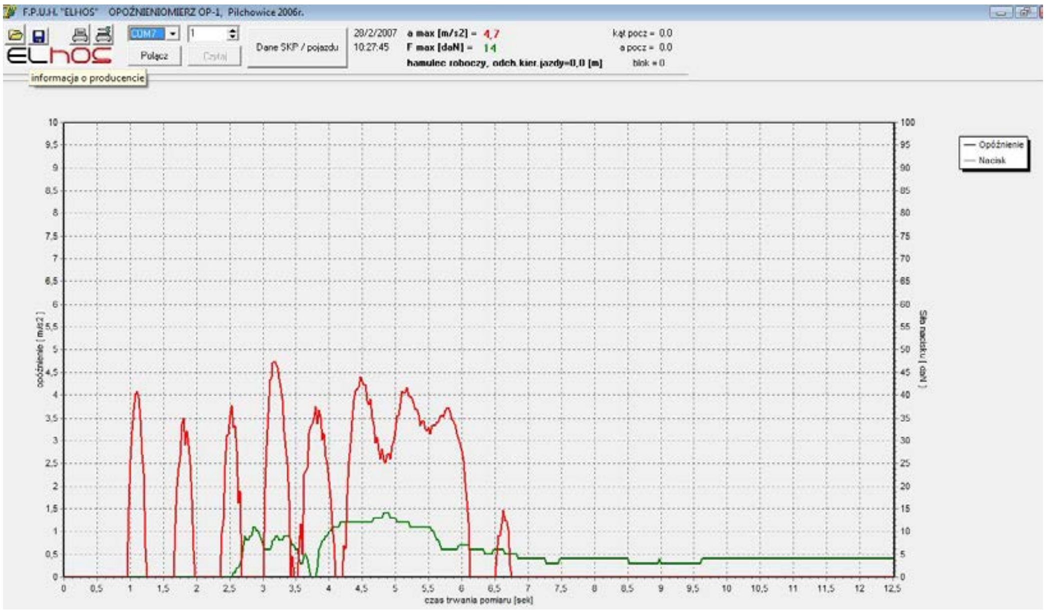


Fig. 9. Shock absorber graph—shock-absorbing fluid level of 25%

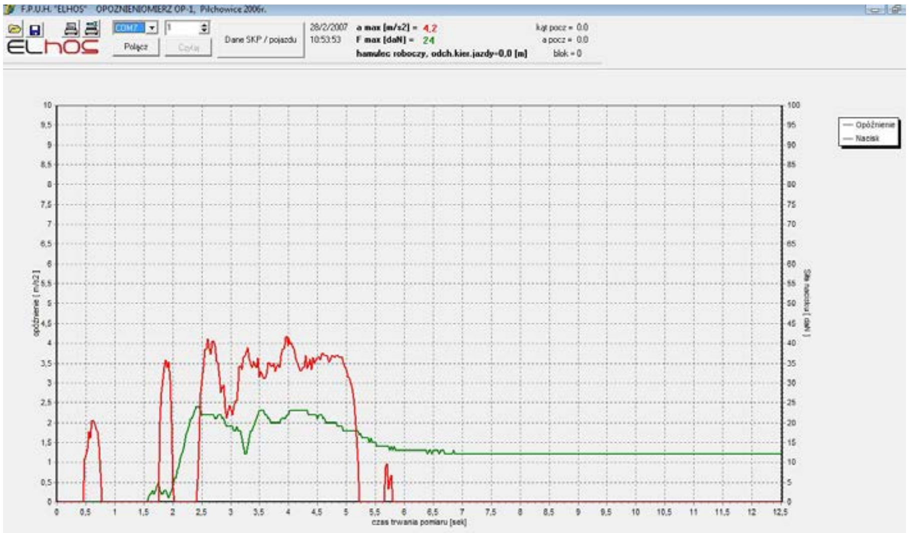


Fig. 10. Shock absorber graph—shock-absorbing fluid level of 50%

Fig. 11. Shock absorber graph—shock-absorbing fluid level of 75%

Fig. 12. Shock absorber graph—shock-absorbing fluid level of 100%

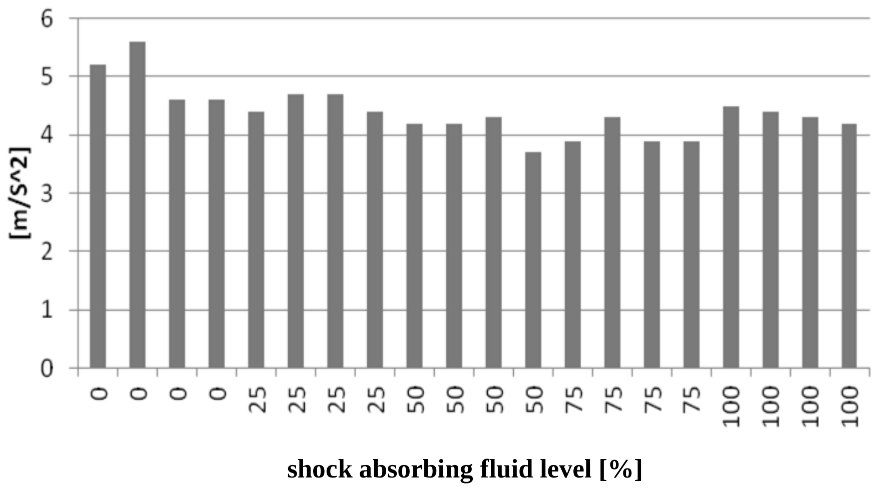


Fig. 13. Maximum deceleration values for individual shock-absorbing fluid levels

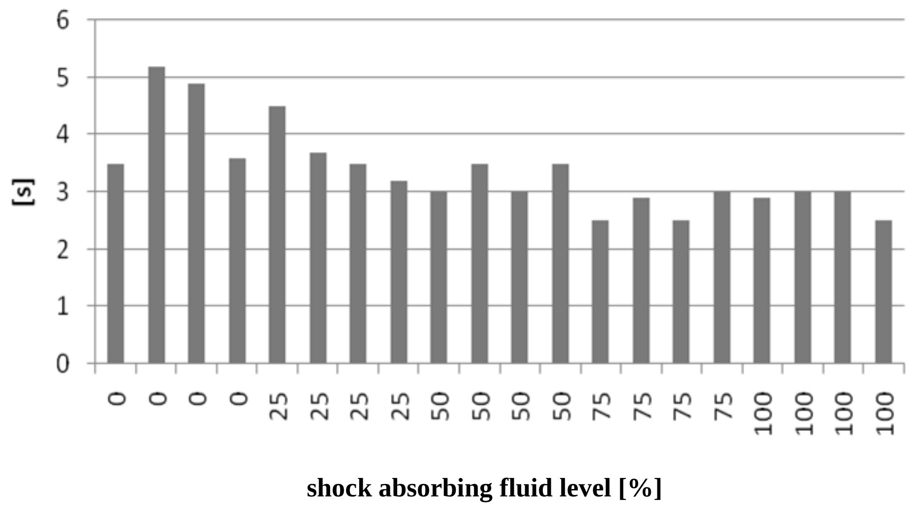


Fig. 14. Breaking time values for individual shock-absorbing fluid levels

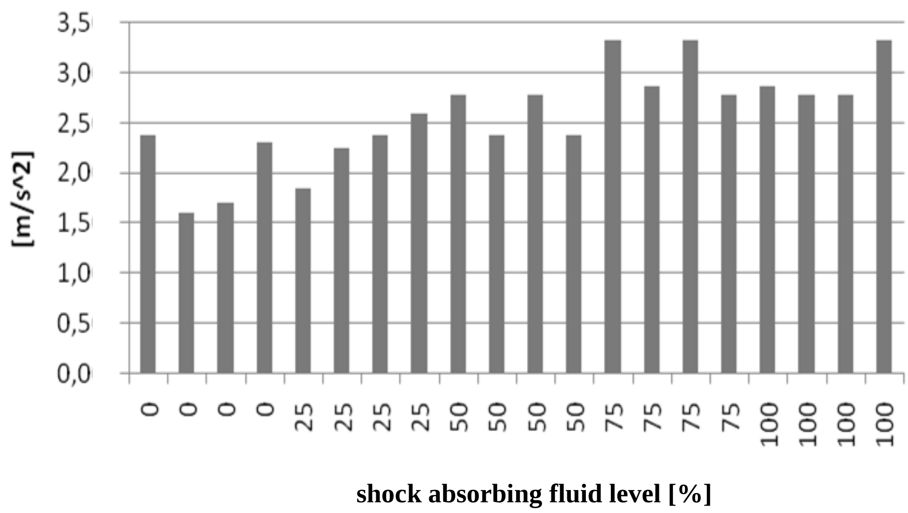


Fig. 15. Mean deceleration values for individual shock-absorbing fluid levels

4. CONCLUSIONS

Having compared the results obtained from the road tests, one may conclude that they were practically unaffected by the condition of shock absorbers. However, with reference to the braking deceleration time curves recorded, one can establish that during braking on cobbled pavement and with the shock absorbers having ca. 50% or less of the shock-absorbing fluid, there are considerable changes to the instantaneous values of deceleration, while the change curve profile is more classical with the fluid level of 50% and lower, comprising the deceleration increase, the phase of braking with a preset deceleration value and the deceleration drop to zero. The average braking deceleration values determined on the basis of the measurements and the braking time itself have confirmed that braking time was longer, and so being the braking distance, which conforms with the test results discussed in other publications and referred to in this paper.

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