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The influence of temperature on the damping value of shock absorbers determined by the Eusama method

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Abstract

The article presents the legal requirements for shock absorbers in suspension, for a vehicle in which they are mounted to be allowed on Polish roads. A short description of the working methodology of the device used to determine the effectiveness of a shock absorber's damping (sometimes referred to as relative wheel adhesion) is given on the basis of the Eusama method. The method of carrying out the tests on a sample of five passenger cars are described, along with the tests carried out at different temperatures for shock absorbers installed in a suspension system. The results of the diagnostic tests of the shock absorbers carried out on a diagnostic stand, in accordance with the Eusama method, are presented. The results confirm that the ambient conditions – the temperature of the chassis components (including the shock absorbers) – only slightly influence the values of their damping efficiency.

Introduction

The suspension is one of the fundamental systems in a vehicle; its main task is to ensure proper driving comfort and safety. Older cars (from the last century) were designed to provide maximum comfort while driving; this has changed with improvements in their design and speed, and safety aspects have also become more important.

It comes as no surprise to anyone that in today's vehicles there is quite a significant interaction between the way the suspension system works and the operation of many other systems. In motor vehicles, two of the most important systems in terms of active safety are the braking and steering systems. Currently, there are many mechatronic systems in modern cars that assist the driver, such as ABS, ASR, ESP, emergency braking systems BAS, and obstacle avoidance systems, etc. However, it should be noted that whether or not these systems will work properly depends not only on the functioning of complex electronics, but also on proper contact with the ground. In order for the forces between the wheel and the road surface to be able to transmit both longitudinal and transverse forces, it must be ensured that, in addition to the highest possible coefficient of friction, there is sufficient pressure. When a vehicle is moving on a flat road, the dynamic loads on the individual wheels vary only slightly. When moving at higher speeds, let alone on uneven roads or when cornering, the pressure changes to a much greater extent.

Reducing wheel pressure reduces the longitudinal and transverse forces between the wheels of the car and the road surface, and can cause the wheel to slip; this undeniably affects the stability of the vehicle.

One of the factors determining wheel adhesion may be the inadequate damping performance of the shock absorbers. In this way, not only does the driving comfort deteriorate, but above all, the effectiveness of the braking and steering systems deteriorates (Juzek et al., 2016).

Analysing the data from the Polish Police Headquarters (Police Headquarters Report, 2018) about the accident statistics in Poland (Jaśkiewicz & Jurecki, 2013; Jurecki & Poliak, 2018) it is easy to see that the defectiveness of a vehicle has a relatively small impact on the occurrence of accidents. There were "only" 40 accidents in 2017 and 38 in 2018 which could be attributed to the defectiveness of vehicles, wherein about 30% were caused by damage to the steering system or the braking system (Police Headquarters Report, 2017; 2018). This damage is often revealed during on-site inspections of vehicles, even though they did not experience a direct impact during the incident. The cause of 23% of accidents is "not adjusting the speed of the vehicle to the prevailing road conditions". In such situations, in addition to the undeniable influence of the driver, the road and its surroundings are also important. The influence of the technical condition of vehicles in the occurrence of road accidents can be considered to have not been fully estimated. It is certain, however, that the possible poor condition of shock absorbers may significantly affect braking efficiency and, consequently, contribute to the occurrence of a road accident.

In vehicles manufactured today, in which modern mechatronic systems that support the driver are commonly used, there is a need for comprehensive control of their technical condition and their diagnosis.

In the case of shock absorbers, it is very important to periodically check the effectiveness of their damping during technical inspections. In vehicle inspection stations, the technical condition of shock absorbers is commonly checked in Europe with the use of devices based on the Eusama method (**EU**ropean **S**hock **A**bsorber **M**anufacturers **A**ssociation) (Gardulski, 2009). This method allows for very quick testing of the technical condition of a vehicle's shock absorbers. However, more importantly, this method allows analyses to be carried out without any technical data for the tested vehicle, e.g. its sprung mass. An additional advantage is that the devices used do not require any complicated activities to be performed by the diagnostician.

These devices, as shown in many publications, have certain disadvantages in addition to their advantages (Kupiec & Ślaski, 2004; Stańczyk & Jurecki, 2014). Unfortunately, a major flaw of this method is the strong impact of various factors on the obtained values of the effectiveness of the damping of shock absorbers (Zdanowicz, 2010), as documented in many publications (Jurecki, Jaśkiewicz & Wdowski, 2014). These factors include e.g. a change in the tyre pressure or a different sprung weight of the examined vehicle (Bocheński, Lozia & Mikołajczuk, 1999; Jurecki, Jaśkiewicz & Wdowski, 2014). A change in tyre pressure may cause a significant change in the shock absorber's damping efficiency index for a tested quarter of a vehicle (Kemzūraitė, Žuraulis & Więckowski, 2014; Stańczyk & Jurecki, 2014). In the case of changes in the vehicle's load, this is surprising as the devices measure the mass for each wheel (static pressure) before the measurement is carried out.

It was indicated in the literature (Bocheński, Lozia & Mikołajczuk, 1999) that the results obtained from this method very strongly depend also on the amplitude of the control plates. Changing the value of the plate's amplitude "peak-to-peak" (from 1 to 7 mm) caused a change in the damping efficiency determined on the device from 90% to 0%. The same shock absorber could then be considered as either being very good or extremely bad. This is an important conclusion, because devices with a plate amplitude range of 4–8 mm are available on the market.

Diagnostic tests should give a preliminary answer as to whether the shock absorbers installed in a vehicle are working or not (Lozia, 2000; Jaskiewicz & Jurecki, 2017). Despite some simplifications in the methods used (Stańczyk & Jurecki, 2014), a positive or negative answer gives a general view on the technical condition of the shock absorbers. However, unlike typical scientific tests of shock absorbers carried out under strictly defined conditions, such diagnostic tests may be carried out under different environmental conditions and, depending on the validity period of the technical test, at a significantly different external temperature.

The aim of this paper is to analyse whether the date of the realization of this type of tests and weather conditions, especially temperature, can affect the obtained results. The answer to the question of whether identical shock absorbers subjected to tests in the winter (at low ambient temperatures) will show the same "efficiency" during a check in summer temperatures, as well as allowing any possible error to be determined and exclude the possibility of any manipulation aimed at the successful completion of the check-up.

Measurement methodology

Cars in Poland are subjected to periodic diagnostic testing, the scope of which is specified in numerous regulations. The main requirements are set out in the Regulation of the Minister of Infrastructure and

Development of 31 July 2015 item 776 on announcing the consolidated text of the Regulation of the Minister of Transport, Construction and Maritime Economy "on the scope and manner of conducting technical inspections of vehicles and drafts of documents used for such inspections" as amended in the years 2016, 2017 and 2018 (Announcement, 2015).

Appendix 1, section 5.3.2 of the Regulation, sets out the actions that must be taken by the diagnostician during the check-up of a vehicle's shock absorbers. In appendix 2, regarding the scope of additional technical inspection that are to be carried out, in point 1.2.1 the method of measuring the damping efficiency of suspension is determined.

Test results obtained by the EUSAMA method are inconsistent with the requirements when:

1) the degree of adhesion of the wheel to the plates, referred to as the Eusama Indicator Value (EV) is less then:
   - 15% for cars whose kerb weight does not exceed 900 kg,
   - 20% for cars whose kerb weight ranges from 900 to 1500 kg,
   - 25% for cars whose kerb weight is greater than 1500 kg;
2) the relative difference of the EV on the same car axle exceeds 30%, higher values on the axle is used how 100%;
3) the absolute value of the difference in the degree of wheel adhesion, EV, on the same axle is greater than 15%.

Conditions 2 and 3 apply when the degree of adhesion on the same axle exceeds 35%.

In this paper, the efficiency tests of shock absorbers were conducted on an SA640 Bosch Beissbarth Device presented in Figure 1.

Figure 1. Control plates of the Beissbarth Bosch SA 640 test stand

The SA640 device uses a kinematic system which generates vibrations in the plates up to frequencies of 25 Hz with a constant amplitude of 6 mm (Bosch, 2014). The starting process and visualization of the obtained results is possible through a computer control system shown in Figure 2.

Figure 2. Control system of the Bosch Beissbarth SA 640 test stand

When the wheels of the vehicle roll onto the measuring plates, the first step is to measure the static pressure of both wheels of the tested axle. Then, after the automatic start of the vibration excitation system, the tested system receives the appropriate frequency of vibration excitation (about 25 Hz). Then the kinematic force of the stand plates is switched off, the vibration is stopped and the pressure of each of the tested wheels and the frequency of the excitation as a function of time are continuously recorded until the wheels are stationary.

The measurement results are displayed on the display in real-time in the form of wheel pressure characteristics as a function of time. After completion of the test, a test report, presented in Figure 3, is generated for both axles.

The report contains the determined values of the minimum Eusama value (EV), also referred to as relative wheel adhesion for all the analysed wheels (yellow fields). The report also includes the resonant frequencies, in which they were determined (blue fields). They are a measure of the "stiffness" of the chassis and their value mainly depends on the characteristics of the elastic elements used in the suspension. Serially produced vehicles show resonant frequency values usually in the range of about 13 to 18 Hz (Bosch, 2014). Lower values indicate soft

BEISSBARTH — PROTOKÓŁ URZĘDOWY KONTROLI POJAZDU — [redacted] L00000603

Dane urządzenia — Beissbarth GmbH SA600
Numer homologacji — Wersja programu TL V2.82/SL V3.30
Numer seryjny 9356033346_01_E__0006860_ — Następna kalibracja

ciepły Transit		Dane pojazdu	
		Producent	
		Typ	
		Data rejestracji	
		Przebieg	
Numer klienta	L00000306	Numer podwozia	
Numer zamówienia	L00000603	Numer licencji	[redacted]

Wyniki testu zawieszenia

	Przednia oś po lewei	Przednia oś różnica	Przednia oś po prawei	Tylna oś po lewei	Tylna oś różnica	Tylna oś po prawei
Częstotliwość drgań	17 Hz	0 Hz	17 Hz	16 Hz	1 Hz	15 Hz
Przyczepność	77 %	12 %	68 %	34 %	18 %	28 %
Masa koła	712 kg		663 kg	517 kg		451 kg
Masa osi		1375 kg			968 kg	

Początek pomiaru 25.01.2019 12:19:49 — Koniec pomiaru 25.01.2019 12:20:55

Podsumowanie

	Jest	Granica	Status
Test zawieszenia			
Różnica przyczepności oś przednia	12 %	30 <=%	OK
Różnica przyczepności oś tylna	18 %	30 <=%	OK *
* Ocena zawieszenia			

Figure 3. View of the original generated basic report

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Wyniki testu zawieszenia

	Przednia oś po lewei	Przednia oś różnica	Przednia oś po prawei	Tylna oś po lewei	Tylna oś różnica	Tylna oś po prawei
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Początek pomiaru 25.01.2019 12:19:49 — Koniec pomiaru 25.01.2019 12:20:55

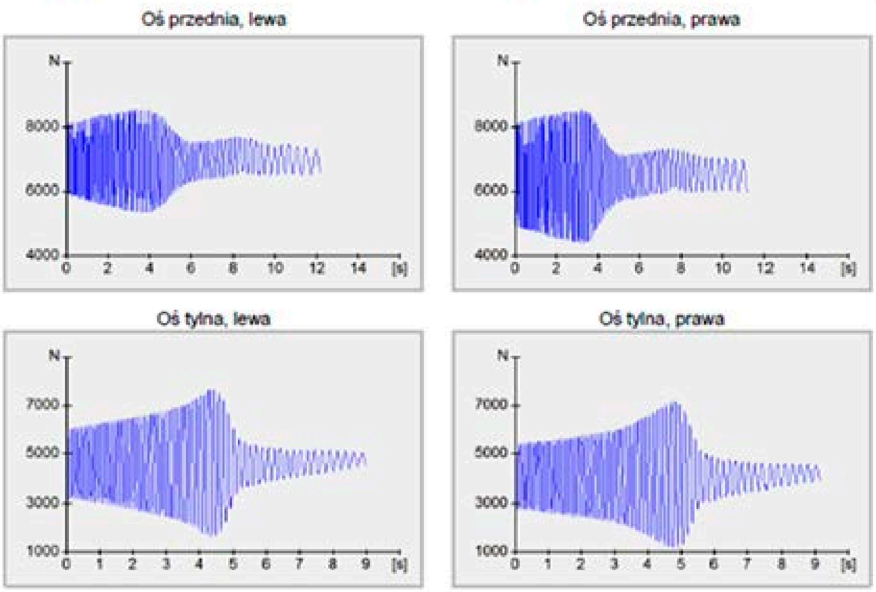

Figure 4. Progress of wheel pressure values on the measuring plates as a function of time on the orginal report

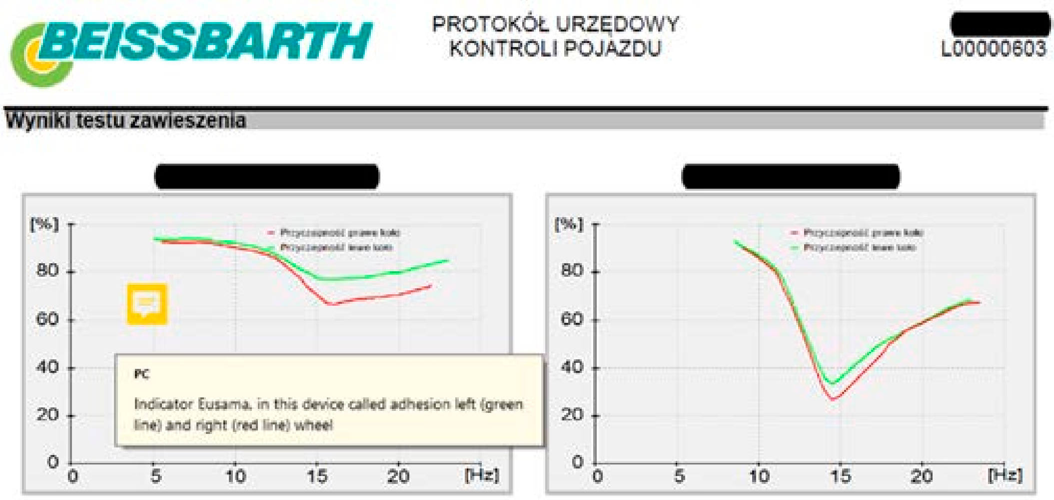

Figure 5. View of the expanded report

suspension – and higher values are usually found in sports vehicles. However, the difference in resonant frequency between the two sides should not exceed 3 Hz. The report also shows the values of the static load on each wheel of the tested axle (red fields).

The additional report (Figure 4) presents graphs of the changes in the wheel pressure force and the Eusama value (EV), also referred to as relative wheel adhesion as a function of the excitation frequency (Figure 5). Such additional presentation of the results provides the possibility of verifying the symmetry of the suspension and detecting any possible damage.

The Eusama value (EV), also known as the relative coefficient of wheel-surface contact, is calculated as the quotient of the minimum dynamic wheel pressure on the test plate and the static pressure measured before the measurement.

The tests were conducted on five vehicles with different kerb weights; the data for these vehicles is shown in Table 1.

Table 1. Data of the tested vehicles

Vehicle Number	Make	Model	Year of production	Weight kg
1	Opel	Astra G Kombi	1999	1220
2	Skoda	SuperB	2002	1520
3	Audi	A4 B7	2007	1630
4	Opel	Astra G	1999	1380
5	Ford	Transit	2013	2250

The damping efficiency tests of the shock absorbers were conducted for all the vehicles in two variants:

1) the vehicle was tested after 12 hours of being parked outdoors at an ambient temperature of –5°C (Figure 5), so that all parts of the vehicle, including the shock absorbers, had a sufficiently low temperature;
2) the vehicle was tested after a 12-hour stay inside the laboratory hall, where the temperature was 20°C.

In the first case, a situation was simulated in which a test of the shock absorbers of the vehicle was realized e.g. in winter, when the outside temperature is considerably below zero. In the second case, a situation was simulated when the same vehicle was tested in summer, when ambient temperatures exceed 20°C.

The outdoor temperature was measured using the weather station shown in Figure 6, while the temperature control of the shock absorbers (suspension) was measured just before the test using a FLIR E53 thermal imaging camera using FLIR™ Tools software, shown in Figure 7.

Figure 6. Weather measuring station

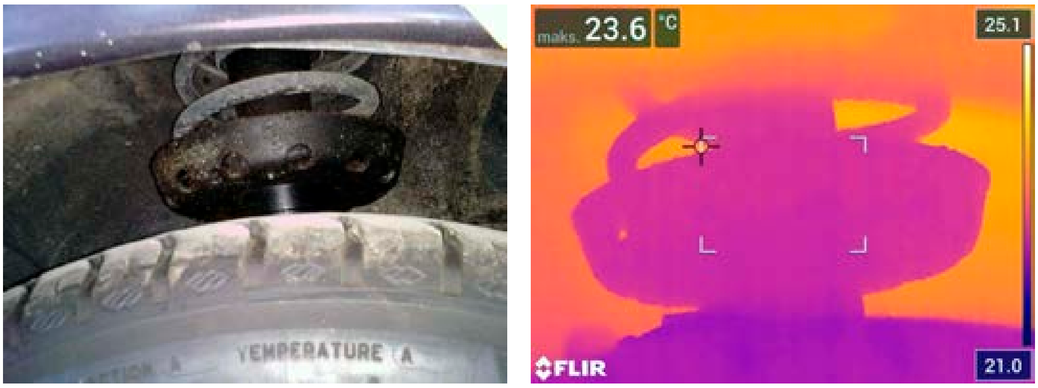

Figure 7. View of a FLIR™ camera image

Test results

The efficiency tests of the shock absorbers were conducted for five different vehicles. The results of the tests conducted at temperatures of –5°C and 20°C are presented in Tables 2 and 3, respectively. The tables contain percentage values of the damping efficiency of the shock absorbers, EV, (determined by the Eusama method) in different conditions.

Table 2. Results of the effectiveness of the shock absorbers (EV) in the test conducted at a temperature of –5°C [%]

Vehicle number	Effectiveness of the shock absorbers (EV), %			
	Front axle wheels		Rear axle wheels	
	Left	Right	Left	Right
1	72	66	76	69
2	65	71	65	62
3	79	77	73	72
4	82	72	62	57
5	78	71	44	38

Table 3. Results of the effectiveness of the shock absorbers (EV) in the test conducted at a temperature of 20°C [%]

Vehicle number	Effectiveness of the shock absorbers (EV), %			
	Front axle wheels		Rear axle wheels	
	Left	Right	Left	Right
1	65	59	62	57
2	63	61	59	58
3	75	74	70	68
4	82	69	60	54
5	77	68	34	28

The changes in the value of the damping effectiveness of the shock absorbers, EV, for different conditions are presented in Table 4 and in Figure 3.

Figure 8 shows the value of the relative change in the coefficient determining the effectiveness of the shock absorbers (EV), where a value of 100% is the value obtained at 20°C.

Table 4. Changing results of the damping effectiveness, EV, of the shock absorbers in tests conducted at temperatures of –5°C and 20°C [%]

Vehicle number	Difference of the effectiveness of the shock absorbers (EV), %			
	Front axle wheels		Rear axle wheels	
	Left	Right	Left	Right
1	7	7	14	12
2	2	10	6	4
3	4	3	3	4
4	0	3	2	3
5	1	3	10	10

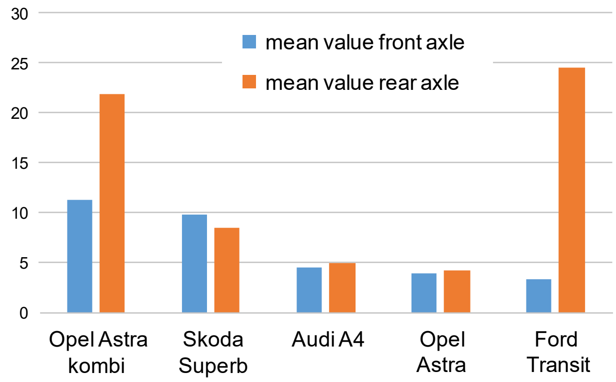

Figure 8. Relative change of EV

In the presented values of temperature it is easy to observe that the lower the temperature, the higher the value of the damping indicator of the shock absorbers, EV. In two of the tested vehicles, the relative change in the values of the effectiveness of the shock absorbers, EV, was very similar and almost unnoticeable, at a value of about 5%. In one case these differences were not much bigger – up to about 10%. In two vehicles, especially for the rear axles, the relative change of the effectiveness of the shock absorbers, EV, exceeded 20%.

Conclusions

From the results in the literature, it can be seen that the value of the damping effectiveness indicator of shock absorbers measured with the Eusama method (EV – Eusama Value) depends on several factors.

Hydraulic or hydraulic-gas shock absorbers used in a vehicle contain oil inside the casing, the physical properties of which, e.g. viscosity, can change significantly at lower temperatures.

As the test shows, the outside temperature can have a small influence on the values of the effectiveness of a vehicle's shock absorbers, as measured by a device using the Eusama Method. When the same car is tested using this device in higher temperatures, the values of the *EV* damping indicator of its shock absorbers do not decrease significantly. In some cases the relative increase of the damping effectiveness of the shock absorbers EV might even reach a value of 20.

On the basis of the tests conducted in this paper, a relatively small, but noticeable influence of the external temperature on the possible outcome of a diagnostic test has been indicated. In Poland's climatic zone, external temperatures below –5°C are not unusual. Thus, in the case of the inspected vehicles (after a long period of downtime), there may be a slight distortion of the results during low-temperature periods. It should be noted that even lower temperatures are common, usually from December to February, even reaching below –20°C. In such low temperatures, these differences can be even greater. In such cases, the display values of the device may over read slightly.

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