EFFECTS OF USING VARIOUS METHODS FOR CAR SHOCK ABSORBERS DIAGNOSTIC TESTS

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Abstract

The work concerns the diagnostic assessment of the technical condition of the car suspension. The paper discusses practical problems that usually appear during testing of car shock absorbers mounted in a vehicle. The results of experimental tests for passenger car, carried out according to the EUSAMA standard test, were compared with the results obtained using newer methods (phase angle method and half power bandwidth method - HPBM). The article also deals with the issue of incompatibility of typical excitation at diagnostic devices for testing suspension with the one that often occurs in road conditions (by simulation method).

The main purpose of the work was to assess the usefulness and reliability of various diagnostic methods intended for the testing of vehicle shock absorbers without disassembly them from the vehicle. The analyses carried out indicated the advantages and disadvantages of these methods in practice. It is also shown that the conditions of diagnostic tests correspond poorly to the operating conditions of the shock absorbers under normal vehicle operating conditions. An important factor in this case is the sliding friction in the suspension.

Keywords: shock absorbers testing; EUSAMA test; phase angle method; half power bandwidth method; simulation tests

1. Introduction

The technical condition of automotive shock absorbers is essential for vehicle motion safety and occupants' comfort [5]. With the development of damping components of suspension systems, newer and better methods of diagnosing such parts are continuously sought. The "on-vehicle" tests are particularly useful thanks to their low cost and short duration time. Predominantly, "forced vibration tests" are used for this purpose [3, 4, 6]. A similar approach can be found in [8, 9, 11] as well as in [12, 13, 14] and [16, 17]. At present, efforts are made in Europe to adopt an identical (standard) vibration excitation method for all the shock absorber testers. As one of the peculiarities of such a method, the stroke of the tester vibration plate is to be constant, equal to e.g. 6 mm, as it is in the case of the EUSAMA machines [2, 4, 12] (see also [18, 19]). Unfortunately, such testers, which are most popular, suffer from a major drawback: the final test result strongly depends on tire

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inflation pressure [13, 14, 15], sprung mass [11, 13, 14], sliding friction in the suspension system [18, 19], test conditions, and tester characteristics [10, 16].

In consideration of the above, the authors decided to verify the reliability and usefulness of the phase angle method [3, 11, 16] (see also [17]) and the half power bandwidth method (HPBM) [4, 6, 7] in relation to the classic EUSAMA test, the newer methods are based upon. This was the main objective of this work. At this opportunity, the issue of incompatibility of the typical excitation applied by diagnostic suspension testers with the one that often occurs in road conditions has also been addressed (see also [18]).

2. Impact assessment of viscous damping and sliding friction in suspension on the final tests results of shock absorbers by various diagnostic methods

The usefulness and reliability of the diagnostic methods under consideration, used for the on-vehicle testing of motor car shock absorbers, was assessed on the grounds of measurement results obtained with using a prototype tester TUZ 1/E. In every test, a sinusoidal input was applied with a constant amplitude of 3 mm and a frequency declining from about 25 Hz to zero at a rate of 1.6(6) Hz/s; the outputs recorded were time histories of the vertical force under the tester vibration plate and of the vertical displacement and acceleration of the plate (necessary to eliminate the distorting impact of the force of inertia of this exciter component, see also [10]). All the tests were carried out for the rear suspension system of an Opel Agila 1.2 Twinport, in which the viscous damping was changed stepwise by applying 15 known damping levels "γ" varying between 0.050 to 0.394. Such tests were repeated twice, with the sliding friction in the suspension system being raised from 20 N to 100 N and 200 N; all the other vehicle parameters remained at their nominal levels.

In result of an analysis of results of the EUSAMA test (Figure 1), which were determined from the normal reaction at the tire-exciter contact point (instead of the force measured under the vibration plate, see also [10]), with the main test phase being extended to 15 s, the following has been found:

- the EUSAMA indicator value vs suspension damping curves have degressive shapes;
- despite large changes of shock absorber viscous damping, there is a fairly small range of diagnostic parameter variability (even for the lowest level of sliding friction in the suspension does not exceed 35 percentage points);
- even with very high damping in the rear suspension, it is difficult to get EUSAMA indicator values greater than 50%;
- the growth of the sliding friction in the suspension system by 180 N could cause here the final test results to be overestimated by as much as 30 percentage points.

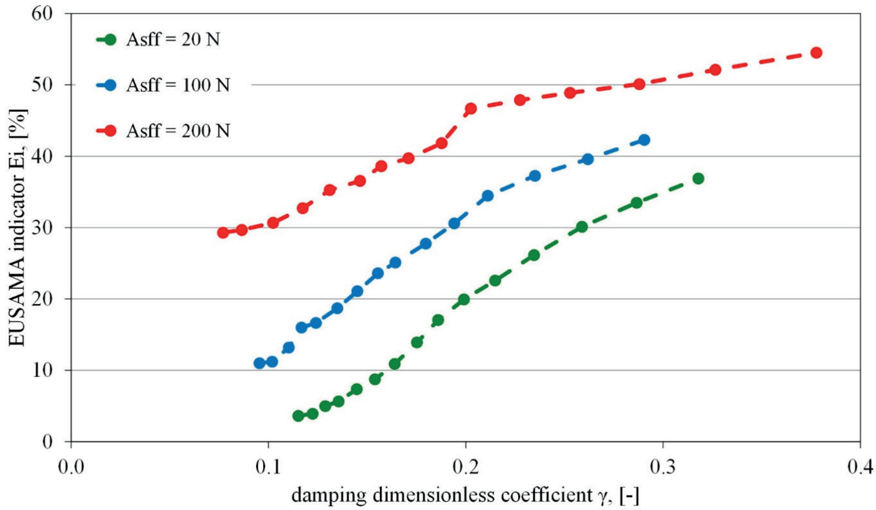

Fig. 1. Example results of diagnostic testing of the rear suspension system of an Opel Agila 1.2 Twinport with using the EUSAMA method, for various levels of viscous damping in the shock absorber, at a nominal and raised sliding friction in the suspension system (Asff = 20 N, Asff = 100 N and Asff = 200 N, respectively)

When the reliability and usefulness of the phase angle method proposed in [3, 11, 16] and [17] was assessed, the following was observed:

- At high values of the viscous damping and sliding friction in the suspension system, a minimum of the phase shift angle between the excitation and the tire-exciter contact force may be hardly noticeable or not exist at all (Figure 2).
- The minimum phase shift angle value vs suspension damping curves have linear shapes approximately (Figure 3).
- for all considered Asff values, the diagnostic parameter changed here in quite a wide range (to about 0.6 rad, see Figure 3).
- The growth of the sliding friction in the suspension system by 180 N caused here the final test results to be overestimated by as much as 0.9 rad (Figure 3).

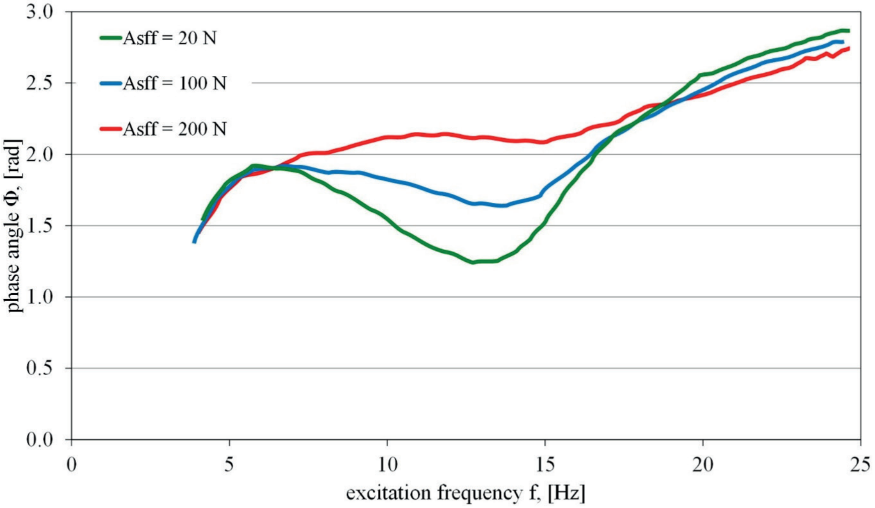

Fig. 2. Example results of diagnostic testing of the rear suspension systemof an Opel Agila 1.2 Twinport with using the phase angle method, for a shock absorber in a very good condition, at a nominal and raised sliding friction in the suspension system (Asff = 20 N, Asff = 100 N and Asff = 200 N, respectively)

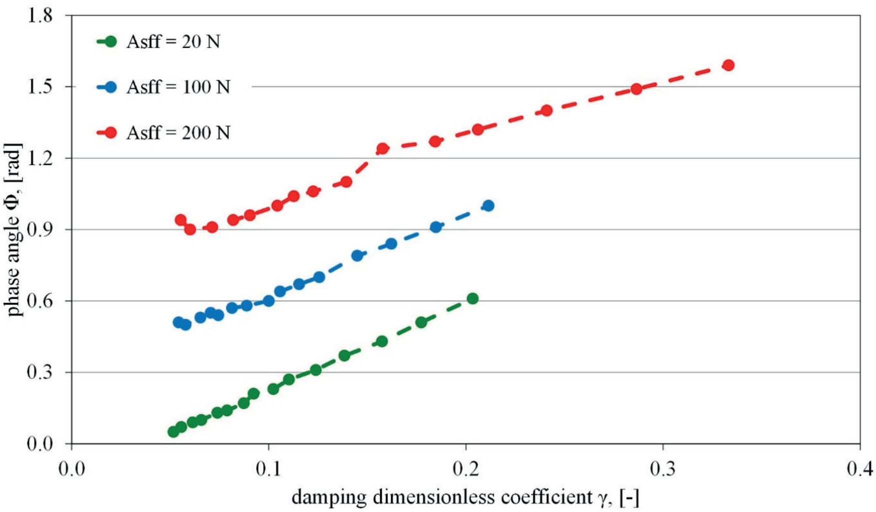

Fig. 3. Example results of diagnostic testing of the rear suspension system of an Opel Agila 1.2 Twinport with using the phase angle method, for various levels of viscous damping in the shock absorber, at a nominal and raised sliding friction in the suspension system (Asff = 20 N, Asff = 100 N and Asff = 200 N, respectively)

When the dimensionless coefficient of damping in the test vehicle's suspension system was estimated by the half power bandwidth method (HPBM) in accordance with [4] (see also [6] and [7]), the normal reaction signal recorded at the tire-exciter contact point was used (with eliminating the distorting impact of the force of inertia of the tester vibration plate). Based on appropriate measurements and calculations, the following was ascertained in this case (Figure 4):

- parameter θ quite well describes the actual condition of the shock absorber under test, except for excessive sliding friction in the suspension (e.g. when Asff = 20 N);
- the growth of the sliding friction in the suspension system by 180 N caused here the final test results to be very high overestimated (even by 100%);
- at high values of the viscous damping and sliding friction in the suspension system, the diagnostic parameter becomes indeterminate.

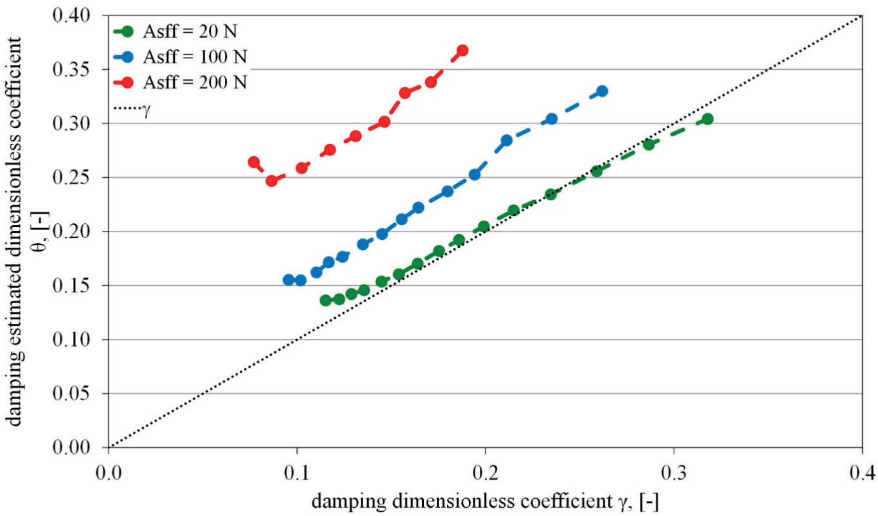

Fig. 4. Example results of diagnostic testing of the rear suspension system of an Opel Agila 1.2 Twinport with using the half power bandwidth method (HPBM), for various levels of viscous damping in the shock absorber, at a nominal and raised sliding friction in the suspension system (Asff = 20 N, Asff = 100 N and Asff = 200 N, respectively)

3. Comparison, by simulation, of selected operating parameters of the motor car suspension system in a typical diagnostic test and in road conditions

To depict the differences in the vehicle suspension system functioning in diagnostic test and real road operation conditions, simulation test results were used. This work was done on a front "quarter" of the Isuzu D-max motor vehicle. Although two transverse arms were provided in the front suspension system of this vehicle, the system was characterized by relatively strong sliding friction force (Asff = 158 N), typical for passenger cars with McPherson struts.

In the simulations, a non-linear "quarter-car" model was used, where sliding friction in the suspension system and tire separation from the ground ("lift-off") were taken into account (see also [18]). Most of the model parameters had been previously identified in rig tests. Only the shock absorber and tire damping was described in a linear form. The viscous damping in the suspension system was changed for the dimensionless coefficient of damping γ to vary from 0 to 0.5 in steps of 0.02 and the tire damping adopted was based on literature data.

Due to low amplitude (3 mm) and moderate frequency (10 Hz to 20 Hz) of the excitation, at which the final test results are determined, rather low suspension deflection rates are obtained in the EUSAMA test, even if the shock absorbers under tests are worn out very badly. During such a diagnostic test, the maximum absolute values of the viscous damping force (meant as the force reduced to the vertical axis in the "quarter-car" model) very seldom exceed 500 N, even if the shock absorber condition is very good. We have to be aware of the fact that in the conditions where the EUSAMA test result is good, i.e. the EUSAMA indicator value (denoted here by "Ei") is higher than 40%, the amplitude of the viscous damping force only slightly exceeds the value of the force of sliding friction in the suspension system (Figure 5). If, however, the half-cycle average values are used then the value of the amplitude of the viscous damping force may turn out to be markedly lower than the value of the sliding friction force. Hence, a statement may be made that the final result of diagnostic EUSAMA shock absorber testing depends to a considerable degree on the frictional resistance in the suspension system (see also [18]).

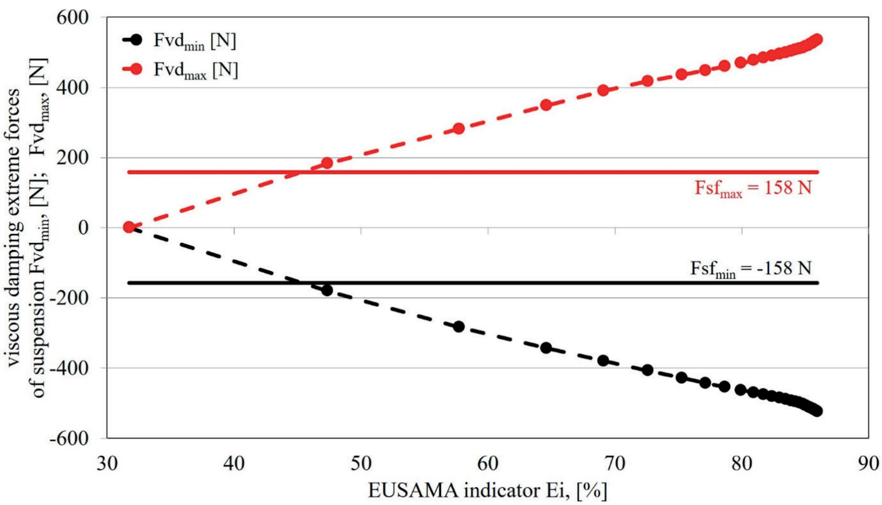

Fig. 5. Example extremums of the viscous damping forces (Fvd_{min} and Fvd_{max}) and sliding friction forces (Fsf_{min} and Fsf_{max}) in the suspension system for various values of the EUSAMA indicator (results of simulation tests with changes in the technical condition of the shock absorber in a front "quarter" of the Isuzu D-max motor vehicle)

For the same vehicle moving on an average road (pavement category C, according to [1]) with a speed of 90 km/h, the suspension deflection rates will be much higher (Figure 6). In such suspension system operation conditions, the peak-to-valley values of the viscous damping forces in the shock absorber markedly increase (linearly, in rough terms) with growing relative damping in the suspension system (Figure 7). For the nominal values of vehicle parameters ($\gamma \approx 0.3$), the sliding friction resistance made here merely about 10% of the viscous damping force in the suspension system and did not have any significant impact on the process of dissipation of the energy of vertical vehicle vibration. It can also be clearly seen that for the simulation of vehicle motion on an average road (pavement category C), the damping force generated by a nominal shock absorber would be three times as strong as that generated in the EUSAMA test (see also [18]).

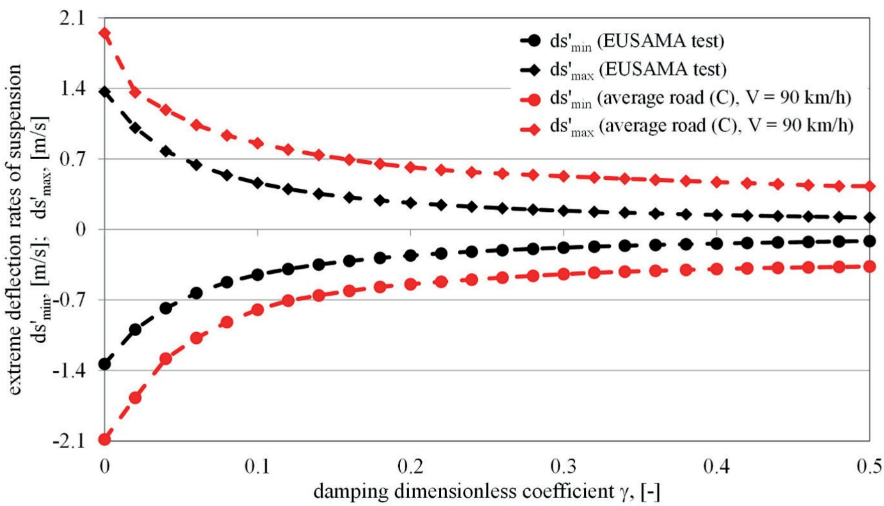

Fig. 6. Comparison of the example extremums of the deflection rates (ds'_{min} and ds'_{max}) in the vehicle suspension system at various values of the dimensionless coefficient of damping in the suspension system (results of a simulation of the EUSAMA test and a test of vertical vibration of the vehicle on an average road (C pavement category) for a front "quarter" of the Isuzu D-max motor vehicle)

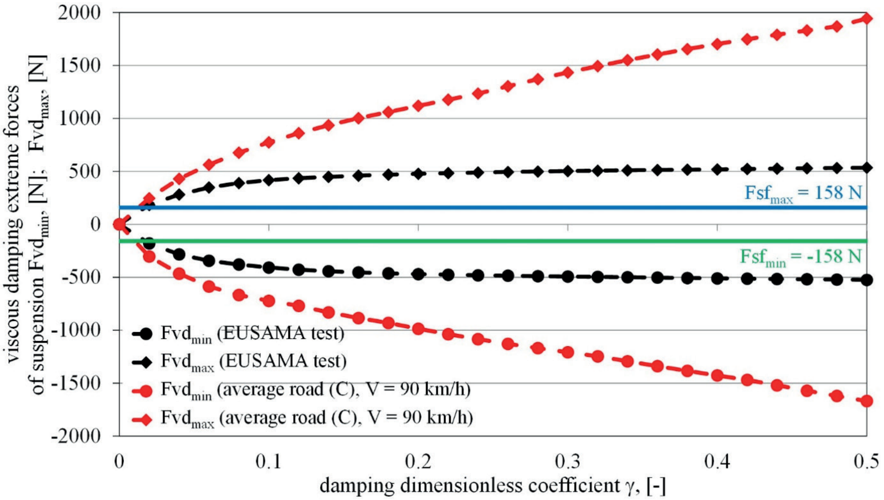

Fig. 7. Comparison of the example extremums of the viscous damping forces (Fvd_{min} and Fvd_{max}) and sliding friction forces (Fsf_{min} and Fsf_{max}) in the vehicle suspension system at various values of the dimensionless coefficient of damping in the suspension system (results of a simulation of the EUSAMA test and a test of vertical vibration of the vehicle on an average road (C pavement category) for a front "quarter" of the Isuzu D-max motor vehicle)

4. Conclusions

Among the diagnostic shock absorber testing methods discussed herein, the most promising one is the phase angle method. On the other hand, the poorest opinion is deserved by the half power bandwidth method (HPBM), which intrinsically may only be used for the estimation of the dimensionless coefficient of damping in linear systems with one degree of freedom and with a low energy dissipation level. For the reliability and, simultaneously, usefulness of the EUSAMA test to be raised, this method needs improving. A modification has already been proposed by one of the co-authors of this study, but it cannot be disclosed at present because of a patent application planned.

In all the methods, there is a problem because the excitation applied on a diagnostic test stand is incompatible with the one that often occurs in real vehicle operation conditions. While the sliding friction in the suspension system can, so to say, "substitute" for the viscous damping during a diagnostic shock absorber test (making the test result satisfactory), it will be definitely insufficient to disperse the vertical vehicle vibration on a road.

5. Acknowledgement

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6. Nomenclature

EUSAMA	European Shock Absorber Manufacturers Association
Ei	EUSAMA indicator - indicator of the technical condition of the shock absorber, proposed by EUSAMA
HBPB	half power bandwidth method
Asff	sliding friction in the suspension system, [N]
γ	dimensionless coefficient of damping, [-]
$Fvd_{min/max}$	extreme viscous damping forces, [N]
$Fsf_{min/max}$	extreme sliding friction forces, [N]
$ds'_{min/max}$	extreme suspension deflection rates, [m/s]

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