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ANALYSIS OF CAUSES OF FALSE-NEGATIVE EVALUATION OF EUSAMA METHODOLOGY FOR SUSPENSION ASESSMENT

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Abstract: *The article deals with recent failures of the EUSAMA methodology which is used for non-destructive testing of the car chassis without disassembling. On simulated data, there is performed an analysis of false-negative evaluation of car condition which occurs often on cars in actually good technical shape. High tire stiffness in combination with small axle load are identified as main causes of the methodology failures. Such combination of technical features is common for car chassis designed according contemporary trends in automotive industry. Adjustment of the too high excitation stroke is suggested as possible future recourse. Therefore the testing conditions should comply with contemporary quality of the road surfaces.*

Keywords: Technical diagnostics of vehicles, car suspension, EUSAMA methodology.

1 Introduction

The shock absorber is an important design element of the car chassis. It has appeared on cars in various design forms since their “birth.” Nowadays, the shock absorber has at least the same importance to ensure good vehicle adhesion and crew comfort as quality of the tires or brake system have. According Calvo (2008) or Coylu (2013), worn shock absorber significantly prolongs the braking distance, causes much faster wear of other chassis parts etc. Therefore, recent pressure to perform regular technical diagnostics of car suspension condition is fully understandable.

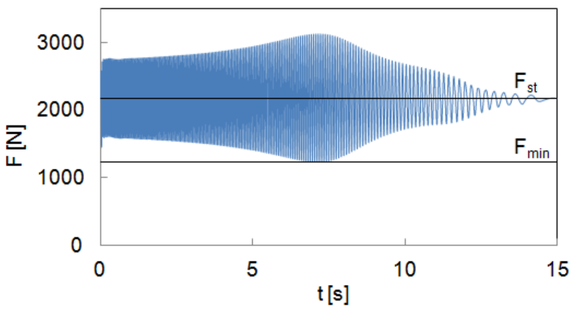

Fig. 1 Pressure force - time response during EUSAMA test procedure

These testing devices evaluate the adhesion of the wheel to the oscillating platform according to the EUSAMA methodology. This methodology was introduced by "European Shock Absorber Manufacturers Association" in the '70s last century. The wheel of the car is placed on the vertically oscillating platform. Stroke of the platform oscillations is 6 mm and it simulates road roughness. Wheel pressure force to the platform is acquired during test. Frequency of platform oscillation decreases gradually from 25 Hz to stop after the driving motor is switched off. Main goal of the test is to acquire the wheel pressure force time response during whole testing interval – i.e. frequency range. EUSAMA value is determined as division

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of the minimum pressure force F_{min} which acts between the wheel and the oscillating platform and the static force F_{st} which acts on the platform at rest (figure 1). The minimum permissible value of 20 % relative downforce is recommended by EUSAMA (1976) prescription.

2 Formulation of problem

The EUSAMA methodology is able to directly measure mechanical grip of the examined wheel which is huge advantage. The criterion of the wheel relative pressure to the road is easy to understand and quantifiable. However, a new phenomenon arose in the last decade when the test results were negative for a brand new cars. The faulty assessment of the rear axle suspension of the FIAT 500 car model is a typical representative of this new category of phenomenon as mentioned by Tassiaux (2009) and Winter (2010). The assessed vehicle could be declared as unfit for purpose provided that too low EUSAMA value is obtained through the test.

3 Objectives

Main goal was to elaborate the analysis of most serious causes of frequent negative EUSAMA evaluation occurrences of vehicles otherwise in good technical condition. Knowledge obtained by analysis is invaluable to further solution of the problem.

4 Methods

Selected method of solution was based on analysis of simulated dataset which imitates signals obtained by real tests at testing facilities. An explicit linear mathematical model was used to enable calculation of large number of possible input variants. There was generated curve which describes response of dynamic force acting on the oscillating platform $F_{dyn}(\omega)$ in dependency on the angular frequency (ω). Similar response curve was generated for phase shift $\Phi(\omega)$ of this force delay to excitation stroke in dependency on angular frequency. Both curves were generated from the transfer function of excitation stroke and tire deformation for each of the simulated chassis variant.

4.1 The simulation model

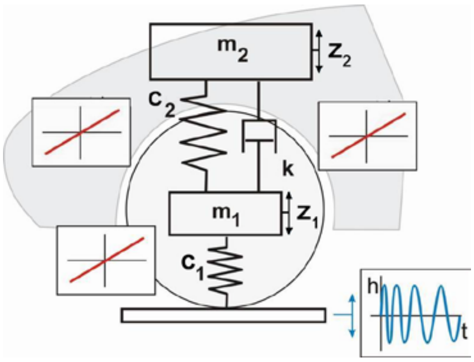

Fig. 2 ¼ model of the wheel suspension on EUSAMA testing rig

Analysis of inaccurate diagnostics results was made with ¼ simulation 2 DOF (degree of freedom) model of the wheel suspension similar to Malmedahl (2005), Simms (2002) and Sun (2002) ones, which describes motion of the masses excited by tester (figure 2). The oscillating masses m_1 and m_2 are separated by springs c_1, c_2 and by the damper k. Motion of masses can be described by transfer function between the excitation platform stroke $h(\omega)$ and the force of adhesion $F_{dyn}(\omega)$:

$$W_F(\omega) = \frac{F_{dyn}(\omega)}{h(\omega)} = c_1 \cdot \left| \frac{c_1}{c_1 + c_2 + i\omega \cdot k - \omega^2 \cdot m_1 - \dfrac{(c_2 + i\omega \cdot k)^2}{c_2 + i\omega \cdot k - \omega^2 \cdot m_2}} - 1 \right| \quad (1)$$

EUSAMA relative downforce is defined as the ratio of the minimum force acting on the platform during its oscillating motion and the static force acting on standstill platform:

$$EUSAMA = \frac{F_{\min}}{F_{st}} = \frac{F_{st} - F_{dyn\max}}{F_{st}} = \frac{g \cdot (m_1 + m_2) - F_{dyn\max}}{g \cdot (m_1 + m_2)} \tag{2}$$

The damping ratio is usually used to evaluate damping efficiency of linear dampers in dynamics branch. It is possible to determine damping ratio of the unsprung mass of the wheel suspension (fig. 2) which is given by equation:

$$\xi_1 = \frac{k}{2 \cdot \sqrt{m_1 \cdot (c_1 + c_2)}} \tag{3}$$

According to the literature by Reimpell (1996), Tsymberov (1996) and Dixon (2007), minimum damping ratio of sprung mass should be $\xi_1 = 0.1$.

5 Results and discussion

The test procedure was simulated for large dataset of the wheel suspensions with respect to current designs of suspension and chassis of cars. Overview of the range of simulated input variables is as follows: unsprung mass: m_1 = 20 to 60 kg; ratio of masses m_2 and m_1: $p_m = m_2/m_1$ = 3 to 13; static deformation of tire: $sbt = g.(m_1+m_2)/c_1$ = 7.5 to 22.95 mm; natural freq. of mass m_2: $f_2 = \sqrt{(c2/m2)}/2\pi$ = 0.95 to 2.2 Hz; damping constant: k = 100 to 2000 Ns/m.

Calculation of the transfer function $W_F(\omega)$ in simulation model enables to obtain simulated values of EUSAMA relative downforce very efficiently. Relative downforce was calculated for 11164 chassis variations using ¼ suspension model and equation (2). In figure 3, there are plotted obtained EUSAMA values proportionally to input damping ratio (each dot represents one chassis design). Unfortunately, used linear model is unable to simulate the tire's ability to flex only in pressure region. Therefore, simulated adhesion values could have negative value (in fact, they cannot fall below 0 in reality).

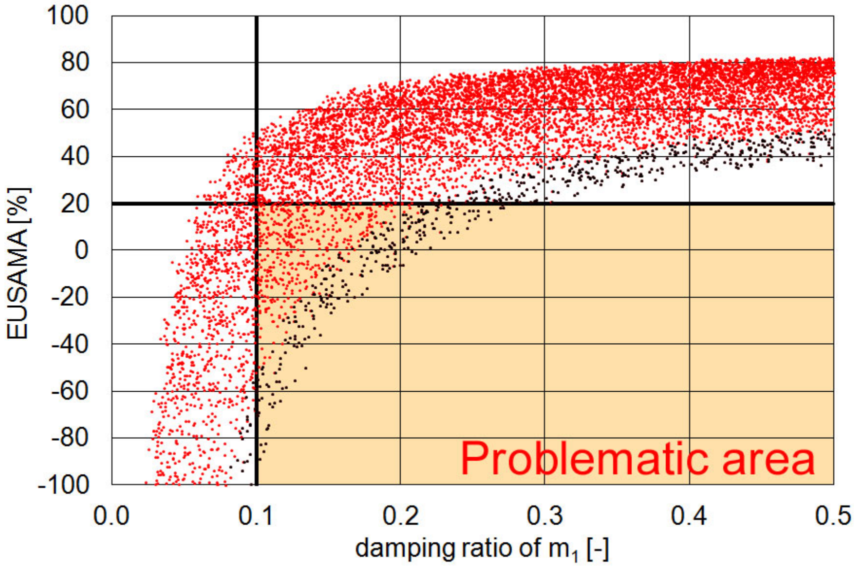

Fig. 3 Simulated EUSAMA test procedure (excitation stroke 6 mm)

Two problematic areas of the resulting values are depicted in figure 3. First group of problematic results contains EUSAMA value ≥ 20%, although $\xi_1 < 0.1$. Second group of suspicious results contains EUSAMA values <20% despite $\xi_1 \geq 0.1$. The first group can be put aside as it is on side of high adhesion safety. On the contrary second group of results requires urgent solution. Among all simulated variants, there were 9346 of simulated test procedures with input value of the damping ratio of the unsprung mass above 0.1. However, 794 of such simulations ends with EUSAMA value below 20%, which is roughly a tenth of them. Thus, it can be concluded that inaccurate diagnostic result of the methodology is an objective phenomenon which occurs thanks to interference of several partial effects. These are the most important of them:

•High tire stiffness (low profile number, runflat design)

•Low load on axle (especially non driven rear axles)

It could be assumed that vast majority of cars which does not pass the test criteria was equipped with tires with higher stiffness. This assumption is based on many available recordings of routine test performed by PTI (periodical technical inspection) facilities. This rising trend is mainly based on the recent demands to reduce rolling resistance and thus acoustic noise generated by tires. Black points in figure 3 represents results of simulation with smallest ratio of axle load and stiffness of tire $(m_1+m_2)/c_1$. Obviously, the assessment of the relative downforce is affected severely by value of this ratio at most.

6 Conclusions

Essentially, the EUSAMA methodology simulates driving on a road with certain surface roughness. However, it was created in the '70s last century when general condition of the roads was completely different compared to the present. With some exaggeration one can say that quality of driving on modern roads approaches conditions on the racetrack. Frequently, the designers of the passenger car chassis are therefore using similar designs of suspensions as competition cars have. There are clearly visible trends such as to equip low profile tires, increasing of the tire stiffness, reduction of suspension stroke and increasing overall efficiency of suspension.

The situation requires urgent solution regarding the perspective of users and producers of the EUSAMA principle testing devices. We suggest that the possible solution is to adjust the testing hardware. Thus the test conditions should better reflect the current general quality of road surfaces (it means reduction of the excitation stroke). Such solution should lead to a significant reduction of errors in assessment of the technical condition of the car suspension occurring especially within contemporary cars. Therefore, it seems that further study of effect of excitation stroke value to the relative downforce assessment is essential in future. Provided such analysis is available there would be possible to determine the new value of the excitation stroke for testing.

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