THE USE OF AMPLITUDE MEASUREMENT IN THE DIAGNOSIS OF HYDRAULIC SHOCK ABSORBERS OF PASSENGER CARS

Janusz Gardulski

Silesian University of Technology
Faculty of Transport
Department of Automotive Vehicle Construction
Krasińskiego Street 8, 40-019 Katowice, Poland
tel.:+48 32 6034164, fax: +48 32 6034118
e-mail: janusz.gardulski@polsl.pl

Abstract

The article presents the amplitude measurement used in the diagnosis of hydraulic fluid leakage from the shock absorbers of passenger cars. Measures used to assess the distribution of the peak using the free vibration method with force extortion. To verify the results of study the FFT were used. In particular illustration of a random vibroacoustic process, acceleration of sprung mass for front and rear suspension, spectrum of acceleration of sprung mass for front suspension, larger differences of spectrum of acceleration of sprung mass for front suspension are presented in the paper.

Analysis results of the of the peak and of the spectrum for the front suspension with losses of shock absorber fluid show decrease in amplitudes of vibrations corresponding increase in shock absorber fluid. Asymmetry of the damping characteristics affects the differences in compression and tension of shock absorber. Spectral analysis is better measure then the study of period. For the rear shock absorbers, differences are smaller. This is due to difference in design of Fiat Seicento front and rear suspension). The presented method of diagnosis requires further study carried out on a large shocks absorbers population to their averaging and comparing test results using different testing methods and estimators and stochastic analysis of vibroacoustic signals.

Keywords: *road transport, shock absorbers, free vibration method*

1. Introduction

A vehicle represents a complex material system affected by a number of kinematic and force excitations with a wide frequency spectrum. The effective vibrations are then transmitted to the driver and passengers, in addition to those produced by the road surface, car chassis, wheels and tires. They contribute to deterioration of operating and motion parameters of the vehicle, accelerated fatigue of vehicle components, and thus lead to a reduced durability.

Safety of road traffic depends on multiple factors one of which is technical condition of car suspension systems. In the course of operation, their components wear out and their elastic and damping characteristics change which influences the car's traction properties and thus the driving safety.

Suspension systems prevent vibrations. They consist of a set of devices which connect the wheels to the chassis or frame, using connectors, springs and dampers in order to reduce, among others, dynamic loads caused by a rough road surface. The suspension system transmits to the chassis all the forces and torques occurring between the wheels and the body. Suspension systems are expected to solve a number of, sometimes conflicting, problems.

Driving comfort requires high vertical wheel travel combined with high longitudinal rigidity of the wheel mounting. However, excessive suspension travel leads to reduced reaction to lateral forces affecting the wheels, thus causing loss of both maneuverability and driving safety. Likewise, large

wheel travel leads to problems with restricting longitudinal shift produced by acceleration or braking. Driving conditions also affect the above-mentioned effects, namely:
- Road surface,
- Vehicle dynamics (accelerating or braking),
- Vehicle load (number of passengers, luggage, their weight, etc),
- Type of vehicle motion (straight line or curvilinear),
- Weight of unsprung mass.

There are a number of various suspension designs, depending on the vehicle maneuverability and powertrain characteristics. Contemporary passenger cars feature independent suspensions, with the wheels mounted independently of one another laterally, longitudinally or in a mixed pattern, depending on the design. In every suspension type the wheel is typically mounted to the body using one or two suspension arms.

All these structural solutions have one common element – a viscous damper, i.e. a telescopic shock absorber installed in all types of suspension systems used in the contemporary passenger cars.

Some of the effects of shock absorber inefficiency are:
- large amplitudes of the car body vibration accelerations,
- transverse and longitudinal tilts of a car decisive for the driving safety and safety,
- longer braking distances,
- extensive dynamic forces causing faster wear of the car components and damaging of the road pavement.

Unlike for other suspension components, assessment of technical condition of shock absorbers is difficult due to their asymmetric and non-linear characteristics on deflection and rebound.

2. Vibroacoustic processes

Mechanical vibrations they create vibration processes describing subsequent changes occurring one by one which constitute a uniform motion. In mechanics, such sequences of events are represented using the following physical quantities variable in time, i.e.:
- displacement x(t),
- vibration velocity v(t),
- vibration acceleration a(t),
- acoustic pressure p(t),
- force F(t).

All presented measures are functions of time.

3. Analysis of random signals

In the actual technical systems, random physical phenomena are assigned with various random signals which cannot be described analytically in an unambiguous manner, since in the consecutive intervals of observation of the given phenomenon, various, unrepeatable time courses are recorded.

A single time notation of a random phenomenon is called its realisation, whereas a set of all realisations of the given random phenomenon is called a random process or a stochastic process. The signal obtained as a result of observation of a random phenomenon can be considered as a section of a single physical realisation of the random process. If the s(t) signal is a random function, then as a result of every experience, one obtains a different functional relation depending on a non-random parameter of t, known as the $s_1(t)$, $s_2(t)$… $s_N(t)$ realisation of the random process. The $\{ s_k(t)\}$ set of all realisations of a random function characterises its properties in a greater or smaller extent.

A random vibroacoustic process can be represented in three domains the diagram of which has been depicted in Fig. 1.

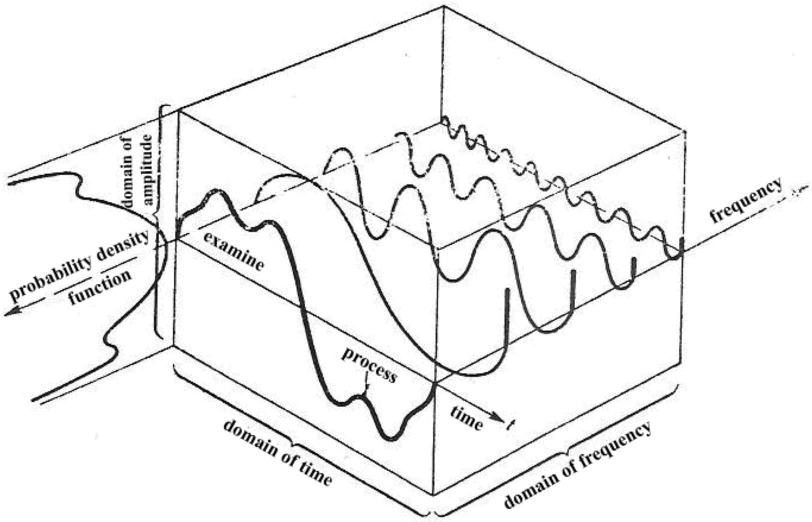

Fig. 1. Illustration of a random vibroacoustic process

Vibrations of suspension are stochastic, which the statistical analysis is carried out using the so-called amplitude measurements. These measures include:

a) peak value containing the information on the distribution of the maximum values,
b) mean value, i.e. the so-called first grade central moment which determines the modulus of the signal amplitude,
c) root-mean-square value containing the information on the signal energy,
d) second grade moment expressing the average process strength in a physical sense,
e) variance being the square of the standard deviation,
f) histogram.

The aforementioned measures are defined a follows:

- peak value is the maximum value in observation time T from the value of the absolute amplitude:

$$s_{sz} = E\{\max_{0<t<\tau}[s(t,0)]\}, \tag{1}$$

often is defined as:

$$\text{S sz = Sp-p /2}, \tag{2}$$

- mean value (expected value):

$$m_s(t) = E[s(t)] = \int_{-\infty}^{\infty} s\ f(s,t)ds = \lim_{n\to\infty}\frac{1}{N}\sum_{k=1}^{N} s_k(t), \tag{3}$$

where:

f(s,t) - probability density,
N - number of random realisations,
E - symbol of the expected value,

- mean square value of the realization:

$$\psi_s^2(t) = E[s^2(t)] = \int_{-\infty}^{\infty} s^2 f(s,t)ds = \lim_{n\to\infty}\frac{1}{N}\sum_{k=1}^{N} s_k^2(t), \tag{4}$$

- signal root-mean-square value (RMS)

$$s_{RMS} = |\sqrt{\psi_s^2(t)}\,|, \tag{5}$$

- variance characterising the dissipation of the temporary signal values from their mean value:

$$D_s^2(t) = E[\{s(t) - m_s(t)\}^2] = \int_{-\infty}^{\infty} [s - m_s(t)]^2 f(s,t) dt =$$

$$= \lim_{n \to \infty} \frac{1}{N} \sum_{k=1}^{N} [s_k(t) - m_s(t)]^2, \quad (6)$$

- standard deviation

$$\sigma_s(t) = \sqrt{D_s^2(t)} = \sqrt{\psi_s^2(t) - m_s^2(t)}, \quad (7)$$

4. Object and test method

The object of the study were shock absorbers with identified technical state with the programmed defects – shock absorber fluid loss amounting to 10%, 20%, 30%, 40%, built in the car Fiat Seicento 900. Identification of the damping characteristics are obtained on the position of the indicator. Then shock absorbers were built in the test car and were subjected to force extortion, the method of free vibration, (the suspension was dump from the "doorstep" with a height of 100 mm). Measured values were accelerations of the sprung masses recorded in discrete form on a PC. Results of investigation were subjected to analysis of research carried out in MATLAB. Thus, the resulting material was used to analyze the usefulness of this estimate of the loss of fluid in the diagnosis of hydraulic telescopic shock absorbers cars.

5. Analysis of test results

Obtained results are presented in the graphic form of changes of the peak amplitudes of free vibrations for the front (Fig. 2) and rear (Fig. 3) signals versus time for different states of technical condition, set programmed loss of fluid, while in Fig. 4-6 – spectrums corresponding to these changes. In order to improve readability of drawings aggregate in the drawings in the windows (Fig. 5, 7) showing larger differences occur.

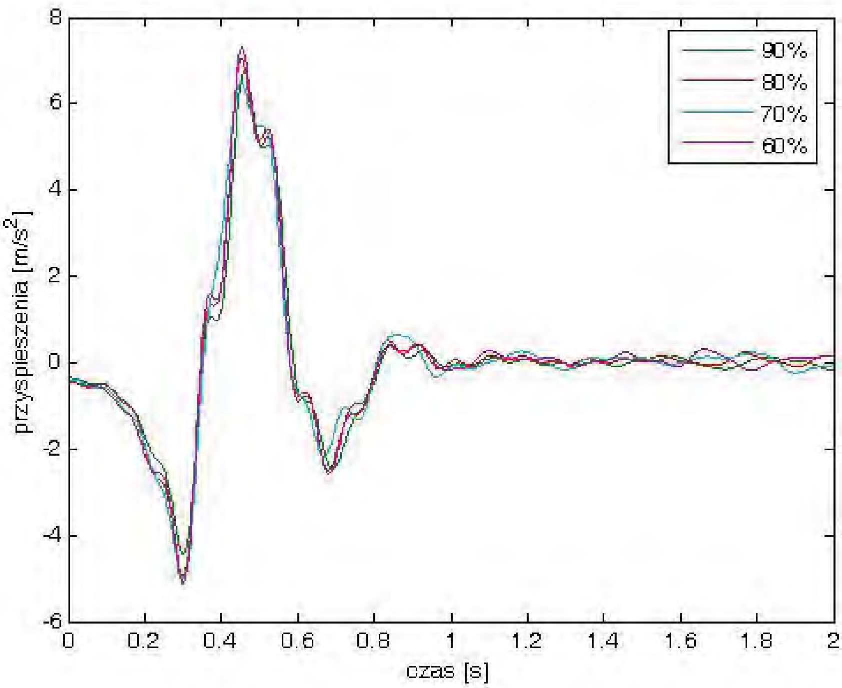

Fig. 2. Acceleration of sprung mass for front suspension

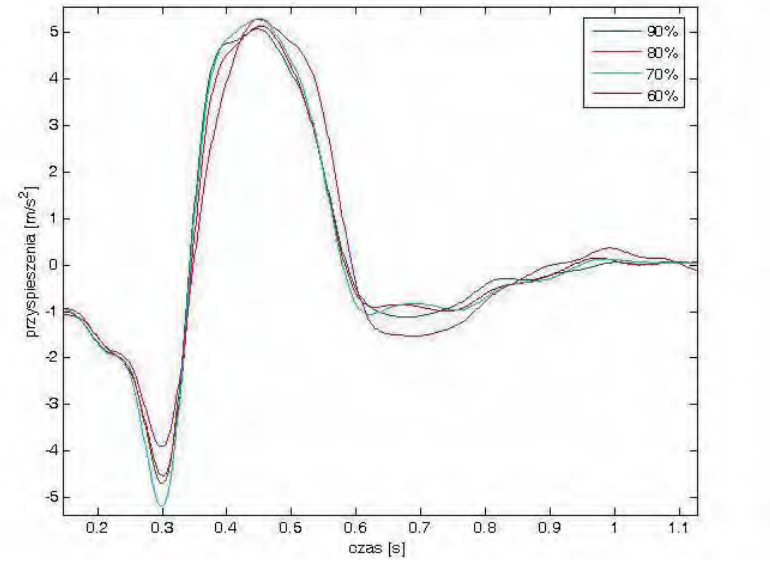

Fig. 3. Acceleration of sprung mass for rear suspension

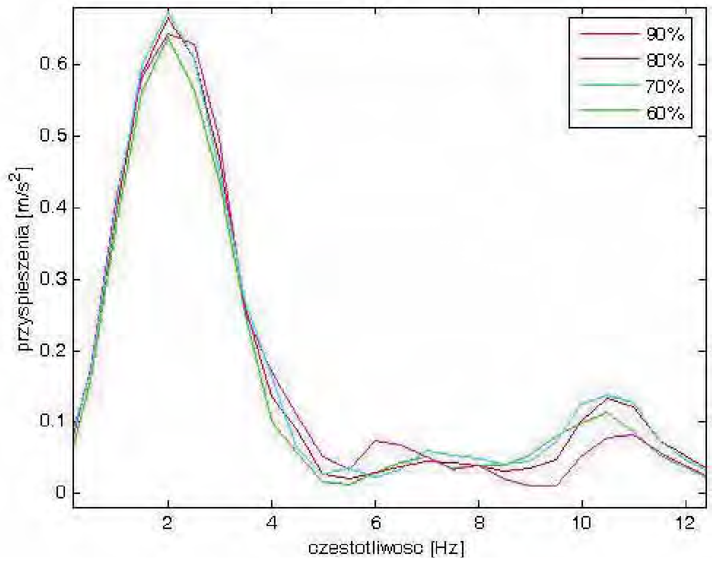

Fig. 4. Spectrum of acceleration of sprung mass for front suspension

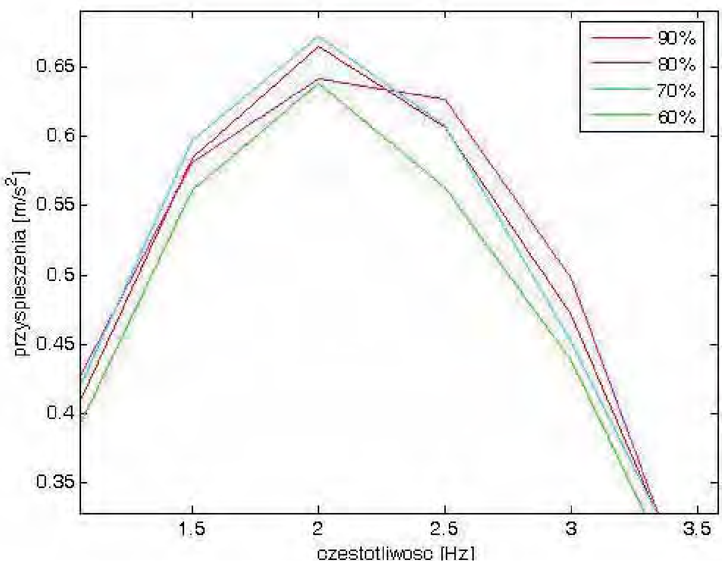

Fig. 5. Larger differences of spectrum of acceleration of sprung mass for front suspension

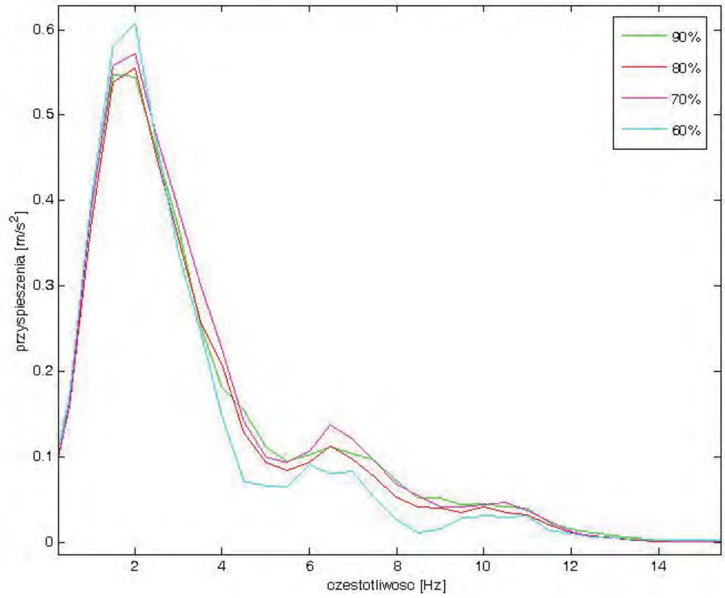

Fig. 6. Spectrum of acceleration of sprung mass for rear suspension

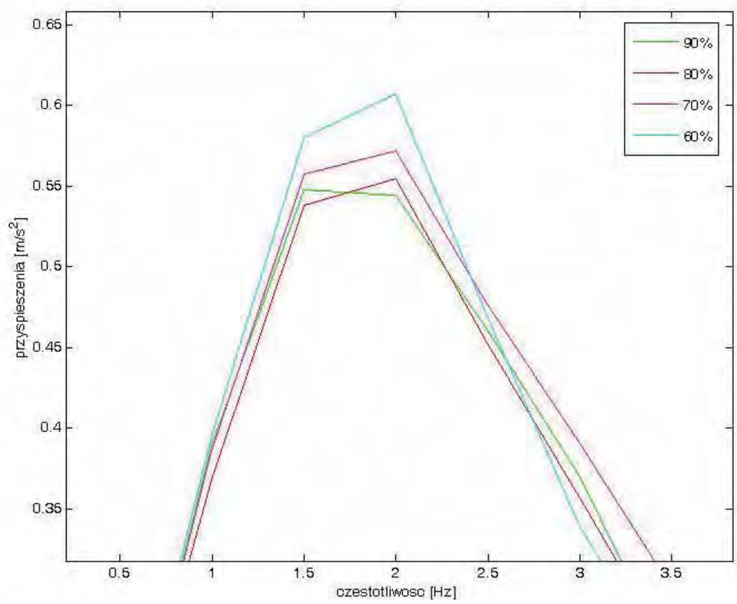

Fig. 7. Larger differences of spectrum of acceleration of sprung mass for rear suspension

6. Summary

The results of the analysis of the peak and of the spectrum for the front suspension with losses of shock absorber fluid show decrease in amplitudes of vibrations corresponding increase in shock absorber fluid. Asymmetry of the damping characteristics affects the differences in compression and tension of shock absorber. You may find that the spectral analysis is better measure then the study of period. For the rear shock absorbers, these differences are smaller. This is due to difference in design of Fiat Seicento front and rear suspension (namely the large tilt of the axis of the rear shock absorbers).

The presented method of diagnosis requires further study carried out on a large shocks absorbers population to their averaging and comparing test results using different testing methods and estimators and stochastic analysis of vibroacoustic signals.

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