# DIAGNOSING OF SHOCK-ABSORBERS OF CAR VEHICLES AT CHANGEABLE PRESSURE IN TIRES

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Summary

Road traffic securing safety is supervising purpose in the course of all operate and service actions and in the course of exploitation of car vehicle and during their project designs and production. Consequently regulatory records of state laws order range of check action and certifying, which enable verification according to strictly definite criteria of correctness of individual operations of units of cars.

Periodic check research enables estimate of technical condition state of chosen element of vehicle. Regulatory records of state laws directions define range of executable action in the course of research. However, in practice some actions are very often neglected, which can effect diagnosis. The paper presents the results of effective diagnostic experiments, which purpose was the analysis of influence of value of pressure in tires on results of research of shock-absorbers in vehicles controls stations. It also presents chosen results of ranges of analytical experiments, which purpose was the comparison of sensitivity of chosen diagnostic estimators on changes of values of pressure in tires.

Keywords: diagnosing of shock-absorber, changeable pressure in tires, signal processing.

DIAGNOZOWANIE AMORTYZATORÓW W POJAZDACH SAMOCHODOWYCH PRZY ZMIENNYM CIŚNIENIU W OGUMIENIU

Streszczenie

Zapewnienie bezpieczeństwa ruchu drogowego jest podstawowym celem podczas obsługi, czynności naprawczych oraz podczas eksploatacji pojazdów samochodowych a także w trakcie procesów projektowania i produkcji. Odpowiednie przepisy i ustalenie prawa określają zakres czynności kontrolnych i wymagania certyfikacji, które umożliwiają weryfikację poprawności działania poszczególnych elementów i zespołów pojazdu według ściśle określonych kryteriów.

Okresowe badania kontrolne umożliwiają ocenę stanu technicznego wybranych elementów pojazdu. Odpowiednie regulacje prawne dokładnie określają zakres obowiązkowych czynności kontrolnych, jednak rzeczywistość ukazuje, że niektóre czynności są bardzo często pomijane w trakcie badań kontrolnych, co może wpływać bezpośrednio na diagnozę.

W artykule przedstawiono wyniki czynnego eksperymentu diagnostycznego, którego celem była analiza wpływu wartości ciśnienia w ogumieniu na wyniki badań amortyzatorów na stacji kontroli pojazdów. Przedstawiono także wybrane wyniki eksperymentu analitycznego, którego celem było porównanie wrażliwości diagnostycznej wybranych estymatorów na zmienne ciśnienie w ogumieniu.

Słowa kluczowe: diagnozowanie amortyzatorów, zmienne ciśnienie w ogumieniu, analiza sygnału.

## 1. INTRODUCTION

According to adequate regulatory records of state laws, which were analyzed in [1] vehicles technical research consist in vehicle regulatory compliance verification. Road traffic securing safety is supervising purpose in the course of all operate and service actions and in the course of exploitation of car vehicle and during their project designs and production. Consequently regulatory records of state laws order range of check action and certifying, which enable verification according to strictly definite criteria of correctness of individual operations of units of cars [4].

The commonly used methods of shock absorber testing such as EUSAMA or BOGE facilitate the assessment of the technical condition in terms of reliability (good or bad). That is why define range of executable action in the course of research fulfillment is so important. However, in practice some actions are very often neglected, that can effect diagnosis. Authors decided to conduct effective diagnostic experiments, which purpose was the analysis of influence of value of pressure in tires on

results of research of shock-absorbers in vehicles controls stations.

Publications are known about the influence of value of pressure in tires on results of research of shock-absorbers in vehicles controls stations [2]. It was decided to conduct analytical experiments, which purpose was the comparison of sensitivity of chosen diagnostic estimators on changes of values of pressure in tires. It would be very helpful to find diagnostic estimators insensitive to changes of values of pressure in tires.

## 2. VIBRO-ACOUSTICS DIAGNOSTICS

Based on the analysis of the problem the acceleration signals of oscillation from those elements of the vehicle which have and which don't have suspension were chosen for the diagnostic signals.

Acoustics or vibrations signal as the results of changes which occur in technical system or associated processes is a medium of the vibro-acoustic information. As the information we understand everything what is used to get more efficient selection of leading operation to specified objective [3]. Information is related indissolubly with the signal because this signal is medium of it. It informs us about conditions, changes or process of physical or technical system taking under consideration. Vibro-acoustics signals have the biggest information's capacity which enables to observe changes in wide frequency band. That is why vibro-acoustics research methods are use in wide application in technical objects diagnostics [8, 14].

Vibro-acoustics signals analysis is very difficult. There are many methods of signals analysis. The main problem in vibro-acoustics research is difficulty of useful signal components separation from the rest of signal without any important information [5].

It is possible to consider many of measurement problems on general signal level so it is considered as the total signal in observation time. To define this kind of signals there can be used such quantities:

a) amplitude domain,
b) time domain,
c) frequency domain.

Signal analyzed in time domain can use autocorrelation function, probability density function etc.

Spectrum of signal is signal energy distribution in frequency domain. In digital signal transformations the Fast Fourier Transform (FFT) is used [6,7]. Using FFT is well-grounded only in case of stationary signals.

In analysis of non-stationary signals random processes have fundamental meaning, in which interesting random effects can be functions of frequency and time domain. For this kind of processes the most often used analysis methods are:

– short time Fourier transform (STFT),
– continuous wavelet transform (CWT),
– Wigner-Ville distribution (WVD).

The results of these transformations are signal distribution in time-frequency domains. Multidimensional analysis methods of non-stationary signals enable to observation with good quality of distributed signal but they are time-consuming.

Different methods of non-stationary signals analysis used in shock-absorber diagnosis were compared in many publications [9, 10, 11, 13]. The new method of vibro-acoustic signals processing for estimation purposes was developed [13]. New measures of the conditions of shock absorbers were proposed [9, 10, 13].

Based on gain experience and knowledge the continuous wavelet transform (CWT) was chosen. Additionally the diagnostic signal was analyzed in time and frequency domain separately.

## 3. EFFECTIVE DIAGNOSTIC EXPERIMENTS

Purpose of effective diagnostic experiments was the analysis of influence of value of pressure in tires on results of research of shock-absorbers in Fiat Seicento on EUSAMA test controls station (fig. 1).

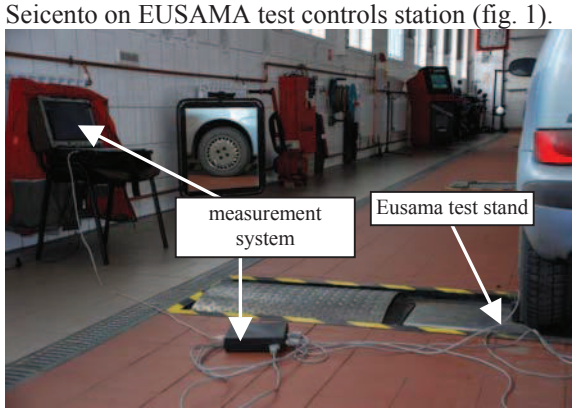


Fig. 1. Effective diagnostic experiment

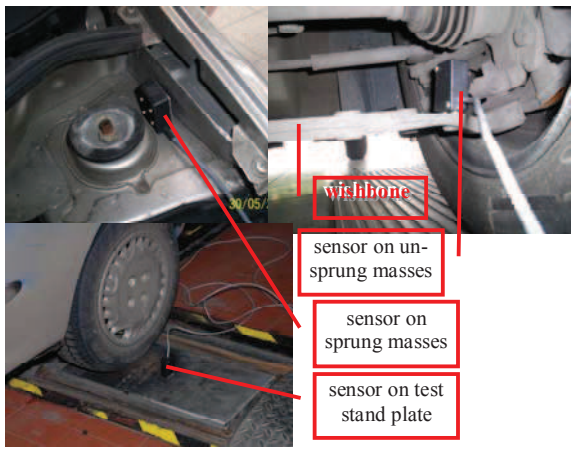


Fig. 2. Elements of measurement system

The acceleration signals of oscillation from those elements of the vehicle which have and which don't have suspension and test stand plate oscillation were recorded during research (fig. 2).

Scope of research contained measures of Eusama index and acceleration signals of oscillation at changeable pressure in tires from 0,6 [bar] to 2,6 [bar] with 0,2 [bar] gradation.

## 4. RESULTS OF SHOCK-ABSORBER DIAGNOSING ON EUSAMA TEST STAND

As the results of Eusama methods and shock-absorber technical condition measure obtain Eusama index. Distribution of Eusama index at changeable pressure in tires is shown at fig. 3.

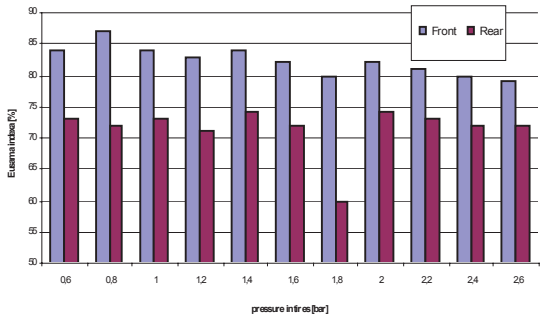


Fig. 3. Eusama index distribution at changeable pressure in tires

Differences between Eusama index values for changeable pressure in tires reached 10% or even more. That can be reason of incorrect diagnosis.

That is why so important is to find another diagnostic estimators or project new diagnostic system.

## 5. METHODS OF SIGNALS PROCESSING FOR ESTIMATION PURPOSES

The sprung masses accelerations of vibration signals were chosen to analysis.

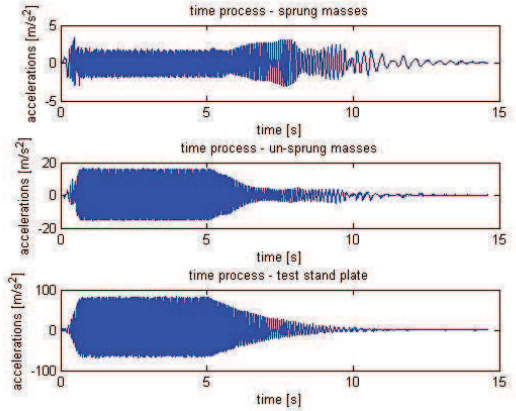


Fig. 4. Recorded signals

The methods of vibro-acoustic signals processing for estimation purposes were presented. Some measures of the conditions of shock absorbers were compared.

Algorithm of time domain signals processing for estimation purposes was presented on figure 5.

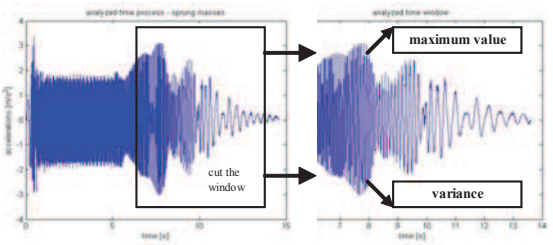


Fig. 5. Time domain estimators determine algorithm

Algorithm of frequency domain signals processing for estimation purposes was presented on fig. 6.

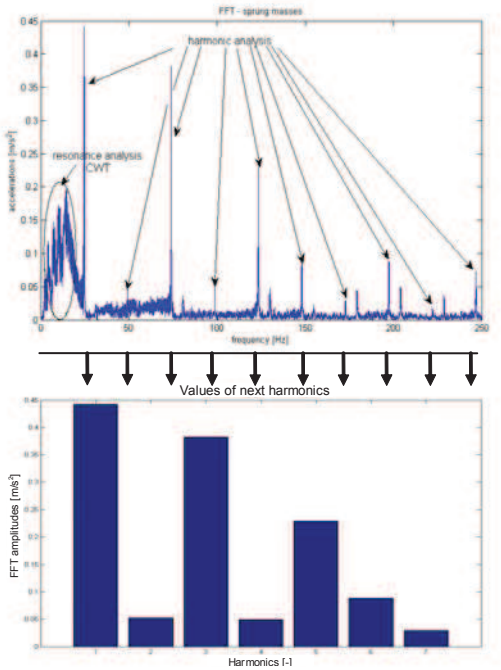


Fig. 6. Frequency domain estimators determine algorithm

It was presented on figure 6 that range of resonance analysis based on FFT is difficult, because the signal is non-stationary random processes. That is why next signals processing method for estimation purposes based on CWT was presented. Multidimensional analysis methods of non-stationary signals enable to observation with good quality of distributed signal [9, 10, 11].

It was used two different scales vectors for each frequencies range for better localization of resonance of sprung and un-sprung masses. The Morlet wavelet was used in transformation.

It was proposed diagnostic estimators define as:

$$E_{sr} = Wz_{sr} + Wn_{sr} \quad (1)$$

where:

$Wz_{sr}$ - average value of CWT coefficients in un-sprung masses resonance window,

$Wn_{sr}$ - average value of CWT coefficients in sprung masses resonance window.

$$E_{\max} = Wz_{\max} + Wn_{\max} \tag{2}$$

where:

$Wz_{\max}$ - maximum value of averaging CWT coefficients in un-sprung masses resonance window,

$Wn_{\max}$ - maximum value of averaging CWT coefficients in sprung masses resonance window.

$$E_w = \frac{E_{\max}}{\frac{E_{sr}}{2}} \tag{3}$$

The algorithm was presented on fig. 7.

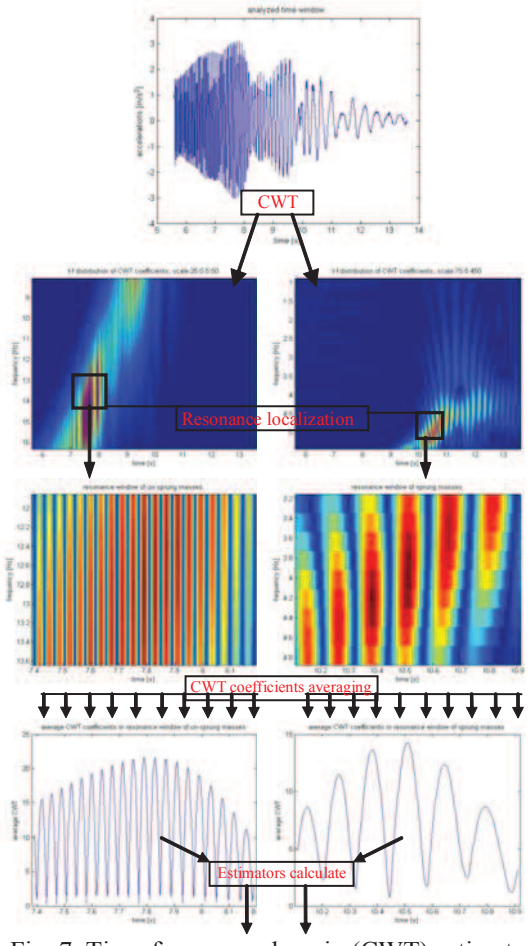


Fig. 7. Time-frequency domain (CWT) estimators determine algorithm

## 6. RESULTS OF ANALYSIS

As the results of presented methods of vibro-acoustic signals processing obtained proposed estimators distribution at changeable pressure in tires.

Time estimators distribution presents fig. 8 and 9.

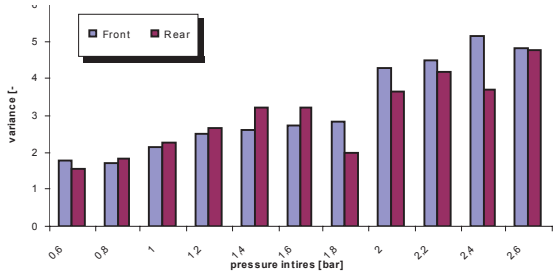


Fig. 8. Variance values distribution at changeable pressure in tires

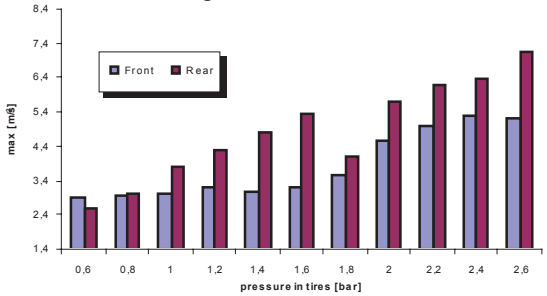


Fig. 9. Maximum values distribution at changeable pressure in tires

Frequency estimators based on harmonic analysis distribution presents figures 10 and 11.

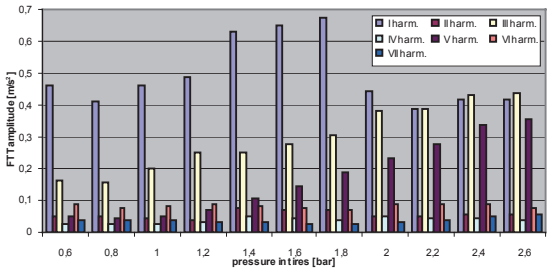


Fig. 10. Harmonic values distribution at changeable pressure in front tires

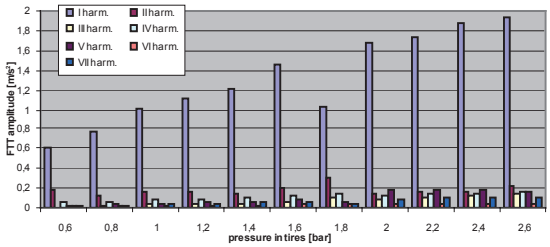


Fig. 11. Harmonic values distribution at changeable pressure in rear tires

CWT estimators distribution presents fig. 12-14.

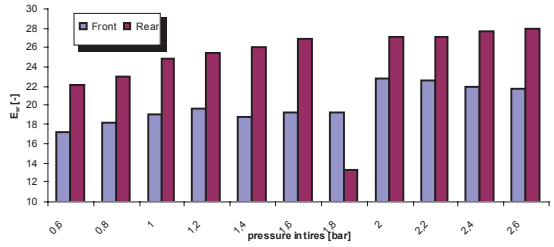


Fig. 12. $E_{sr}$ values distribution at changeable pressure in tires

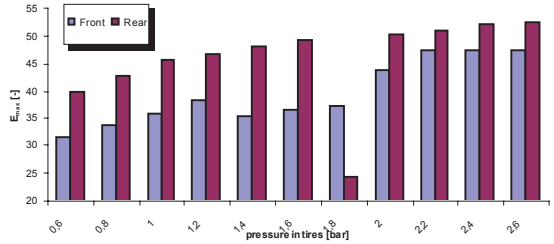


Fig. 13. $E_{max}$ values distribution at changeable pressure in tires

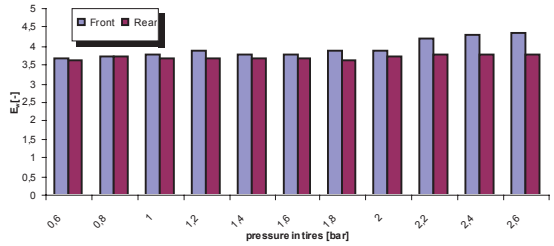


Fig. 14. $E_w$ values distribution at changeable pressure in tires

As it is presented the proposed estimators are very sensitive to changeable pressure in tires. In most cases accumulative trend can be adopted according to rising pressure in tires. The results are much better then results of Eusama index.

Results of $E_w$ values distribution at changeable pressure in tires are very interesting. Constant values can be adopted according to rising pressure in tires. In this circumstance this estimator is resistant to changes pressure in tires. As it was proved in [13] $E_w$ is sensitive to shock-absorber technical condition changes.

## 7. SUMMARY

The paper presents chosen results of ranges of analytical experiments, which purpose was the comparison of sensitivity of chosen diagnostic estimators on changes of values of pressure in tires. Presented methods of diagnostics information receiving as the results of vibration signals processing enables elaborate of automatic system of passenger cars shock absorbers diagnosis. However it is necessary to make more investigation in this direction.

The presented estimators could be used as one measure as technical state vector, which can be input of classification system of shock-absorber technical condition [12]. Sensitive estimators on changeable pressure in tires can be used to detect any anomaly of normative pressure in tires and $E_w$ as measure insensitive to this kind of change.

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