

vibration; safety; comfort

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VIBRATION ISSUES IN PASSENGER CAR

Summary. Vibration phenomena occurring in vehicles are very relevant for safety and comfort. Passenger car must be considered as a multi-technical system in which there are non-linear phenomena. Therefore, vibrations occurring in vehicles should be analyzed in many points of car structure and relate them to other criteria analysis. The paper presents examples of the results of vibration and their distribution at selected points during laboratory research and road tests.

ZAGADNIENIA DRGANIOWE W SAMOCHODACH OSOBOWYCH

Streszczenie. Zjawiska drganiowe występujące w pojazdach samochodowych mają bardzo istotne znaczenie dla bezpieczeństwa i komfortu jazdy. Samochód osobowy należy rozpatrywać jako wieloelementowy system techniczny, w którym występują zjawiska nieliniowe, dlatego drgania występujące w pojazdach należy analizować w wielu punktach konstrukcyjnych i odnosić je do innych kryteriów analizy. W artykule przedstawiono przykładowe wyniki badań drgań i ich rozkładu w wybranych punktach podczas testów laboratoryjnych i drogowych.

1. INTRODUCTION

The vibration phenomenon is a very important issue for means of transport. The vehicle vibration causes many difficulties as: increases of fuel consumption, damages elements of vehicle and causing vibration of roadside buildings. It becomes even more important if we consider the passengers transport. This is due to importance of comfort for the evaluation of transport service. Driving safety and comfortably depend on many parameters. One of those parameters is vibrations transfer. The character of the car vibration transferred from road to car body is very important. Road traffic securing safety is supervising purpose in the course of all operating service actions and in the course of exploitation of car. The evaluation of comfort becomes much more difficult because of subjective human perception on vibration. The compromise between comfort and safety of the vehicle driving is very difficult to achieve. For driving safety it is extremely important to provide constant contact of vehicle wheels to the road surface. It determines the high damping coefficient. For the comfort of the passengers it is important to minimize the vibration perception. It can be achieved by the gradual and smooth absorbing vibration [1, 2]. The driver and passengers exposure to whole-body vibration of the vehicle can affect from short-term body discomfort and inefficient performance to longterm physiological damage. The vibrations of the vehicle body are main problem in ride comfort. Thus the analysis of complex vibration occurring in vehicle should be conducted [3].

2. VIBRATION IN MEANS OF TRANSPORT, HUMAN PERCEPTION

During operating of means of transport there are many vibration generated by different sources. Motor engine should be considered as the vibration generator as well [4]. This kind of machine generate a disturbing force of one sort or another, but the frequency of the disturbing force should not be at, or near, a natural frequency of the structure otherwise resonance will occur, with the resulting high amplitudes of vibration and dynamic stresses, and noise and fatigue problems. There are two basic types of structural vibration: steady-state vibration caused by continually running machines such as engines, air-conditioning plants and generators either within the structure or situated in a neighbouring structure, and transient vibration caused by a short-duration disturbance such as a lorry or train passing over an expansion joint in a road or over a bridge.

Ride comfort is extremely difficult to determine because of the variations in individual sensitivity to vibration [5]. The vibration sensitivity of organs has been depicted in fig. 1. Therefore many researchers have concentrated their efforts on reducing the amount of vibration from vehicles. Some interesting researches were conducted for the low frequency discomfort for human analysed [6]. Ride vibrations are transmitted to the driver lumbar spine and back by the seat. The floor panel, pedal and steering wheel transmit additional vibrations to the feet and hands of the driver. These vibrations are producing a level of discomfort for driver. There are many publication about rail transport researching [7, 8] and modelling on rail vehicle in vibration comfort aspects [9, 10]. Interesting model of the rail vehicle was presented in [11] as modular type and internal forces of each component calculated, using nonlinear description functions and system states.

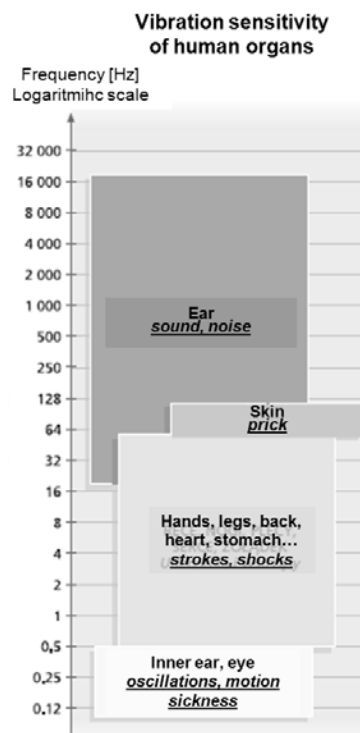


Fig. 1. Vibration sensitivity of chosen human organs

Rys. 1. Wrażliwość na drgania wybranych organów człowieka

3. VIBRATION DISTRIBUTION IN PASSENGER CAR

Studying vibration phenomena in automotive vehicles should primarily pertain to their effects on people and the chosen structural elements of a vehicle. In the scope of the impact on structural

elements, one should perceive vibrations in terms of destructive factors. Consequences of the human exposure to vibrations include various harmful changes occurring in the organism. They have a direct or indirect influence on comfort and safety [12-15].

Some experiments on passenger car were conducted as stationary tests on research bench and road tests. During the road tests the car vibration were measured during drive with speed of 70 km/h [16]. For the analysis of the dynamics of the vibration the Fourier transformation have been made. The Fast Fourier Transformation (FFT) in Matlab program was used. The results of acceleration of vertical vibration on car body were presented in figure below. The research on distribution of vertical vibration on car body was done. The vibration was measured in 4 points localized in places for feet of the driver and all passengers. The obtained results for driver and for passenger have been depicted in figures 2 and 3.

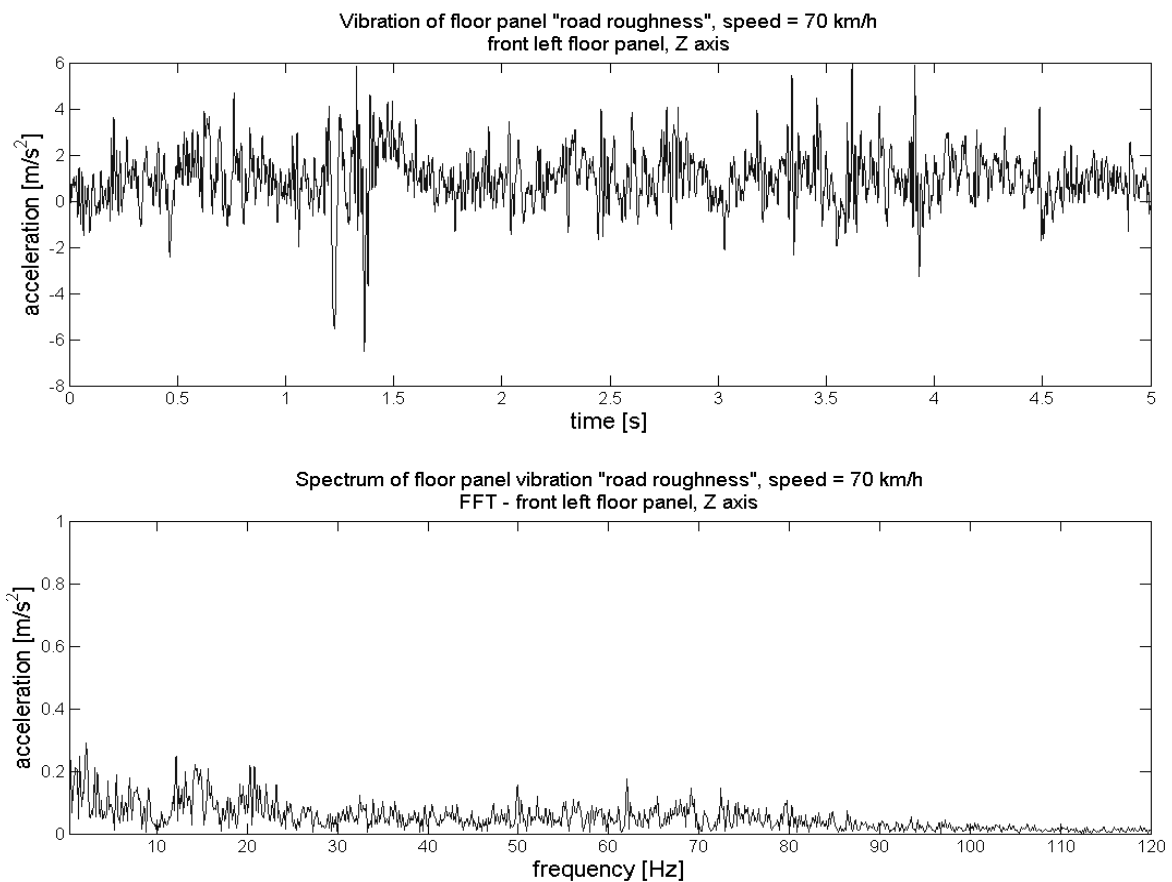


Fig. 2. Acceleration of vibration measured on floor panel under the feet of the driver: up- time realization, down- spectrum of vibration

Rys. 2. Przyspieszenia drgań zarejestrowane pod stopami kierowcy, góra – przebieg czasowy, dół – widmo częstotliwościowe

During the stationary tests the car prepared for the tests was subject to oscillatory input functions. For that purpose, a station enabling kinematic vibration excitation was used. The input frequency range envisaged comprised frequency bands of both sprung and unsprung masses. The vibration accelerations were recorded at the chosen points of the structure.

The results of the investigation as the vibration signals have been depicted in fig. 5.

For the sake of the signal transformation, the FFT was applied, as it enabled determination of the Fourier spectra of signals. The comparison of the vibration dynamics for the chosen points in the vehicle structure enables evaluation of the dominant frequency components. It can be observed that for

those locations in the vehicle structure there are different frequency components carrying most vibration energy values.

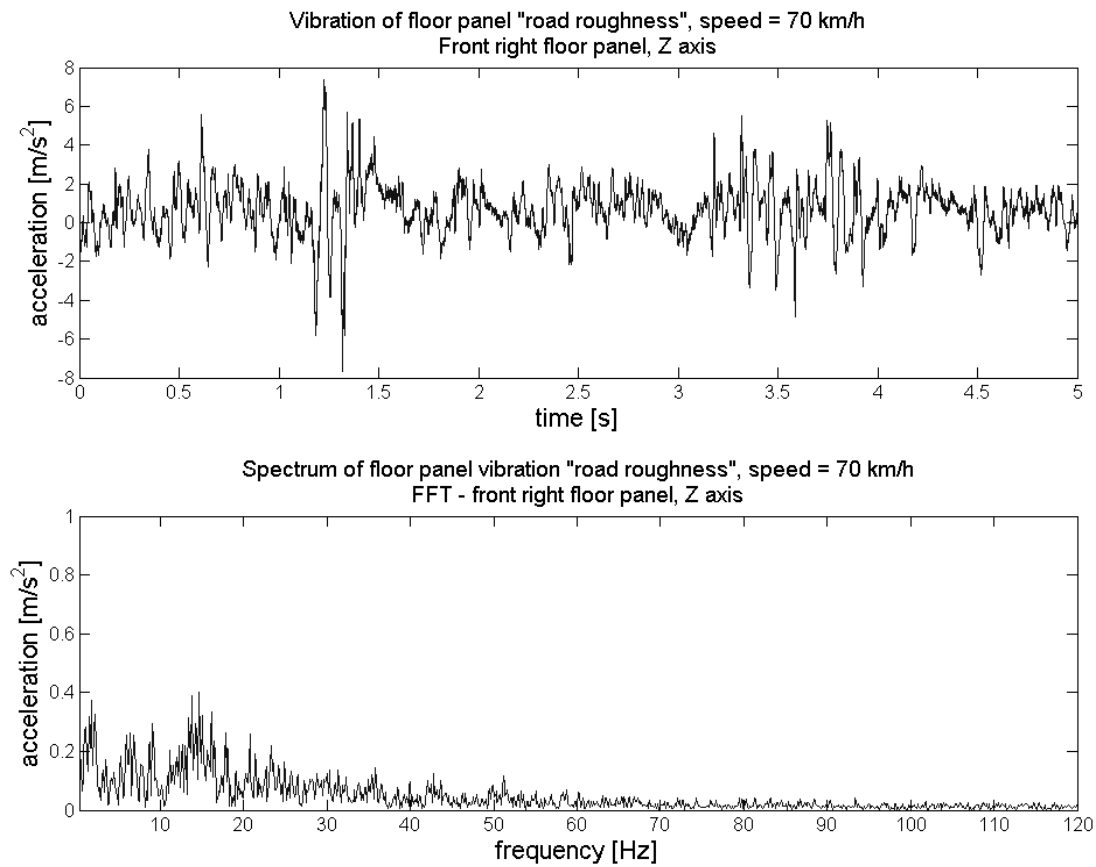


Fig. 3. Acceleration of vibration measured on floor panel under the feet of front passenger: up- time realization, down- spectrum of vibration

Rys. 3. Przyspieszenia drgań zarejestrowane pod stopami przedniego pasażera, góra – przebieg czasowy, dół – widmo częstotliwościowe

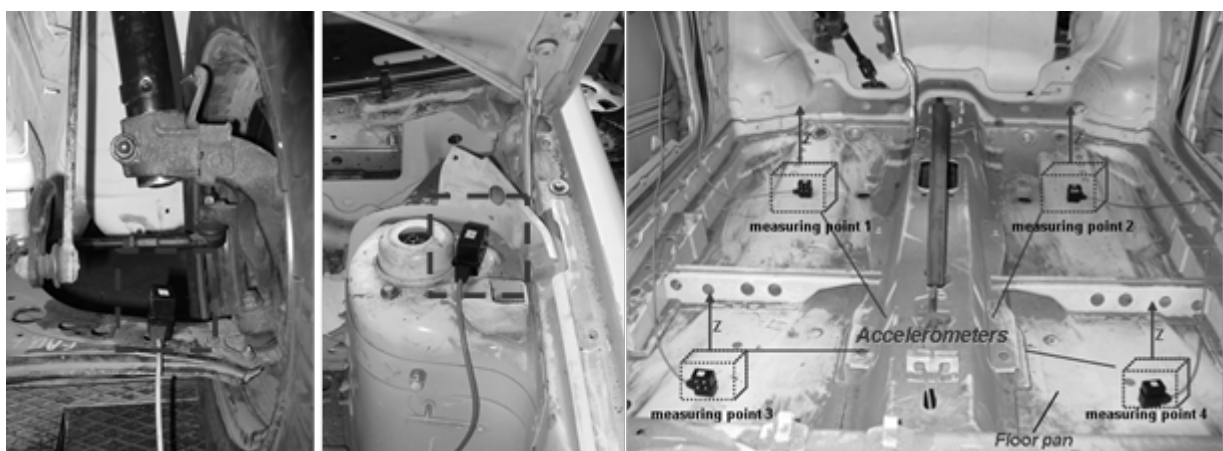


Fig. 4. Arrangement of vibration sensors across the structure of the vehicle tested

Rys. 4. Rozmieszczenie czujników przyspieszeń drgań w badanym pojeździe

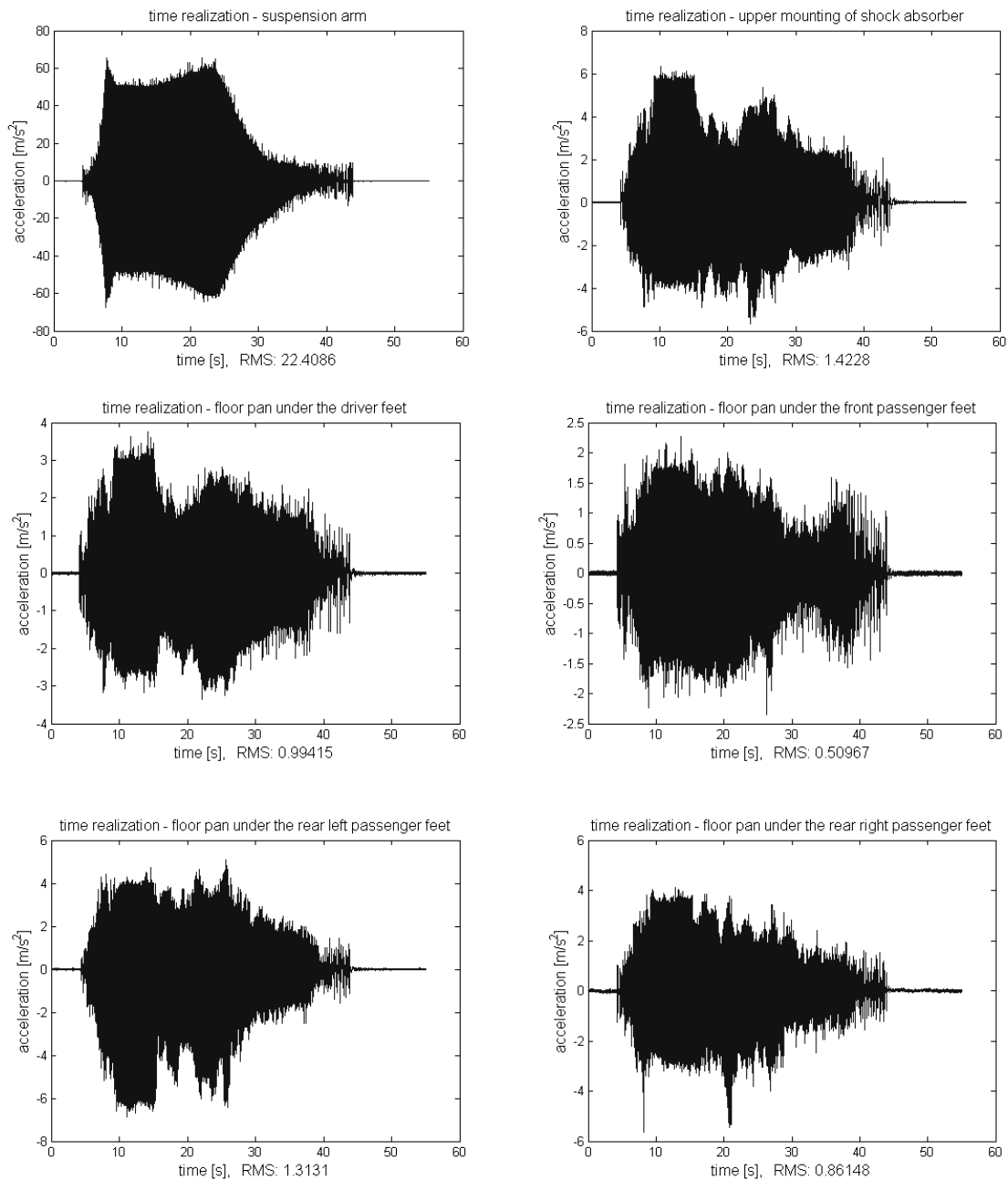


Fig. 5. Vibration signals of suspension and carbody

Rys. 5. Zarejestrowane sygnały drgań zawieszewnia i nadwozia pojazdu

Sample spectra of the signals recorded have been depicted in the figure 6.

The evaluation of the differences in the vibration dynamics for chosen locations in the vehicle structure has been conducted as analysis of the signals spectrum of next frequency bands. Based on the analysis and comparison of the vibration spectrum of the suspension arm and upper mounting of shock absorber the evaluation of the damping properties can be done. The best results of the evaluation would be obtained by the analysis of the resonance of the unsprung masses (ca. 10-12 Hz). The presentation of the analysis has been depicted in upper chart in fig. 7.

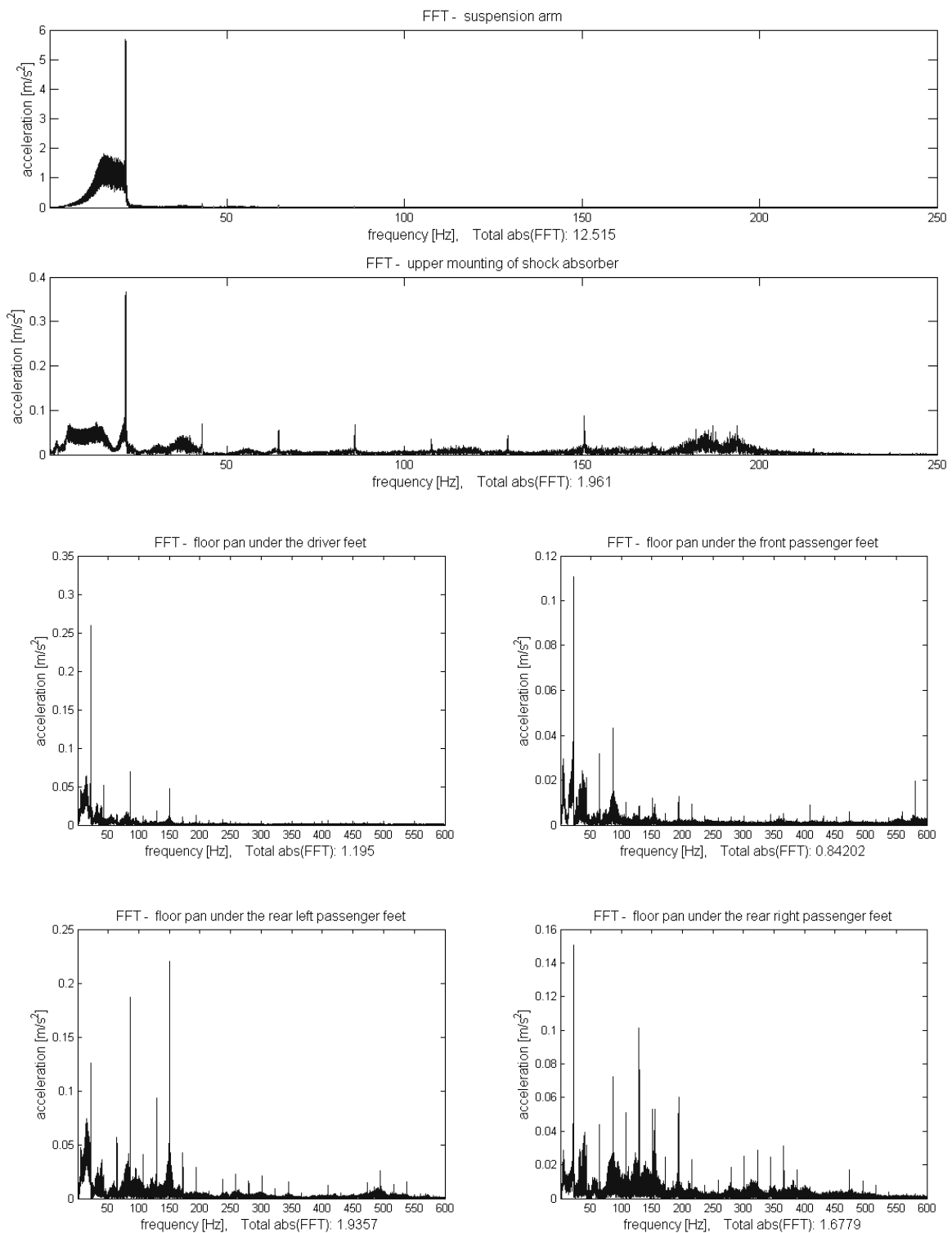


Fig. 6. Spectrums of vibration signals of suspension and carbody
 Rys. 6. Widma sygnałów drgań zawieszewnia i nadwozia pojazdu

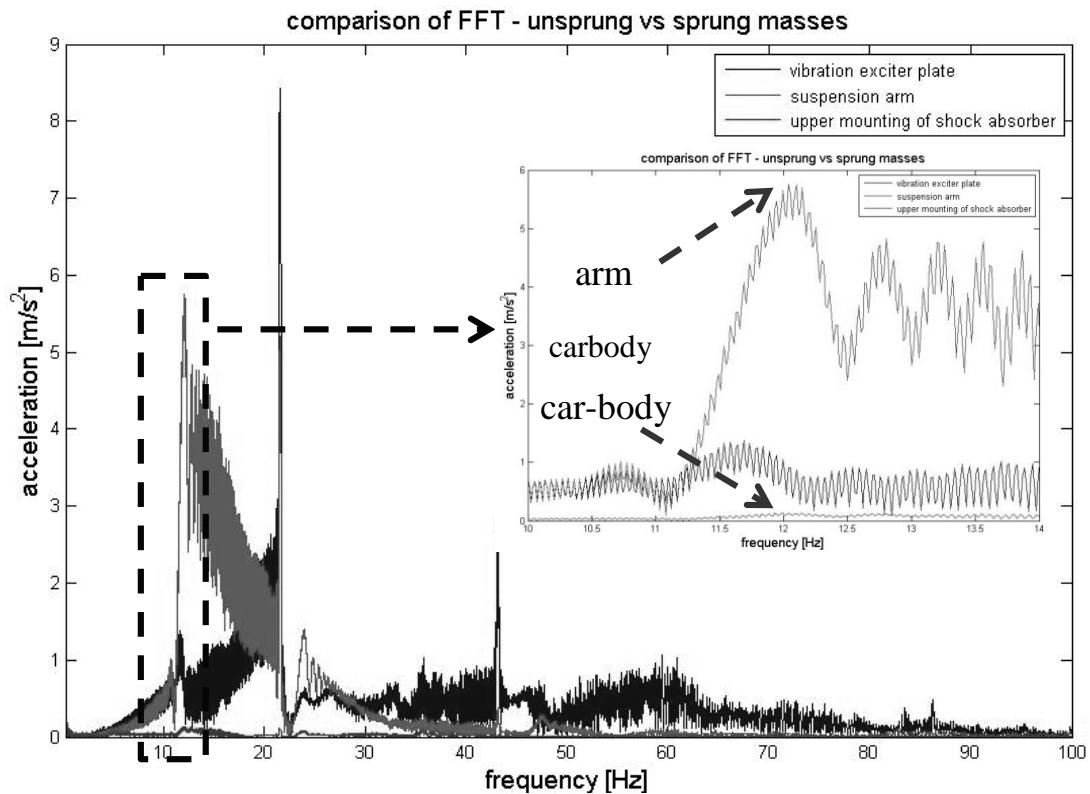


Fig. 7. Comparison of spectrums of vibration signals of suspension and carbody

Rys. 7. Porównanie widm drgań zarejestrowanych w zawieszeniu i nadwoziu pojazdu

4. CONCLUSION

The impact exerted by transport induced vibrations on people is a particularly important problem. Sudden or intensifying vibration phenomena of local nature may compromise safety. A man operating a means of transport subject to local vibrations may lose control over the vehicle. Also general vibrations are very significant in this respect, as they influence the feeling of discomfort to a considerable extent.

Thus the vibration in different location of vehicle construction should be considered. For the safety purpose it is important the vibration occurring on unsprung elements, as suspension, and sprung elements, as upper mounting of shock absorber. The comparison of those vibration allows evaluation of vibration damping properties which are extremely important for driving safety. The presented results show that for the resonance frequency of unsprung masses, which have been represented as suspension arm vibration, the difference in the value of the vibration between suspension arm and upper mounting of shock absorber (sprung masses) is much more than ten times. During many more such experiments for different passenger cars these results have been confirmed.

The observation of vibration of car body in location of their transfer to human organism via feet allows evaluation of vibration comfort. The presented result shows differences between vibration affecting men in different location of vehicle (front, rear, left right passengers). For the purpose of vibration comfort analysis those signals should be observed simultaneously for whole floor panel in locations where vibration are transferred into human organism via feet. The signals should be evaluated for many frequency bands responsible vibration sensitivity of chosen human organs. The determination of spectrum of the signal is very helpful and it allows to observe energy of the vibration affecting man in separate frequency bands. It can be a way to develop very sensitive estimator of exposure to human vibration.

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Received 24.02.2013; accepted in revised form 16.08.2014