inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 7.4

APPLICATION OF WAVELET TRANSFORM TO NOISE ANALYSIS OF RAIL WHEEL WITH DE-NOISE DEVICES

J. Smutny*, L. Pazdera**

* TU, FCE, Department of Railway Construction and Structures, Veveri 65, 662 37, Brno, Czech Republic

** TU, FCE, Department of Physics, Zizkova 17, 602 00, Brno, Czech Republic

Tel.: ++420 5 41147325 / Fax: 420 5 745147 / Email: zksmu@fce.vutbr.cz

Keywords:
TIME-FREQUENCY ANALYSES, WAVELET TRANSFORM, NOISE ANALYSIS, RAIL WHEEL

ABSTRACT
The main topic of this article is the description of using the time-frequency tools named Wavelet transform at the rail wheel damper design. Procedure of measured acoustic parameters is a part of the article too. The Wavelet Transform represents a good tool from time-frequency analysis to identification of the acoustic sources and its ways. The article describes advantages of joining new mathematical techniques and practical experiments for projecting more ecology constructions in rail engineering.

1 - THEORETICAL INTRODUCTION
Wavelet analysis is similar to Fourier analysis in the sense that it breaks a signal down into its constituent parts for analysis. Whereas the Fourier transform breaks the signal into a series of sine waves of different frequencies, the Wavelet transform breaks the signal into its "wavelets", scaled and shifted versions of the "mother Wavelet". The Wavelet transform allows exceptional localisation in both the time domain via translation of the mother Wavelet, and in the scale (frequency) domain via dilations. The translation and dilation operations applied to the mother wavelet are performed to calculate the wavelet coefficients, which represent the correlation between the wavelet and localised section of the signal [1]:

$$WT(\tau, s) = \frac{1}{\sqrt{|s|}} \cdot \int_{-\infty}^{\infty} x(t) \cdot \psi^* \left(\frac{t-\tau}{s} \right) \cdot dt \tag{1}$$

where '*' denotes the complex conjugate, $x(t)$ is the signal, t is time, τ is translation factor, s is scale factor (frequency) and ψ is mother wavelet. Morlet wavelet and Mexican hat wavelet mostly are used as mother wavelet for continuous Wavelet transform. For noise analysis and vibration measurement there is preferable mother wavelet Morlet, which is a multiplication of the Fourier basis with a Gaussian window according to equation 2:

$$\psi = e^{-j \cdot \omega_0 \cdot t} \cdot e^{-\frac{t^2}{2}} \tag{2}$$

2 - EXPERIMENTAL SET-UP
There is described the procedure of laboratory measurements of acoustic vibration parameters of rail wheels ORE ϕ 920 mm, in comparison with measuring and analysis wheels and wheel set without and with application of plated radial inhibitor Schrey & Veith (Fig. 1).
For measuring and evaluation of efficiency acoustic inhibitors it has been elaborated complex procedure containing partly approved methods and partly progress with includes new modern trends in the area of measured techniques and in process of measured data [2].
For comparison and testing the wheels with and without the inhibitor there was used the method of measuring responses on a mechanical shock. Stroked generation is an advantage for determination natural frequencies of given system, because the shock activates all frequencies, especially resonance

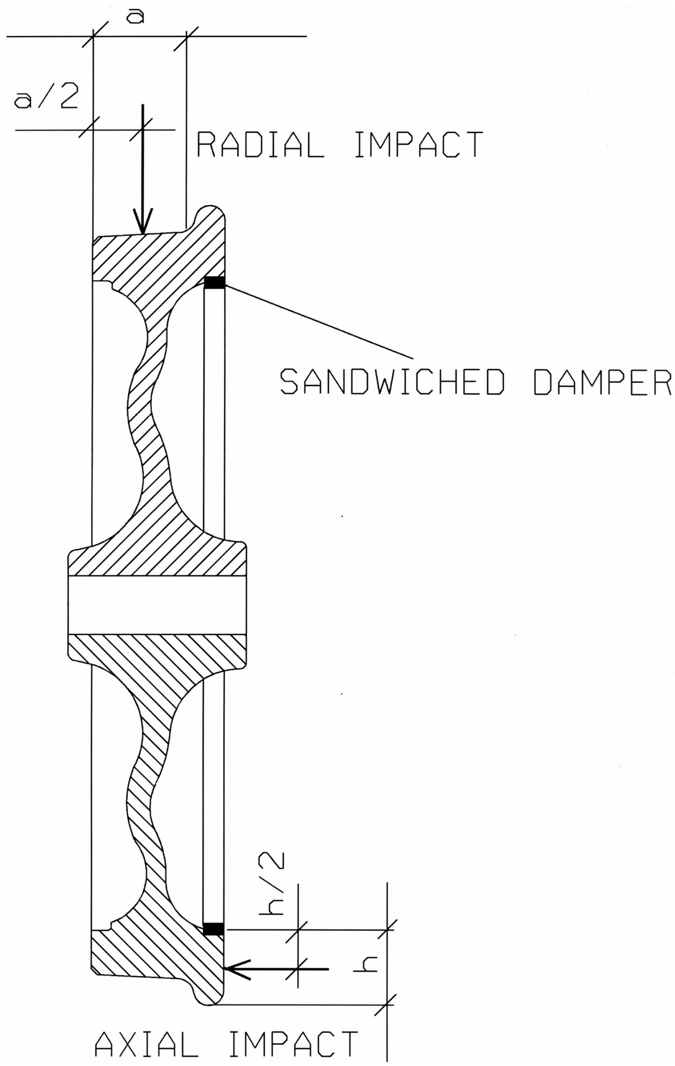

Figure 1: Schema of the rail wheel with application of plated radial inhibitor Schrey & Veith.

ones. The mechanical shock was generated by the steel ball (average = 0.05 m, mass = 0.5 kg, density = 7800 kg/m^3).
The measured wheels were hung on specially designed preparations on V-belt forms so-called freely of free placing. The high of the wheel axis was 0.95 m. The ball was dropped axially (stroke place edgewise roundabouts 40 mm from top margin) and radial (stroke place in the centre widths tread) with reinforcement 0.5 m. The impulse excitation was used at four each other about 90° turn positions. Each measuring was repeated 10 ×.
For the reason of complex of the quality appreciation of single modification within measuring railway wheels, characteristics of dynamic-acoustic responses were picked-up by microphone and by acceleration sensors. The microphone was placed in tripod in the distance of 1 m from measured wheels and up on high wheel axis, thus ups on high 0.95 m from the floor. The response on the mechanical shock was measured by service including apparatus for measuring of acoustic and vibration parameters of firm Bruel&Kjaer. After analyses it was realised check measurements and computations, there was used for analyses responses on mechanical shock following methods and parameters:

- at picking-up measured data by the microphone
  - levels of pulsed noise L_I
  - displaying time characterisation of immediate value noise level L, from it was subsequently evaluated time drop noise level and determine damping constant (decay)
  - frequency analysis by utilisation of power spectral density

  - time-frequency analysis of amplitude spectra by application continuous Wavelet transform

- at picking-up measured data by the accelerometer sensors
  - time displaying process of immediate value acceleration
  - frequency analysis by utilisation of power spectral density
  - time-frequency analysis of amplitude spectra by application of continuous Wavelet transform

In Figs. 2 and 3 there is displayed response to analysis on the radial mechanical shock at the wheels with and without plate radial inhibitors. The application of inhibitors on railway wheel is evident in changes as in time, so also frequency spaces. Responses time course at wheels without inhibitor (Fig. 2 graph left up) shows the exponential decay with long time constants, whereas at wheels with the inhibitors (Fig. 3 graph left up) there is this time constant considerably lesser.
The time frequency spectrum computed by application reassigned Continuous Wavelet Transform shows at wheels with inhibitors substantially more frequency components, however their time occurrence is not too long. Value of maximum pressure is approximately the two-thirds on the benefit to wheels with inhibitors. The difference in frequency spectrum is not much evident. The maximum frequency components are in both cases in the range from 1.5 kHz to 4.5 kHz. At wheels without inhibitors this component has long duration. The decay about 20 dB is about in 1 s on different from the wheels with inhibitors, where the inhibition is almost in the tenfold less time 0.1 s.

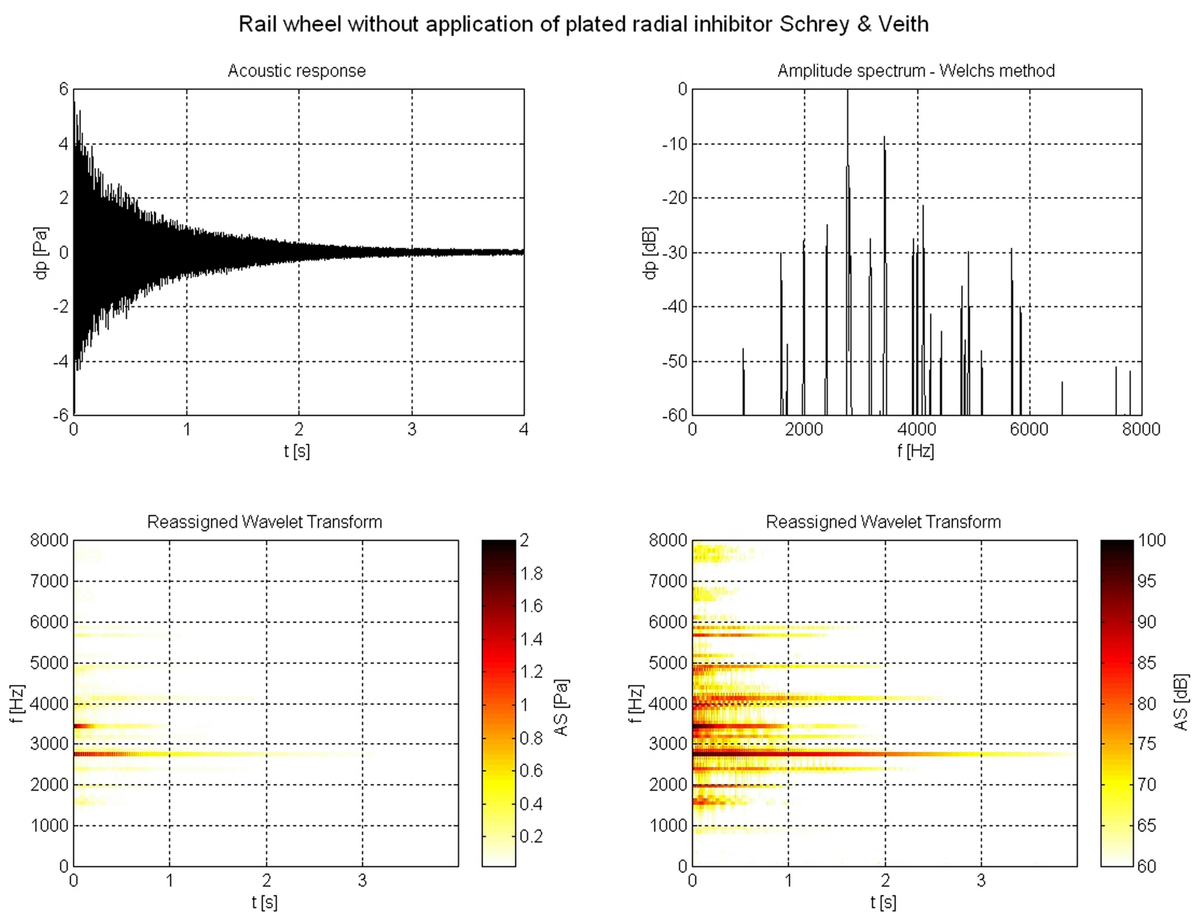

Figure 2: Time, frequency and time-frequency analysis of the rail wheel without application of plated radial inhibitor Schrey & Veith.

3 - CONCLUSIONS

On the base of executed analyses of measured signals and by comparison of results it is possible to form following conclusion:

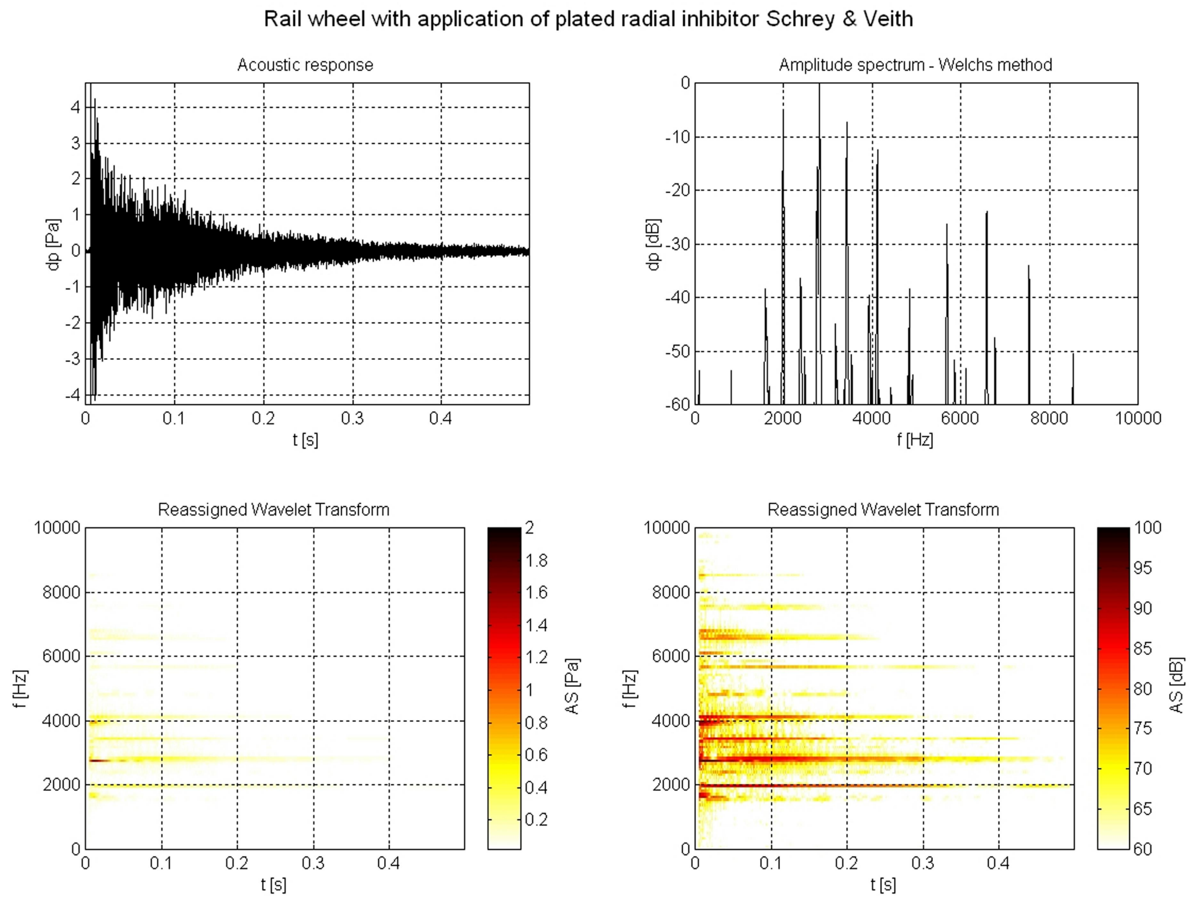

Figure 3: Time, frequency and time-frequency analysis of the rail wheel with application of plated radial inhibitor Schrey & Veith.

- Methods of time-frequency analyses enlarge information of the given technically occurrence by stating the time locality of frequency components, i.e. they determine the size of spectral power density by appropriate frequencies at the given moment.
- Measurement and analysis of non-stationary signals with the use of time-frequency methods provides a new view to transfer and non-stationary characteristics by the measurement of railway wheels from the point of view of noise and vibrations.
- Wavelet transform is suitable mainly for analysis and reconstruction of different types of non-stationary signals, gained for example by measurements of noise and vibrations. This transformation can find its use there, where classical methods of frequency analyses (i.e. Fourier transform) are not sufficient and where it is necessary to execute the frequency analysis time bound as well.

ACKNOWLEDGEMENTS

This research has been supported by the research project CEZ J22/98 No.∼261100007 ("Theory, reliability and mechanism of failure statically and dynamically loaded building construction").

REFERENCES

1. **Poularikas A. D.**, *The Transform and Applications Handbook*, IEEE Press, pp. 756-775, 1996

2. **Smutný J., Pazdera L**, Modern methods of noise and vibration analysis applied to rail transport, In *Slovakian Technical University, Bratislava*, pp. 355-360, 1998