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FILTER SIGNALS A FIRST STEP IN INTERPRETING EXPERIMENTAL RESULTS

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ABSTRACT

After recording and storage of experimental data, a first step in their processing is filtering, ie, removal of parasitic components (noise) accompanying the signal due from other machines or equipment in service or system of units for purchase experimental data. The presence of noise in the signal acquired, can lead to misunderstandings of dynamic quantities obtained by processing experimental data.

KEYWORDS: wavelet, vibration, signal, filter

1. Wavelet functions

Wavelet functions are relatively new algorithms, used to represent stationary or non-stationary signals in the form of basic terms easily characterized in terms of time-frequency characteristics. It is noted in the wavelet-type functions, the development of two types of algorithms, namely:

a. Intended signal decomposition algorithms - Fire (direct) - FWT (Fast Wavelet Transform) or Discreet Wavelet Transform - DWT (Discrete Wavelet Transform)

b. Algorithms intended recombination signals - Fire inverse Wavelet Transform - IFWT (Inverse Fast Wavelet Transform).

2. Transform wavelet denoising

Based on the theory of wavelet functions, was developed an algorithm for eliminating stray signals (unwanted components) which accompany useful signals met called wavelet denoising. These stray signals, called noise, negatively affect qualitative and quantitative particular signal of interest. For this reason, it is necessary that the ratio of useful signal power and noise power signal component from entering the receiver, to have values as large as possible. General denoising procedure involves three steps as follows:

1. Signal decomposition

It is considered an acquired signal x[n] that is considered consists of two signals, such

$$x[n] = u[n] + z[n] \qquad (1)$$

where u[n] is useful signal and z[n] - noise. Decomposition of signal x[n] by Discreet Wavelet Transform - DWT is performed on each component part of the signal acquired.

$$\begin{aligned} y[n] &= DWT\{x[n]\} = \\ &= DWT\{u[n]\} + DWT\{z[n]\} \end{aligned} \qquad (2)$$

Basically the stage of decomposition, the signal is separated into two vectors CA1 and CD1, displaced by successive passage of the signal by passing up a series of filters that allow analysis of high frequency signal and a series of low-pass filters that allow analysis of low frequency signal, fig. 1.

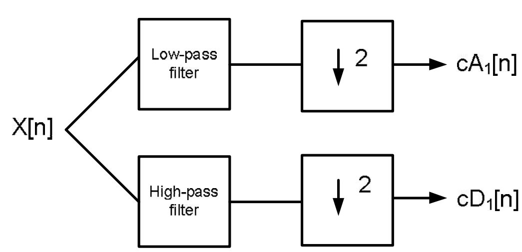


Fig. 1 Signal decomposition

Vector elements are called CA1 approximation coefficients and detail coefficients vector elements of D. The basic procedure is repeated for CA1 and successive approximation vector for any new Vector range of type Caj, so this node is represented by "tree wavelet" fig. 2, where j means the number of iterations (repeating) the basic procedure.

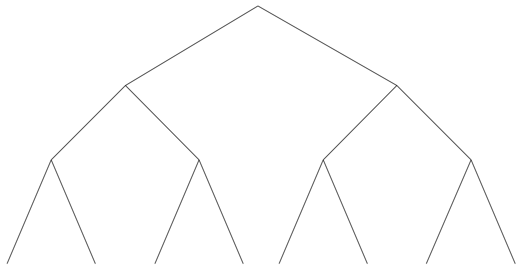


Fig. 2 Tree wavelet

Wavelet decomposition, multiple levels of resolution j, means connecting the cascade, the low-pass filter branch, the numerous systems identical to that in fig. 1. Thus, in fig. 3 is an outline of signal decomposition on three successive levels [5]. Filter banks, the different branches of the decomposition in fig. 3 Frequency responses will be covering different frequency bands of widths. After each pass through the filter signal to precede to an exit filter decimation factor 2, which does not involve a significant loss of information because at this time discrete signal bandwidth is half the original band.

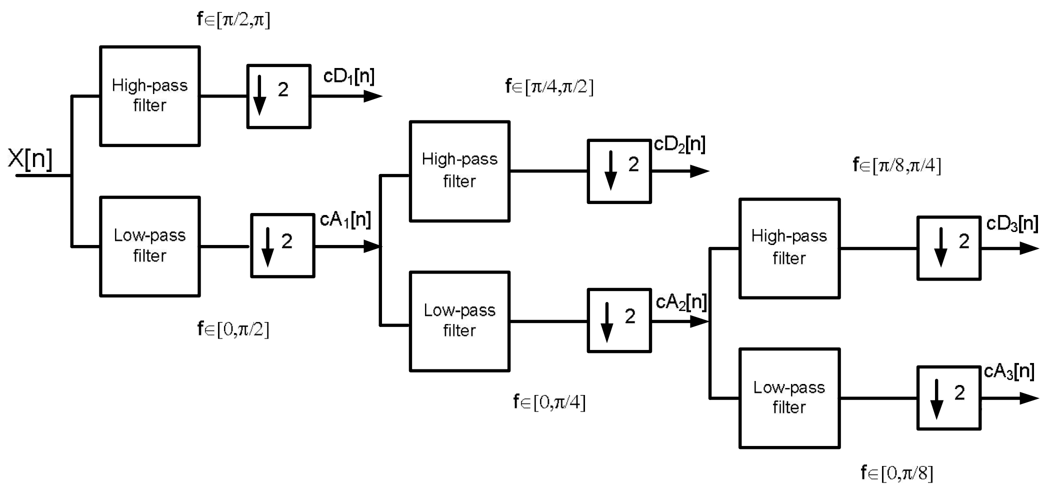


Fig. 3 Signal decomposition on three successive levels

2. Application of segmentation techniques sub signal previously obtained by thresholding method (binarize threshold)

In this stage it is eliminate noise components from useful signal by using a nonlinear filter as follows

$$z[n] = F\{y[n]\} = \\ = F\{DWT\{u[n]\} + DWT\{z[n]\}\} \quad (3)$$

In most cases, nonlinear filter is described by input-output relationship

$$y = \begin{cases} sgn(y)(|y| - qt_{hr}), & |y| > t_{hr} \\ 0, & |y| < t_{hr} \end{cases} \quad (4)$$

where $0 < q < 1$, and t_{hr} is the threshold. For q=0 is called hard thresholding and soft thresholding for q=1. There are several criteria [4] for choosing the threshold value t_{hr}:

- SURE (Steins unbiased risk estimate) sets the threshold so

$$t_{hr} = \sqrt{2\log_e(n\log_2(n))} \quad (5)$$

where n is the number of sampling.

- FIXTHRESH sets a threshold value by the relation

$$t_{hr} = \sqrt{2\log(n)} \quad (6)$$

- Heuristic SURE method is a variant of SURE
- MINIMAX determined threshold value by the relation

$$t_{hr} = 0,3936 + 0,1829\log(n) \quad (7)$$

For each input signal x [n] is an optimal threshold value so as to obtain maximize signal noise ratio.

3. Recombination signal

Wavelet transformation phase involves the application of reverse Fire - IFWT signal z[n] obtained in the previous stage:

$$v[n] = DWT - 1\{z[n]\} = \\ = DWT - 1\left\{F\left\{DWT\{u[n]\} + DWT\{x[n]\}\right\}\right\} \quad (8)$$

where the signal v[n] signal is actually estimate u[n]. Recombination signal is line with the algorithm described in fig. 4 and the signal shown in fig. 3, it recombination is based on synthesis filter banks under the procedure in fig. 5, [5]. To improve the signal to noise signals experimentally acquired was used toolbox Stationary Wavelet Transform De-noising (SWTD) implemented in MATLAB computer program.

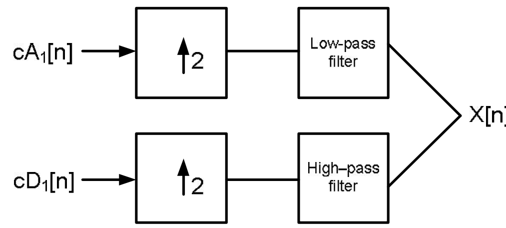


Fig. 4 Recombination signal

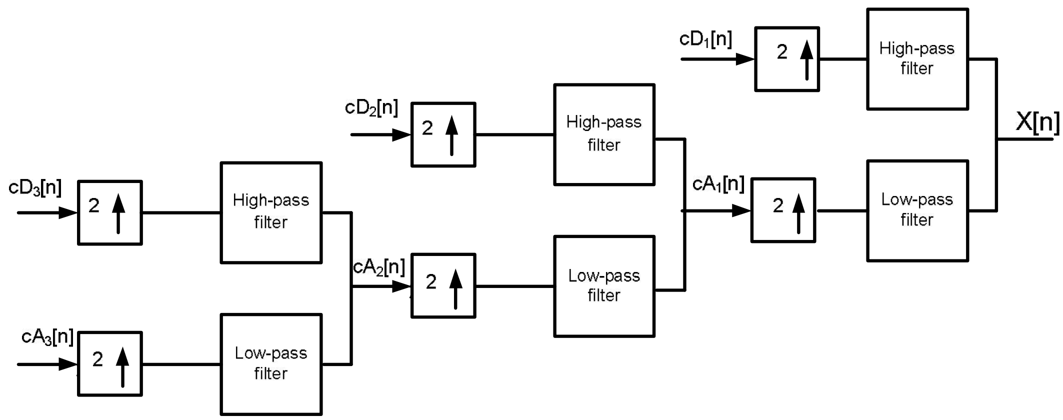


Fig. 5 Recombine signal on three successive levels

To demonstrate how to work with the toolbox, the following is an example in which a real signal is filtered to remove noise. In the first stage, the original signal is decomposed in the undersigned by using transformation wavelet filter implemented type Haar, up to a resolution of the order of five (fig. 6). For this procedure, toolbox SWTD offers several types filters known: Haar, Daubechies, Symmlet, Coiflet.

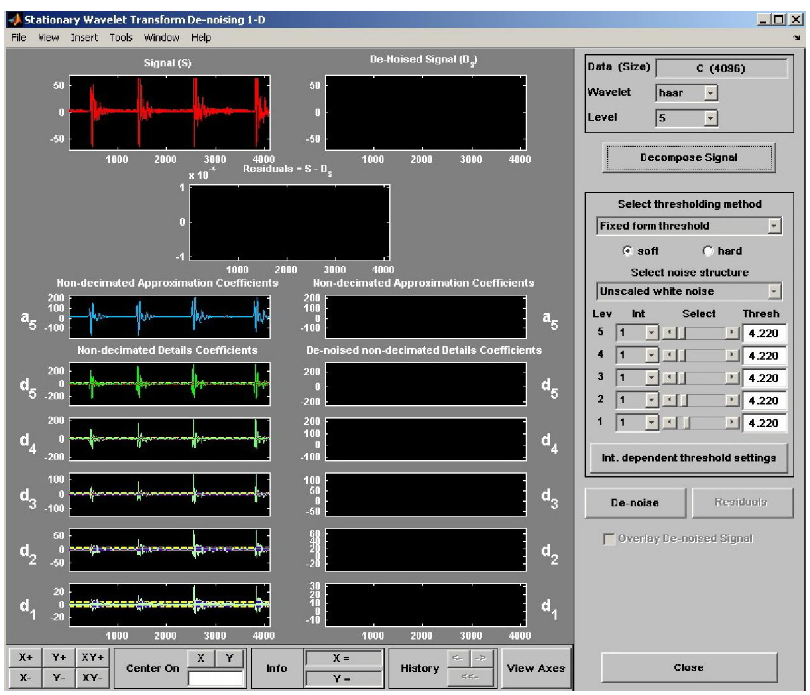


Fig. 6 Stationary Wavelet Transform De-noising - decomposing signal

The second phase, which reconstructs the signal due subsignal results initially, were previously subject to a threshold binarize methods, fig. 7. Depending on the type of signal analyzed, you can select a method binarize threshold (thresholding) of those provided by the work environment: soft thresholding, hard thresholding, SURE, FIXTHRESH, Heuristic SURE, MINIMAX.

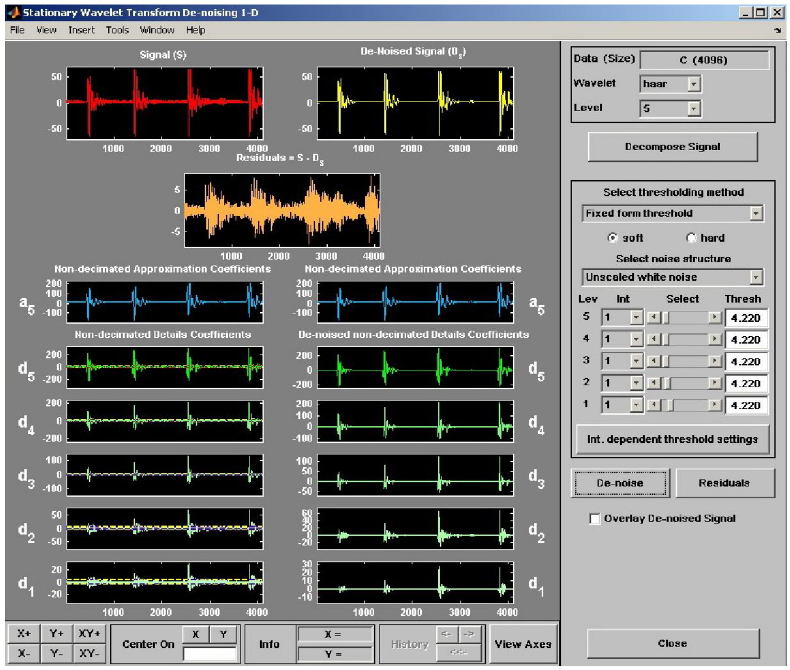


Fig. 7 Stationary Wavelet Transform De-noising - filtering and recomposition signal

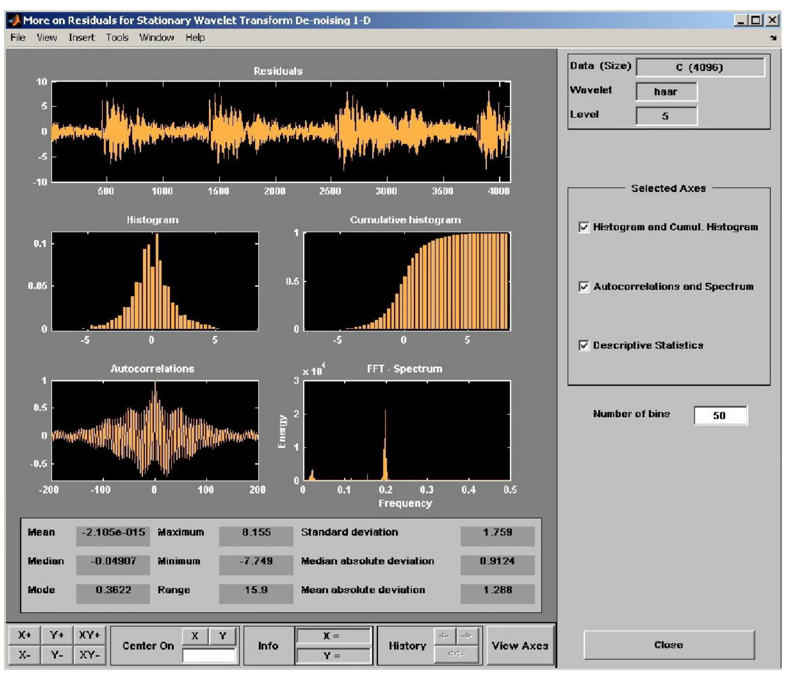


Fig. 8 Analysis of residual signal

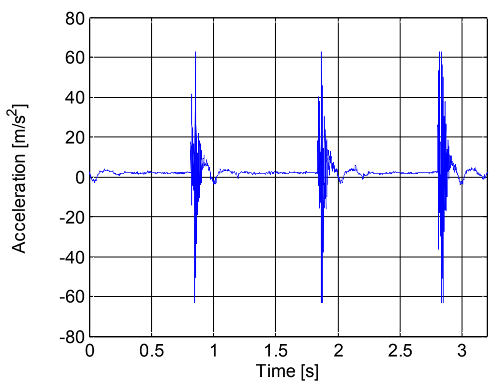
Particularly useful is a detailed analysis of the residual signal, by providing information on sources of noise that accompanies good signal (fig. 8). Analysis of residual signal, both in time and in frequency provides information about the source of noise can be a criterion in the control chain measuring apparatus and purchase necessary experimental determinations.

3. Presentation and interpretation of experimentally results

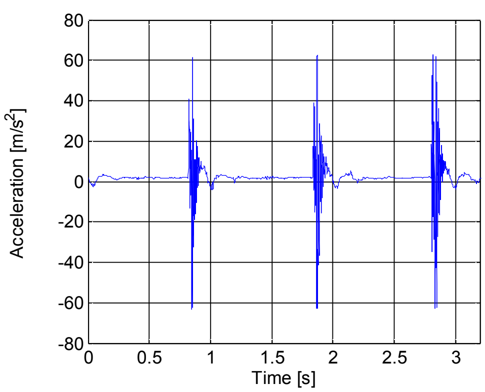
Experimental determinations were made in the Tools Company (IUS) of Brasov, in the section designed for plastics processing activity on die forging hammers, [3]. Measurements were made in operating conditions in the task of die forging hammer during a full work cycle in forging a semi-product in current production:

a. simultaneous recording of signals from two RTF transducers placed on the bed plate and the vat;
b. simultaneous recording of signals from two RTF transducers placed on the pad and foundation

As mentioned previously, the signals acquired in these experiments (acceleration), were filtered using wavelet denoising technique, in fig. 9, 10 are shown compared signals recorded on the bed plate and the vat, before and after filtered.



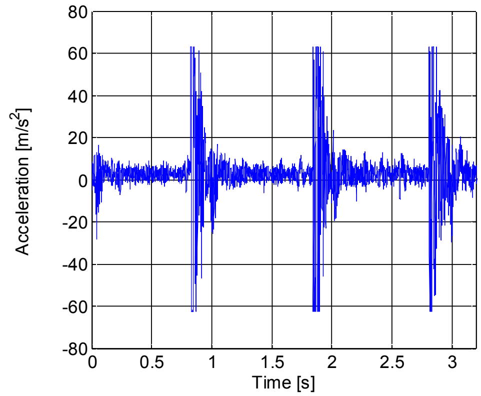
a. Real signal



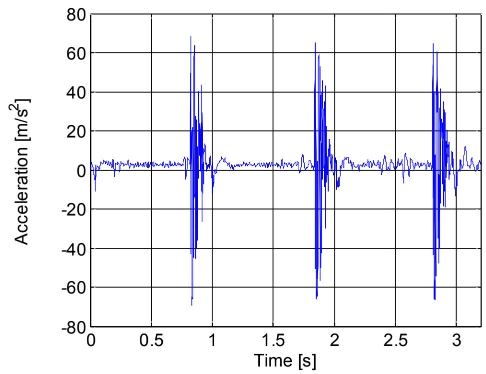
b. Filtered signal

Fig. 9 Signal recorded on bed plate

Representation of acceleration signals versus time recorded on the vat, known as the signature hammer, are of great interest because they may be determined based on the degree of harmful vibration source and propagated during equipment operation.



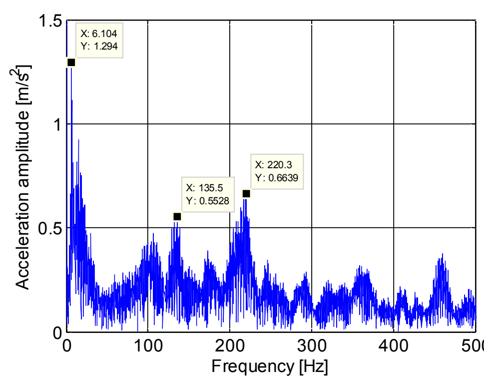
a. Real signal



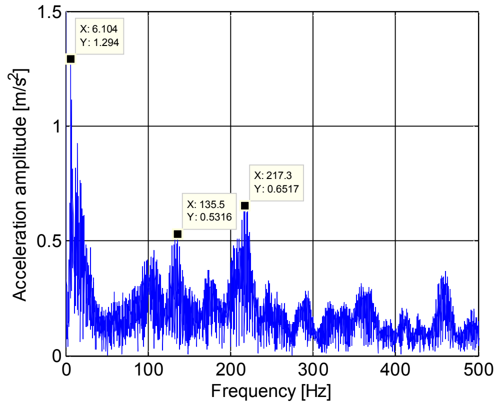
b. Filtered signal

Fig. 10 Signal recorded on vat

Seen from these representations that the acceleration signal recorded on the pad, it is less influenced by background vibration from sources other than the source considered possible, while the signal recorded on the tank is heavily distorted. Application of Fourier transform acquired acceleration signals, is a type interspectral analysis in order to highlight mutual characteristics signal in the frequency domain.

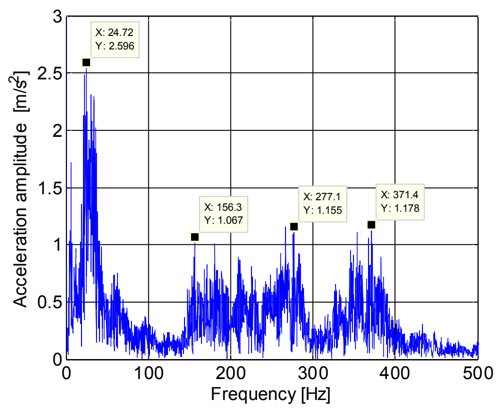


b. Real signal

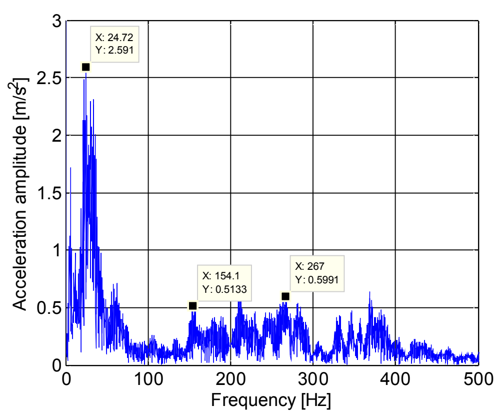


b. Filtered signal

Fig. 11 Frequency response of acceleration signal on the bed plate



b. Real signal



b. Filtered signal

Fig. 12 Frequency response of acceleration signal on the vat

Signals corresponding to that bed plate, are represented in the frequency spectra of acceleration, to reflect the coresponding frequency band components of maximum amplitude. Frequency analysis of acceleration signals, filtered and unfiltered, recorded by bed plate, fig. 11, not shows it remarkable differences because the stray signals from the neighborhood are isolated by anti-vibration systems as the foundation equipment.

For these representations is obvious difference in frequency of representation of acceleration signals recorded on vat (filtered and unfiltered), fig. 12. These obvious differences may induce qualitative and quantitative errors in the interpretation of these measurements with negative effects on the activity of predictive monitoring of equipment with impulsive action.

4. Conclusion

This paper highlights several techniques used on experimentally acquired signals to remove signal parasite from useful signal. It is described the filtering process of the experimentally acquired signals using wavelet denoising toolbox of MATLAB program. By applying this technique obtain good signal and can also separate analysis residual signal, leading to the identification of point sources of pollution of the signal concerned. Application of filtering techniques using wavelet denoising toolbox is useful both for the time and frequency analysis of experimentally acquired signals.

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