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EXPERIMENTAL ANALYSIS OF THE REFLECTED WAVES DURING COAXIAL IMPACT OF CYLINDRICAL RODS

Voichița HULE[1], Cristiana CĂPLESCU[2], Florin BLAGA[1]
[1] University of Oradea, [2] "Politehnica" University of Timişoara

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Abstract: The paper presents an experimental analysis of phenomena that appear during coaxial impact of two elastic bodies having the longitudinal dimensions much greater than those transversals, based on the longitudinal wave propagation theory. The acquired experimental data refers to the verification of the propagation and reflection of mechanical waves in metallic rods theory during their impact at low speed. Data conditioning methods in time, frequency and in scale-frequency range were used to relieve the analyzed phenomena.

1. INTRODUCTION

The paper deals with experimental study of the coaxial impact of two elastic bodies having the longitudinal dimensions much greater than those transversals (such as light gauge rods) based on the longitudinal wave propagation theory.

An experimental setup for finite length rods was conceived in order to reveal the phenomena that appear during the impact period which are the longitudinal wave's propagation inside rods, analyzing the incident wave and also the reflected wave movements through rods and also the contact time analysis between rods [2].

A variant with suspended rods was used for the experimental setup. Elastic wires through metallic rings fixed on holders were used to suspend the rods. This solution offers a series of advantages comparing to that one in which the rods are guided, mainly because the suspending system does not absorb the wave's elastic energy and the metallic ring offers a good insulation of the system. The construction is simple and is suitable for the testing of a wide variety of rods' lengths and sections.

The experimental setup is composed on two OLC 45 suspended cylindrical rods having 40 mm, respective 35 mm in diameter and 2 m, respectively 6 m in length. Strain gauges were mounted on the rods equally disposed at L = 2 m, respectively L/2 = 1 m (Fig. 1). They transmit the signals through a Wheatstone bridge to a data acquisition board. The study was made in the low velocity impact zone, with v_0= 2m/s.

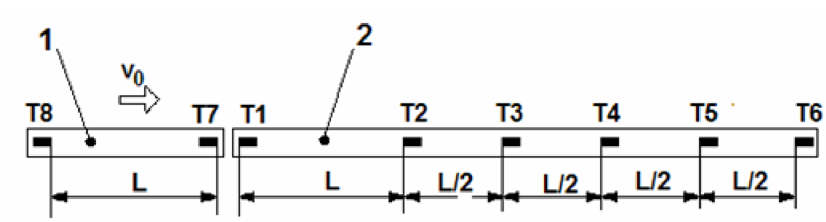

Fig.1. Strain gauge mounting schema on the percussion rod (1) and the stricken rod (2)

At the impact moment compress strain occurs, together with mechanics waves which propagate inside the rod material. Compression strains cause the strain gauges to deform proportionally with their magnitude, thus generating electric signals toward Wheatstone bridge.

Experimental data acquired refers to the experimental verification of the propagation theory and the reflection of the waves in free metallic rods as a result of their impact at low speeds and also to the impact time verification in these conditions. Data processes in the time range, frequencies range and scale-frequency range methods were used to identify the analyzed phenomena [1].

2. EXPERIMENTAL ANALYSIS OF THE WAVES' PROPAGATION GENERATED AT THE RODS' IMPACT

For the test rig described earlier some experiments were conducted connecting the strain gauges in full bridge. The voltage generated during rods' impact on every strain gauge was measured, using a single analog channel of the acquisition board. Time correlation of the measurements has been realized with a trigger.

For the phenomena analysis which constituted the subject of the experimental studies, software data acquisition in Visual C++ along with computing software in MATLAB needed for experimental data computation and conditioning were made.

MATLAB software was used for data processing because it possesses a series of predefined functions useful for the data analysis such as FFT and wavelet.

For a better comparison of the signal shapes acquired from the T1,…, T6 strain gauges mounted on stricken rod a single diagram, presented in Fig. 2, was used for display them.

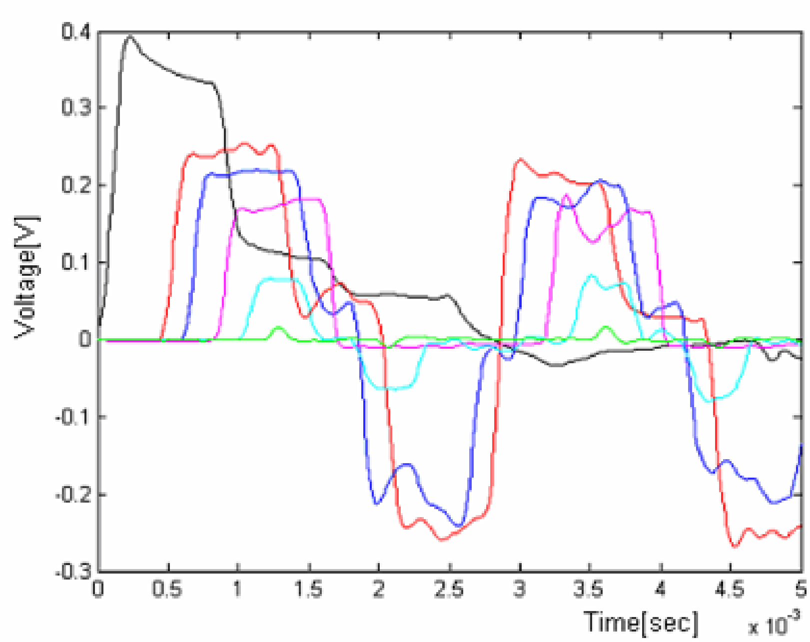

Fig.2. Cumulated diagram for the signals acquired from the 6strain gauges (T1 – black; T2 – red; T3 – blue; T4 – cyan; T5 – magenta; T6 – green)

Because of the great length of the stricken rod is difficult to relieve the reflected wave from it's free end. The main cause of this difficulty is that the wave is significantly absorbed along the rod. Beside its attenuation, a series of other effects occurs (side reflections, bending vibrations of the rods) which significantly diminishes the possibility of detecting the reflected wave.

Two sets of 5 measurements were conducted to detect and analyze the reflected wave. In the first set the signal acquired from the T1 strain gauge was measured for an impact realized in the conditions mentioned above. The second measurement set was conducted in the same conditions excepting the fact that at the free end of the stricken rod a vaseline film was applied. This layer of viscous material absorbs partly the reflected wave energy thus the reflected signal being diminished. The average of the 5 unabsorbed signals (without vaseline layer – ms_{fa}) and also the average of the 5 absorbed signals (with vaseline layer – ms_a) were computed. Both average diagrams are presented in Fig. 3.

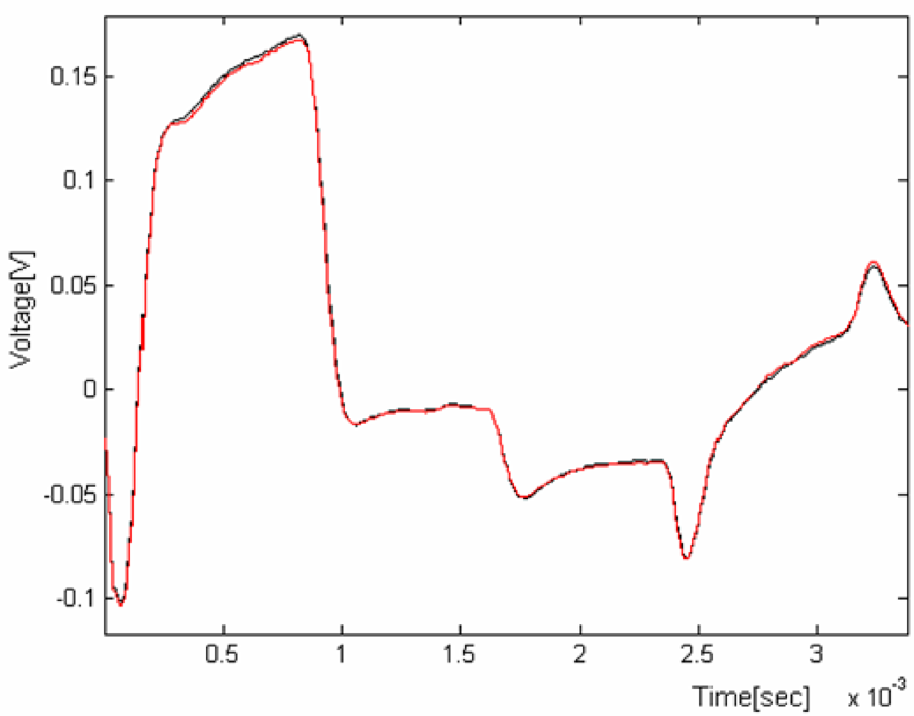

Fig.3. Unabsorbed signals average (black) and absorbed signals average (red) diagram

The difference between those signals should be noticed at the moment of time $t = 2{,}313 \times 10^{-3}\ \sec$, on which (based on computed values and also on conducted measurements) both the separation of the rods and the reflected wave return in the section which corresponds to T1 strain gauge position occurs. Because of the reduced damping caused by the vaseline layer, this difference couldn't be easily noticed on the diagram in Fig. 3.

Because of this a frequency analyze program created in MATLAB which computes and displays the frequency spectrum of the signal was realized. The software offers the possibility of signal filtration eliminating the insignificant frequency ranges (from the analyzed signal point of view) after which an inverse transformation from the frequency range to the time range is applied. This way noise can be eliminated (for example the 50 Hz frequency component induced by the a.c. net (Fig. 4).

Fig. 5 shows the frequency spectrum of the ms_{fa} (black) and ms_a (red) signals.

Three domains appear on the diagram in Fig. 5 in which significant differences between the two signals type occur. In the A domain a phase delay can be observed while in B and C zones a significant amplitude difference can be noticed.

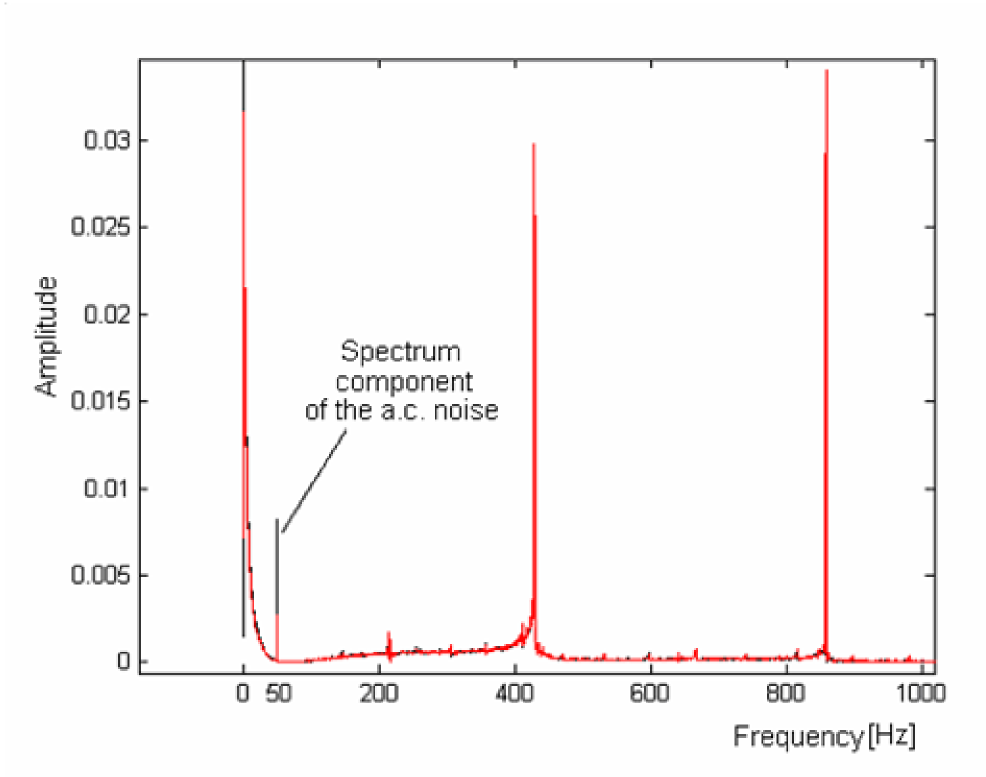

Fig.4. Spectral diagram of the T1 strain gauge (detail)

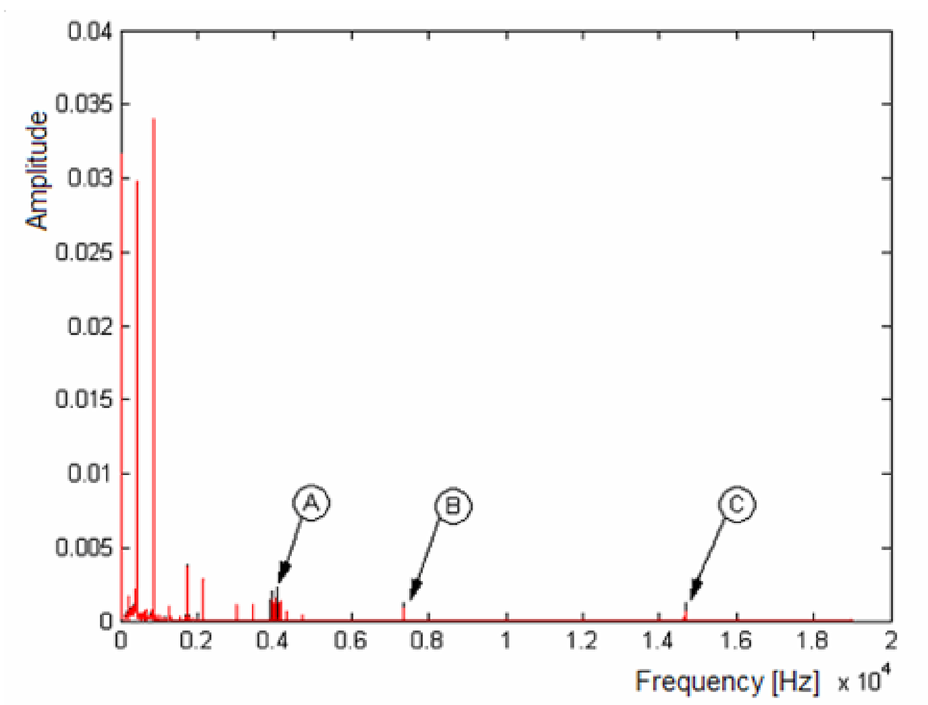

Fig.5. Spectral diagram of the damped signals (red) and undamped signals (black) for the T1 strain gauge

Keeping these frequencies domains and eliminating the others in which differences were not been noticed, and then applying an Inverse Fourier transforming the diagram presented in Fig. 6 is achieved. The diagram is detailed in Fig. 7 in which the damped signal (*sm_a*) is red, the undamped signal (*sm_{fa}*) is black and the difference between them after an Inverse Fourier transformation (*dif_{sm}*) is blue.

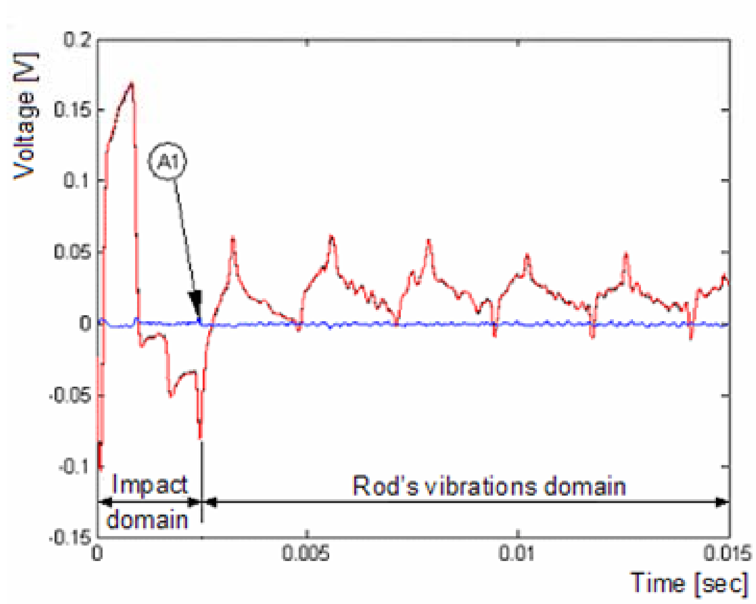

Fig.6. Signal diagram after filtering in frequency range

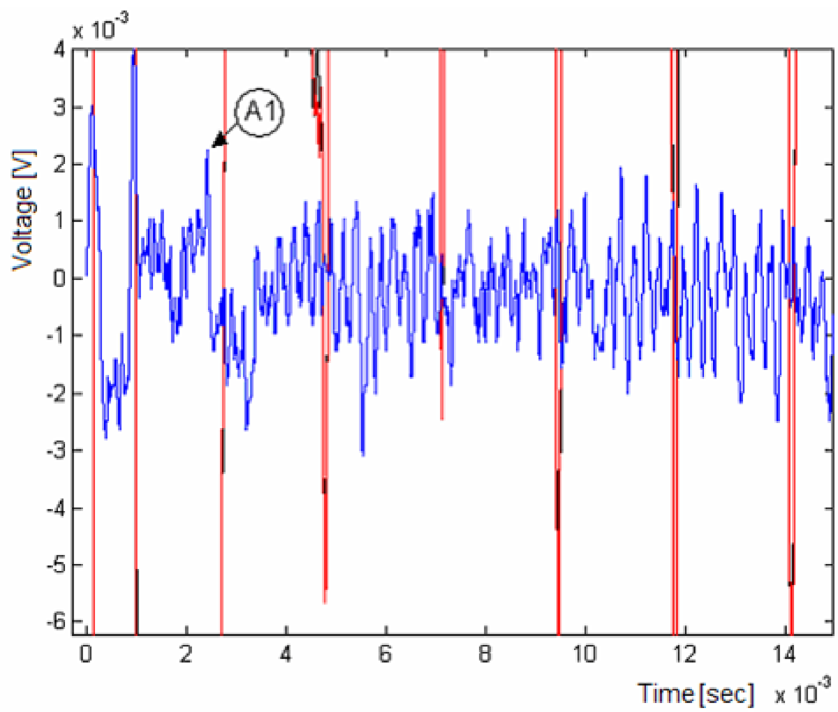

Fig.7. Signal diagram after filtering in frequency range (detail)

In the diagrams shown in Fig. 6 and Fig. 7 a significant variation of the difference between the signals (point A1) can be noticed, but such variations can be noticed in other time ranges in which the apparition of the reflected wave is not estimated, such as the range (0 … $1x10^{-3}$) seconds. The limitation of the Fourier transformation can be noticed in this case; this means that it is useful for signal filtration but presents the major disadvantage of loosing information about time localization of the phenomena.

To localize the reflected wave in time the dif_{sm} signal was analyzed using the MATLAB software. The diagram shown in Fig. 8 was created with this software. The program uses the „rbio 3.1" wavelet (Reverse Biorthogonal wavelets version 3.1).

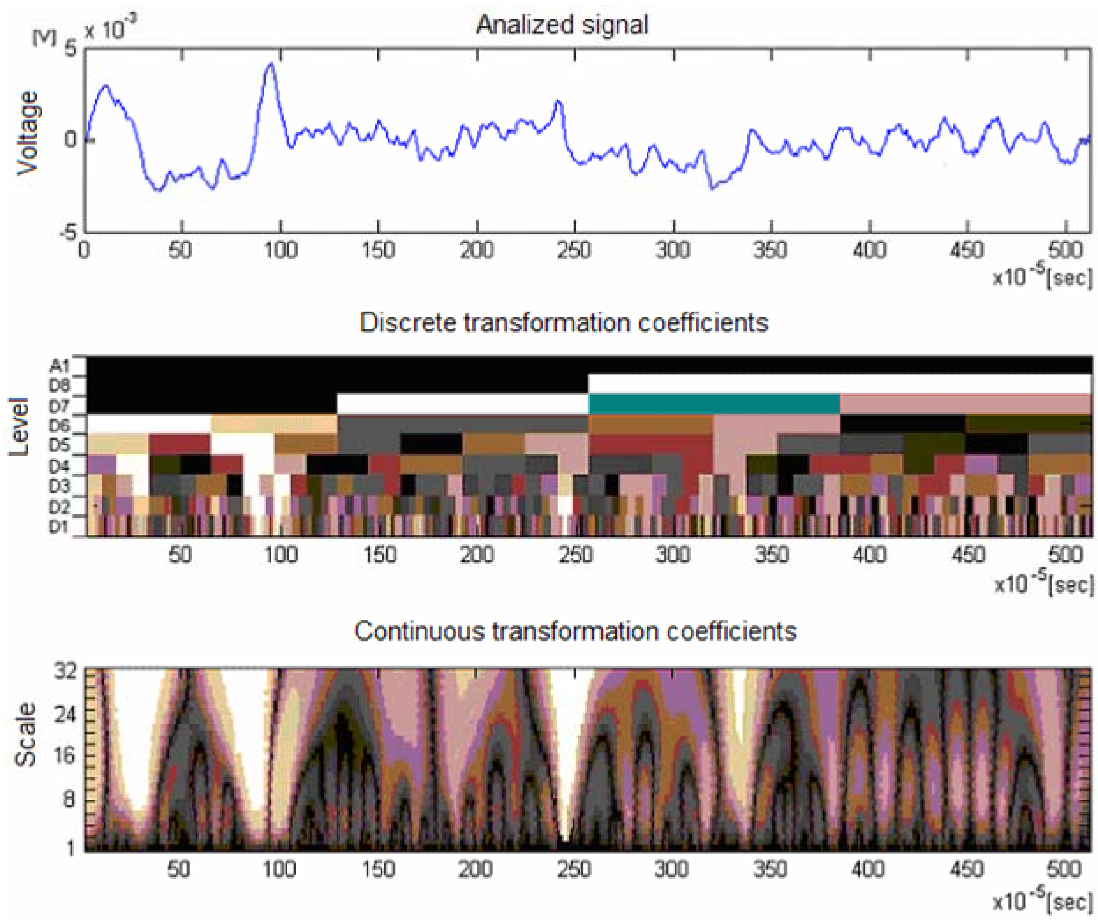

Fig.8. dif_{sm} signal diagram achieved using the wavelet transformation „rbio 3.1"

From the time-level diagram it can be noticed that in the range of interest (around 2,4 x 10^{-3} seconds) a prominent amplitude of the signal exists on the D1 and D2 detail levels.

Using this notice the reflected signal synthesis was realized through the selection of the "rbio3.1" wavelet transformation coefficients corresponding to D1 and D2 details. Fig. 9 shows the steps of the transformation, coefficient selection and the resulted time range diagram.

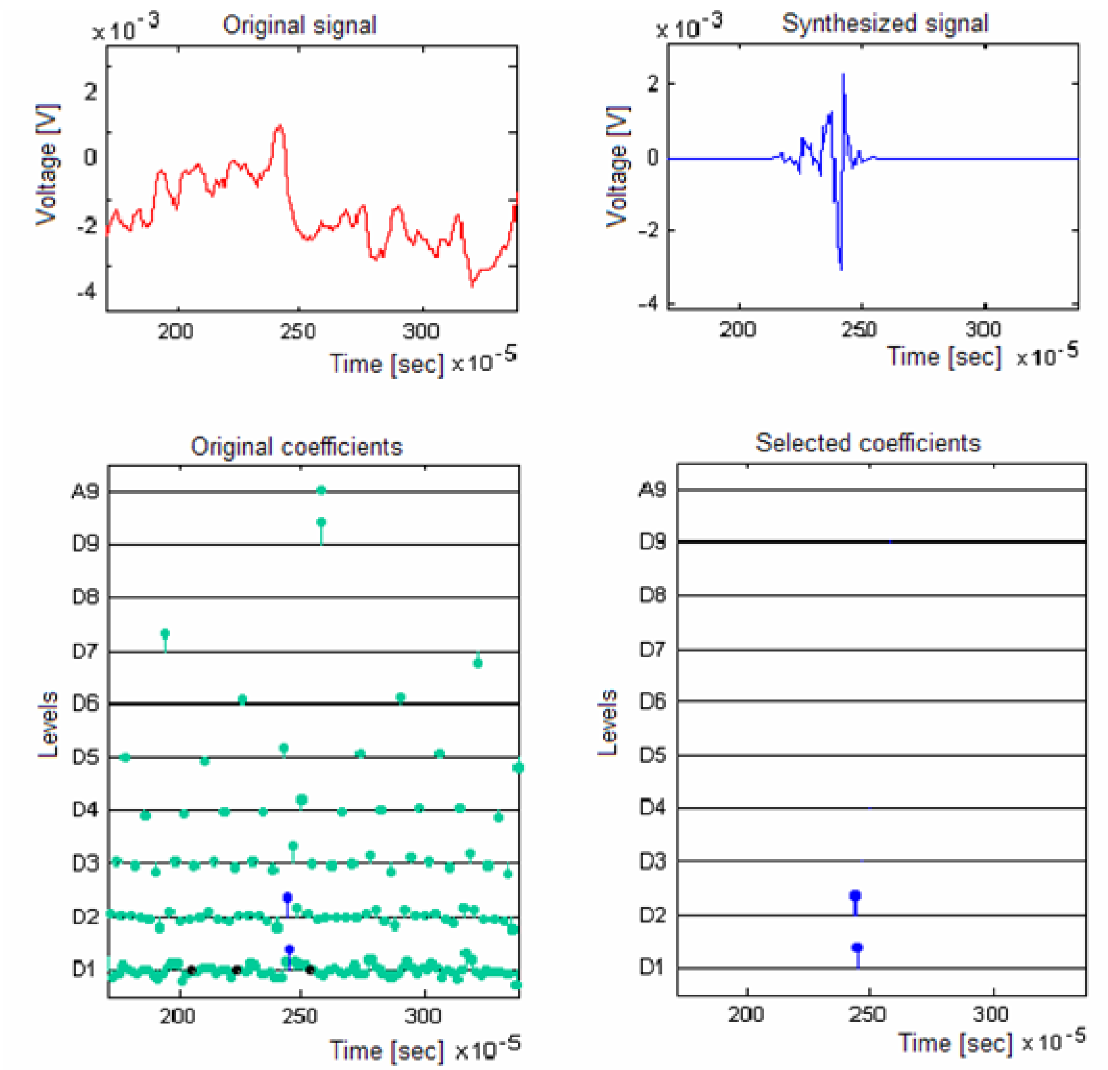

Fig.9. Reflected wave signal syntheses using wavelet coefficients selection

Through the synthesis of the reflected wave signal achieved from the dif_{sm} signal using wavelet transformation, its share in the base signal can be estimated (the estimation of the reflected wave amplitude can be made) and also the shape of the signal together with the frequency range in which the signal appears.

3. CONCLUSIONS

The parameters used for data acquisition were correctly been defined, the analyzed phenomena being properly relieved.

Because the reflected wave at the free end of the stricken rod measured on the T1 strain gauge is difficult to be detected, a viscous layer was applied on the free end thus observing the differences between the damped and normal reflected signals. This technique didn't offer remarkable results neither in time analysis nor in frequency analysis. This is why the wavelet analysis (in time-scale range) was used thus resulting the signal filtration and the reconstitution of the component due to the reflected wave.

For the phenomena analysis which constituted the subject of the experimental studies, software that can be used for further researches for data acquisition and signal conditioning was made.

4. BIBLIOGRAPHY

[1]. Davis, G. M., Nosratinia, A., *Wavelet-based Image Coding: An Overview*, www.geoffreydavis.com , 2001

[2]. Hule, V., Trip, D., Abrudan, G., *Experimental study of wave propagation in circular cross section beams,* Annals of the Oradea University, Fascicle of Management and Technological Engineering, Vol. V (XV), 2006, ISSN 1583 – 0691, pp.517-522