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Mathematical Modelling in Civil Engineering
Vol. 16-No. 4 : 25-33-2021
Doi: 10.2478/mcee-2021-0018

PARTIAL EXPERIMENTAL CONTRIBUTIONS ON THE VALIDATION OF BIOMECHANICAL MODELS OF THE HUMAN BODY SUBJECTED TO THE ACTION OF MECHANICAL VIBRATIONS

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Abstract: This paper focuses on the field of mechanical vibrations experimental analysis in hand arm vibrations (HAVs) for people who by the nature of their job are subject to the mechanical vibrations.

Keywords: vibrations, transmission, experimental analysis

1. Introduction

The doctoral theses of the first three authors have as general objective the conduct of research that makes possible new perspectives in the field of vibration measurement *in the arm-forearm system* for people who by nature are subject to mechanical vibration, transmission and monitoring of this data in real time via GPRS.

Starting from the biomechanical modeling scheme of the interaction between the human body and the machine it works with and considering the fact that for a space-time model of machine with a degree of freedom, a differential equation can be written that describes the dynamic behavior over time which cannot have a written solution as a relation characteristic of the system x excitation force therefore is found the need to perform a frequency analysis which results in determining quantities by applying the Rapid Fourier Transform (FFT) to a data set collected by the acquisition system with the help of Matlab commands.

Thus, a device model was conceived and designed that used the integrated processing platform (Arduino) on which vibration measurement sensors (accelerometers) were positioned, the results being able to be collected, transmitted and displayed in real time via GPRS.

GPS / GLONASS asset tracking device, GSM connectivity and standalone battery, is able to collect GPS coordinates and transmit them via GSM / GPRS to VPS in order to perform permanent data storage in a MySQL database or view them in real time on a webpage directly on the laptop.

The data obtained can be viewed on any mobile phone running Android +4.2 and on any laptop running Windows, OS X via a Python script.

Given the need for the data to be analyzed, the entire device has been designed and the components that ensure the capture and transmission of this data have been dimensioned. In addition, for the acquisition and processing of experimental data LabView was used.

Once the data capture and transmission system was dimensioned, it was mounted on a subject and experimental determinations were made in two concrete situations, namely determinations without the use of vibrating equipment and determinations with the use of two equipments: compactor plate, respectively percussion drill.

Determinations without the use of vibrating equipment were made by mounting the system on the subject and recording the data in case the subject moves on a flat surface. The obtained results were processed and represented graphically.

2. The first set of experimental research

The experimental part of this work was done in two stages. The first data were collected following the measurements performed in the laboratories of the Research Institute for Equipment and Technologies in Construction - ICECON. In the second part of the tests, Arduino-type devices were used to collect the information, and the measurements were performed outside the laboratory.

Within ICECON, the measurements were made with professional vibration sensors, use in various static demanding situations. The purpose of these tests was to measure the vibrations perceived on the human elbow and knee areas by a subject using a small machine tool, in this case a drill. To perform the tests, the accelerometers were attached in sequence to the drill, the elbow and the knee of the human subject.

Subject A, aged 43, the anthropometric data of subject A, subjected to laboratory tests, are presented in the table below:

Table 1

The anthropometric data of the tested subject

The subject	Total mass [kg]	Arm length [m]	Forearm length [m]	Thigh length [m]	Height calf [m]	Height foot [m]	Height total [m]
A	104	0.31	0.23	0.43	0.45	0.09	1.71

The devices used to perform the experiments were: vibration accelerometers with cable connection from Brüel & Kjaer, HVA 4447 and 4506-B 003 ; USB connection device; laptop.

The experiments started, after fixing the 4506-B 003 accelerometer on the drill (fig.1.), with the first verification and calibration measurements.

Subsequently, the accelerometer was attached to the subject's elbow using duct tape (fig. 2). Measurements were made with the drill operating freely, and the subject had his arm positioned in front of his forearm at an angle of 90° and 180°. The following data were obtained with the load-bearing drill, used to drill two types of materials - wood and concrete, and the angle between the arm and the forearm was in turn 90° and 180°. Then the accelerometer was attached to the subject's knee area (fig. 3) and the measurements were resumed.



Fig.1 - The accelerometer on: drill



Fig.2 - Elbow



Fig.3 - Knee

The results obtained were processed using the LABVIEW program and are presented below. Figure 4 shows the calibration of the accelerometer on labView.

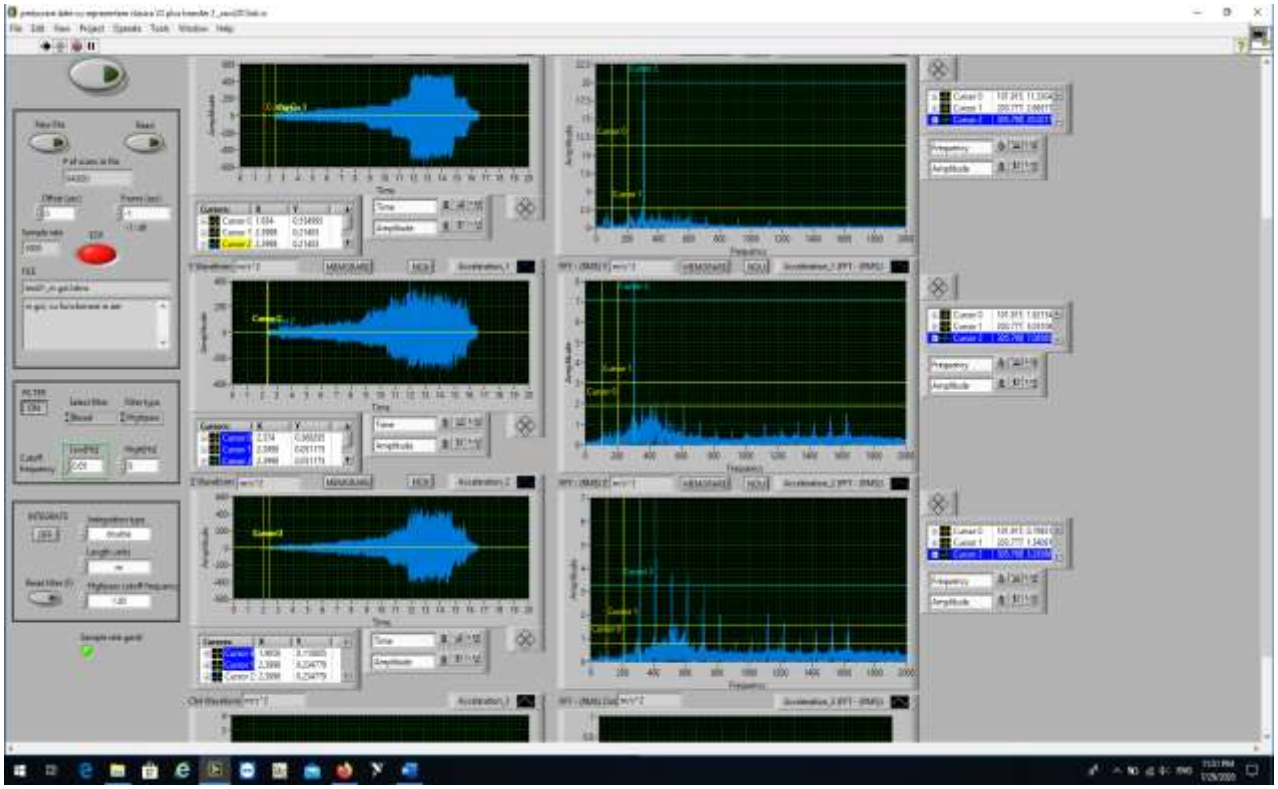


Fig.4 - Calibration of the accelerometer on LabView

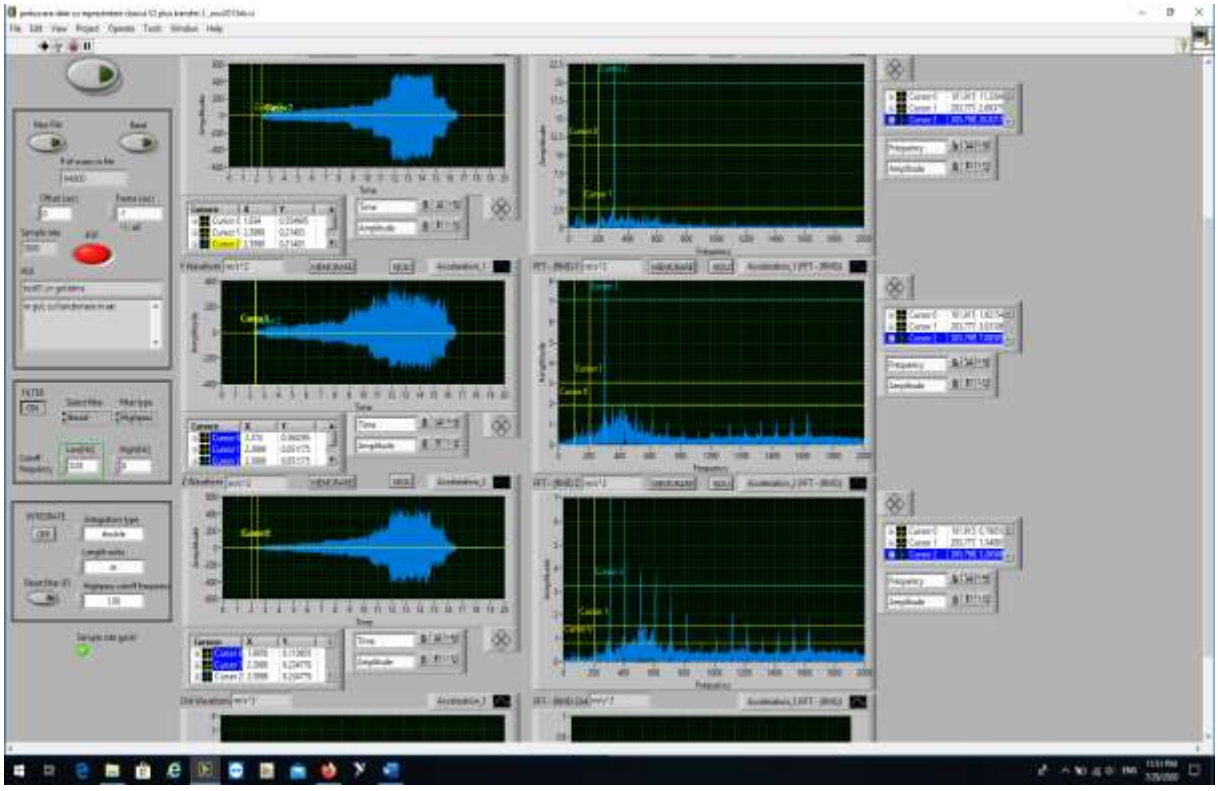


Fig.5 - Measurements with the drill operating freely, the sensor on the drill

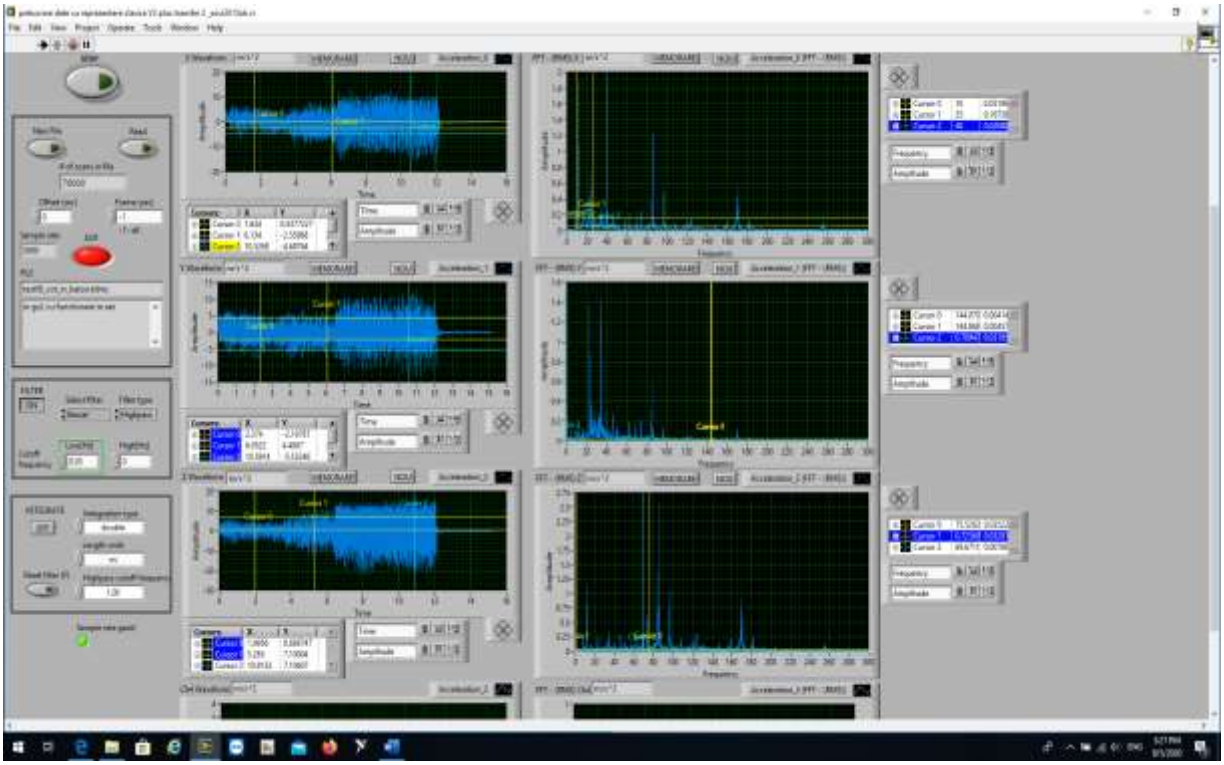


Fig.6 - Measurements with the load-bearing drill, concrete, sensor on elbow

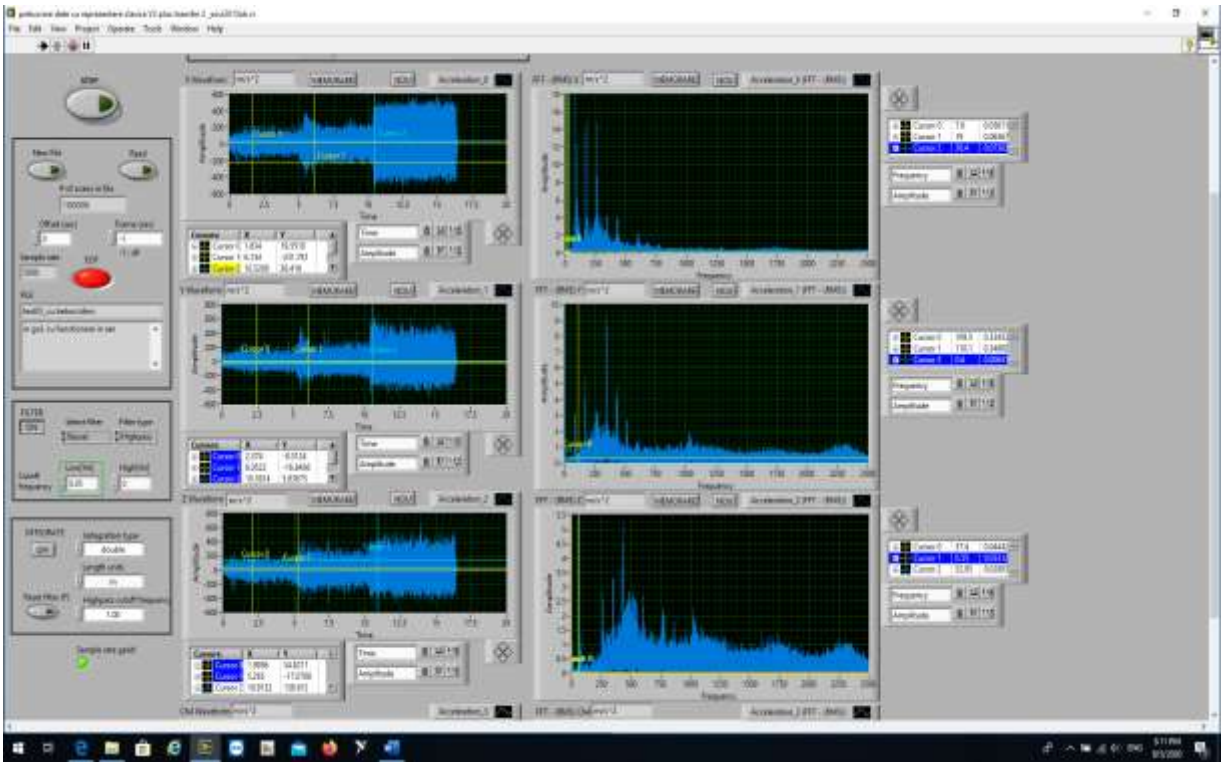


Fig.7 - Measurements with the load-bearing drill, concrete, the sensor on the drill

3. The second set of experimental research

We proceeded to install the data acquisition system whose components are presented in figure 8, on the subject [fig.9, 10, 11] and the collection of recorded data [fig.12, 13, 14] when handling a percussion drill in the following situations:

- accelerometer mounted on the handle of the equipment with/ without FFT;
- left and right arm with/ without FFT;

- left and right forearm with/ without FFT.

Technical characteristics of the percussion drill:

- model: Bosch GBH 2-26 DFR;
- motor power: 800W;
- drill diameter: 6mm;
- speed: 1300RPM;
- drill length: 10cm.

Components that have been used for data capture and transmission [fig.8.]:

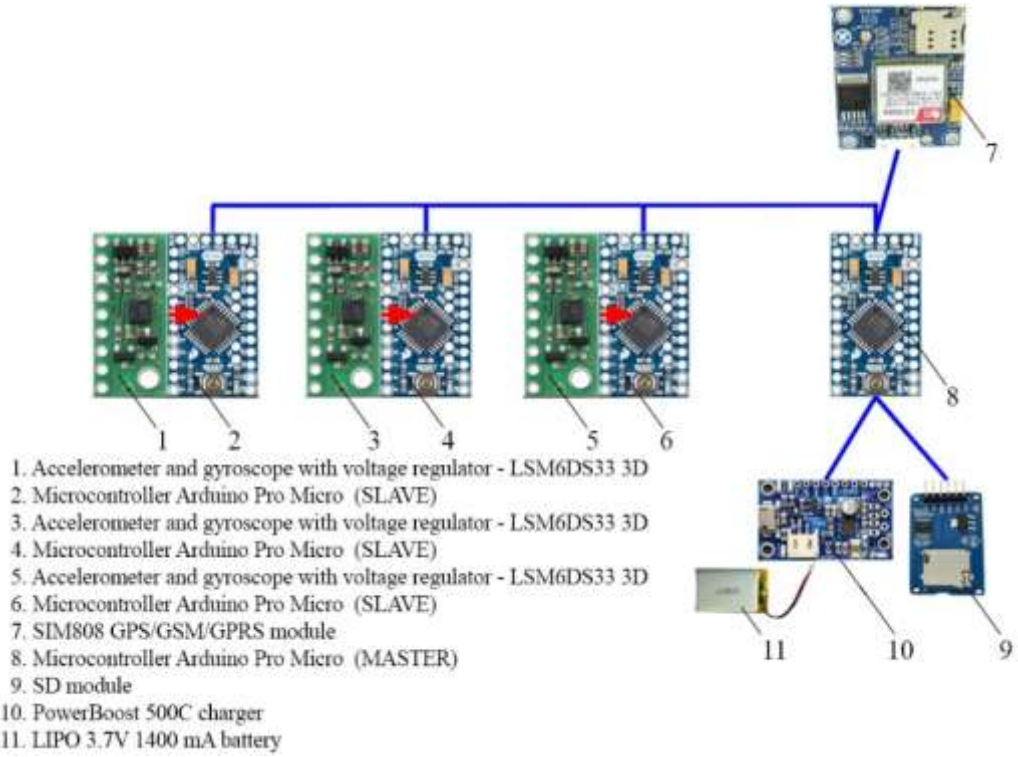


Fig. 8. The data acquisition system components



Fig.9 - Data acquisition system mounted for percussion drill data collection - side view



Fig.10 - Data acquisition system mounted for percussion drill data collection - side view



Fig.11 - Data acquisition system installed for percussion drill data collection - back view

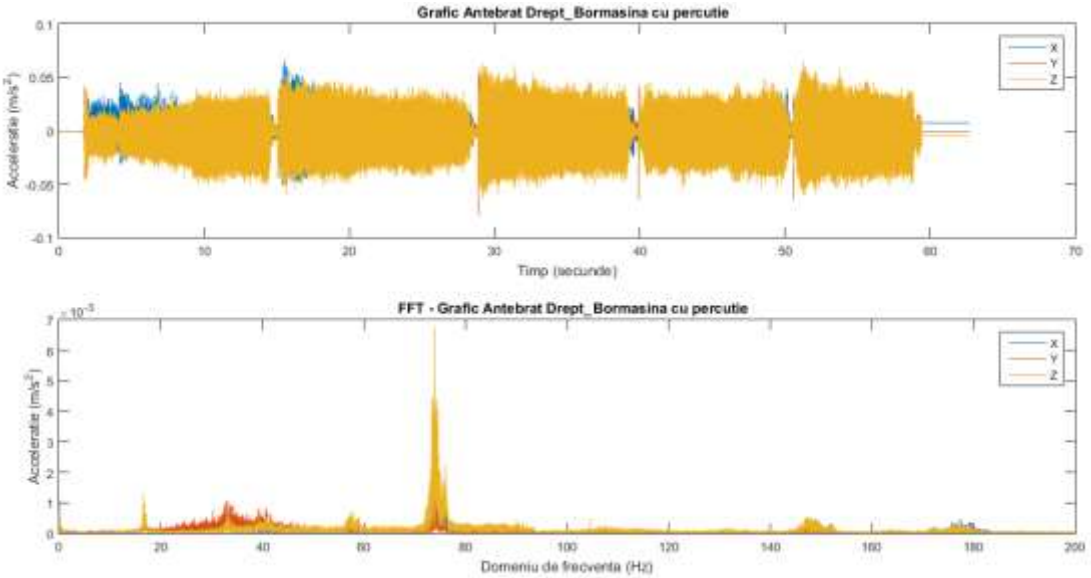


Fig.12 - Accelerometer mounted on the handle of the equipment with / without FFT

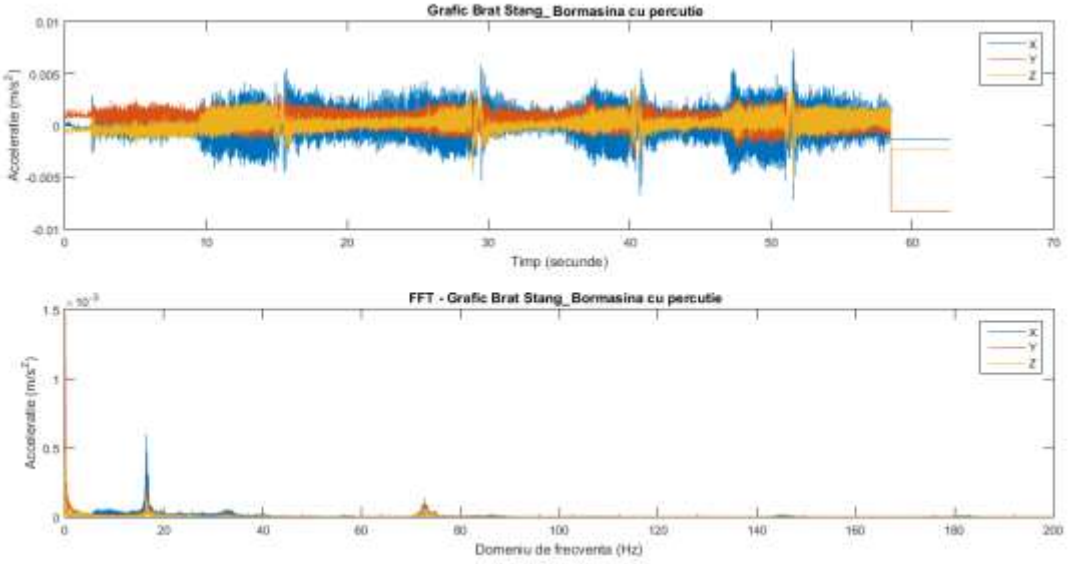


Fig.13 - Accelerometer mounted on the left and right hand arm with / without FFT;

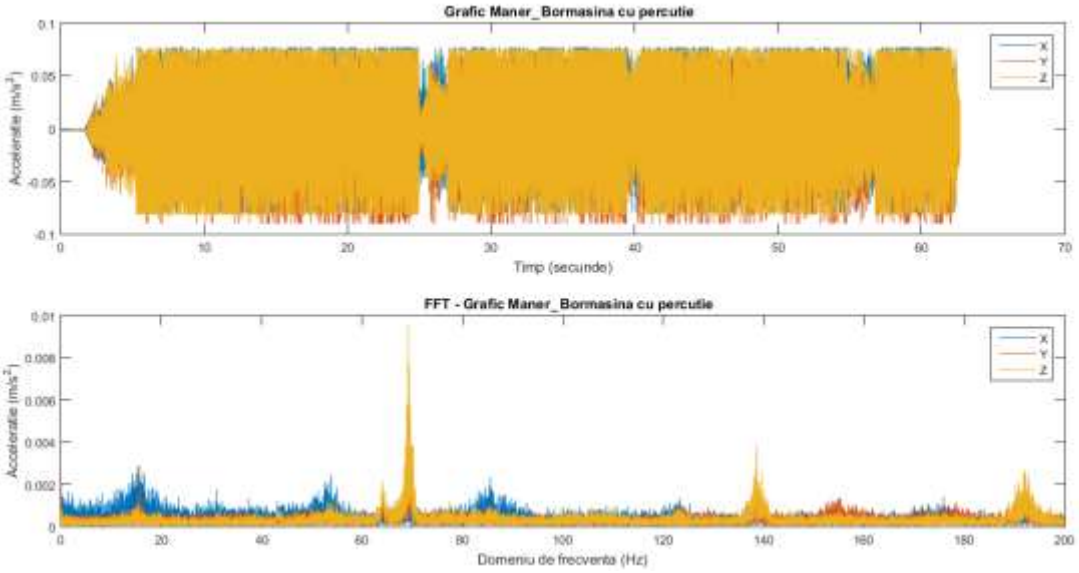


Fig.14 - Accelerometer mounted on the forearm left and right hand with / without FFT;

4. Conclusions

From the analysis of the graphs when using the percussion drill, the frequency 70Hz was obtained for all measurement points, a frequency that is found in the studies performed in [1], resulting in a first validation of some biomechanical models.

In [1], a STERN Austria rotary drill was used for the measurements, with the following characteristics:

- 710 W motor power;
- Maximum drill diameter 13 mm;
- Speed 0-2400 rpm.

It should also be noted that the machine tool is used at maximum speed with a drill bit $\Phi = 8$ mm and a length of 120 mm for concrete. The measurements were performed in the case of drilling a concrete slab measuring 200x600x150 mm. Also the positioning is shown in fig.15.

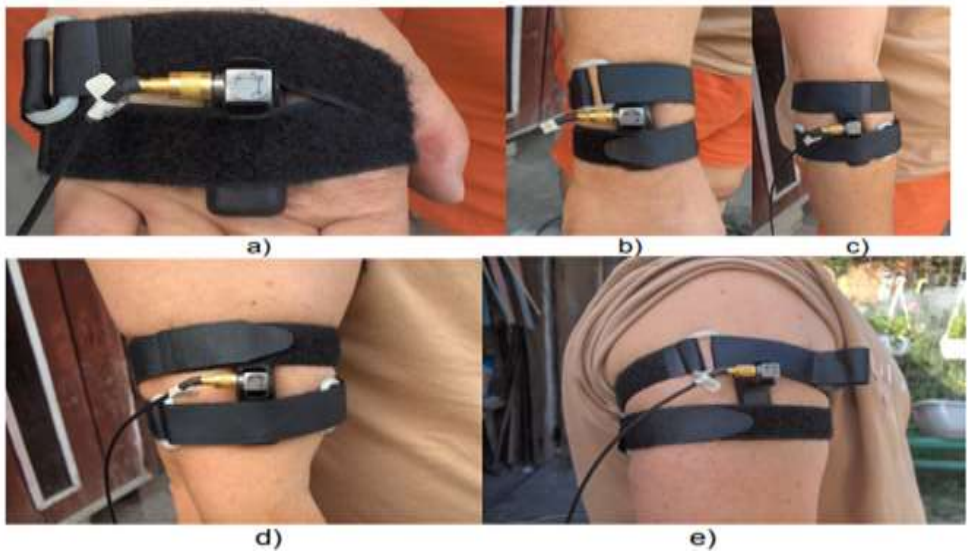


Fig. 15. Positioning of the accelerometer on the operator's arm: a) on the hand, b) on the wrist, c) before the elbow, d) after the elbow, e) on the shoulder

On the X axis: the measured RMS acceleration has significant values at frequencies 50, 70, 150, 250, 350, 450, 550, and 650 Hz and is attenuated by the hand remaining a single maximum at 130Hz, after the wrist it translates to 136 Hz and from here it suffers attenuation, disappearing completely after the elbow.

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