

## DIAGNOSE EQUIPMENT SPECIALIZED IN VIBRO-ACOUSTICS

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**Rezumat.** Această lucrare prezintă o metodă de înregistrare și prelucrare de date utile, cu un echipament de diagnoză vibro-acustică în scopul de a le folosi în cercetarea și sarcinile de consultanță prestate de laboratorul Optimum. S-a realizat înregistrarea cu echipamentul Soundbook, apoi testarea și analiza vibrațiilor în vederea comparării și validării cu modele de calcul analitic sau numeric.

**Abstract.** This paper present a method to record and process useful data with an diagnose equipment specialized vibro-acoustics, in order to use them in the research and consultancy tasks provided by the laboratory Optimum. For the recordings of vibrations, were made using the Soundbook and tested vibrations recording on simple beam in order to compare result to finite element modelling and analytical calculation, then made a calibration with calibrator device.

**Keywords:** diagnosis, vibration, signal, dynamometer

### 1. Introduction

All installations or industrial structures are exposed to vibrations. The installation can be source of vibration or can suffer because of them.

Vibration analysis can be an interesting tool in predictive maintenance of production tools. We used vibration analysis in order to characterize the behavior of several machines in several operations. For measurement and analysis of dynamic phenomena, we use a range of equipment vibration. [2,3]

Soundbook is equipment for vibro-acoustic diagnosis, and is the equipment of laboratory CNCPST-Optimum from UPB.

### 2. Presentation of the equipment

The Soundbook is typically a tools adapted for industrial using. It's in fact a laptop, which integrate data acquisition card. The opposite table presents most important technical features.

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**Table 1.** Technical characteristics Soundbook

<i>Soundbook</i> <sup>®</sup>	<i>Octav</i>
Input channels	8x ODU-Triax
Accuracy according to IEC 651/804/61672	Class 1
Sensor power supply	ICP 2 mA
Sampling frequency	48.0 kHz 51.2 kHz
Tacho inputs	2
AUX/Tacho connector	1x LEMO2
Output channels	4 (2x LEMO3)

### 3. Vibration analysis

#### 3.1 Calibration

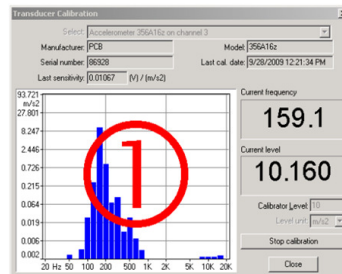
The previous tests have shown the accuracy of records frequency. Even if a calibration certificate is delivered with the accelerometer. We decided to repeat this important step because the accelerometer sensitivity wasn't given with the Soundbook device.

**Table 2.** Technical characteristics Calibrator.

<i>Signal shape</i>	<i>Displacement</i>	<i>Velocity</i>	<i>Acceleration</i>
Sinusoidal	10 $\mu\text{m}$	10 mm/s	10 $\text{m/s}^2$

Soundbook owns a transducer calibration function. The device detects automatically the calibration frequency and their current level. I set that calibrator acceleration is 10  $\text{m/s}^2$  and function calculate the new sensitivity.

It's important to notice: gap between last and new sensitivity and gap between detected frequency and real frequency are lower than 0.2%.

**Fig. 6.** Transducer Calibration



### 3.2 Tests

When we proceeded to vibration acquisition, the two most important things are frequency and amplitude vibrations.

In order checking records precision frequency, we suggested to:

- Test the vibration recording on simple beam (Soundbook + three axial accelerometer);
- Obtain results by the finite element modelling method (Catia);
- Obtain results by analytical calculation (Beam theory).

**Table 3. Validation measurements**

<i>Theoretical calculations</i>	<i>Analytical calculation</i> $f_n = \frac{R_n^2}{2\pi} \sqrt{\frac{E \cdot I}{\mu \cdot S \cdot L^4}}$	<i>Catia analysis</i> 
Experimentation (Soundbook)	4%	3%
Catia analysis 	2%	(Cell is shaded grey)

We can made the observations:

- First thing which is important to notice is the gap between analytical calculation and finite element modelling method. Even if the model used by the simulation is simple, Catia finite element module is not known for his accuracy. The other point, which can explain the gap, is the way that we had made restraint model.
- The other gap between experimentation and calculation can be explained by: we know that the beam is in steel but we don't know exactly the steel grade; restraint used to block the beam is not enough "strong"; finally, weight of the beam is not enough important in comparison with captor weight.

Following observations can be concluded: we decided to retry test in better conditions:

- Used a better solution to block the beam (Alstom power);
- Used beam with more weight;
- Making tests in order to know characteristic of the beam (Young modulus).

### 3.3 Experimental device

We mainly used the accelerometer with the Soundbook but not only. We also employed laser tachometer and laser vibrometer. A lot of projects refer to rotating machines. It's important to know which frequency match with the rotation velocity. With this device, no calibration was necessary. We only checked if the information given by the device was true.

Laser vibrometer is useful when you can't fix accelerometer on your target. In order to check the device, we made an installation (see Figure 3) with the accelerometer and the vibrometer.



Fig. 7. Installation with accelerometer and vibrometer

The record frequency was equal and I had notice a delay of 90° degree between the two sinusoidal signals. The amplitude of the calibrator was matching with the recording signal.

### 4. Processing data software

Processing data software were done with the following restraints:

1. Restraint "Using .Wav format" (signal importation) is due to the way that SAMURAI export data signal.
2. Restraints "GUI user-friendly" and "Software portability" are important because the software will be used for instance by students. The software had to be intuitive in order to be used without specific training. "Software portability" means that it can be installed on any computers.
3. Signal resizing

Tachometer: correlation with accelerometer signal;

Dynamometer: correlation with accelerometer signal;

Three dimensional representation;

Restraints are functions needed by the staff and not available on SAMURAI.

In order to satisfy all restraints, we made research and finely decided that we will program application in Matlab. Indeed, it's possible to code graphical interface and compile sources. It's also possible to import wav files.[1,4]

### 4.1 Wave

#### Wave application

We begun by made a tree with all the functions that I need to implant.

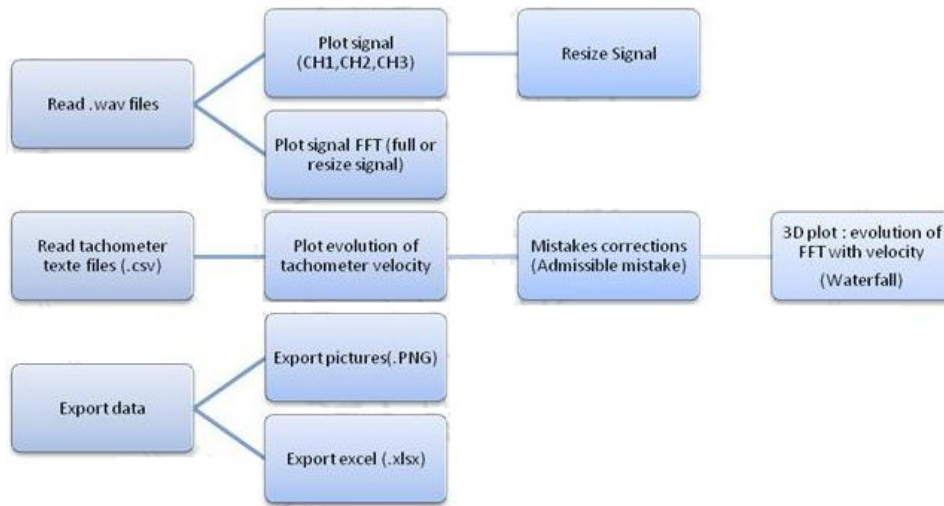


Fig. 8. Functions tree

Before implanting functions in graphical interface, we always wrote them in the command line of Matlab. The “Figure 5” presents the graphical interface of the Software

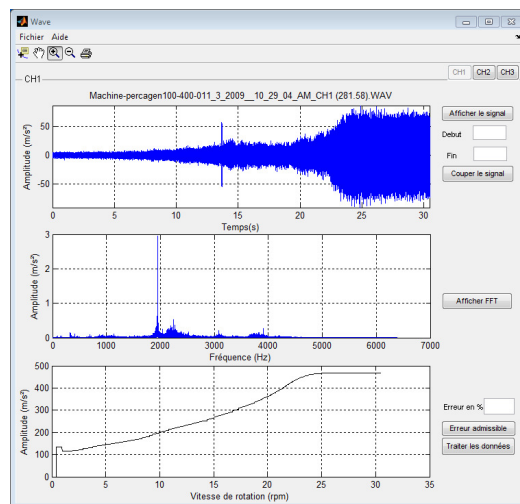


Fig. 9. Graphical interface

The Wave application is composed from three tabs, which match to acquisition canal (usually  $CH1 \rightarrow x$ ,  $CH2 \rightarrow y$ ,  $CH3 \rightarrow z$ ). Each tab is composed from three graphics, one for the acceleration, one for the FFT and the last one for the tachometer. All the functions mentioned in the tree functions are implanting in the software by means of push button or main menu.

### Occurred problem

The main issue that I occurred was when I developed the wav opening function. We were able to read the wav file but data that we got wasn't the same than the Soundbook data. It appears that the data was proportional but the coefficient of proportionality was not the same for each canal.

We understood that the coefficient was the sensitivity of the transducer.

### Code explanations

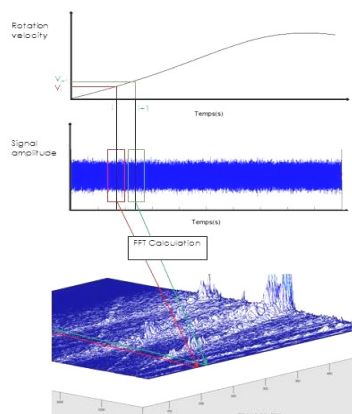
Most part of the code is comment. We had just taken one example with the waterfall. We chose this function because when we developed it, occurred different kind of issues due to:

- Data which are not generate by the same source
- Cash memories
- Convergence time
- Signal processing

The aim of this function is to plot in threedimensions, the signal FTT in function of the rotation velocity.

Because the data didn't came from the same source. We have to keep one scale time (the most small) in order to correlate data.

At each iteration, the FFT is calculating for one value of the tachometer velocity. I choose a step of 5 between two consecutive FFT because of cash memories problems. The following figure (see Figure 6) shows what append during two iterations.



**Fig. 10.** Waterfall function

## 4.2 Dynamometer

To developing the dynamometer software I have used the same base of code than for the wave application. The main differences was software have to open text files (.csv) and not wave files.

On the following picture (see Figure 7) you can see the graphical interface with the opening procedure for dynamometer files.

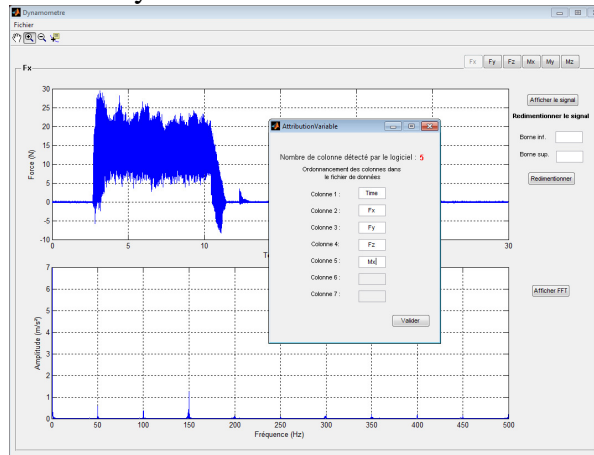


Fig. 11. Dynamometer

The windows entitled “AttributionVariable” is used to precise which column in the .csv file match witch which effort or torque.

## 4.3 Graph 2D/3D

To developing this application, I had used all the previous code. The aim of this application is to draw graphical figures where users can choose what they want in each axes.

**5. Case study:** Dynamic measurements on fiberglass materials processing. The main objective is to design machine tools in composite materials. What we have done there, is trying to determine the machinability of this material. We don't have just only measure the vibration, a recording of force and torque has been made too. The followings pictures present the acceleration time signal (see Figure 7) and the FFT of this signal (see Figure 8).

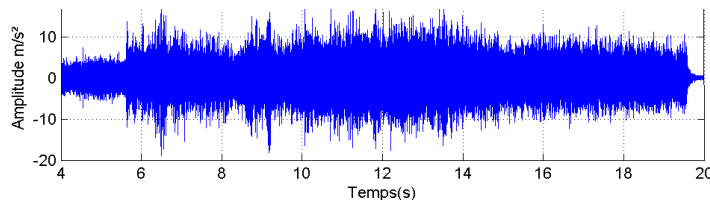
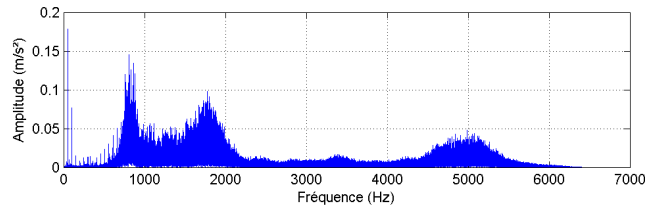


Fig. 12. Time signal



**Fig. 13.** FFT

### **Conclusion**

In this paper was made implementation of specialized applications for analysis to vibrations measured by equipment Soundbook.

These applications are integrated into a number of industrial uses, for NC machining quality analysis, maintenance of robots or machine tools and industrial equipment.

Were made a series of tests and measurements to identify quality measurement and system parameters.

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## **R E F E R E N C E S**

- [1] Ispas C., Baușic F., ș.a. - *Dynamics of machinery and equipment* (AGIR Publishing House, Bucharest, 2007);
- [2] Ispas C., Predinca N., ș.a. - *Machine tools, testing and acceptance* (Technical Publishing House, Bucharest, 1998);
- [3] Ispas C., Ionescu F., ș.a. – *Vibration machine tools* (I.P.B, Bucharest, 1985);
- [4] Matlab Program, <http://www.mathworks.com/products/matlab/>