

Practical work : Measurement techniques  
Measurement of the natural frequencies of a structure  
TP guide report



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## 2 Introduction and presentation

### 2.1 Objectives of the TP

The objectives of this practical work of measurements techniques are as follows:

- Be able to understand and use a method for measuring the transfer function of a mechanical structure.
- Know how to interpret the different representations of those transfer functions.
- Perform a analysis of the resonance frequencies of a structure.
- Understand the relation between resonance frequency and the distribution of mass in a structure.

The main points addressed in this TP are:

- Assembling the measurement setup.
- Selecting adequate settings for the measurements and justify your choice.
- Understanding the FRF (Frequency Response Function).
- Interpreting and extracting meaningful information.

### 2.2 Organization

This practical work is carried out in groups of 3 during the 4 periods at disposition for this purpose. The TP starts with an introduction and presentation of about 20-25 minutes. For the actual practical work, it is required to follow this guide step by step.

It is strongly recommended that you start writing the report directly during the TP, and that you divide the work equally among the members of the group. For example, each member should write a part of the report and perform at the very least one measurement. The final writing of the report can be done after the TP (you will maybe not have enough time during the TP to

complete the redaction). Note that a TP grade weighting **30%** is awarded during the session, based on your motivation, participation and interest and ability to work by yourself! The answers provided in the report will make the remaining **70%**.

The group report has to be downloaded from the web (Word template) and filled in directly with a computer, in English or French (please no hand writing!). The report must be sent at the latest 2 weeks after the TP by email to your assistant.

All the necessary documents for the practical work can be found on the web at:

<http://wiki.epfl.ch/me301-tdm/tpc>

During the practical session, a certain independence will be expected from you. Of course, the assistants are present to help you if necessary. Nevertheless, be aware that if you constantly require help to move forward through the TP, your grade will be influenced. Additionally, note that each group will work with a different structure, and therefore the measurements and results will differ from group to group.

### 2.3 Structure studied

The structure studied during the TP is one of the three available miniaturized plane wings of type NACA (Figure 1, Figure 2 and Figure 3).



Figure 1 : Wing of type NACA 3510, design 1



Figure 2 : Wing of type NACA 3510, design 2



Figure 3 : Wing of type NACA 3510, torsioned design

## 2.4 Approach

The approach adopted in this TP is as follows:

- Assembling the measurement setup (wing, hammer, accelerometer).
- Check the settings of the measurement software (*LabView*).
- Measurement of a frequency response function of a structure.
- Study and understand the effect of mass addition to the structure.

### Special precautions:

- Be careful not to drop the accelerometer! This equipment is expensive and very delicate.
- Do not step foot on the accelerometer cables!
- The hammer itself has integrated equipment, and is therefore delicate. It is not a hammer designed for banging nails!

## 3 Measurement system

### 3.1 Wing setup

#### **Warning!**

Before mounting the wings, beware because the wings are very edgy! Therefore, put on gloves and be very careful when handling the structures, in order to avoid cutting yourself.

#### 3.1.1 Suspended to the setup horizontal beam

For this configuration, you simply place two metallic wires through the 2 outer holes of the wing (no wire in the center hole) and then fix them around the suspended metallic bar of the setup.

#### 3.1.2 Clamped on one end to the setup horizontal beam

This configuration requires a little more work from your part. First, the wing is clamped between two counter parts specifically adapted and the assembly is held together with 3 M10 screws. Use washers in order to avoid applying pressure from the screws and nuts directly on the counter part (Figure 4). Then, the assembly is mounted on the plate with the help of 4 M8 screws (Figure 5). Finally, the whole setup is placed in front of the corresponding mounting points in the horizontal suspended bar and screwed in with 2 M8 screws on each side of the metallic plate.



Figure 4 : Wing assembly, step 1



Figure 5 : Wing assembly, step 2

### 3.2 LabView measurement software

All the measurements will be performed with the help of a *LabView* software. It presents itself as a panel of 4 different measurement tabs (hammer, accelerometer, FRF mag and phase, FRF real and imag) located below 4 control settings: Trigger level, Acquisition time, Sampling frequency and Frequency range.

The hammer and accelerometer tabs display the time and frequency responses from those devices.

Additional information on the different parameters will be given orally during the TP.

### 3.3 Hammer heads settings

At your disposition, you will have three different hammer heads: Aluminum, Teflon and Rubber. For choosing a suitable hammer head, you must take into account the hardness and impact duration of each configuration.

First, you mount the metallic hammer head, and observe the behavior of the time-domain and frequency-domain responses at different sampling rates. To do so:

- Get a measurement (hammer blow)
- Check the impact response (time domain)

In order to perform FFT of this time signal, the impact must be resolved accordingly. This means that we need enough sampling points for the impact. Additionally, a single impact is preferable than multiple impacts (the FFT will look more flat, see Figure 6)

Q1(a) What are the number of points that you have in your impulse for different sampling frequencies?

- Check the excitation spectrum (frequency domain)

Observe how the energy is distributed with respect to the frequency. You are going to notice the presence of a decaying response.

Q1(a) What is the maximum excitation frequency, with each sampling frequency?

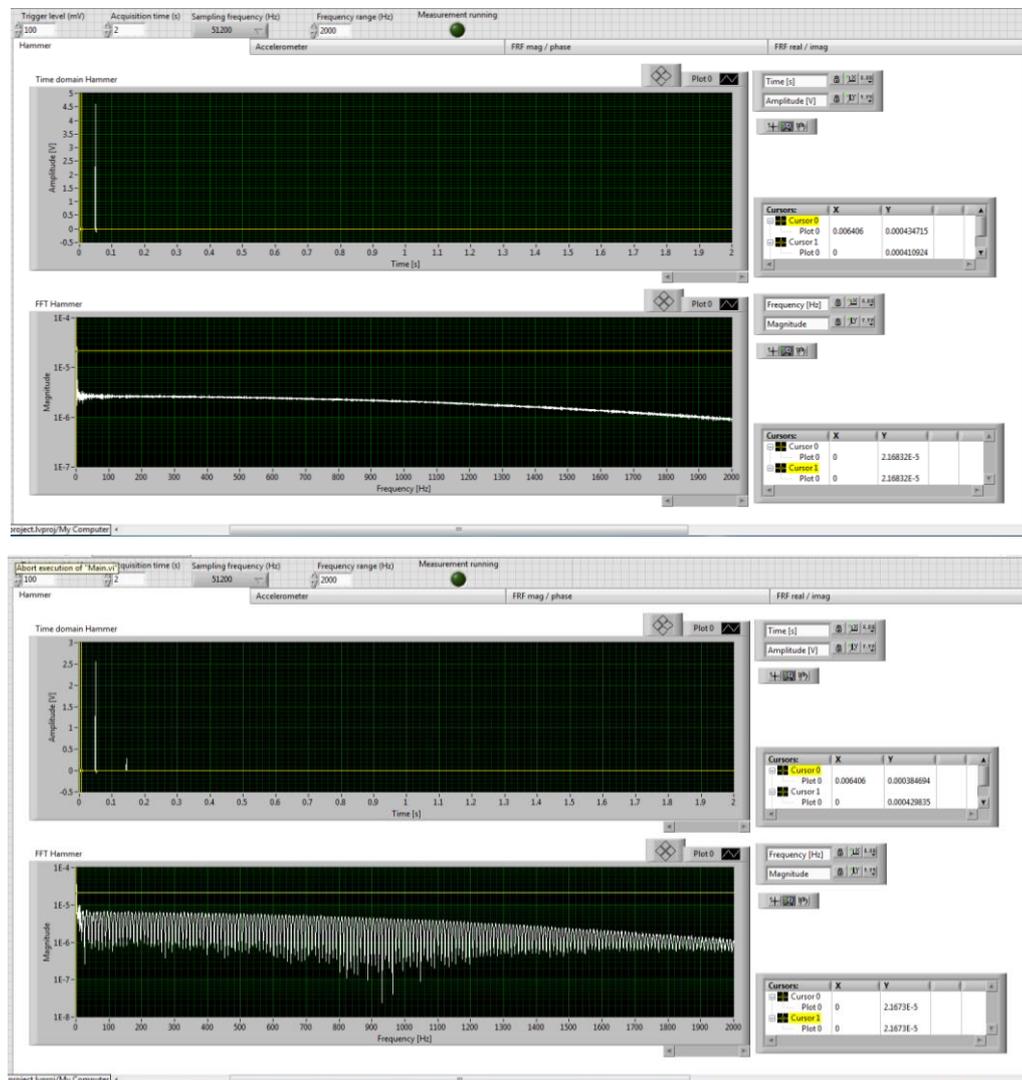


Figure 6(a,b) : Time and frequency response of a single and multiple impacts from the hammer.

Then, please change the hammer heads (rubber and Teflon), select the highest sampling frequency possible, and evaluate what are the number of points that you obtain in your impulse, as well as the maximum frequency of excitation (Q1(b)).

### 3.4 Accelerometer settings

An analysis by discrete Fourier transform lies in the fact the measured signals are periodic. In a vibration measurement, we need to carefully choose the acquisition time in order to have the suitable signal. In our case, as the acceleration of the structure (response from the accelerometer) is zero before impact, we simply need to wait long enough so that the acceleration is zero at the end of the sampling period. As a rule of thumb, we select an acquisition time such that the amplitude at the end of the sampling period is lower than 1% of the amplitude just after the impact. The response in time and frequency should look similar to Figure 7.

Q2. What is the minimum acquisition time required so that the signal amplitude is not more than 1% of the maximum amplitude at the end of the sampling period ? Explain how you obtain that value.

Q2(b) Are you actually going to use that minimum value, or a higher acquisition time ? Justify.



Figure 7 : Time and frequency response expected from the accelerometer on the structure.

## 4 Measurements

Now that the settings are done, we can move on to the actual measurements.

### 4.1 FRF of the structure

Now that the measuring system is correctly set for the case studied, we can start measuring the frequency response function (FRF). The Frequency Response Function is given by the ratio of the output (response of the wing) over input (response of hammer). In the software, the FRF is divided in two tabs. The first one shows the magnitude and the phase. The second one shows the real and imaginary parts. If you are not sure that a peak displayed in the magnitude plot is an effective resonance or not, a good thing to do is check the real and imaginary parts. That will give you confirmation of what you are observing. Figure 8(a,b) show examples of the graphs obtained for the FRF.

Q3(a,b). What are the first six resonance frequencies of the wing? Please include screenshots of your response function in the report.

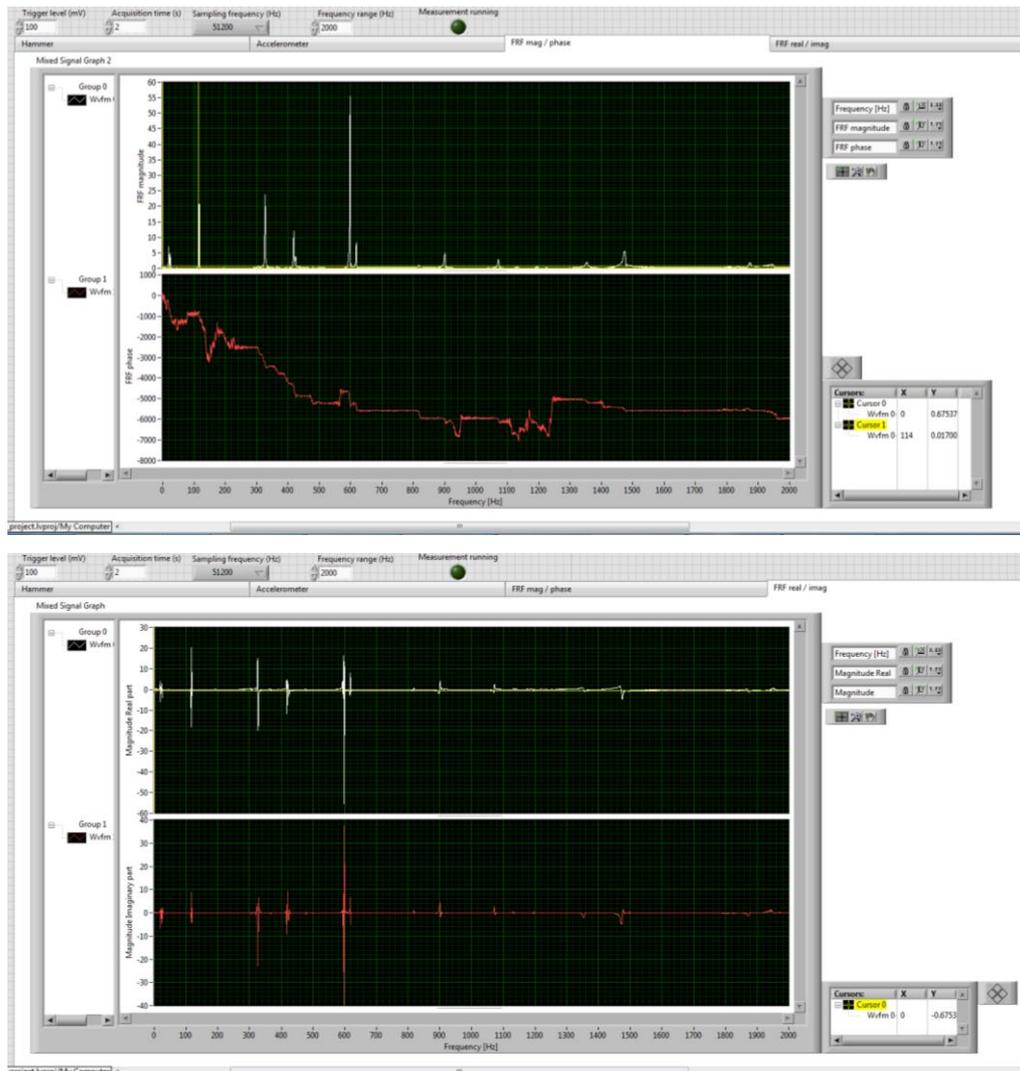


Figure 8(a,b) : FRF magnitude, phase, real and imaginary parts

## 4.2 Effect of a change of mass

As it is well known by the relation  $f_{\text{res}} \sim \sqrt{\frac{k}{m}}$ , the resonance frequency of a structure is inversely proportional to the square root of its mass. Adding a mass on that structure will therefore directly affect its resonance frequency. The position at which the mass is added also affects the resonance frequency, and this is closely linked to the mode shape. In this last part of the TP, we will try to show those effects.

From here on, each member of the group has to choose a mode of his choice and carry the analysis alone. Then, all group members share their results, summarize them, and answer the question as a group. Please report all your results in the answer sheet, but submit only one per group.

Q4(a) Hit the structure at each of the 9 points (marked with blue tape) along the wing and write down the magnitude of the FRF for the mode of your choice. Additionally, write down the resonance frequency of that mode.

Q4(b) What do you conclude from the data you have collected?

Now, normalize the magnitudes at the different points by dividing each value by the magnitude obtained for point 1.

Q4(c) Add a mass (5 magnets together) at each of the 9 points successively and write down the resonance frequency  $f_m$  of the same mode as before. After that, calculate the normalized difference in frequency  $\frac{f_m - f_0}{f_0}$  for each point, with  $f_0$  being the resonance frequency of the wing without added mass, as in Q4(a).

**Note :** for this part, you have to hit the structure at point 1 for all 9 measurements.

Q4(d) What relation can you extract from your experiments? You should add graphs, drawings, etc...