WoodMusICK

FPS COST Action FP1302

Short-Term Scientific Mission

Scientific Report

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STSM period: 7th-19th February 2016

From University of Belgrade (Serbia) to Edinburgh Napier University (UK)

Date of report: 17th March 2016

Purpose of the STSM

Purpose of this Short-Term Scientific Mission is to determine whether, and to what extent, prolonged exposure to vibration, and changes in moisture content, may affect the characteristics of wood. The main motive was to determine whether the non-uniform distribution of stresses due to the prolonged vibrations, at a resonant frequency, can lead to change in the vibroacoustic characteristics of wood specimen.

It is necessary to determine the period of time that is long enough for vibrations to make changes in wood structure, and to see how that period can be shortened by changing and controlling environment conditions. Samples excited with vibrations will be scanned with microphone while vibrating. By scanning samples with their initial moisture content in Very Near Field (microphone distance from sample must be less then 5 mm) Eigen modes of specimens will be recognized. Shakers, which will excite wood samples, must be adjusted to frequency of flexural modes. After every prolonged exposure to vibrations, vibroacoustic characteristics of specimens must be assessed by scanning in VNF. Repeat vibration treatment and assessment cycle for different parameters (frequency of excitation, period of excitation, moisture content, orientation of specimen etc.). Finally, specimens should be divided into segments and measure moisture content within them by the gravimetric method.

The Centre for Wood Science & Technology is perfect place for these experiments, primarily because of their knowledge in mechanical properties of timber. Also, possession of an apparatus for controlling the condition of timber samples will enable different measurements. People involved in this experiment were: Filip Pantelić, scientist on the STSM, Dan Ridley-Ellis, scientist at the host institution and Mélanie Libeau, intern scientist at the host institution (from Ecole Nationale Supérieure des Sciences Agronomiques de Bordeaux-Aquitaine, France)

Work carried out and the main results obtained during the STSM

Prior to STSM

- Planning of the experimental work, determining the samples required.
- The host institution obtained the samples, conducted initial measurements, prepared the equipment and conditioned the samples.

Sunday, 7th February

- Checking the measuring equipment after arrival.
- Working on matlab code for the measuring routine.

Monday, 8th February

- Sharing ideas and analyzing results obtained prior STSM beginning. Discussing about Very Near Field (VNF) measurements, Comsol simulations, Impulse excitation method, Ultrasonic measurement of relative longitudinal, radial and tangential modulus of elasticity, and FEM model analysis. Trying to modify all methods to match each other so we could compare results obtained from different methods.
- Sample preparation and checking the conditions (humidity, temperature). All samples came from the same strip (almost certainly Pinus sylvestris). They were cut in series in the longitudinal direction. Sample 1 next to Sample 2, Sample 2 next to Sample 3 etc. Small dimension of cross section is radial and large dimension of cross section is tangential.
- Ultrasonic measurements of relative modulus of elasticity are obtained with Pundit Lab, 54 kHz ultrasonic pulse velocity (UPV) test instrument.

	s2	s6	s7			
2:30pm	15.935	16.035	16.057	g	mass before measurement	
2:50pm	15.888	15.984	16.013	g	mass after measurement	
	0.29%	0.32%	0.27%		change in mass during measurement	
Pundit, 54 kHz						grain direction
length	46.50	45.50	45.00	microseconds	time of flight	longitudinal
width	12.00	11.50	12.50	microseconds	time of flight	tangential
thickness	4.00	4.00	4.50	microseconds	time of flight	radial

Length	247.63	247.37	247.83	mm
Width	17.72	17.64	17.61	mm
Thickness	6.18	6.25	6.24	mm

Speed of sound

longitudinal	5.33	5.44	5.51	km/s
tangential	1.48	1.53	1.41	km/s
radial	1.54	1.56	1.39	km/s

Speed of sound squared

longitudinal	28.36	29.56	30.33
tangential	2.18	2.35	1.98
radial	2.38	2.44	1.92

Ratio of E

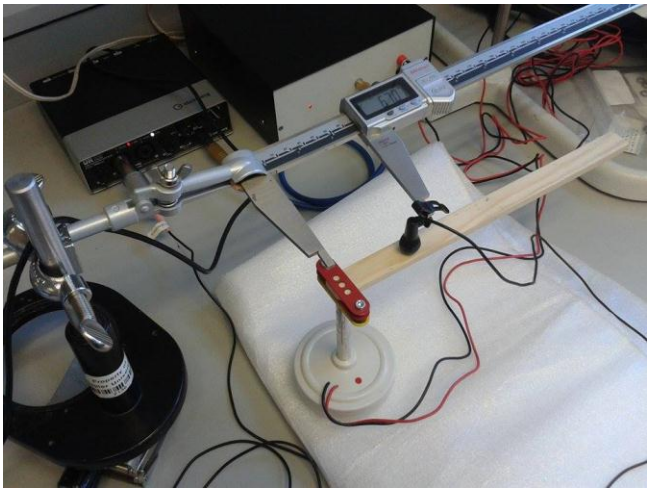
longitudinal:tangential	13	13	15
longitudinal:radial	12	12	16

Table 1. Ultrasonic measurement of relative longitudinal, radial and tangential modulus of elasticity

- Discussing about new questions and goals.

Tuesday, 9th February

- Sample fixing problem for VNF measurements was solved using a metal clamps. Previously we had to drill a hole in wood sample to attach it with bolt to shaker. Using a clamp drilling a hole in the sample was avoided and now it's possible to attach sample in different points (not only where hole is drilled). Measuring microphone, attached to digital caliper, gives a possibility to know exact place of the measuring point while sliding above vibrating sample. Modification gave the possibility to measure in mm space resolution.
- Daily measurements of humidity, width and length of the samples.
- Modifying matlab code to work with a new (higher) space resolution
- Preparing shakers (speakers) for working (vibrating wood samples) in climate chamber. Solving technical problems like implementation of cables in the climate chamber (20 C and 65% RH) for power supply and audio signals.



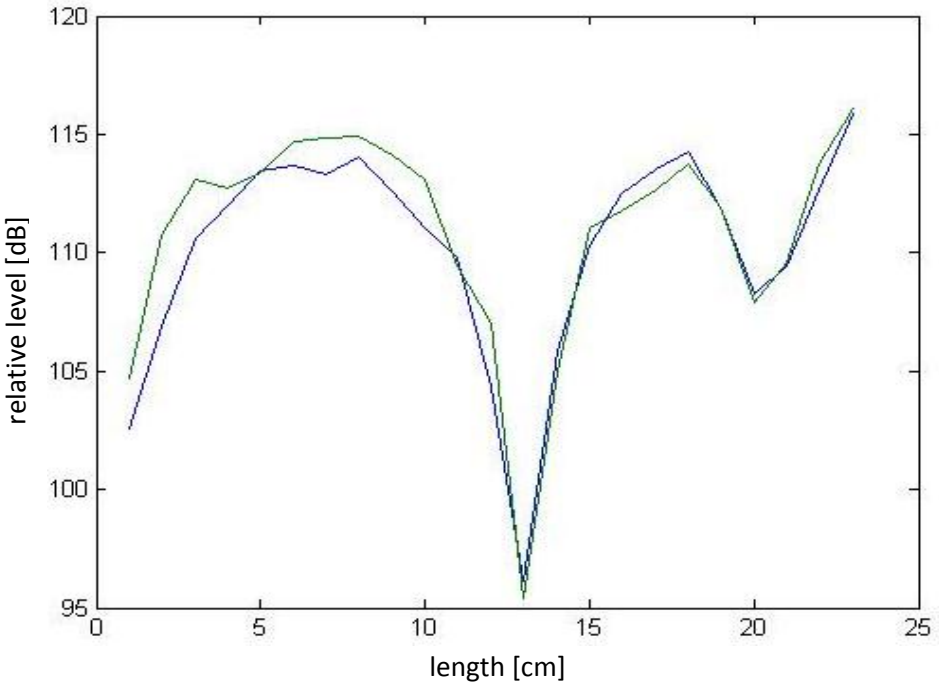
Picture 1. Left: Equipment for measurement in VNF, Right: Samples in climate chamber

Wednesday, 10th February

- First VNF Measurement with Sample 1. This sample is one of eight samples that will be used in this experiment. Sample 1 is used for mode identification and setting of system parameters before the beginning of the experiment.
- Daily measurements of mass, width, thickness and length of the sample. Three samples (Sample 2, Sample 6 and Sample 7) have most similar characteristics so they will be tested in first experiment.
- Problem with calculating the Q factor – different approaches gives different results.
- Test measuring with Grindosonic, instrument for the non-destructive measurement of the elastic properties of materials linked to a Picoscope 4224, a digital oscilloscope.
- Identification of vibrating modes of Sample 1 using Chladni patterns. Identification of modes using VNF recordings. Comparing of the results with FEM simulations.

Picture 2. Chladni pattern on vibrating sample (combined flexural vibration, about both minor and major axis, and torsional vibration)

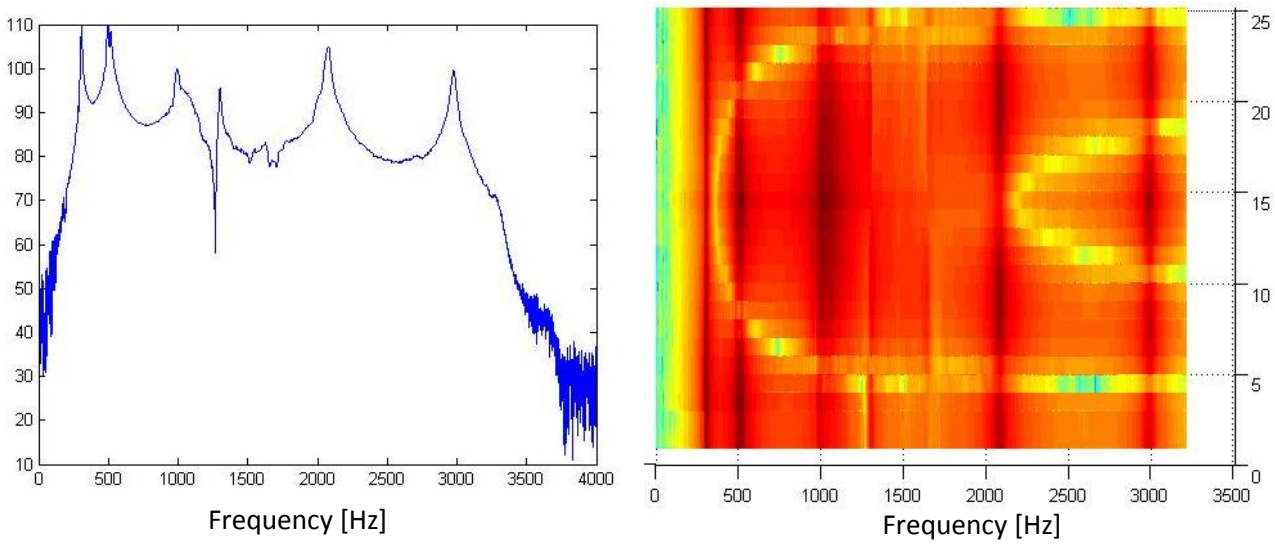
- Problem with sound level of exciting shakers. Higher level causes the distortion and appearance of harmonics. Adjusting the level to minimize this effect.
- Setting up the matlab code for VNF and testing repeatability with Sample 1.
- Determining the optimal level of excitation. Low level makes no distortion, but with more energy graphs from VNF are better.



Picture 3. Repeatability for measuring a distribution of sound pressure level over vibrating sample @ 1282 Hz

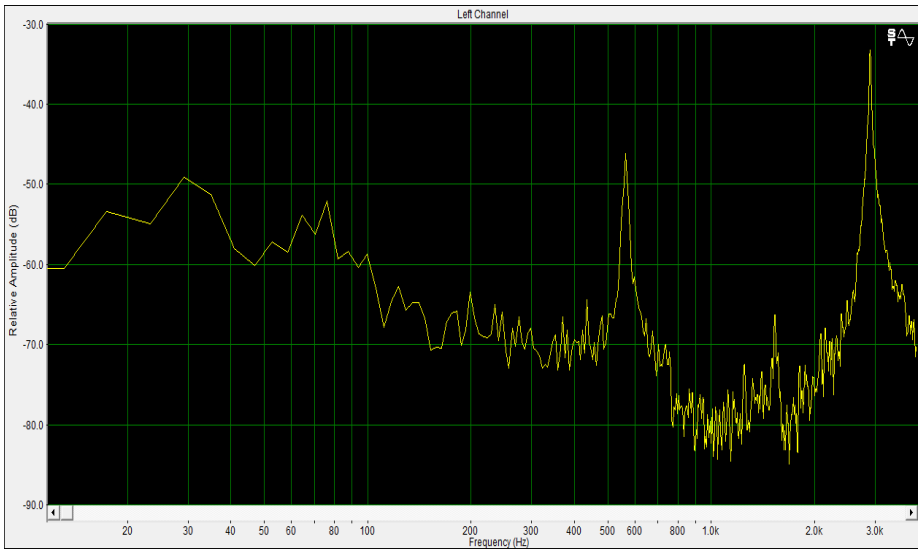
Thursday, 11th February (d1)

- Day 1 (d1) of the first experiment with Sample 2 (s2), Sample 6 (s6) and Sample 7 (s7).
- Daily measurements of mass, width and length of the samples.
- Measurements in VNF with samples s2, s6, s7. Excitation, during the measurements, will be from now on attached in the middle of the sample. Two measurements (m2) are carried out for all three samples in 25 points (1 cm resolution)
- Due to the observed non-linearity measurement excitation should be precisely adjusted to avoid that effect. Output voltage of 8V is determined as optimal for running a shaker.



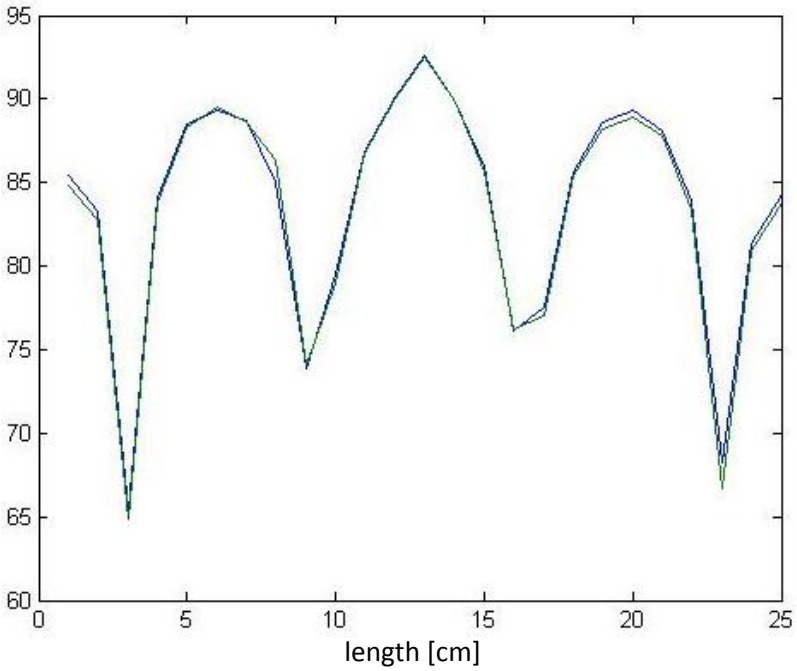
Picture 4. Measuring in VNF. Left: Spectra - identification of vibrating modes for sample s7, Right: Space distribution of sound pressure level along vibrating sample for all analyzed frequencies for s7

- Measurements of s2, s6, s7 with impulse excitation



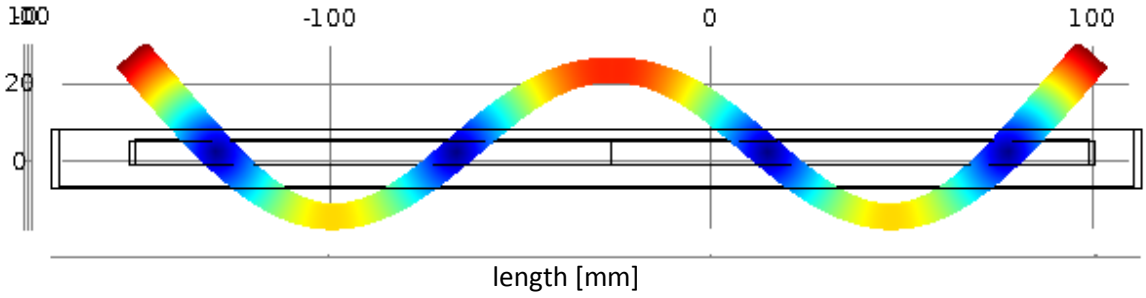
Picture 5. Spectra of impulse response for flexural vibration modes about the minor axis for Sample 7 (s7)

- Discussing and comparing results of two methods. Picking excitation frequencies for samples from obtained spectra avoiding combined modes. Sample s2 will be with out of excitation (control sample), s6 will be excited with 537 Hz (first mode of flexural vibration about the minor axis) and s7 will be excited with 2887 Hz (third mode of flexural vibration about the minor axis).



Picture 6. Distribution of sound pressure level over vibrating sample s7 @ 2887 Hz obtained with VNF measurement. Repeatability for two measurements (green and blue line)

- Vibrations in climate chamber for s2, s6 and s7 are turned on at 16:15
- Adjusting the level of excitation in climate chamber to make sure that batteries are charging faster than discharging.
- FEM simulation for new exciting conditions (attached in the middle of the sample)

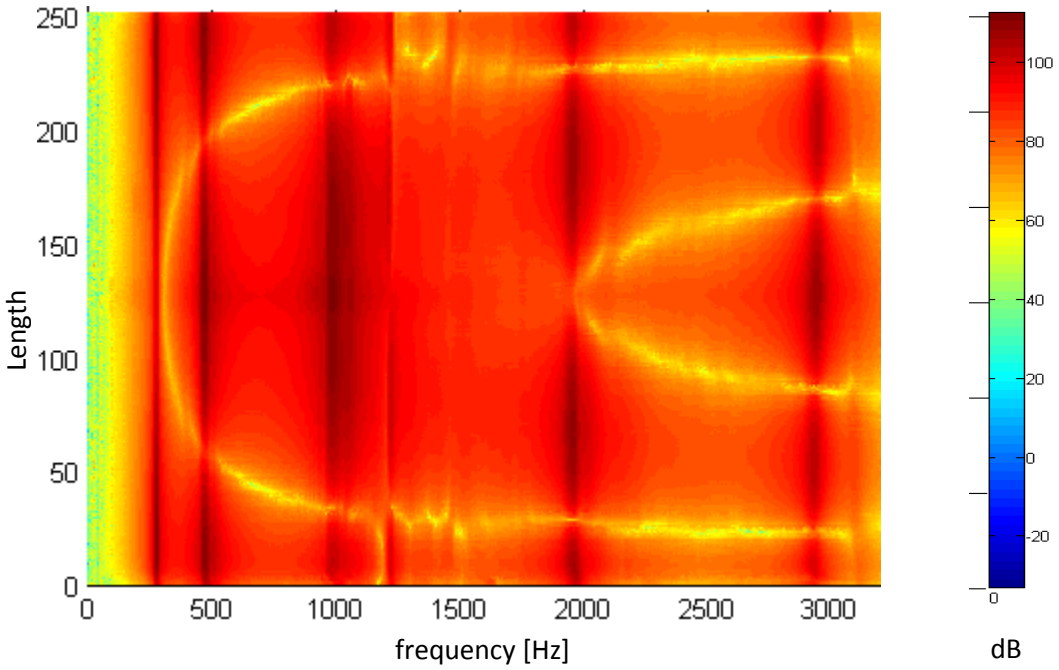


Picture 7. FEM simulation for excitation attached in the middle of the sample for 2887 Hz

- During the measurements moisture content of sample drops by 1% of moisture content. Measuring procedure should be faster.

Friday, 12th February (d2)

- High resolution (1 mm steps) measurement in VNF with Sample 1 (s1).

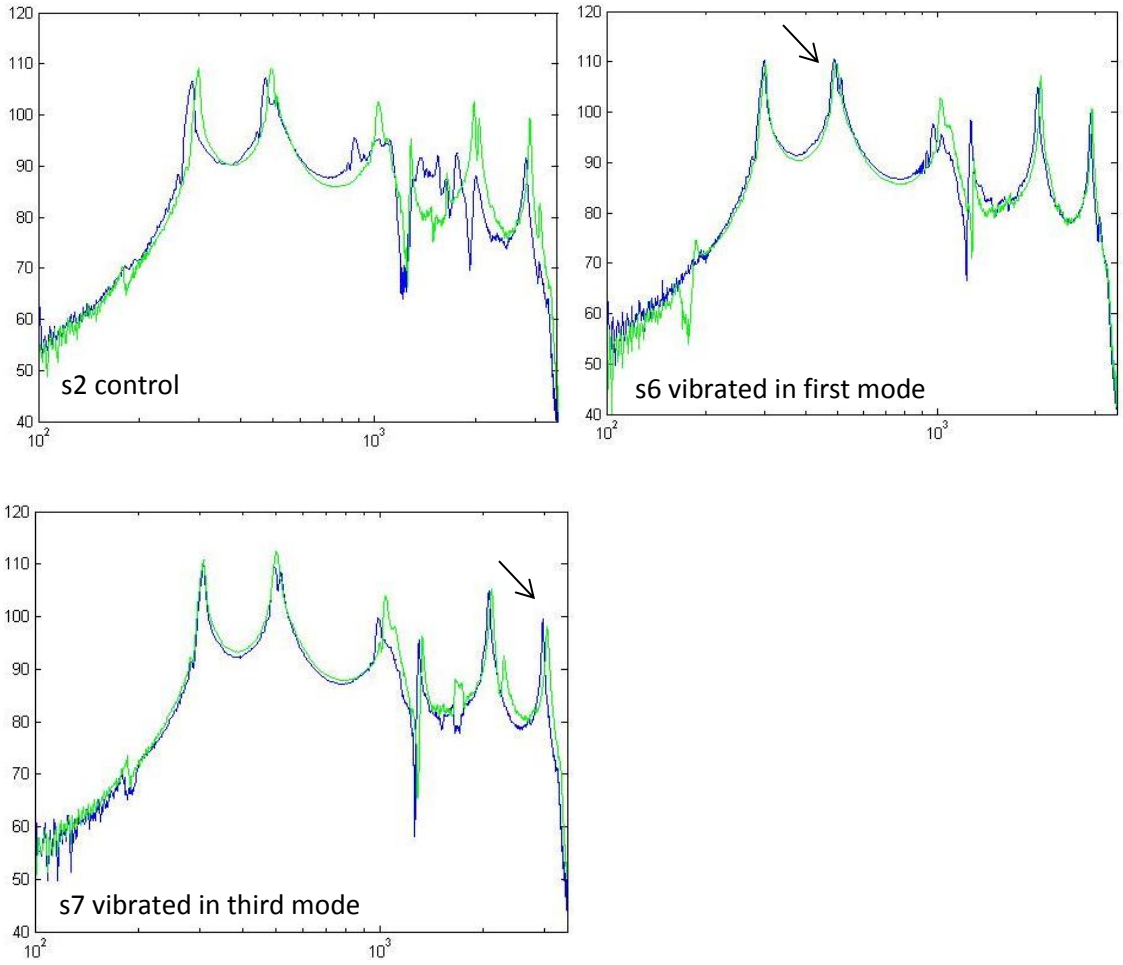


Picture 8. Space distribution of sound pressure level along vibrating sample for all analyzed frequencies for s1 (1 mm resolution) recorded in VNF

- Measurements of s1 with FLIR thermal camera after 20 min of vibrating on 472 Hz shows that there are no discernible changes in surface temperature distribution due to the sample vibrations (i.e. that might be caused by energy dissipation from the damping).
- Daily measurements of mass, width and length of the samples s2, s6 and s7.
- Measurements in VNF with samples s2, s6, s7 after 20 hours of constant vibrations in climate chamber
- Measurements of s2, s6, s7 with impulse excitation

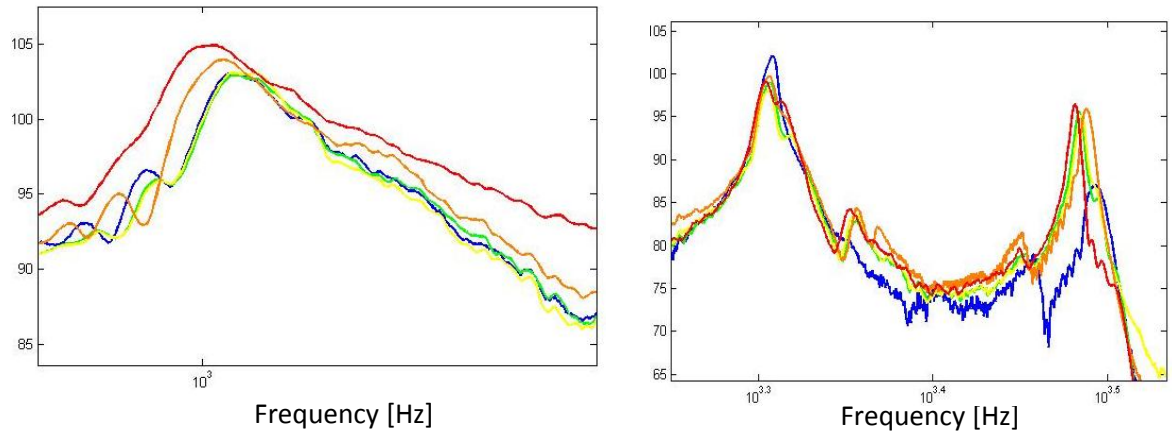
Monday, 15th February (d5)

- Daily measurements of mass, width and length of the samples.
- Measurements in VNF with samples s2, s6, s7 after whole weekend of constant vibrations in climate chamber
- Measurements of s2, s6, s7 with impulse excitation



Picture 9. Vibrating modes for samples s2, s6 and s7 recorded in VNF: blue-first day (d1), green - fifth day (d5); Changes in resonances are noticed but mostly with control sample; arrow shows area of exciting frequency

- Measurement apparatus has been modified to speed up the process of scanning in the VNF (new stands, rubber pad to prevent slipping and sponge for damping unwanted vibrations).
- New experiment with Sample 5 (s5). From 14:15 s5 will be out of the chamber to dry out to study the effects of moisture content on the measurements. Its mass was 15.557 g. Initial measurement was made in VNF. It was measured also in 15:00, 15:35 (15.307 g), 16:01 (15.274 g). At 16:34 its mass was 15.240 g. Relative humidity in room was 33%.



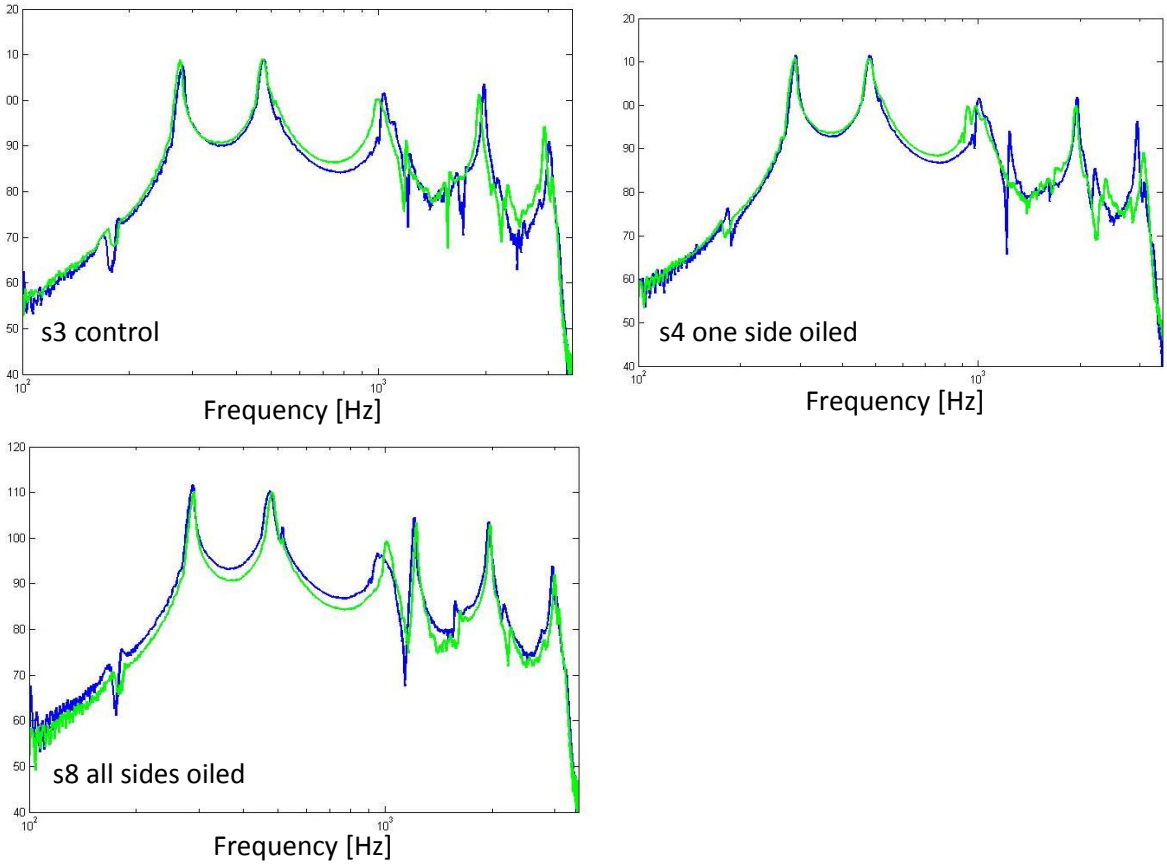
Picture 10. Drying of sample s5 (blue 14:15, green 15:00, yellow 15:35, orange 16:01, red 16:34); Losing mass (humidity) leads to lower resonances but not equal for all mods

Tuesday, 16th February (d6)

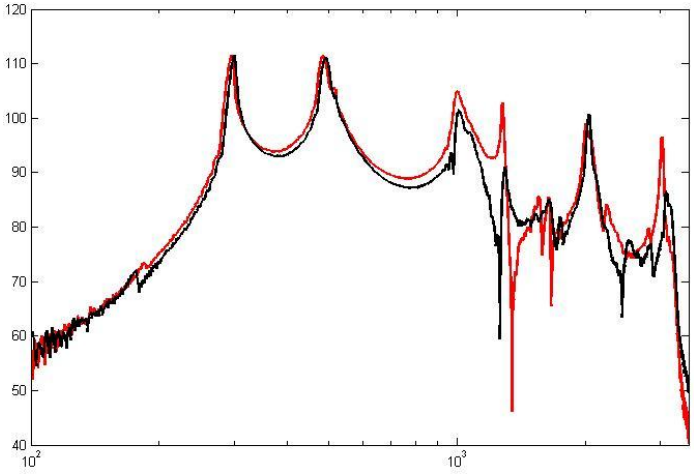
- Sample 5 (s5) was left to dry over the night. It was measured again in VNF at 10:20 and its mass was 14.938 g
- Daily measurements of mass, width and length of the samples.
- Measurements in VNF with samples s2, s6, s7
- Measurements of s2, s6, s7 with impulse excitation
- New experiment with Sample 3, Sample 4 and Sample 8 (s3, s4, s8). Samples will be treated with furniture oil – from all sides (s8), from one side (s4), untreated control sample (s3). All samples will be left outside of climate chamber. Speculate that the oil will slow the process of drying from treated side and there may be a different effect on the vibration response. Initial measurements of samples s3, s4 and s8.

Wednesday, 17th February (d7)

- Measurements in VNF with oil treated samples s3, s4, s8 after whole night out of the climate chamber, measured at 10:00
- Measurements of mass, width and length of the samples s3, s4 and s8.
- Measurements of s3, s4, s8 with impulse excitation
- Measurements in VNF with vibration treated samples s2, s6, s7 at 10:30
- Measurements of mass, width and length of the samples s2, s6 and s7.
- Measurements of s2, s6, s7 with impulse excitation
- Measurement of drying sample s5 in VNF at 14:00
- Second (b) measurement in VNF with oil treated samples s3, s4, s8 at 16:50



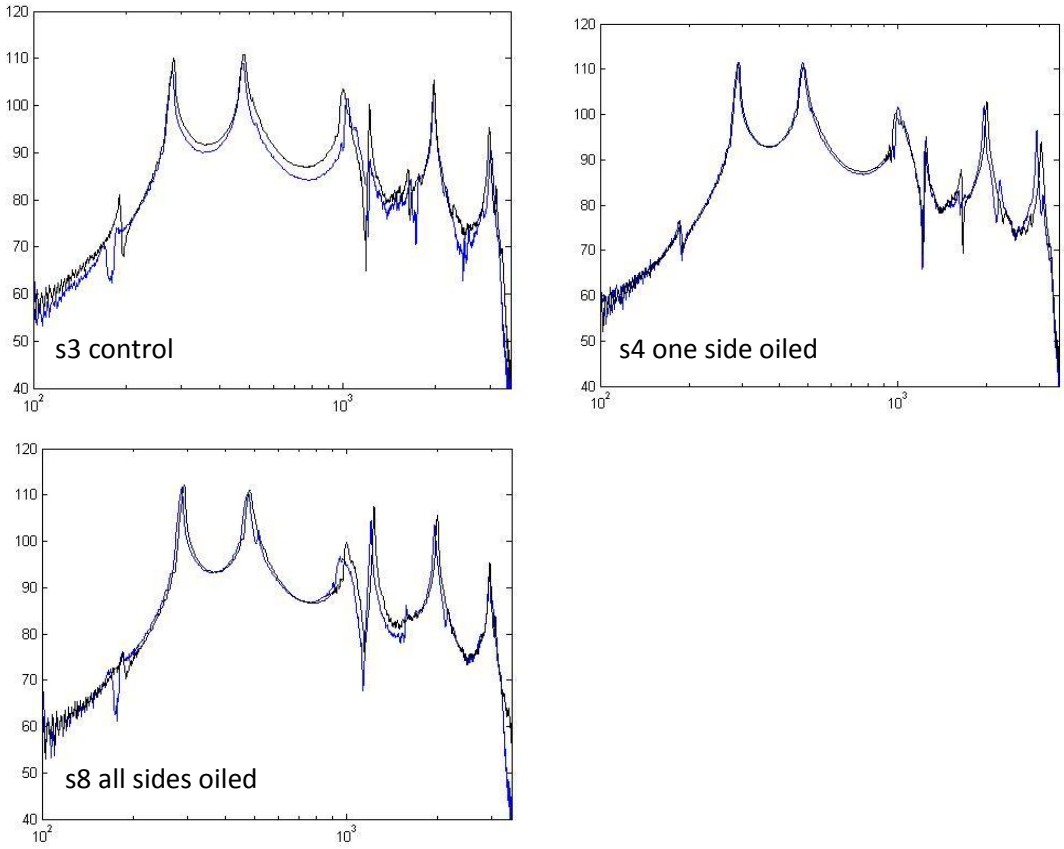
Picture 11. Measurements in VNF with oil treated samples s3, s4, and s8. Blue – first day of oil experiment (d6); Green - after whole night out of the climate chamber (d7); Third peak changed with all three samples, s3 and s4 decreased, s8 increased



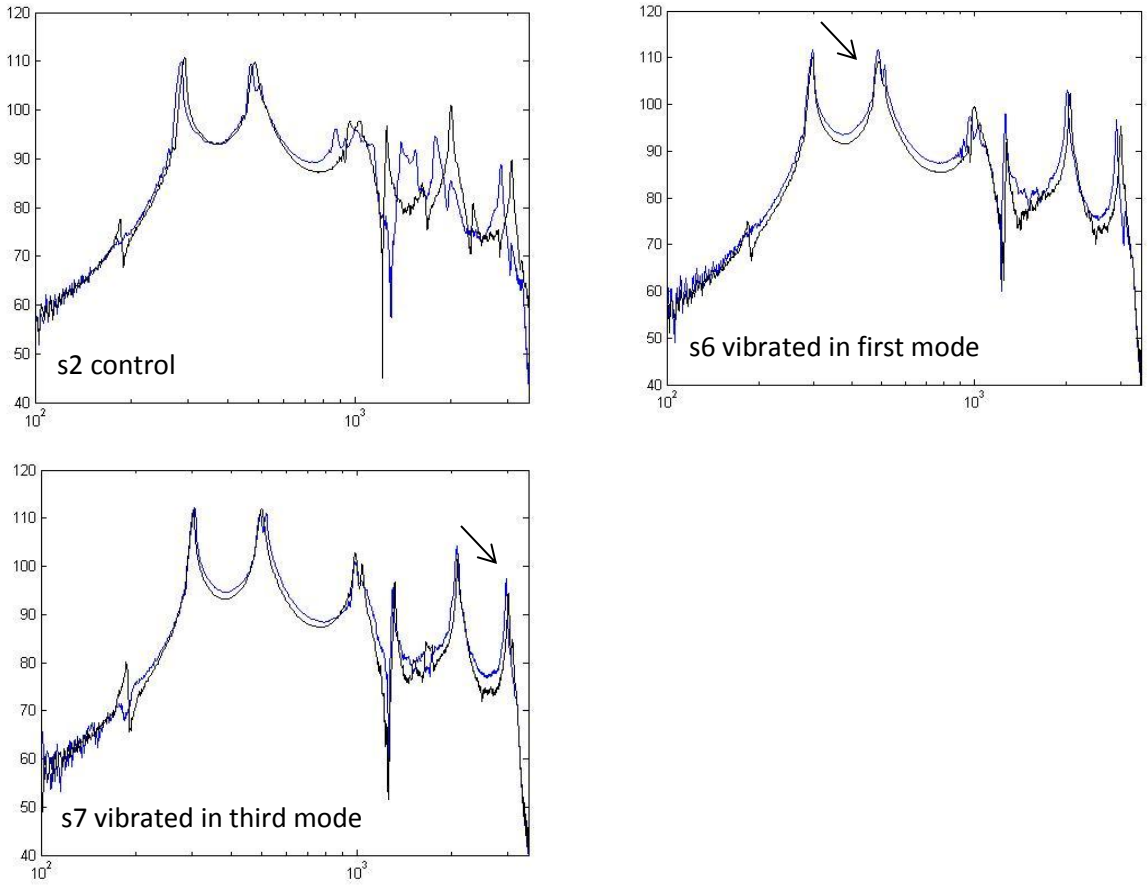
Picture 12. Further drying of sample s5: Red - d5 16:34 , Black - d7; The first few hours of drying brought major changes comparing to further drying shown in this graph

Thursday, 18th February (d8)

- Measurements in VNF with oil treated samples s3, s4, s8
- Measurements of mass, width and length of the samples s3, s4 and s8.
- Measurements of s3, s4, s8 with impulse excitation
- Measurements in VNF with vibration treated samples s2, s6, s7
- Measurements of mass, width and length of the samples s2, s6 and s7.
- Measurements of s2, s6, s7 with impulse excitation
- Visit to Jonathan Santa Maria Bouquet, Conservator of Edinburgh University's musical instrument collection
- Visit to Murray Campbell, Professor of Musical Acoustics in the School of Physics and Astronomy at the University of Edinburgh.



Picture 13. Measurements in VNF with oil treated samples s3, s4, s8. Blue – first day of oil experiment (d6); Black – last day of measurement (d8); No significant changes.



Picture 14. Measurements in VNF with vibration treated samples s2, s6, s7. Blue – first day of vibration experiment (d6); Black – last day of measurement (d8); some changes exist with vibrating samples s6 and s7, but also with non vibrating sample s2; arrow shows area of exciting frequency

Friday, 19th February

- Discussing the results and planning further experiments

Future collaboration with host institution

During this STSM we succeeded to examine influence of prolonged exposure to vibration and changes in moisture content to the characteristics of wood. There is no indication of changes in vibration frequency response (including damping) due to the prolonged vibration. It might be that the changes are very small and that the analysis needs to be more thorough. Changes are spotted in every sample, but we couldn't say that we find some trend in those changes. Sources of experimental error have to be eliminated for final results. After the end of this STSM

experiment did not stop. All data is preliminary and the work is still ongoing. By this day samples are still vibrating in the climate chamber.

In the end it was also planned to divide samples into segments and measure moisture content within them by the gravimetric method. According to the results (no indication of changes in vibration frequency response) we changed plans during this STSM and we started some new experiments (drying sample, oil experiment). Plan is to test some more wood treatments and their influence on vibroacoustical properties of wood. Comparing of VNF method and impulse excitation, nonlinearity in excitation, damping factors calculation are some of questions that will be examined in the future. In the future we will carry on the experiments and we will continue to discuss the results. The objective is to produce a collaborative paper on the work.