FACULTY OF MECHANICAL ENGINEERING — institute of solid mechanics, mechatronics and biomechanics

Experimental mechanics (REM)

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Elaboration date:	17.1.2019	
Assigment name:	**Bent beam**	
Supervisor	Ing. Petr Krejčí, Ph.D.	Evaluation:

Assignment

Determine natural frequency of unilateral one-side fixed beam activated by impulse of force.

1. Experimentally
2. Numerically

Later identify damping in form of logarithmic decrement and depict sag line.

Experiment

Overview

The experiment was performed on apparatus shown below (see fig. 1). There was 16 strain gauges glued at appropriate places (see fig. below). Strain gauges were wired in 1/4 Wheatstone bridges. Used strain gauge amplifier was HBM QuantumX MX1615B.

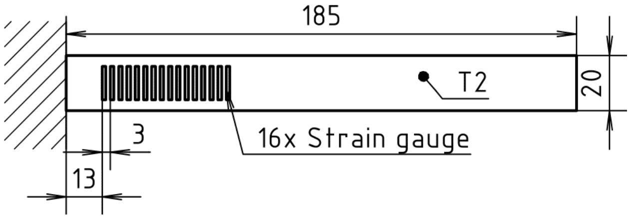


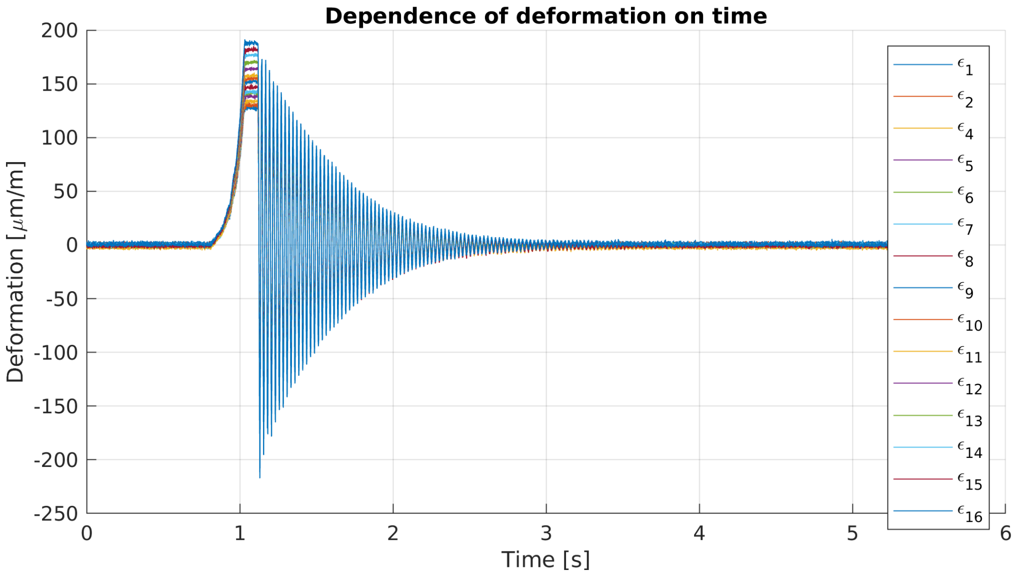
Figure 1: Beam dimensions

Parameters

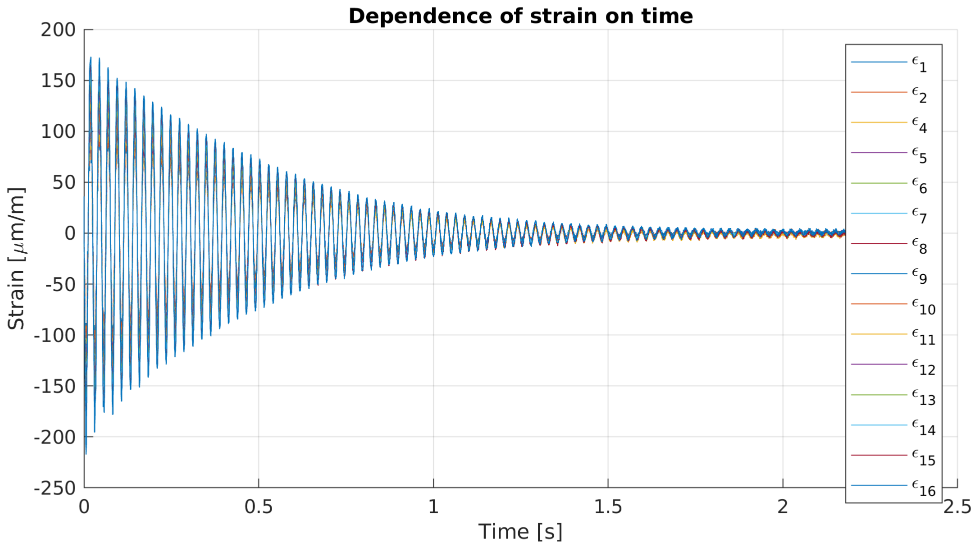
All needed dimensions of rod are evident from figure 1. Edge-to-edge limit of bending is 7 mm due to endstops.

Measurement

Data was measured by 16 strain gauges, but strain gauge no. 3 returned invalid data so final number of strain gauges is 15. Data had to be pruned to be usable due it's nature.



(a) All data



(b) Usable data

Figure 2: Measured data preview

Calculation

Experimental solution

Firstly experimental data were treated. That meant performing `fast fourier transform` (FTT), followed by FEM model done in ANSYS to compare.

To obtain natural frequency of beam, data were treated with FFT algorithm (see fig. 3).

By analysing data returned by fft(), we got natural frequency of beam:

$$f_1 = 39.23\ Hz$$

There were evaluated data from strain gauges 1 and 10 just to show that natural frequency does not differ for whole beam – just amplitude is changing.

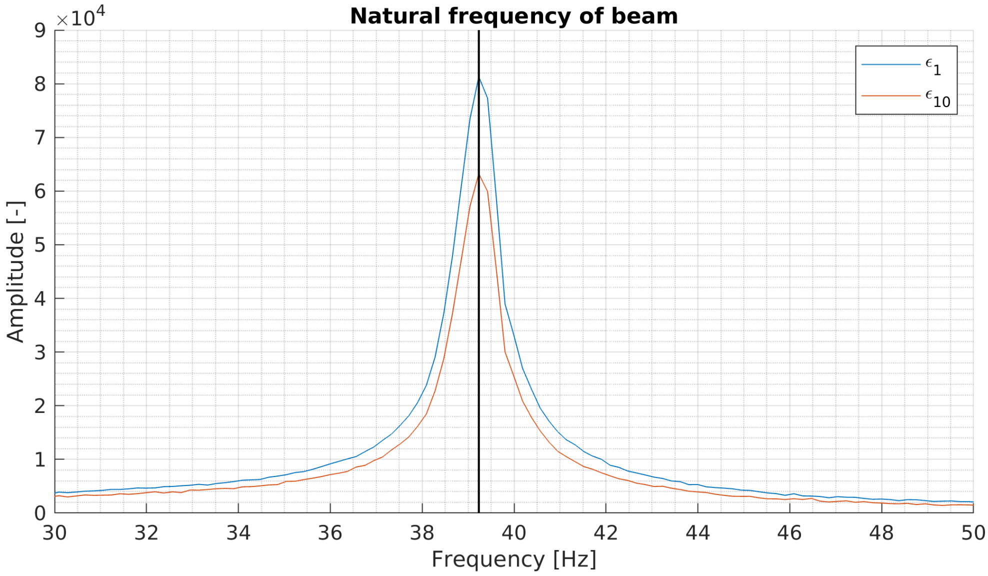


Figure 3: FFT - Natural frequency of beam

FEM solution

Ansys model was created according to figure 1. Choosen material was structural steel with $E = 210\ GPa$ and $\mu = 0.3$. Modal analysis was evaluated and natural frequency gathered.

$$f_1 = 49.277\ Hz$$

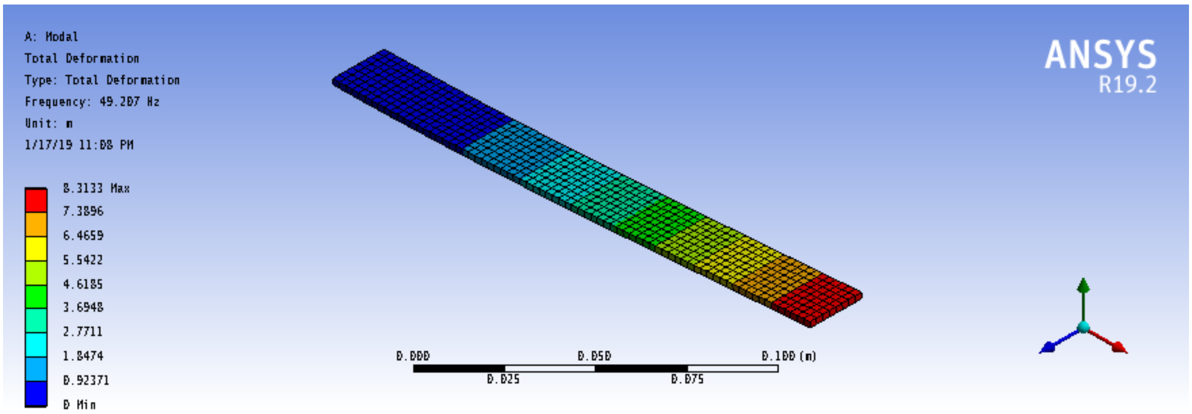


Figure 4: Results of modal analysis − beam deformation

Damping in form of logarithmic decrement

Logarithmic decrement ϑ is used to determine damping b. For its calculation strain gauge 1 is used according to equation below:

$$\vartheta = \log \frac{\epsilon(t)}{\epsilon(t+1)}$$

From all available peaks (see fig. 5), only 5 consecutives were secelcted to calculate logarithmic decrement.

Selected decrements:

$$\vartheta_1 = 1.13 \quad \vartheta_2 = 1.22 \quad \vartheta_3 = 1.09 \quad \vartheta_4 = 1.95 \quad \vartheta_5 = 2.84$$

Damping b is calculated from logarithmic decrement ϑ according to equation below:

$$b_i = \frac{\vartheta_i}{T}$$

Where T is period calculated from natural frequency:

$$T = \frac{1}{f_1} = \frac{1}{39.23} = 0.0255\ s$$

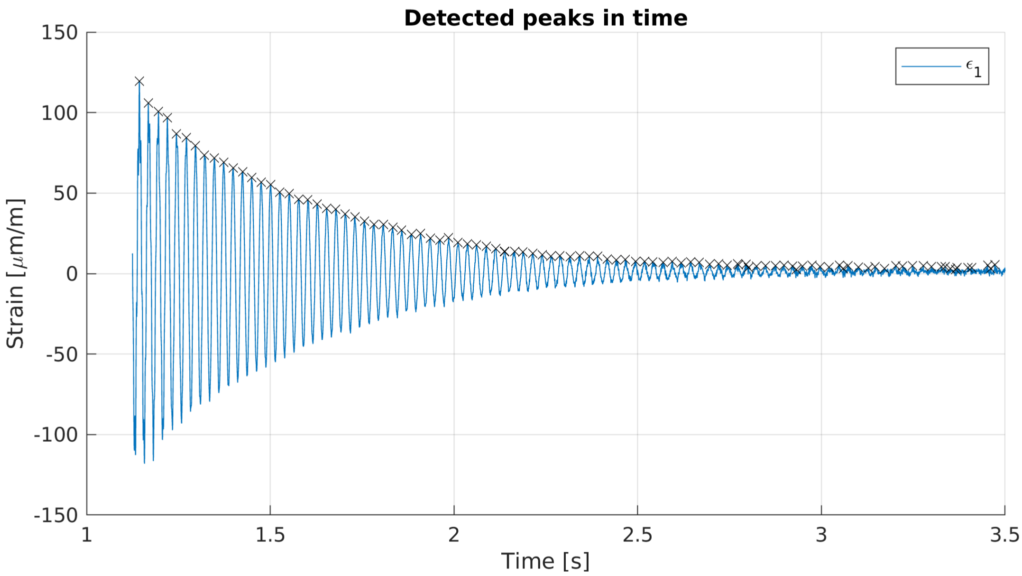


Figure 5: Results of modal analysis − beam deformation

Sag line

Sag line was calculated according following equations:

$$w''(x) = -\frac{M_o}{E*J} = -\frac{\sigma_o * W_o}{E*J} = -\frac{E*\epsilon*\frac{2*J}{Th}}{E*J} = -\frac{2*\epsilon}{H}$$

$$w'(x) = \int w''(x)dx = -\frac{2*\epsilon*x}{Th} + C$$

$$w(x) = \int w'(x)dx = -\frac{\epsilon*x^2}{Th} + C*x + D$$

Where Th is thickness of beam and C and D are contants expressible from boundary conditions. For fixed supprort:

$$w(0) = 0$$
$$w'(0) = 0$$

Therefore:

$$C = 0$$
$$D = 0$$

Resulting equation has form:

$$w(x) = -\frac{\epsilon * x^2}{H}$$

and is used to depict sag line by finding it's points for each used strain gauge followed with approximation – see figure 6.

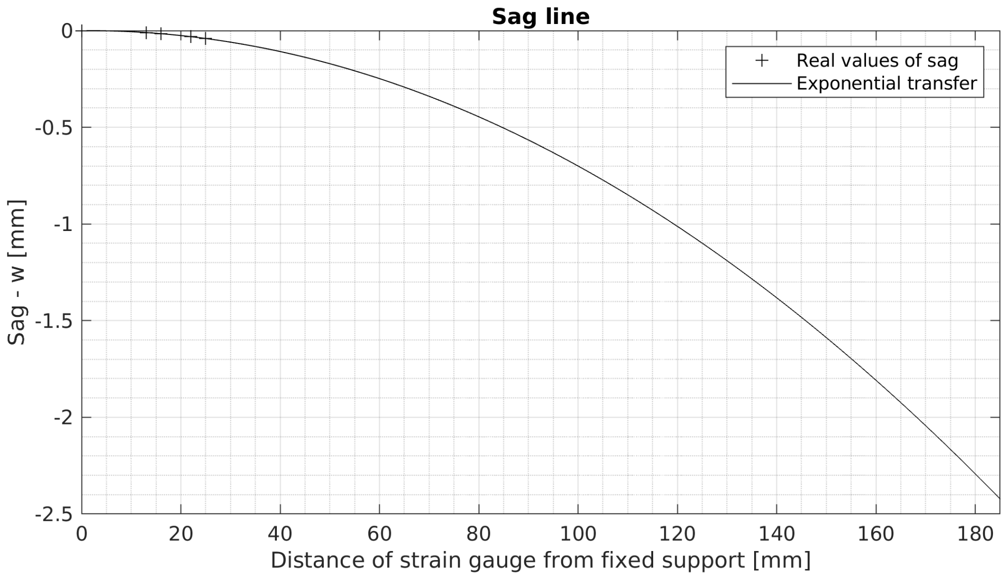


Figure 6: Approximated Sag line

1 Conclusion

Experimentally obtained natural frequency calculated with FFT by Matlab is $f_1 = 39.23\ Hz$. Numerical similation result done by Ansys Modal Analysis is $f_1 = 49.27\ Hz$. Difference between results is roughly 10 Hz, which is not negligible.

Dampling (with help od logarithmic decrement) was calculated too, but values are "shaken" due to big decrement differences between neighbour peaks.

One thing that looks succesfull is sag line, which meets shape expectations and deflection of free end of rod ($-2.5\ mm$) is in the borders of $< -3.5, 3.5 >$ interval defined by endstops on apperture.