Transient oscillation

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Outline

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Production processes

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The deviation from the intended work process is an indicator for accuracy.

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Determination of static stiffness of a system possible with satisfying result during construction. But analysis of dynamic stiffness still challenging! Imbalanced dynamic behavior of machines causes vibrations. The result:

- bad surface quality of the workpiece,
- higher abrassive wear,
- broken die [1].

Improvement of machine tools is a motivation for extensive analyses of vibrations.

Mass-spring systems

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Damping properties are rarely known and difficult to evaluate precisely. If the damping coefficient is assumed to be proportional to the velocity, structures are modelled by

$$M\ddot{u}(t) + D\dot{u}(t) + Su(t) = f(t) \; . \tag{1}$$

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Modal analysis

With the experimental modal analysis the

- eigenfrequencies,
- eigenvectors (modes) and
- compliance.

of vibrating systems are determined via experiments.

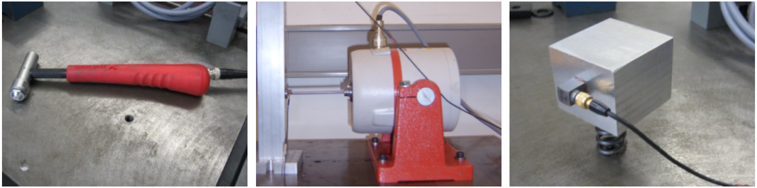

Figure: A modal hammer and an electromagnetic shaker.

The Compliance

The compliance represents the inverse stiffness of a structure at each frequency and may vary for different positions of the acceleration sensor. For measured exciting force E_m and the resulting acceleration A_m, the compliance is computed by

$$H(\omega) = \frac{|\hat{A}_m(\omega)|}{|\hat{E}_m(\omega)|} \; .$$

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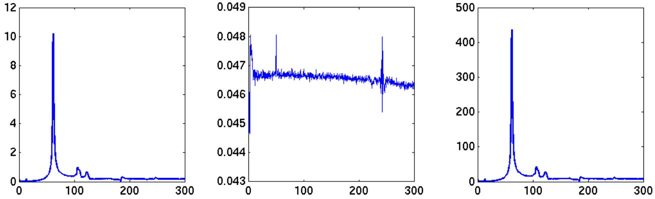

Figure: FFT of measured acceleration, excitation and resulting compliance.

The Stiffness

For given mass m and measurements of the exciting force E_m and the resulting acceleration A_m of the structure in one spatial direction, we can estimate the structures stiffness s by

$$s = \frac{2\pi\omega^2 m}{\sqrt{1 - c^2}}, \qquad (2)$$

where the resonance frequency ω is taken as the maximum of the compliance and c is an estimation of the damping.

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Definition (from Wikipedia)

A transient event is a short-lived oscillation in a system caused by a sudden change of voltage, current or load.

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Problem 1: Dealing with the forced displacement!

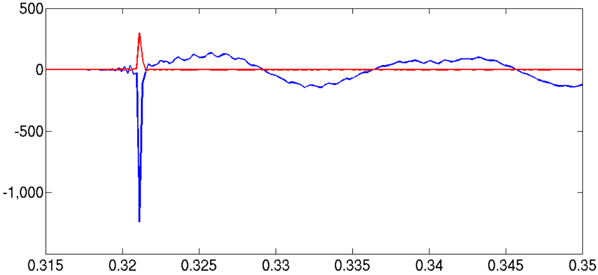

Figure: A close-up on measured excitation and resulting acceleration.

Problem 2: What means “short-lived”?

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Aluminium beam:

- 50x50x550 mm
- 3.846kg

Measurement:

- Sampling 100kHz
- Bandpass 0.1Hz - 10kHz
- Rising Edge trigger 0.5V
- Pretrigger 15000 scans

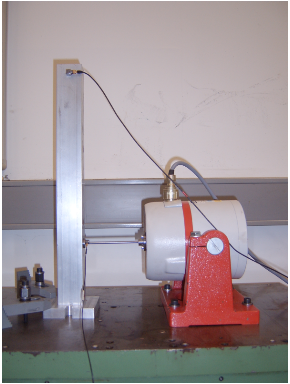

Figure: The experimental setup

An observation

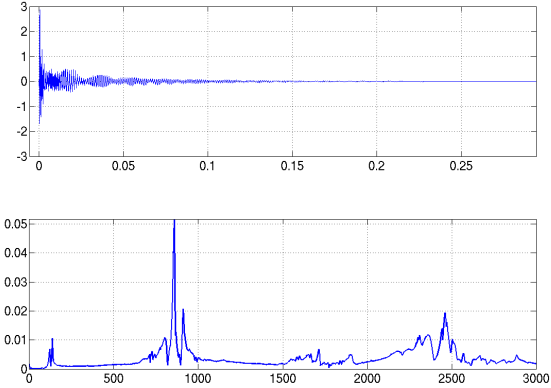

Figure: The complete vibrational response and frequency spectrum.

An observation

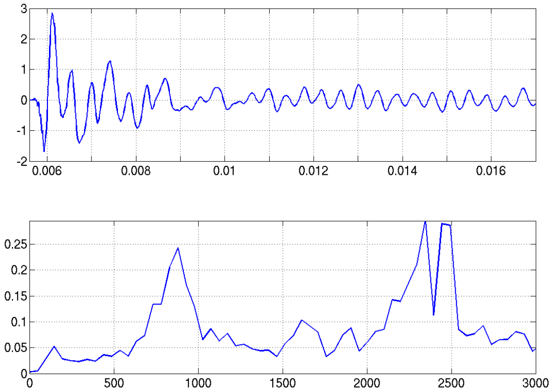

Figure: First 0.017s of vibrational response and according frequency spectrum.

An observation

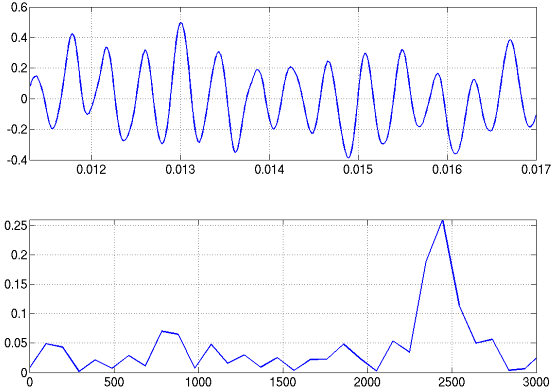

Figure: Windowed view on vibrational response and according frequency spectrum.

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Motivation

Modern production facilities often have irregular and quickly changing load transmissions. This leads to wide-band excitations and may also circumvent complete transient oscillation.

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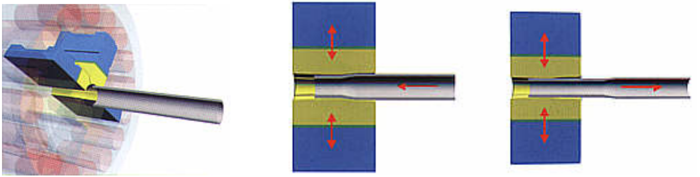

Figure: Rotary swaging

Impulse-type excitation

Assuming force f_0 at the time t_0, an appropriate Gauss curve

$$f(t) = f_0 e^{-\frac{(t-t_0)^2}{\sigma}} \,, \tag{3}$$

models an impulse-type excitation.

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models an impulse-type excitation.
A double impulse-type excitation with forces f_i at times t_i, $i = 1, 2$ may also be modelled by a Gauss curve, e.g.

$$f(t) = f_1 e^{-\frac{(t-t_1)^2}{\sigma_1}} + f_2 e^{-\frac{(t-t_2)^2}{\sigma_2}}\,.$$

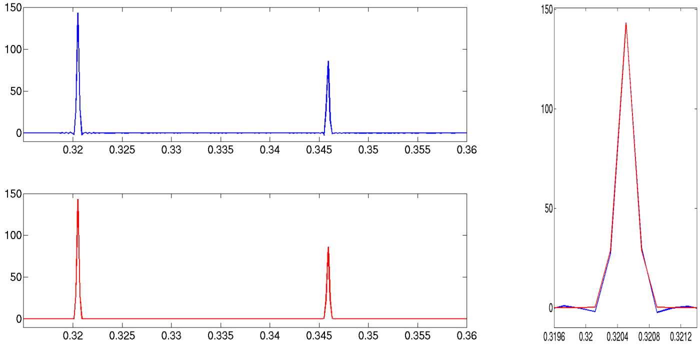

Figure: The measured and simulated excitation in N over time in s.

Analysis and simulation of 1-DOF fig.1

By taking measurements and applying (2) a stiffness of 40950.388N/m was computed and a damping ratio of 0.034 was estimated.
Masses: 0.014kg spring, 0.004kg sensor and 0.25kg qube.

Analysis and simulation of 1-DOF fig.1

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Masses: 0.014kg spring, 0.004kg sensor and 0.25kg qube.

$$0.268\ddot{u}(t) + 1.134\dot{u}(t) + 40950.388u(t) = f(t) \; . \qquad (4)$$

The relation of the two different representations of the damping is

$$D = 2m\omega c \; .$$

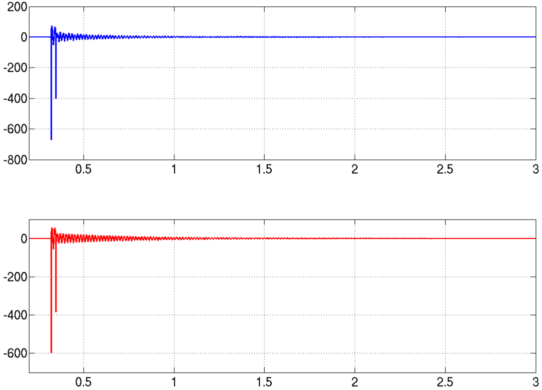

Figure: The measured and simulated acceleration in m/s^2 over time in s.

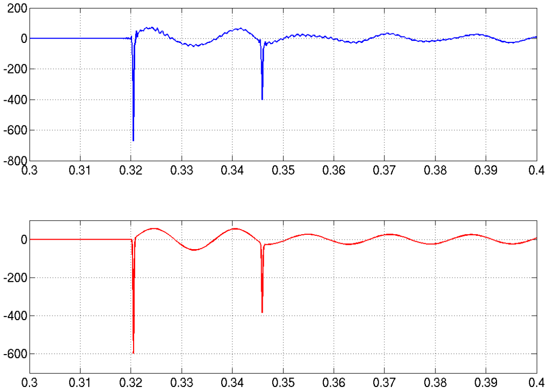

Figure: Close-up on measured and simulated acceleration in m/s^2 over time in s.

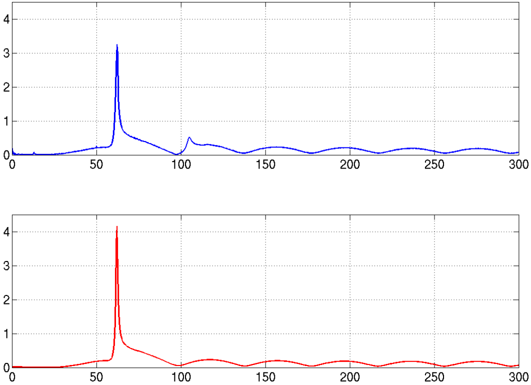

Figure: A FFT of the measurement and simulation in m/s^2 over frequency Hz.

- Weck, M., Brecher, C., *Werkzeugmaschinen - Messtechnische Untersuchung und Beurteilung, dynamische Stabilität*, 7. Auflage, Springer, 2006.
- Gasch, R. Knothe, K., *Strukturdynamik Bd.2 Kontinua und ihre Diskretisierung*, Springer Berlin, 1989.
- Gasch, R. Knothe, K., *Strukturdynamik Bd.1 Diskrete Systeme*, Springer Berlin, 1989.
- Tisseur, F., Meerenberg, K., The quadratic eigenvalue problem, *SIAM Rev.*, Vol. 43, No. 2, pp. 235-286, 2001.
- Singer, N. C., Residual Vibration Reduction in Computer Controlled Machines, *PhD Thesis, Department of Mechanical Engineering, MIT*, 1988.
- Tropp, J. A., Greed is good: Algorithmic results for sparse approximation, *IEEE Trans. Inform. Theory*, Vol. 50, No. 10, pp. 2231-2242, 2004.