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IDENTIFICATION OF VIBRATION CAUSES BASED ON SPECTROGRAMS DURING THE STRAIGHTENING PROCESS

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Abstract: *This paper deals with dynamic analysis of straightening machine loading during straightening process. During it, a crooked bar passing through the machine and the rollers and holders are subjected to the dynamic loadings. The roller's moment amplitudes depend, among others, on straightening speed, size of the bar curvature, bar's diameter, and on friction between the bar and the rollers. The loading is time-varying and knowledge of the frequencies of the moment is important; it can be used for verification of the numerical simulation or for the straightening machine design. Machine operation close to resonance state can cause excessive vibration which can subsequently cause noise and adversely affect the life of the machine and also straightening accuracy. This paper is aimed to analyze frequency spectra of the moments, which are obtained from the computational simulation and find the possible causes of vibration. Although, the straightening process is complex, it was possible to identify three main causes of vibration which are presented as the results of this paper.*

Keywords: Spectrogram, Dynamic Loading, Straightening Machine, Straightening Simulation.

1. Introduction

The straitening machine, analyzed in this paper, is intended for a straightening of crooked cylindrical bars. The machine's configuration is schematically shown in Fig. 1. The scheme consists of seven parabolic rollers in two sizes. Two of them (number 1 and 2) are driven by electromotor. An important element of the design of the machine is that the rollers axes are inclined relative to the straightened bar by angle of 26°. This angle ensures that the rollers circumferential velocity is decomposed into the circumferential (rotation) and axial direction (translation) of the bar. Rollers 1, 2 and 7 have diameter of 580 mm and rollers 3, 4, 5 and 6 have diameter of 370 mm. The bar has diameter of 200 mm. More details of the machine construction and operation conditions can be found in Skalka & Sobotka (2014).

The numerical simulation of the straightening process is performed and described in detail in Skalka & Sobotka (2014). Their work is focused on the loading of the straightening machine in terms of maximum moments during the simulated process. The bar passing speed is controlled by angular velocity of the roller 1 and 2. The friction is considered between the bar and the rollers. The simulation is done for two cases of friction coefficient – 0.1 and 0.2. The history of drive moments (M_{d1} and M_{d2} in Fig. 1) and moments M_{f1} through M_{f7} in Fig. 1 is recorded. This paper extends the work of Skalka & Sobotka (2014) by the analysis of frequency spectra of the moments records. Detailed analyses of shape deviations after bar straightening is described in Fuis (2014), which is based on Fuis et al. (2009 and 2011).

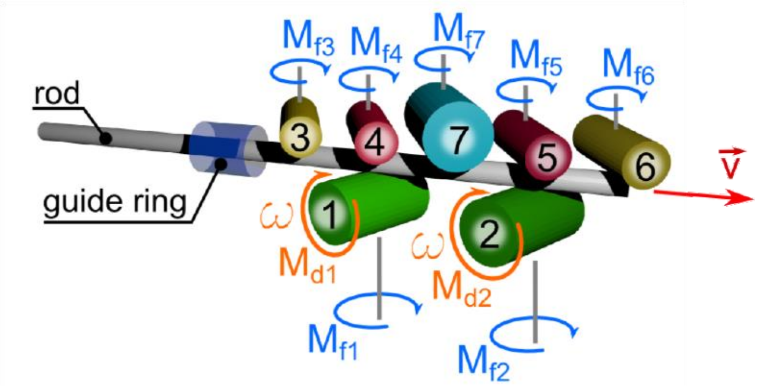

Fig. 1: Schematic layout of the straightening machine.

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2. Visualization of the Time-Varying Frequency Spectra

The moments, obtained from simulation, are in the time domain (Fig. 2). The plots can be useful for determination of maximum moments during straightening process; however, information about frequencies is not clear from them.

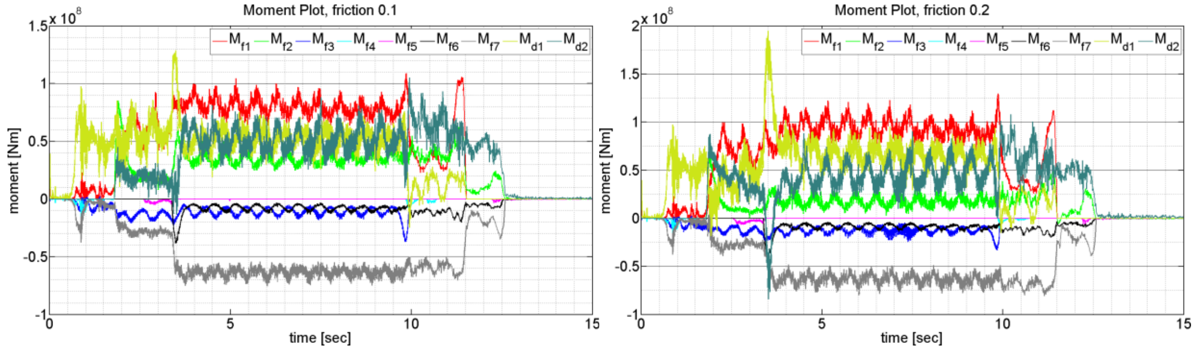

Fig. 2: Time record of the moments for the friction coefficient 0.1 (left) and 0.2 (right).

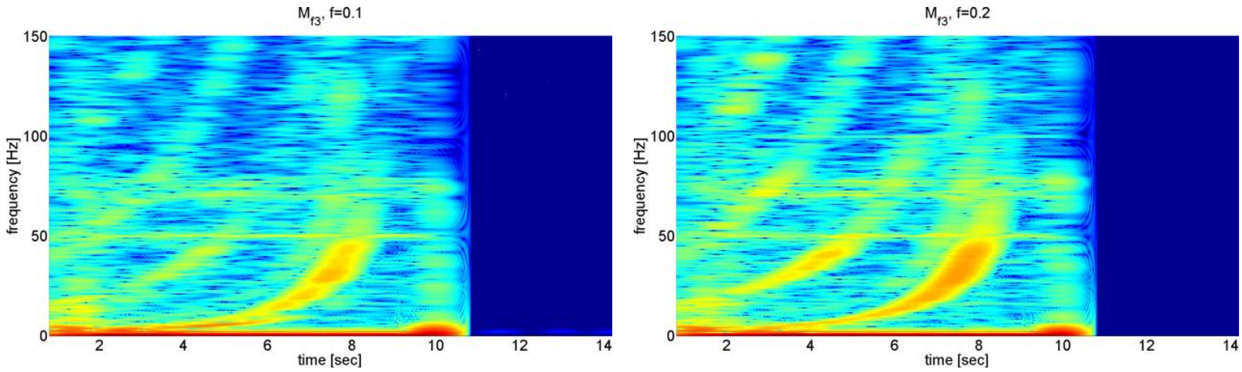

Fig. 3: Spectrogram of the moment M_{f3} for the friction coefficient 0.1 (left) and 0.2 (right).

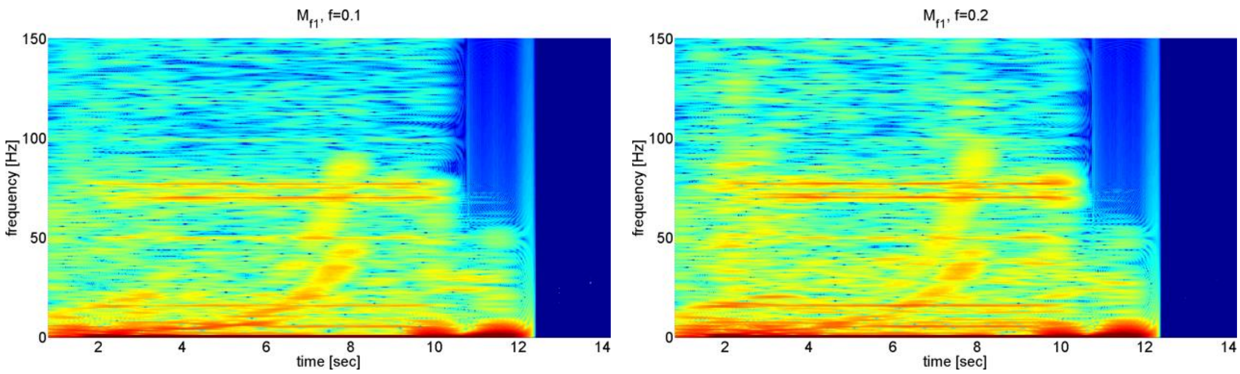

Fig. 4: Spectrogram of the moment M_{f1} for the friction coefficient 0.1 (left) and 0.2 (right).

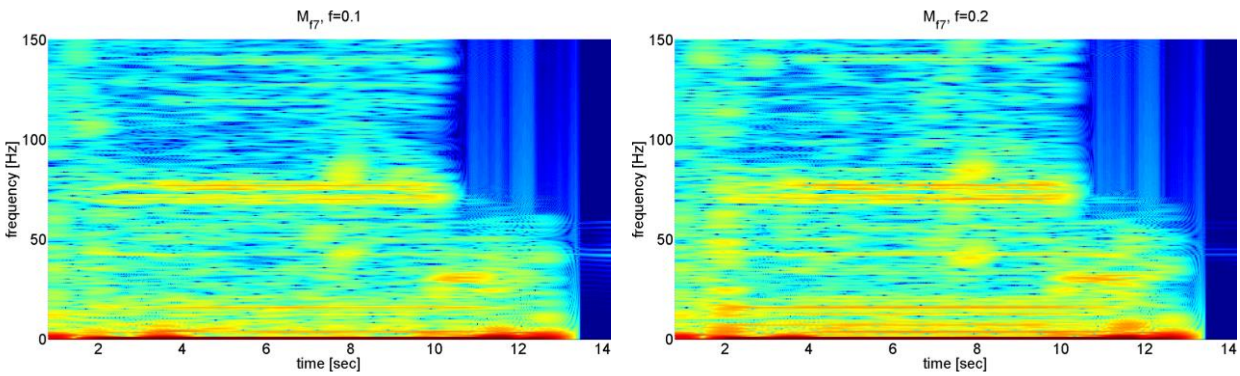

Fig. 5: Spectrogram of the moment M_{f7} for the friction coefficient 0.1 (left) and 0.2 (right).

The spectrogram is one of the best way how to display the frequency spectra of the time-varying signal (more about spectrograms could be found e.g. in Mertins (1999)). They show how the amplitudes and frequencies are changing over the time. The spectrogram of each moment record is computed and some results are shown in Figs. 3, 4 and 5. The horizontal axis represents time, on vertical one is for frequency. Amplitudes of vibration are marked by colors - dark blue stands for zero amplitude, dark red for highest amplitude in the spectrum.

Based on the time it is possible to determine the bar position in the straightening machine. Some of the significant time points are shown in Fig. 6. The position of the bar in the straightening machine is related to the spectrograms and also to causes of vibrations.

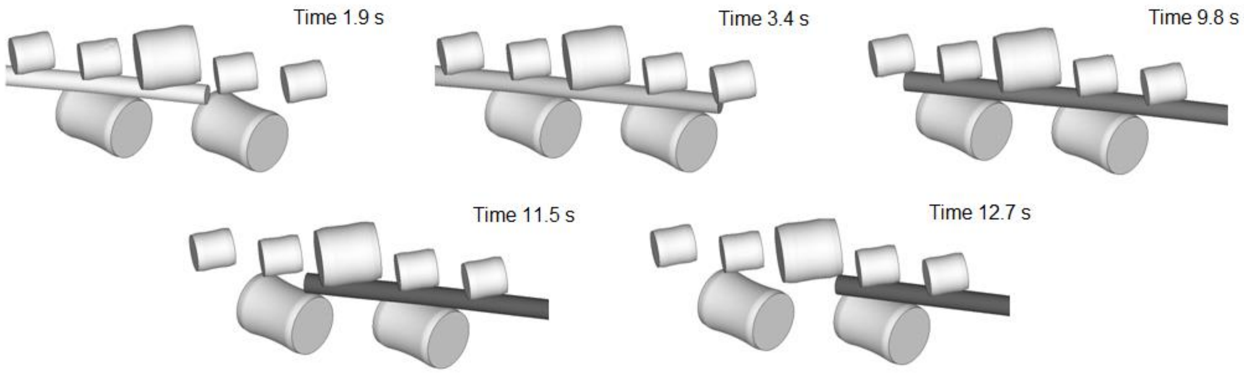

Fig. 6: Bar position in the specific time points.

3. Analysis of the Frequency Spectra

When the bar passes through straightening rollers, the excitation of rollers occurs due to inertia and rotational motion. The most significant vibrations are observed at the free end of crooked side. The displacements are so large that the bar impacts into the guide ring from Fig. 1. The friction coefficient between the bar and rollers has also impact on the frequency spectra.

Three regions of significant amplitudes can be observed in the spectrograms. Regions are highlighted in Fig. 7 and labeled as region A, B and C. Each of these regions is related to one cause of vibration.

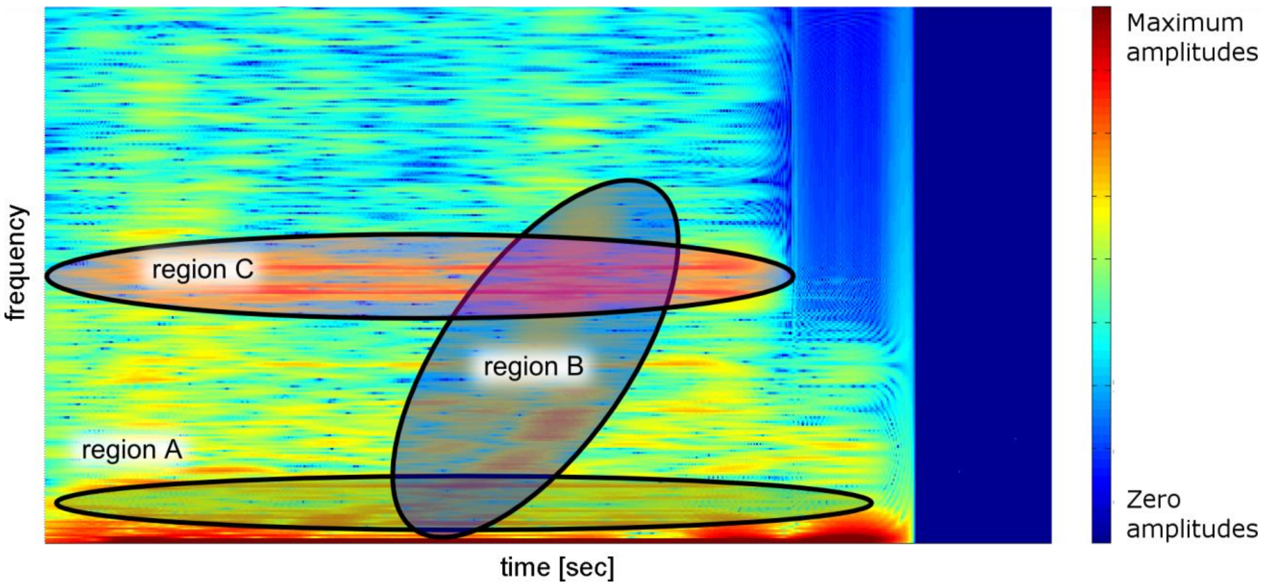

Fig. 7: Significant regions in the figure.

3.1. Region A - Rotation of the bar

The frequencies in the region A are excited by the rotation of the crooked bar. Its curvature causes that the vibrations are transferred into the rollers per each rotation. The frequencies are dependent on inclination rollers axes, their diameters and rollers angular velocity.

3.2. Region B – Natural frequencies of the bar

The numerical simulation shows that the maximum displacement's amplitudes of the free end of the bar are so large that the bar hits the guide ring sometimes. It yields to an excitation of a free response vibration. Then, frequencies in this area are given by natural frequencies of the straightened bar. As the bar free end becomes shorter in the straightening process also the natural frequencies increase. Evidence of this fact is given in Fig. 8.

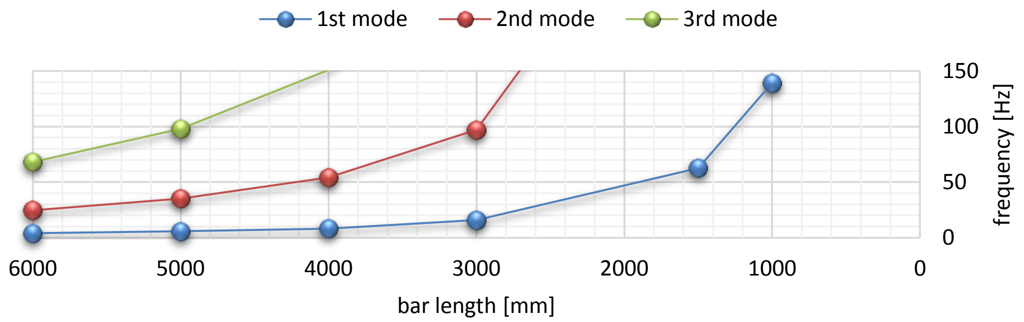

Fig. 8: Dependence of the natural frequencies on the bar length.

This figure indicates an exponential rising trend in the first three natural frequencies of one-side fixed bar for the varying bar length. The same trend can be observed in the spectrograms (mainly in Figs. 3 and 4).

3.3. Region C – Slips of the bar

The simulation shows that the frequencies of the region C are related to modal properties of the bar section, which links rollers 1 and 2.These two rollers are driven. Due to the vibration of bar on the roller 1 there is a slight speed phasing of the bar between the cylinders. This difference is compensated by the bar slips on the one of the rollers. Frequencies in the region C correspond to the natural frequencies of the bar with a length equal to the roller's pitch.

In addition to the three regions, there can be observed the frequencies in the spectrograms without obvious dependence on the known circumstances. But since the straightening process is complex, full of nonlinear phenomena, then other minor excitation actions can occur.

4. Conclusion

This paper was focused on the dynamic analysis of the moments obtained by the numerical simulation of the straightening process. The spectrograms were calculated and areas with significant moment amplitudes were found. These areas were examined in details and the specific causes of excitation were identified. Knowledge of these characteristics can help to prevent undesirable vibrations of the machine already in the design stage.

Acknowledgement

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References

Mertins, A. (1999) Signal Analysis: Wavelets, Filter Banks, Time-Frequency Transforms and Applications, John Wiley & Sons Ltd., ISBN 0-471-98626-7.

Skalka, P., Sobotka, J. (2014) Analysis of Dynamic Loading of Bar Straightening Machine Components, In: Proc. 20th Int. Conference Engineering Mechanics, Svratka, Czech Republic, pp. 564-567.

Fuis, V. (2014) Shape deviations analysis of the aligned bars. In: Proc. 20th Int. Conference Engineering Mechanics, Svratka, Czech Republic, pp. 184-187.

Fuis, V., Koukal, M., Florian, Z. (2011) Shape Deviations of the Contact Areas of the Total Hip Replacement. In.: Proc. 9th Inter. Conference on Mechatronics Location: Warsaw, Poland. Mechatronics: Recent Technological and Scientific Advances, pp. 203-212.

Fuis, V. (2009) Tensile Stress Analysis of the Ceramic Head with Micro and Macro Shape Deviations of the Contact Areas. In: Proc. 8th Inter. Conference on Mechatronics, Luhacovice, Czech Republic, Recent Advances in Mechatronics: 2008-2009, pp. 425-430.