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SOME ASPECTS OF STABILITY ANALYSIS FOR CHATER PREDICTION OF HSM WOODWORKING MACHINING

Eng. LIANA MARTA LUSTUN, Univ Prof.PhD.Eng. MIHĂILĂ V. IOAN
University of Oradea
E-mail: lustunlianamarta@yahoo.com

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Abstract: The paper presents some aspects regarding the modelling of the dynamic behaviour of the wood processing centres at high revolutions: elaborating the SLD stability diagrams on the basis of modelling the cutting process at high revolutions and their appliance in the calculation of HSM working parameters.

HSM processing centres, at high revolutions, refers to the elaboration of the SLD stability diagrams, an expression of the linear DDE function (Delay Differential Equations) of the cutting process, studied by Altintas and Budak [1]:

$$\begin{aligned}\dot{\underline{x}}(t) &= A\underline{x}(t) + Ba_p \sum_{j=0}^{z-1} w_j g_j \left(S(t)\left[\begin{smallmatrix} K_{te} \\ K_{re} \end{smallmatrix}\right] + \left(h_{j,stat}(t) + \left[\sin\phi_j(t) \cos\phi_j(t) \right] \left(C\underline{x}(t) - C\underline{x}(t-\tau_j(t)) \right) \right)^{x_F} \right. \\ &\left. S(t)\left[\begin{smallmatrix} K_{tc} \\ K_{rc} \end{smallmatrix}\right] \right), \\ \underline{v}(t) &= C\underline{x}(t)\end{aligned} \tag{1.1}$$

Identifying the parameters of the cutting forces K_{tc}, K_{rc} and X_f, approximated by the method of the smallest squares can be done by calculating the average values of F_x and F_y forces for a single rotation of the cutter, both theoretical and experimental. [1], [2], [5] Thus, we obtain two curves, the curve with a continuous line is experimental, and the curve with a disrupted line is the one calculated by minimizing the relation:

$$\sum_{\vartheta=0}^{2\pi} \left(\sqrt{x_1(\vartheta)^2 + y_1(\vartheta)^2} - \sqrt{x_2(\vartheta)^2 + y_2(\vartheta)^2} \right)^2 \tag{1.2}$$

The model has a correspondence to the experimental measurements. In order to process the experimental data I used the method of the smallest squares. In figure 1.1 the curves of the measured forces and those calculated at a single rotation of the cutter are represented. [2], [5]

I calculated the SLD diagram and the experiments carried out validated the model [5] (fig. 2b). The vibrations increase together with the increase of the revolution to the peak of the diagram. Then, they decrease to a value corresponding to the bigger revolution. It can be noticed a tendency of increasing the stability with the increase of the revolution at the same depths of processing. It can be observed that the position of the SLD (Stability Lobes Diagram) diagram peaks obtained by modelling coincide with the experimental data at around 27000rpm. For greater revolutions, the peaks of the diagram are wider and towards the right side. At high revolutions, the own frequency is smaller than that corresponding to smaller revolutions (fig. 2a and b). [2], [5]

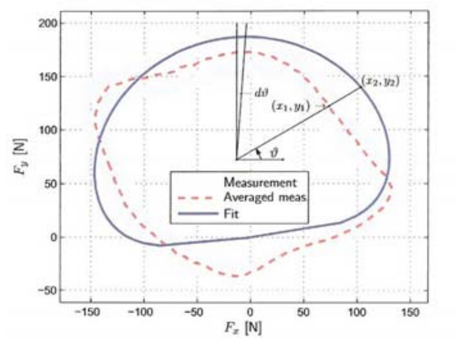
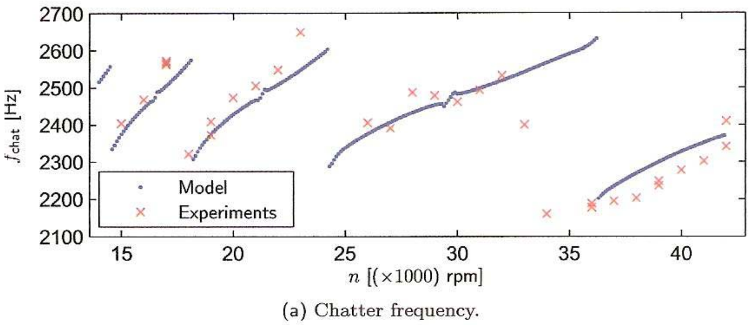


Fig. 1. Comparison between the measured and calculated forces [2],[5],[6]



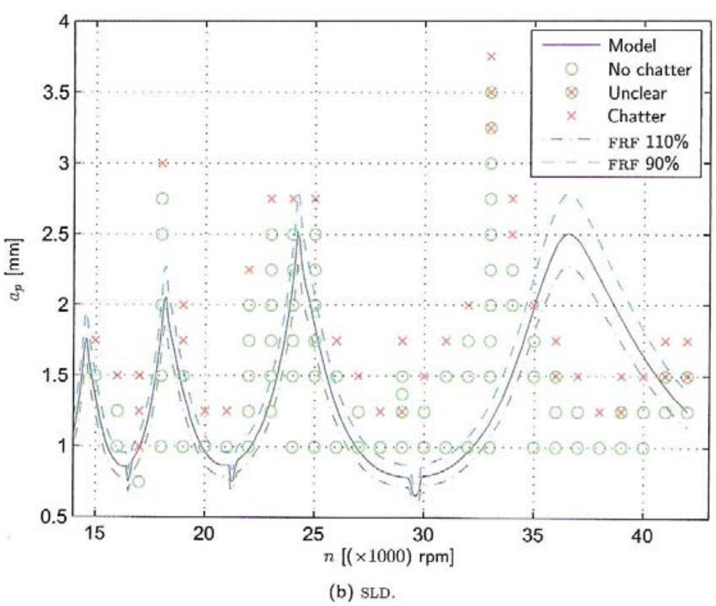


Fig. 2 The stability diagram of HSM ROVER 346 using the tool model LEITZ HSK F63 A 76,5 RH-Dx Modelling and experiment. [2],[5],[6]

The SLD (Stability Lobes Diagram) diagram is much more efficient for identifying the STT dynamic than the determination of cutting parameters, by using a less rigid tool that vibrates, fact which influences the cutting forces. [2], [3], [5]. [6]

The frequency of the tool holding system (STT) (Spindle-Toolholder-Tool) decreases at high revolutions, entirely justifying the improving solutions of the spindles and of the tool holding system. [2], [3], [5]. [6]

In order to adopt the most appropriate constructive solutions I simulated the functioning of a spindle for its modelling (fig.4, fig. 5, fig. 6, fig.7). [5]

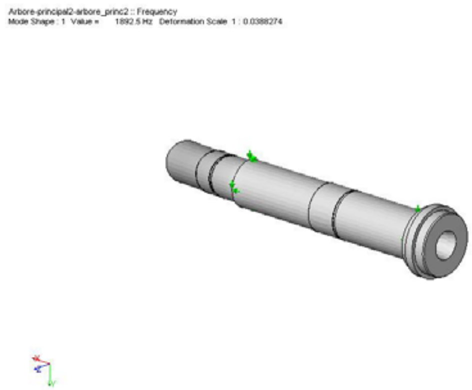


Fig. 3 Radial and axial usage of the spindle [5]

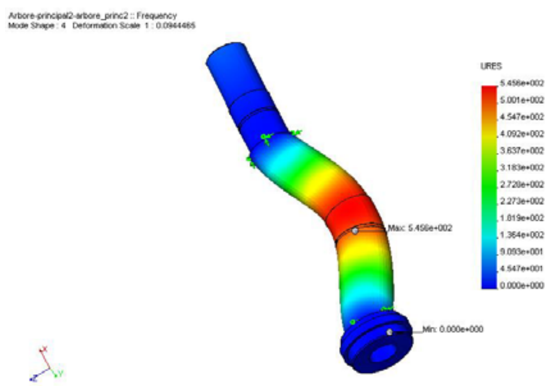


Fig. 4 The final results of deformations depending on the frequency in the rotor area [5]

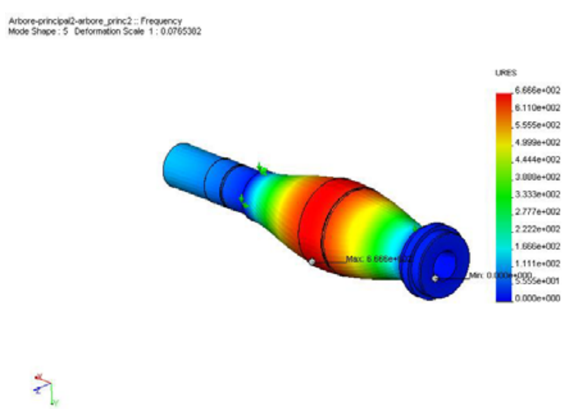


Fig. 5 The final results of deformations and thermic dilatation depending on the frequency in the area of the electric rotor of the spindle [5]

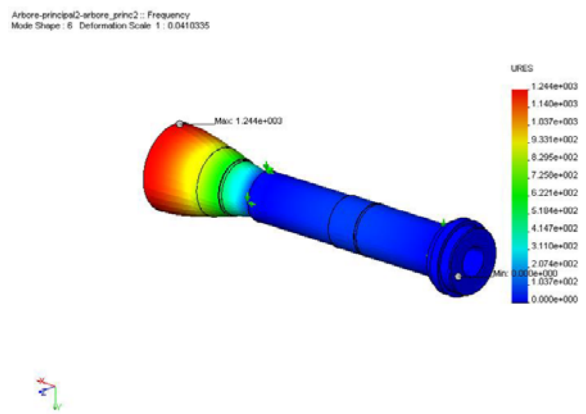


Fig. 6 The final results of deformations and thermic dilatation depending on the frequency in the area of the tool holding system [5]

The simulating and modelling software was elaborated by the COSMOS software packet and MatLab Simulink that gives us results concerning the relative movements and the final results of deformations depending on the frequency [5].

It can be noticed the fact that the most used areas are the following: the spindle's rotor and the tool holding system (STT) that suffer deformations of bending and torsion, but also a thermic dilatation. For this reason, mounting some special radial-axial bearings with ceramic balls, making some special bearings with ceramic rings, cooling and oiling the spindle by the oil-mist system, and the usage of HSK system for holding the tool, are only a few of the constructive solutions necessary for diminishing the unpleasant phenomena that lead to a dynamic instability.

The working parameters can be established as a response to two requirements: the robustness of HSM and the minimization of the vibrations effects during cutting (fig. 8, fig. 9)

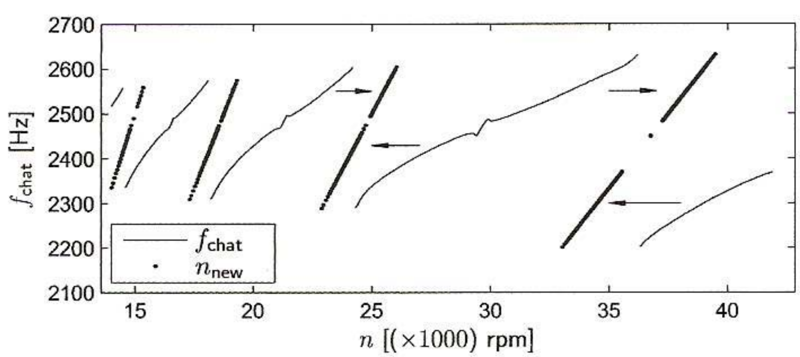


Fig. 7 Operating parameters for the new revolution, the relation (4.2) and (4.3) for various frequencies [2],[6]

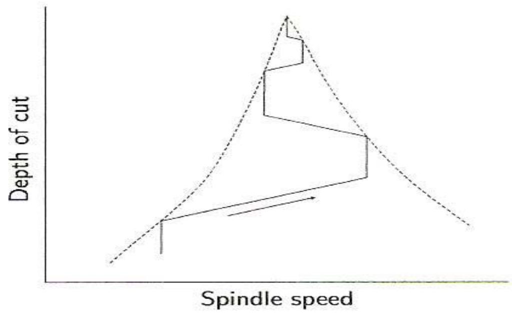


Fig. 8 Example of establishing the centre of SLD diagram using the vibrations detection and control [2],[6]

In order to ameliorate the dynamic stability of HSM, I elaborated a method for choosing the best revolution, so that the dominant estimated frequency f_{chat} to coincide with the highest harmonic of the new excitation frequency of the advance on the tooth (fig. 9). [6], [7]

The frequency of vibration is similar to the phase difference between two consecutive waves: where k is the whole number of the lobes in diagram SLD, and ε is the fraction of the incomplete wave ε=0. The ideal situation is when the dynamic thickness of the splinter is minimal (ε=0). Thus, the optimum number of lobes is calculated by:

$$\varepsilon + k = f_{chat}\frac{60}{zn} \quad [Hz] \qquad (1.3)$$

Where k_n means the approximation to the closest whole number, and n is the current revolution.The new value of the revolution is calculated in this way, by: $\varepsilon = 0$.

$$k_{new} = \{\frac{60\,fchat}{zn}\} \quad [nr.\ întreg] \qquad (1.4)$$

$$n_{new} = \frac{60\,fchat}{Knew \cdot z} \quad [\ rot/min] \qquad (1.5)$$

The relation (1.5) is used for calculating a new revolution. Using this method, the revolution is directed towards the centre of the lobe. The new revolution calculated by relation (1.4) and (1.4) is represented by discontinued thick lines and it can be established in fig. 8, in the point where the leap in f_{chat} takes place (at approximately 27000rpm). At the peak of the stability curve, the new value of the parameters is situated in the area close to the centre of lobe. Although the new value of parameters is situated in the best position, at the peak of the stability curve the revolution may change so much that the following curve to be erased. This disturbance can be foreseen by an alternative definition of the processing parameters once the vibrations have been eliminated. Modifying the revolution leads to a new frequency of vibration and thus the processing parameters are changed. The parameters will be updated as long the cutting process produces vibrations. [2],[5],[6],[7]

By the system of detecting and control of vibrations [6] the centre of SLD diagram is automatically established, this value being then sent to the simulator of the vibrations control system that determines the best value of the revolution and the advance speed for different types of operations (inner cutting, outer cutting, perforations, etc.)

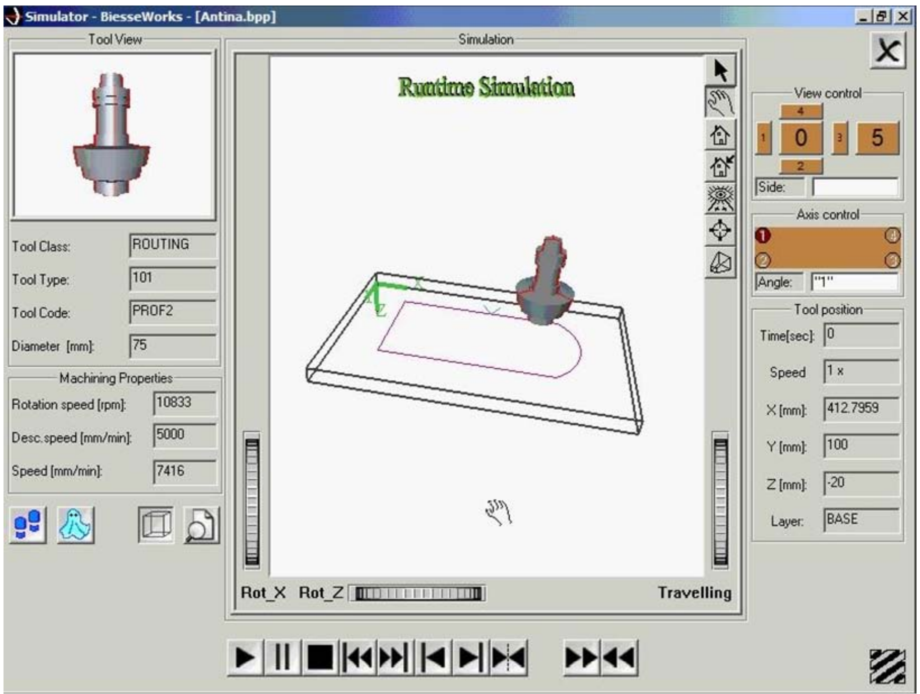


Fig. 9 BiesseWorks simulator of the vibrations control system for the operations of outer and inner cutting [7]

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