DYNAMICS OF THE TOTAL SYSTEM OF THE CIRCULAR SAWING MACHINE

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Abstract
In the paper causes and effects of circular saw teeth position changes are presented. The described measurement method of the circular saw blade dynamics allow the user to determine vibration causes, and furthermore may be a basis of the circular saw blade vibration minimization in an effective way.

Key words: *circular sawing machine, dynamics, saw blade vibrations, wood cutting*

INTRODUCTION

Technical and economical effects of the sawing process of wood and wood-base materials are dependent on accuracy of the circular saw teeth position in regard to a workpiece. In circular sawing machines the spindle system is a part of the sawing system, which substantially affects the circular saw teeth position. The accuracy of circular saw teeth position in sawing process depends on two groups of factors:

- geometrical and kinematical accuracy of the whole spindle system (a circular saw blade, a spindle and circular saw clamping system);
- deformations of the whole spindle system caused by acting forces (cutting forces, back forces, feed forces, driving forces, and forces resulting from unbalanced elements of the spindle system), and moreover thermal loads.

Due to the fact that in the whole spindle system the circular saw blade is the most flexible element a decisive effect on the teeth position is just attributed to it exactly. For that reason the most of disadvantageous sawing effects are ascribed to circular saw blade vibrations whereas not pay much attention to the spindle dynamics is noticed.

Examination of the whole spindle system dynamics may allow the user of circular sawing machines to understand dynamical phenomena occurred in the sawing system much more better. Furthermore, results of this investigation could be a basis for the proper design of circular sawing machines and their further maintenance.

TEETH POSITION IN THE ACTUAL SAWING SYSTEM

In the actual sawing conditions the whole sawing system constantly moves and simultaneously undergoes a deformation. As a result, the working plane P_{fe} does not overlap with the assumed working plane (theoretical) P_f ($P_{fe} \neq P_f$) (Wasielewski and Orłowski, 2008). An example of the actual sawing system of the circular sawing machine is presented in fig. 1.

The direction and a value of the working (actual) plane P_{fe} deflection from the assumed (theoretical) working plane P_f is a result of both geometrical and kinematical inaccuracy of the whole spindle system, and also its deflections caused by the acting forces. During the sawing process the working plane P_{fe} may change its position. The most convenient describing method of these changes periodicity (frequency) Ω_{fe} is to compare it with the characteristic impact (input) periodicity (frequency) ω, which a circular saw blade angular velocity is in the sawing system (fig. 1). The circular saw blade angular velocity ω is calculated as:

$$\omega = \frac{\pi \cdot n}{30} \tag{1}$$

where: n – circular saw blade rotational speed, rpm.

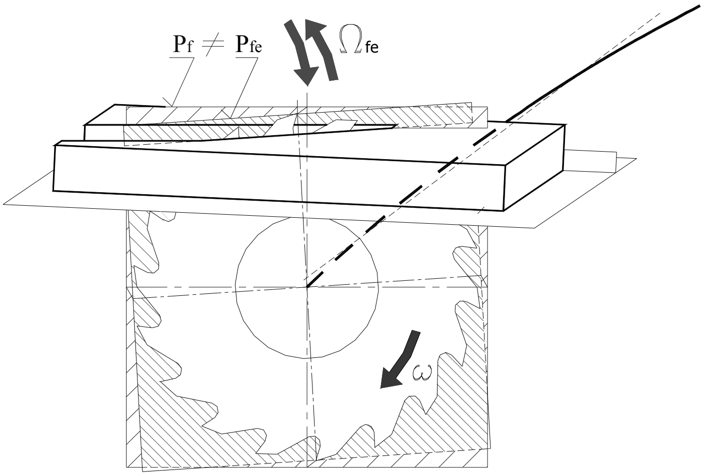

Fig. 1. Actual sawing system of the circular sawing machine

Depending on the change periodicity of the working plane position Ω_{fe} with relation to the impact (input) periodicity (frequency) ω, there could be distinguished three characteristic types of deflections of the circular saw blade and the spindle system (fig. 2):

- while $\Omega_{fe} << \omega$, a manner of deflecting spindle system results from low-changeable cutting forces (Wasielewski and Orlowski, 2008), which may cause circular saw blade deflection (fig. 2Aa). In the second case a manner of deflecting spindle system arises from spindle driving forces (Orłowski, 2005), which could deform the spindle system (fig. 2Ba). In the both cases of low-changeable circular saw blade displacement changes in the lumber thickness and form errors are observed;
- while $\Omega_{fe} = \omega$, a manner of deflecting spindle system may result from an axial run out of the circular saw teeth only or a clamping error on the spindle (Wasielewski 2005) (fig. 2Ab). Moreover, it also can arise from the system unbalance when a centrifugal force deforms the spindle system, and the spindle in this form of deflection swirls

with the periodicity (frequency) ω (fig. 2Bb). Noticed irregularities of the sawn surface, which recur in cycles with an every circular saw blade turn, are an effect of these phenomena;

- while $\Omega_{fe} > \omega$, a manner of deflecting spindle system may result from either circular saw blade vibrations (fig. 2Ac) or spindle system vibrations (fig. 2Bc). As an effect of fast working plane position changes larger roughness of sawn surfaces is observed or in some cases waviness (called often as a washboard pattern) on the workpiece might occur (Tian and Hutton, 2001, Yokochi et al., 1990). The washboard pattern is present if the tooth impact frequency f_t is almost equal to the natural frequency of the saw blade f_n (f_t has to be slightly larger than f_n) (Tian and Hutton, 2001, Yokochi et al., 1990). The tooth impact frequency of the circular saw, which has number of teeth equal to z, is given by:

$$f_t = \frac{n \cdot z}{60} \tag{2}$$

However, in some cases the washboard pattern presence on the sawn surface is not dependent on the tooth impact frequency (Yokochi et al., 1990), and this phenomenon deals with a quasi washboarding phenomenon (Orlowski and Wasielewski, 2006).

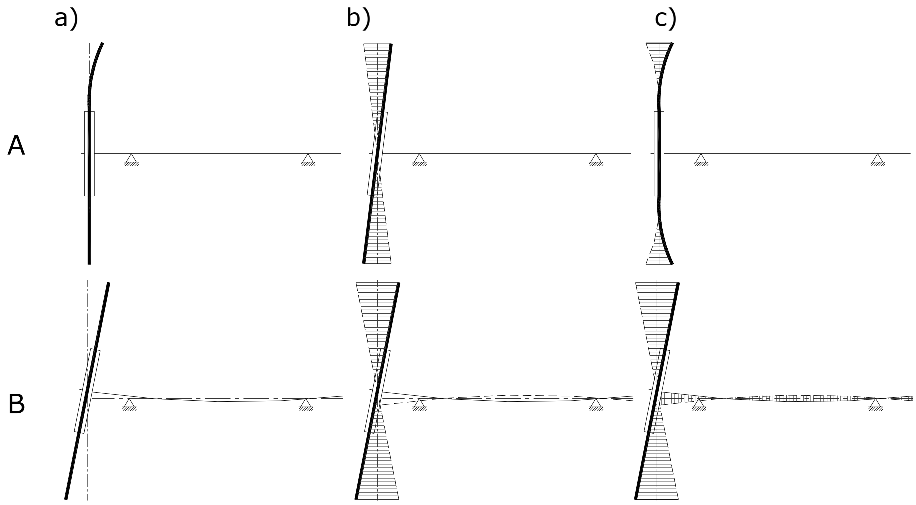

Fig. 2. Characteristic deformations of circular saw blade (A) and spindle system (B) while: a) $\Omega_{fe} << \omega$, b) $\Omega_{fe} = \omega$, c) $\Omega_{fe} > \omega$

The presented above characteristic deformations of the circular saw blade and the spindle system appear in the actual cutting system every time together. However, the dominant mode of deformation depends on the case of emergence and its intensity. In this connection that every kind of deformation may be situated in a different plane of the spindle system, their summation may increase or decrease a total deformation of the whole spindle system.

THE TEST STAND AND METHODS

The experimental investigation of the spindle system dynamics was carried out on the standard circular sawing machine equipped with measurement systems. The scheme of the examined spindle system and positions of the measurement sensors are presented in fig. 3. For measurements two directions of sensor locations were chosen. In direction of the belt transmission collar axial displacements were measured with the sensor O1, and with the sensor P1 radial displacements of the collar were determined. Additionally, axial displacements of the collar were measured with the sensor O2 in the direction perpendicular to the belt transmission direction. Placing sensors O1 and O2 on the collar rim allowed us to assume that displacements measured by them are caused by the spindle dynamics itself and are not an effect of the collar clamped circular saw blade. Furthermore, in the direction the belt transmission the sensor OZ was placed, which registered signals from the element Z. The latter played a role of the marking gauge of the angular position for other measured values. Additionally with the sensor O3 axial circular saw blade displacements, at the rim just below the gullets, were measured.

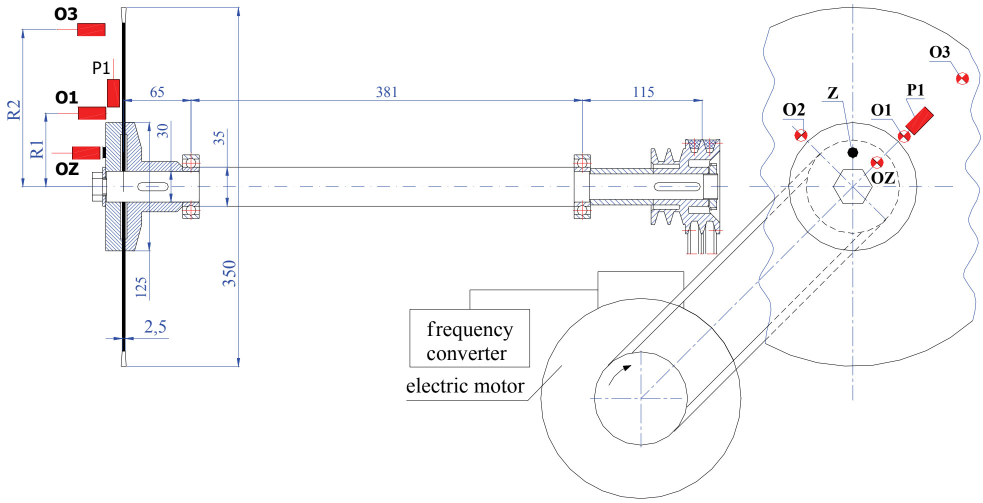

Fig. 3. Scheme of the investigated circular sawing machine spindle system and sensors positions (O1, O2, O3 and P1 – eddy current displacement sensors, OZ – inductive sensor

RESULTS

In figure 4 cumulative measurement results are presented for the complex evaluation of the effect of the rotational speed upon the spindle system dynamics. For each measurement signal, in a function of the rotational speed the maximum and the minimal range value (fig 4a) from the analysed signal average value are shown. The latter values are presented in fig. 4b. The maximum and minimal range values from their average value correspond to either the spindle radial run out or the spindle axial run out. Changes of the average signal values are a measure of the spindle system deflection value.

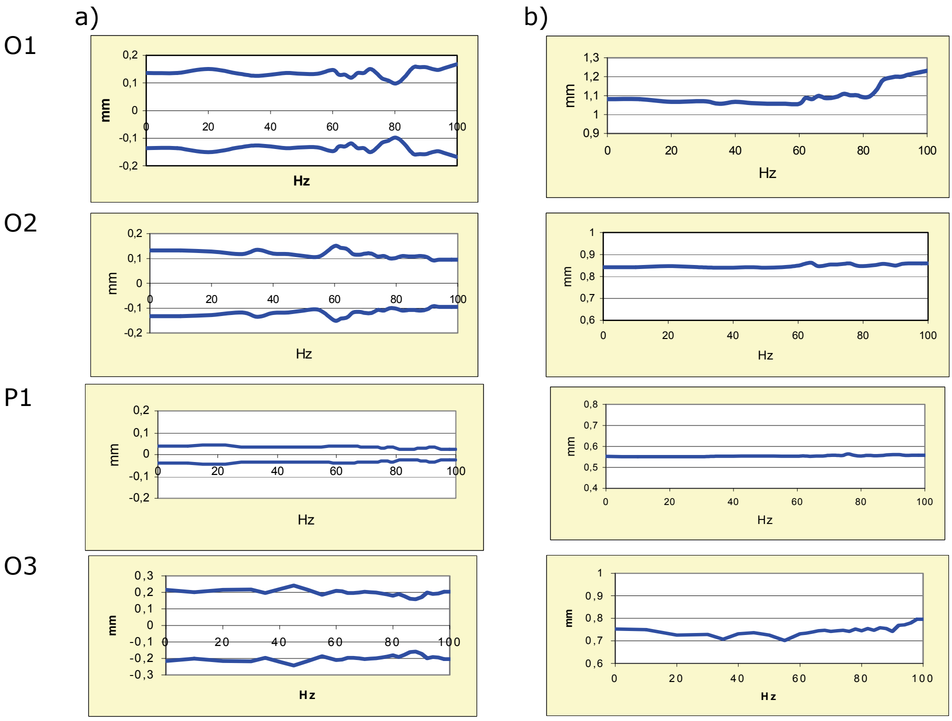

Fig. 4. Cumulative measurement values in a function of the converter frequency, obtained with sensors O1, O2, P1 and O3 presented as: a) maximum and minimal range values from their average value, b) signal average values

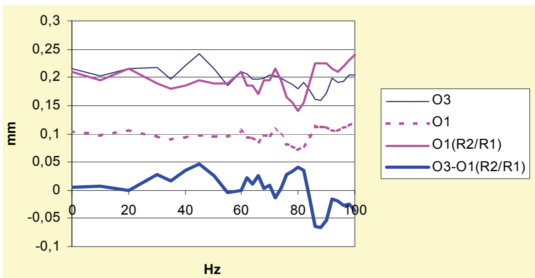

Fig. 5. Maximum values of the total circular saw blade displacement (at the rim below gullets, sensor O3), circular saw blade displacements measured close to the clamp collar (sensor O1), displacements form the sensor O1 reduced at the diameter of the sensor O3 position (signal O1 multiplied by the ratio R2/R1) and pure circular saw blade vibrations (subtraction result of signals O3 and O1 multiplied by the ratio R2/R1)

Total axial circular saw blade displacements, measured at the rim just below the gullets (signal from the sensor O3), are a sum of both circular saw blade vibration and the spindle system deformations (fig. 5). The pure circular saw vibrations, which results from relative displacements of the circular saw blade and clamp collars, may be determined as a result of subtraction of the total axial circular saw blade displacement (signal from the sensor O3) and a value of the spindle system deformation determined at the diameter of the sensor O3 position under the assumption that the circular saw blade is rigid. This value may be determined from the displacements measured close to clamp collars (sensor O1) multiplied by the ratio of sensors O3 and O1 radii $R2/R1$ (fig. 5). Obtained results presented in fig. 5 revealed that in the examined system the spindle system has a crucial bearing on the circular saw blade manner, whereas the effect of circular saw blade vibrations is rather slight.

SUMMARY

The carried out analyses and experimental investigation of the whole spindle system dynamics of the circular sawing machine have revealed that:

- the spindle and the clamping system have a decisive bearing on the circular saw blade manner;
- in the investigated circular sawing machine pure circular saw blade vibrations resulted from relative displacements of the circular saw blade and clamp collars constituted ≈20% of the total circular saw blade displacements

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