THE EFFECT OF THE SPINDLE SYSTEM ON THE POSITION OF CIRCULAR SAW TEETH – A STATIC APPROACH

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Abstract

In the paper causes and error analysis of circular saw teeth positions in relation to the workpiece in static conditions are presented. Mentioned errors originate from the circular sawing machine spindle system. For the exemplary circular saw spindle system determined error values are performed.

Key words: *circular sawing machine, spindle system*

INTRODUCTION

Sawing of wood with circular saws is a typical example of cutting with multi-blade tools. In that kind of cutting, the position accuracy of following tool blades is a crucial factor which affects a cutting process and machining final effects. Position tooth errors may cause: deterioration in cutting conditions, changes in loads of individual teeth and the tool as a whole, and also a decrease in accuracy and surface quality after cutting.

Circular saws belong to the group of multi-blade tools and are highly sensitive to position tooth errors in the cutting process. Changes in tooth loads may cause their additional position errors, and intensify disadvantageous cutting effects because of a small value of the circular saw stiffness [3].

The tooth position errors may by analysed in the static or dynamic conditions. In the static system, the tooth position is an effect of the tooth position accuracy in the saw blade, accuracy of clamping on the spindle, and the spindle axis of rotation static accuracy. In dynamic conditions, cutting system vibrations caused by cutting forces and dynamic forces originating from spindle rotary motion are additional factors affecting position of the teeth. However, these forces are a function of the static teeth position. Hence, the static analysis is a basis for determination of the spindle system effect upon the circular saw tooth position during sawing process.

CIRCULAR SAW TOOTH POSITION ERRORS IN THE SAWING SYSTEM

In the sawing system the circular saw tooth position errors in relation to the workpiece depend on tooth position errors in relation to its axis of rotation, and also position errors of the axis of rotation in relation to the assumed working plane P_f (Fig. 1). In these two cases, the spindle system greatly effect on mentioned error values.

The position of the circular saw axis of rotation is an effect of the whole spindle system deformation during sawing process (Fig. 1).

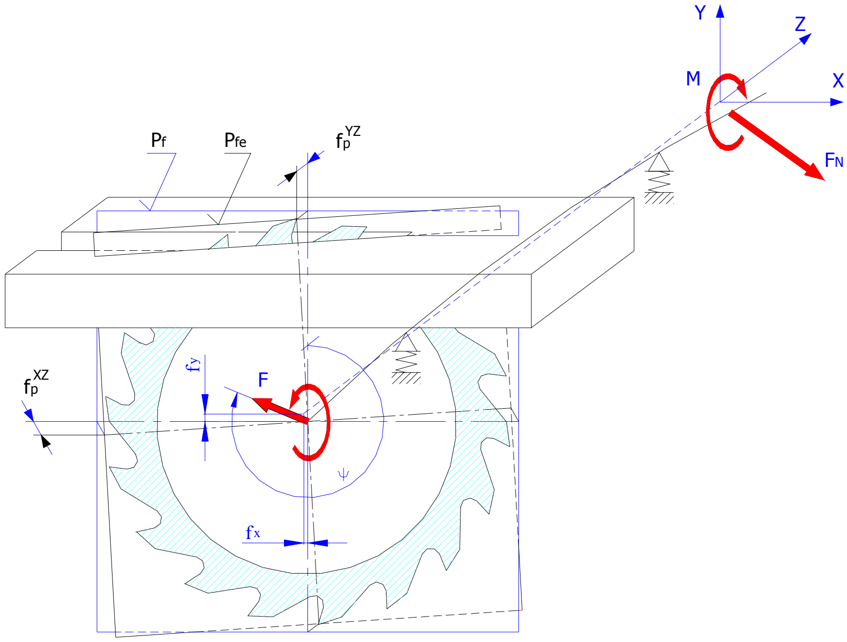

Fig. 1. Deformation of the circular sawing machine spindle system

It is assumed that in the theoretical (rigid, undeformable) system, the circular saw is located in the assumed working plane P_f. This plane is perpendicular to the spindle axis of rotation Z and parallel to the assumed feeding direction v_f. In the true system, spindle loads referred to the spindle axis of rotation (geometrical axis), caused by the resultant cutting force F and the force F_N (originating from the driving system), produce both deformation of the spindle and the bearings. Thus, the saw blade position changes and relocates to the working plane P_{fe} as a result of these displacements. The position of the working plane P_{fe} in relation to the assumed working plane P_f may be determined in two the most characteristic for sawing directions: assumed feed speed direction X and in direction Y perpendicular to the latter (X). In dependence of both the cutting force action direction angle Ψ and the angle of the driving force direction Ψ_N, spindle end displacements f_x and f_y, and also tooth displacements f_p^{XZ} and f_p^{YZ} in two characteristic directions may have different values. In the examined static approach displacements of the axis of rotation depend mainly on [1]:

- factors connected with the load system – cutting forces and driving forces;
- factors connected with the spindle – longitudinal and crosswise dimensions,
- factors connected with bearings – a bearing type and initial stress.

Tooth position errors in the sawing system, besides the circular saw blade displacement to the working plane P_{fe}, may additionally arise from the radial run-out and the axial run-out of teeth in relation to the circular saw working plane P_{fe} (Fig. 2).

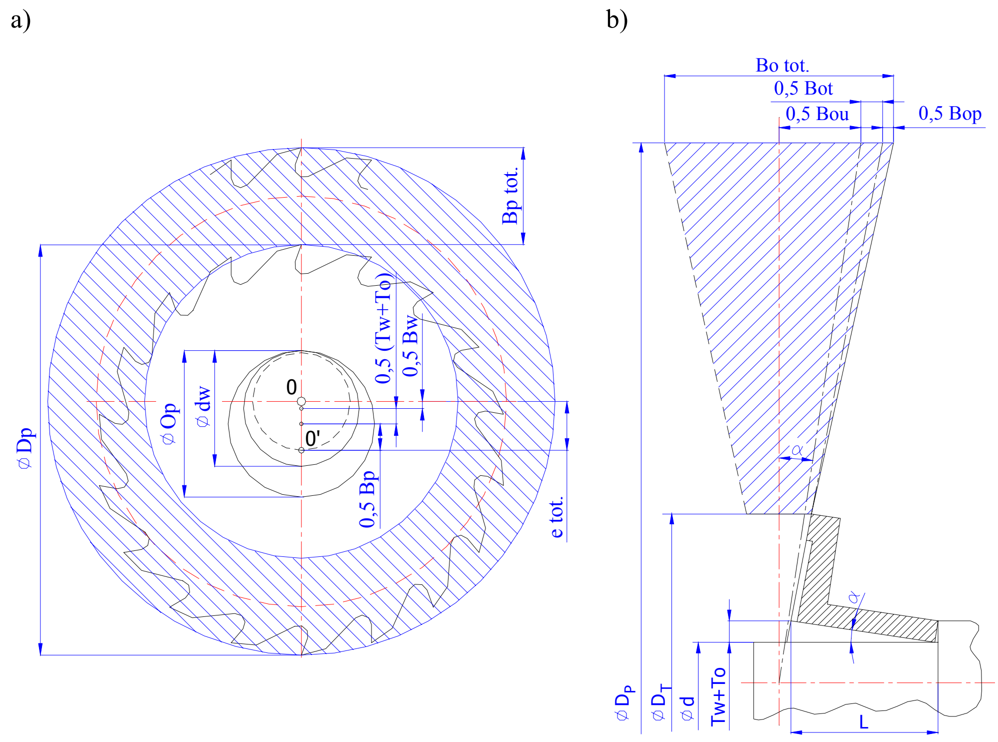

Fig. 2. Circular saw teeth position for collar clamping system on the spindle: a) tooth radial run-out, b) tooth axial run-out

In commonly known designs of circular sawing machine spindles the saw is directly seated on the pin spindle (Fig. 2a), which an axis of rotation is placed in the point *0*. The radial tooth position accuracy is a result of the machine fixing and saw clamping elements quality of work. The value of this accuracy depends on;

- radial run-out of the spindle pin *Bw*,
- dimensional tolerance of the spindle pin diameter *Tw*,
- dimensional tolerance of the saw hole *To*,
- radial run-out of teeth in relation to the saw hole *Bp*.

Furthermore, assuming that inaccuracies of the machine fixing and saw clamping elements quality of work in the radial direction are an eccentricity in character, thus, the saw teeth geometrical centre occupies location at point *0'*, which is remote from the axis of rotation at a distance of the total eccentricity *e tot.*, and saw teeth have radial run-out of *Bp tot.*

In many cases, the clamping accuracy of the circular saw in the axial direction is even worse. It concerns mainly systems in which the circular saw is directly fixed on the spindle pin, or if it is seated with the additional use of the adapter ring (additionally dimensional tolerances of both the outside diameter and the inside diameter of the adapter ring should be taken into account).

In the commonly used designs of circular sawing machine spindles, the circular saw is fixed in the axial direction with the use of the sliding headed bush (sliding collar), which is seated on the spindle pin (Fig. 2b). If the axial pressure is unsymmetrical to the collar, in relation to the spindle axis, the circular saw may take up the position as in Fig. 2b. In these conditions an axial accuracy of the circular saw teeth is a result of the machine fixing and saw clamping elements quality of work, and its value depends on:

- collar axial run-out *Bou* caused by an angular rotation of the collar (angle α at the collar length *L* in the ranges of the sum of the spindle pin dimensional tolerance *Tw* and the collar hole *To*;
- collar axial run-out *Bot* caused by axial run-out of the collar in relation to the collar hole;
- axial run-out of teeth in relation to saw blade *Bop*.

Cleanness of the saw blade surfaces and collar surfaces is an another significant factor affecting circular saw fixing accuracy. Local impurities on these surfaces may cause additional teeth displacements in the axial direction, which values are a function of the ratio of the outside circular saw diameter to the collar diameter D_p/D_T.

ANALYSIS OF TEETH POSITION IN THE SAWING SYSTEM

An example of the effect of the circular sawing machine spindle system upon position of circular saw teeth in the sawing system is performed in Fig. 3. For the traditional design issue of the spindle system (Fig. 3a) there are shown positions of circular saw teeth in the Fig. 3b.

In the presented example of wood cutting with rotational speed n, when the process consumes cutting power P_c, the resultant cutting force F and the driving force F_N have values as in Fig. 3b. It was also assumed that: these force action directions are parallel to each other, their senses are the same and spindle bearings are rigid. In these conditions, a spindle deflection causes movement of the circular saw to the plane defined with the displacement of the spindle axis of rotation F and teeth displacement f_p . Values of these displacements are performed in Fig. 3b [2]. Mentioned displacements originating form the spindle deflection are totalized with position inaccuracies arising from the method of clamping of the saw on the spindle, and also with inaccuracies of teeth positions in the saw blade. For the analyzed sawing design system values of the total teeth axial run-out *Botot* and teeth radial run-out *Bptot* are presented in Fig. 3b [4]. These values were estimated on the basis on the commonly used, by the circular saw producers, dimensional tolerances of the quality of work.

On the grounds of the presented analysis it is visible that for the common applied issues of circular sawing machine spindle systems total values of the spindle deflections, radial run-out and axial run-out of teeth reach considerable values.

The component of deflection caused by the driving force has the biggest value among other constituents. Unloading the driving system as it is shown in Fig. 3c, the spindle form the driving system is only loaded with a torque without the bending moment (originating previously from the driving force F_N). This solution significantly improves the circular saw position in the cutting process. Furthermore, in this design a value of the teeth axial run-out is first of all a function of the saw clamping method. Limitation to the minimum of the fixing element number may also reduce a value of the tooth run-out (Fig. 3c). The further improvement of the system accuracy needs an increase of both the circular saw quality of work and the spindle accuracy.

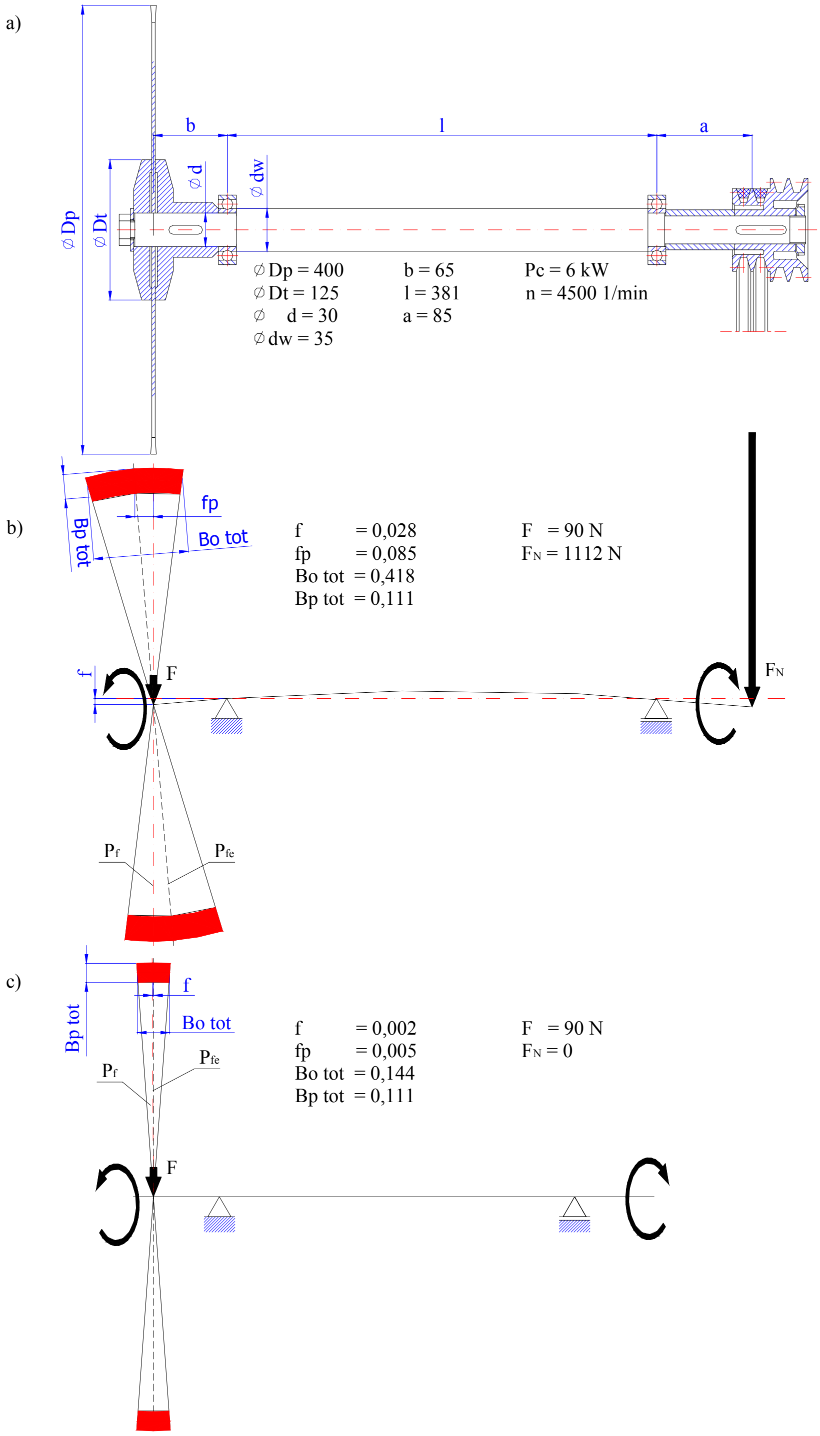

Fig. 3. Analyses of circular saw teeth positions: a) spindle system, b) teeth position errors of the spindle form Fig. 3a, c) teeth position errors of the modernized spindle system (unloaded with a bending force from the driving system)

RESULTS

In the sawing system the circular saw tooth position errors in relation to the workpiece depend mainly on tooth position errors in relation to its axis of rotation, and also position errors of the axis of rotation in relation to the assumed working plane P_f. The position of the working plane is first of all a function of the spindle system stiffness and the motion transfer method. Moreover, values of axial run-out and radial run-out of the circular saw teeth depend on the saw clamping method on the spindle and quality of work of the whole spindle system.

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