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Quality of the workpiece surface at cutting by a circular-saw blade with the irregular tooth pitch

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Abstract: *Quality of the workpiece surface at cutting by a circular-saw blade with the irregular tooth pitch.* The paper describes characteristics of circular-saw blades, their distribution and geometry, problems of the circular-saw blade vibration, effects of their construction adjustments on the resulting surface quality. The main objective of this paper is to provide information on the quality of a saw kerf at cutting by circular-saw blades with the irregular tooth pitch.

Keywords: circular-saw blade, irregular tooth pitch, surface quality, roughness, waviness

INTRODUCTION

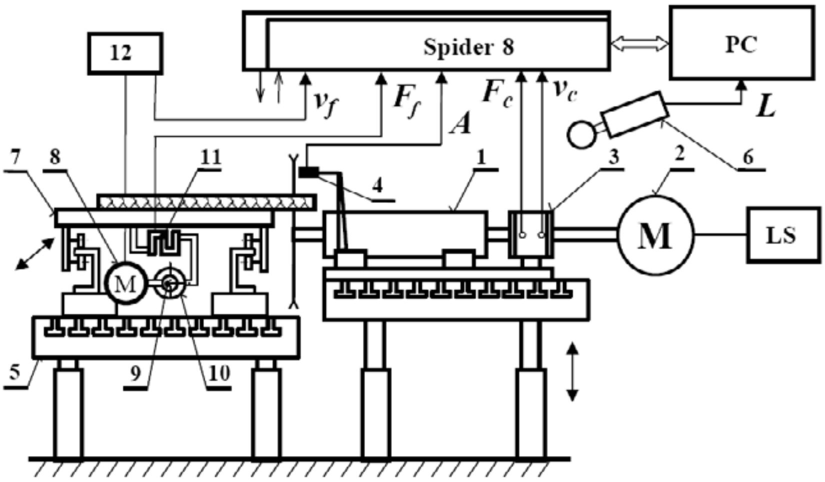
In wood-processing industry, cutting by circular-saw blades is the most often used technology to saw wood materials. At sawing, the wood material is cut by a circular-saw blade rotating in one direction by uniform speed. The quality and accuracy of cutting are derived from the machine construction, shape and the amount of saw teeth, feed per tooth and the size of the circular-saw blade vibration. If we do not consider effects of the machine and feed per tooth, the size of vibration and the shape and amount of saw teeth remain. At present, reduction of the vibration size is dealt with by several basic methods:

- by the construction of the disk body (e.g. rolling and bonding the circular-saw blade)
- cutting out stabilization openings into the circular-saw blade body by means of laser
- cutting out dilatation and noise-damping grooves by means of laser
- using additional stabilization disks
- different spacing of saw teeth

Problems of the effect of the construction and vibration of a circular-saw blade on the quality of the saw kerf surface have not been dealt with yet.

MATERIAL AND METHODS

Our research included the analysis of constructions and construction adaptations of circular-saw blades, the sphere of the theory of vibrations and analysis of the saw kerf surface quality. The experiment was realized on an experimental equipment for cutting by circular-saw blades (see Fig. 1.). Parameters of the cutting process (cutting force F_c, feed force F_f, cutting velocity v_c, workpiece feed velocity v_f) were sampled by sensors built-in on a measuring stand, vibrations were determined by the vibration sensor EPRO PR6423/000-001 (Fig.1, note 4), which works on the principle of vortex currents.



1 – spindle, 2 – electric motor with rpm regulation LS, 3 - cutting force $\boldsymbol{F_c}$ and speed $\boldsymbol{v_c}$ sensor, 4 – contactless sensor of vibrations $\boldsymbol{A}$, 5 - grate table, 6 - noise meter, 7 – feeding carriage, 8 – electric motor for the carriage feed, 9 - ball screw, 10 – nut, 11 – feeding force sensor $\boldsymbol{F_f}$, 12 – frequency converter for the feeding speed change $\boldsymbol{v_f}$

Fig. 1 A scheme of the experimental stand

The kerf quality was evaluated by the Talysurf CLI 1000 top equipment. An optical contactless sensor CLA (Chromatic Length Aberration) is a component of this apparatus. A principle of the sensor operation is based on a fact that white light is decomposed and by means of optics with spectral aberration is focussed on an inspected surface. The optics will analyse light according to wave lengths and only a certain wave length is focussed at every point of the surface. Light reflected from the surface goes through an aperture, which transmits only light of focused wave length. A spectrometer will deflect light to a CCD sensor where a space position is assigned to every point.

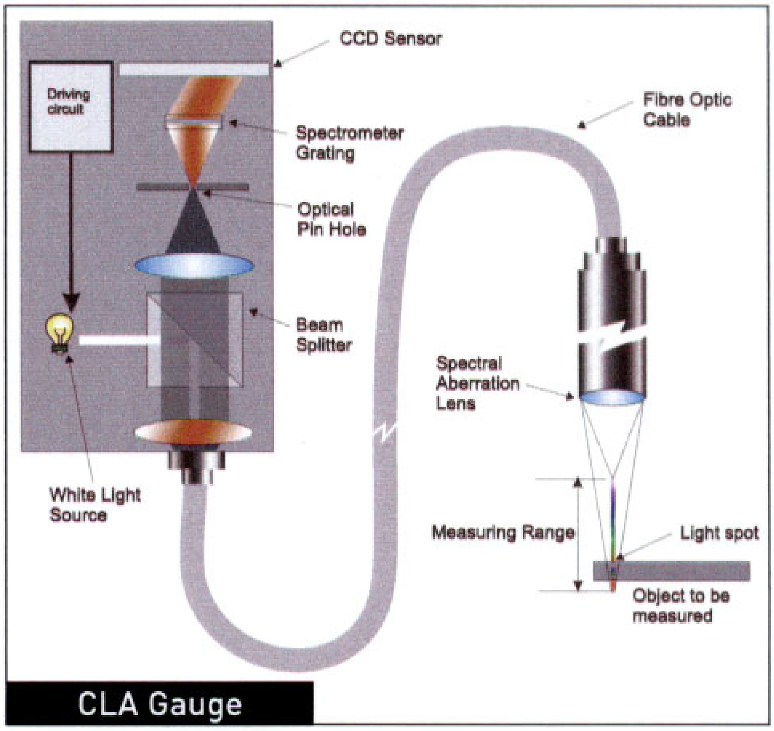


Fig. 2 Confocal sensor CLA

Fast sensing at high resolution and high accuracy rank among advantages of this sensor. The measurement of surface roughness (3D) and the profile waviness (2D) was implemented on an area of 12.5 ×12.5 mm at a step of 20 μm with the measurement velocity 500 $\mu m \cdot s^{-1}$. Evaluation of the cut profile (2D) as well as the area profile (3D) was carried out by the Talymap Platinum program.

Longitudinal native wood cutting (beech and spruce prisms 210×30×700 mm, moisture w = 10%) was carried out by three construction-similar circular-saw blades marked K8, K9 and K10.

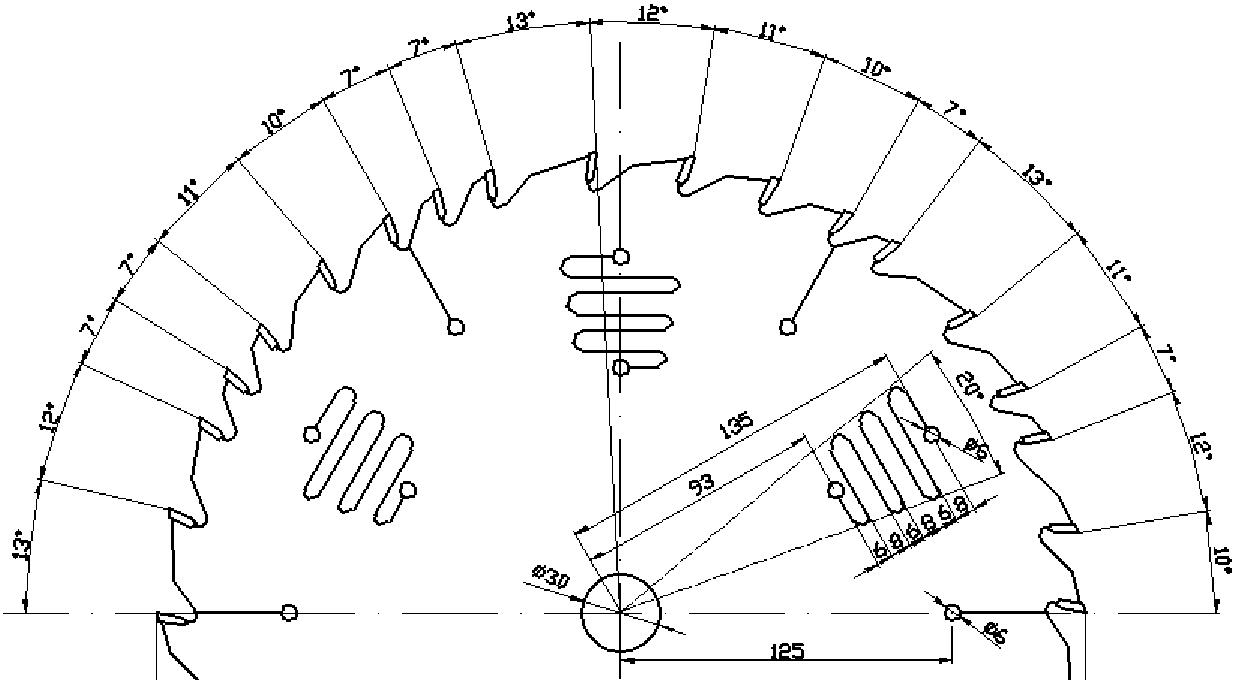


Fig. 3 Tested circular-saw blade – K8

It refers to prototypes manufactured by Pilana Hulín and Stelit Nitra companies. All three disks are of the same thickness *s=2.4 mm*, the same number of teeth *z=36*, the same geometry of teeth $\alpha=15°$, $\beta=65°$, $\gamma=10°$ and the bevel angle $\xi=10°$. There is a substantial difference at a circular-saw blade K8, which is carried out with the irregular tooth pitch devised to reduce noisiness. The circular-saw blade K10 was manufactured without noise damping and dilatation grooves and only with the adjustment of tension by rolling.

The workpiece surface is considerably affected by the process of cutting in a groove with a large number of cutting wedges. At circular-saw blades, the depth of grooving is variable. It is dependent on the position of a circular-saw blade with respect to a workpiece, on the geometry of teeth and tooth pitch, on the position of the circular-saw blade with respect to a workpiece and, last but not least, on the circular-saw blade vibration. It also depends on the tooth position in the ripped material. In our case, the disk axis was placed under the table. It is also known from practice that with the change of the workpiece height with respect to the circular-saw blade axis the chip thickness changes substantially at the same feed per tooth. For swaged teeth or sintered carbide teeth with a trapezoidal profile (Lisičan, 1996), it is possible to determine the theoretical depth of grooves *y* and to calculate it according to an equation (1). By means of an experiment it has been proved that these theoretically calculated values are 5 times to 10 times higher in practice (Kopecký-Rousek-Novák, 2008).

$$\boldsymbol{y} = \frac{\boldsymbol{s}_1}{\boldsymbol{h}} \cdot \frac{\boldsymbol{v}_{\boldsymbol{f}}}{\boldsymbol{n} \cdot \boldsymbol{z}} \cdot \sqrt{1 - \left(\frac{\boldsymbol{a} + \boldsymbol{x}}{\boldsymbol{R}}\right)^2} \quad [\text{ mm }] \qquad \textbf{(1)}$$

where s_1 … distance between the circular-saw blade disk and the workpiece edge
h … tooth height
a … workpiece set-up with respect to the rotation axis of the circular-saw blade
$x \cong 1/2a_e$ (a_e … workpiece thickness)

RESULTS

Vibrations of the disks or the course of the vibration amplitude depending on the disk rpm were proved by the method of the direct sensing the amplitudes of the disk vibrations on an experimental stand (see Fig. 4).

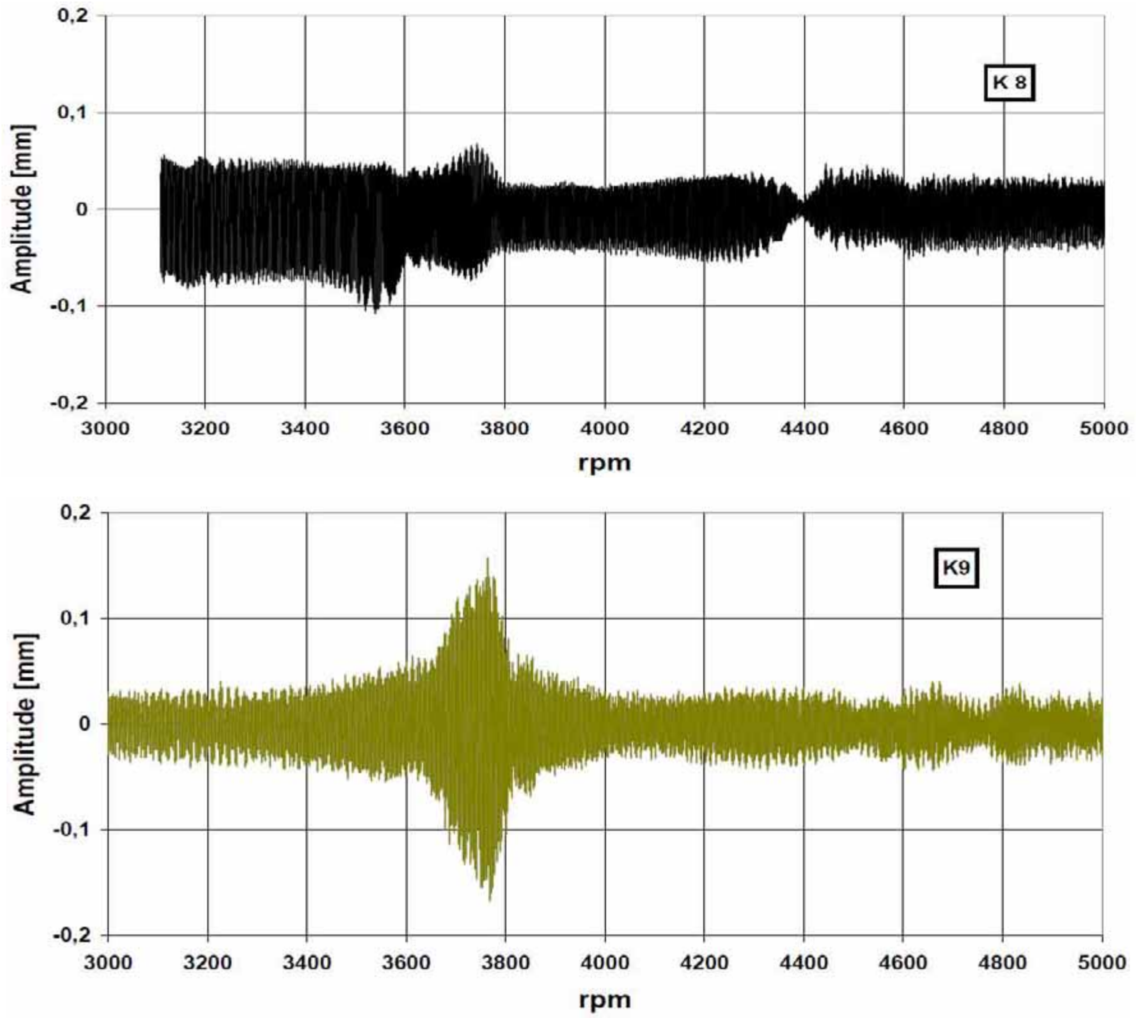


Fig. 4 The course of vibrations of circular-saw blades

Steady running conditions with minimum vibrations occur at all disks in the rpm zone n_{opt} = *4100 rpm*. Cutting in resonance rpm was chosen individually from measured resonance rpm for particular nodal diameters of vibration (K8 and K9 – n_r = *3750 rpm*, K10 - n_r = *3850 rpm*). At all cuts of hardwood (beech) and softwood (spruce), the same feed per tooth was kept with corresponding mean thickness of a chip h_m = 0.05 mm (Hlásková, 2011).

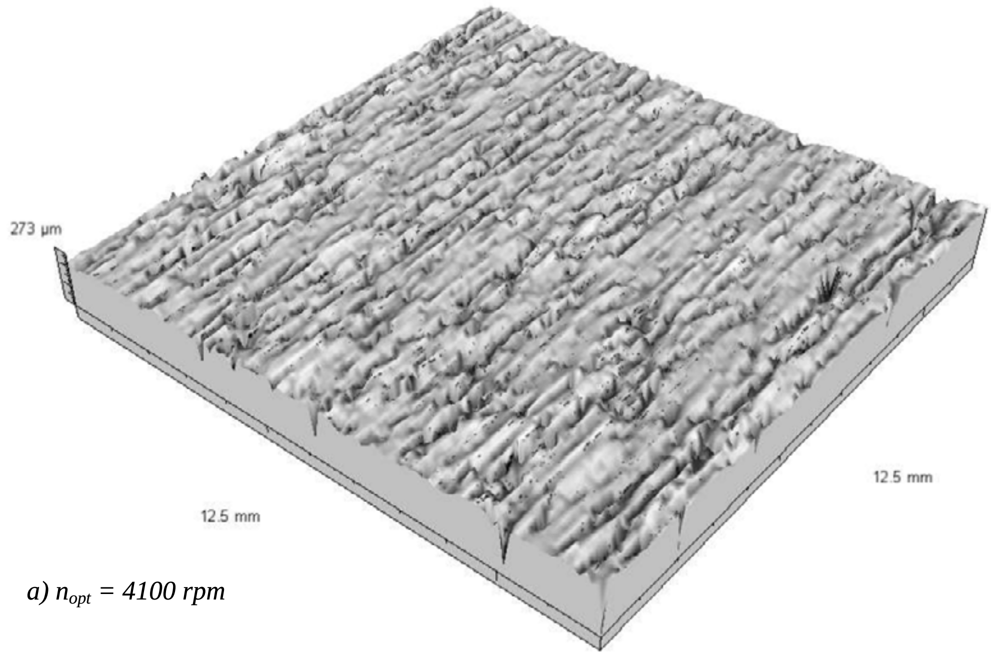
a) spruce, disk K8, optimum - 4100 rpm

b) beech, disk K9, resonance - 3750 rpm

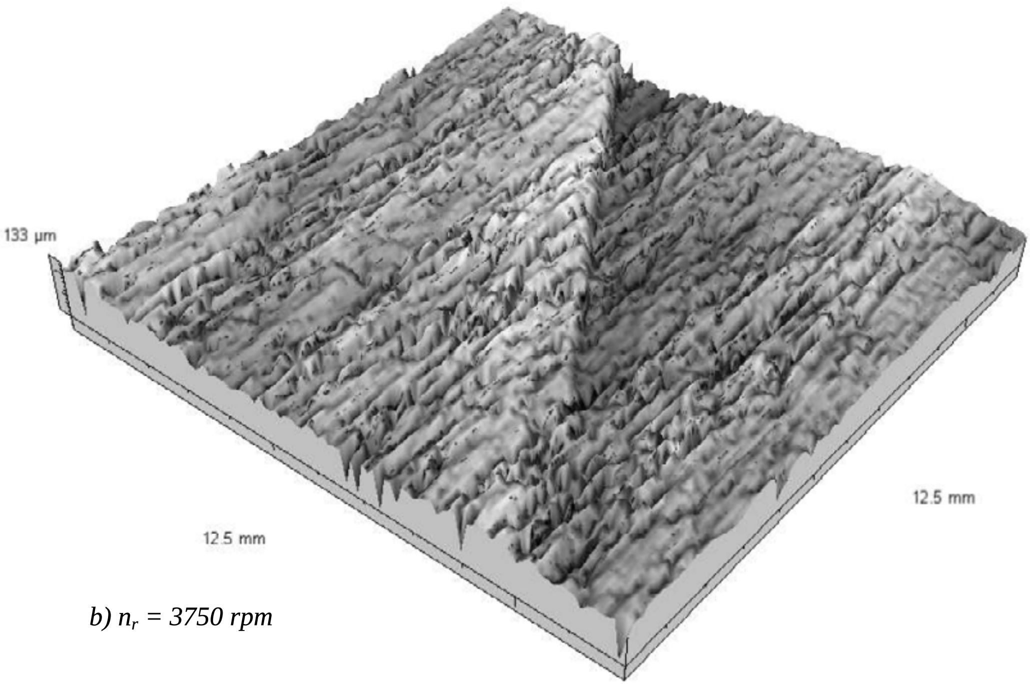
Fig. 5 Evaluated workpiece surface

At evaluating the saw kerf quality, decisive parameters include the surface roughness, and the profile waviness. Therefore, it was necessary to carry out filtration (Gaussian filter, 0.8 mm) with the filter length 2.5 mm. Evaluation of the topography (3D) of the cutting area surface was carried out by means of two parameters, namely Sa from the basic area (see Fig. 6) and Wt from the area of waviness (see Fig. 8). Values of parameters Sa and Wt are given in Fig. 9.

- Sa – average arithmetical deviation of the basic surface – the parameter is included in EUR 15178 EN
- Wt – total height of the waviness profile



a) n_{opt} = 4100 rpm



b) n_r = 3750 rpm

Fig. 6 3D basic profile of the surface – beech, K8

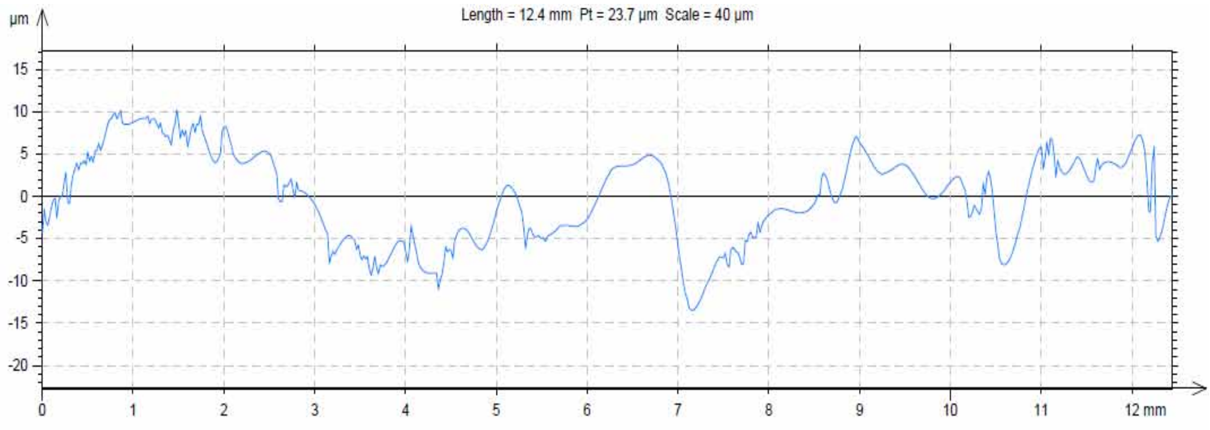


Fig. 7 2D cut of a profile from the basic area – cutting by a disk K8, $n_{opt} = 4100\ min^{-1}$

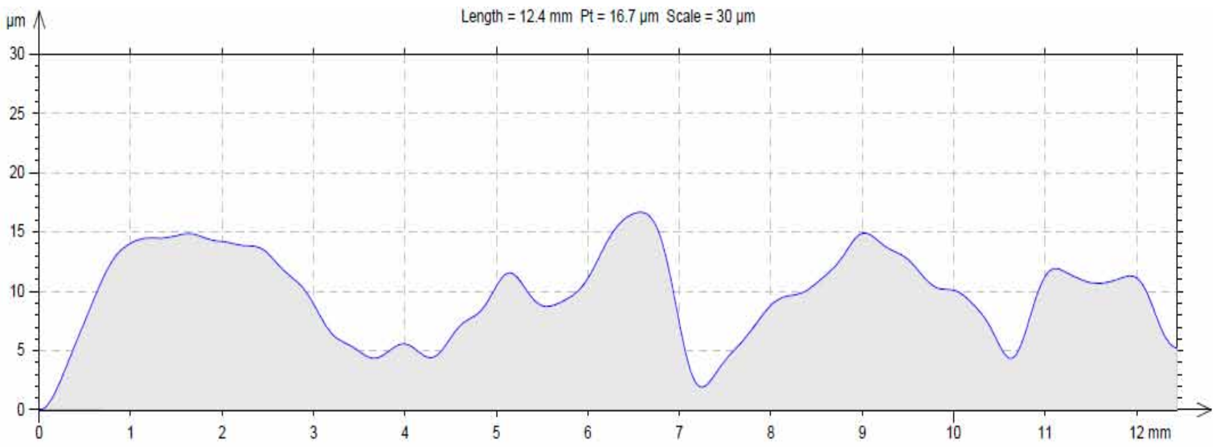


Fig. 8 Waviness – cutting by a disk K8, $n_{opt} = 4100\ min^{-1}$

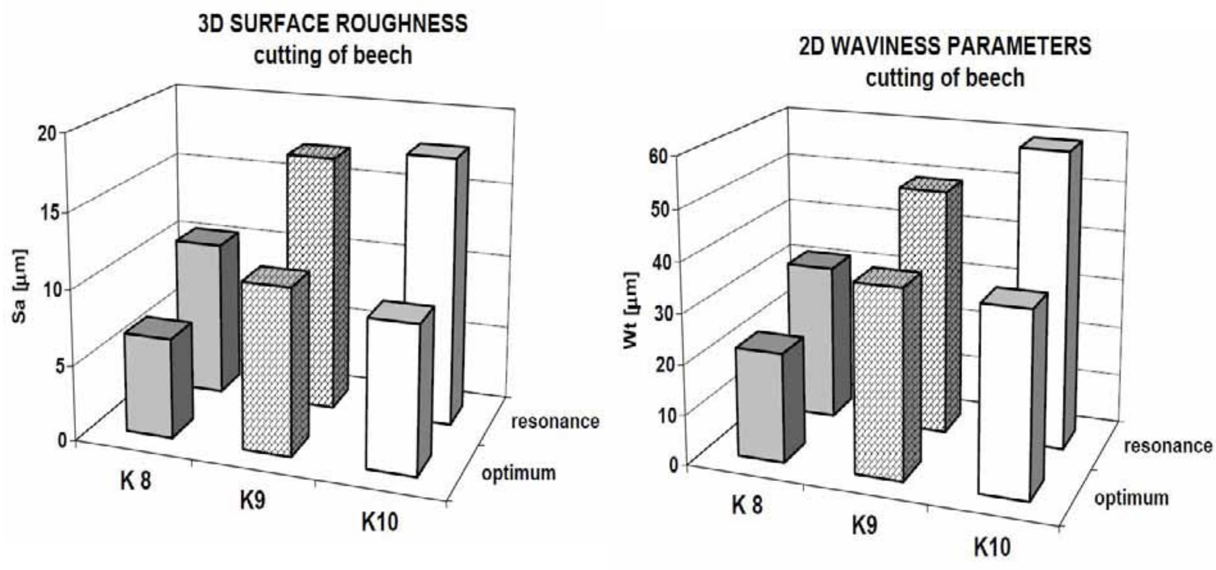


Fig. 9 Comparison of the surface roughness and waviness at cutting beech by disks K8, K9, K10

DISCUSSION AND CONCLUSION

The best surface quality was achieved at cutting by the K8 with the irregular tooth pitch. Under optimum and resonance rpm, 3D values of the surface roughness Sa and 2D surface waviness at K8 are about half compared to values achieved at cutting by K9 and K10 circular-saw blades. Better results are achieved at cutting under optimum rpm using K8 at cutting beech and spruce. The quality of a machined area by K9 and K10 disks is relatively balanced except for higher values of waviness Wt at resonance rpm at K10 circular-saw blade. This phenomenon can be explained by the absence of basic construction adaptations and thus the easier loss of stability at reaching the resonance rpm condition.

Results achieved demonstrating the effect of construction parameters of circular-saw blades on the quality of saw kerf point out a fact that the irregular tooth pitch, thanks to the different thickness of a cut chip and better reinforcing circular-saw blades, has a positive effect on the improvement of the surface quality, namely up to two-fold as compared to a disk with the regular tooth pitch.

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Streszczenie: *Jakość powierzchni przy piłowaniu piłą tarczową z uzębieniem niejednorodnym.* Praca opisuje piły tarczowe, rozstaw zębów, geometrię, wibracje oraz wpływ modyfikacji konstrukcji na jakość obrobionej powierzchni. Głównym celem pracy było opisanie jakości powierzchni przy piłowaniu piłami tarczowymi o zmiennym rozstawie zębów.

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