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Cut layer of a circular saw with radial run-out of cutting edges*

Površina strugotine pri piljenju kružnom pilom različitih ispona zubi*

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ABSTRACT • *This paper presents the influence of the radial run-out of circular saw blade teeth on changes of cut layer thickness for each blade and change of total cut layer thickness for the saw. Additionally the influence is presented of workpiece position in relation to the saw on cut layers thickness.*

Key words: *wood cutting, circular saw, radial run-out*

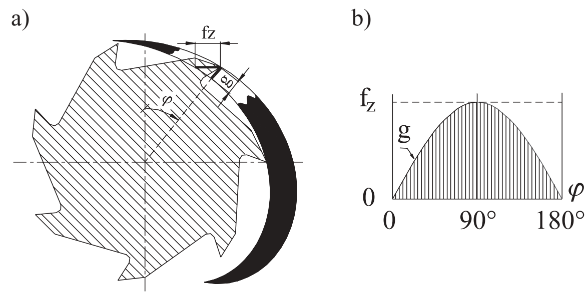
SAŽETAK • *U radu se obrađuje utjecaj radijalnog ispona zubi kružne pile na promjene debljine strugotine za svaku oštricu i na promjenu ukupne debljine strugotine za sve zube na pili. Osim toga, analiziran je i utjecaj položaja obratka u odnosu na list pile na debljinu strugotine.*

Ključne riječi: *rezanje drva, kružna pila, radijalni ispon zubi*

1 INTRODUCTION
1. UVOD

The fundamental parameter that determines technical and economic effects of wood cutting process is the shape and value of cut layer cross-section.

In previous analyses of circular saw cut conditions, very often mean values of the cut layer cross-section have been used derived from geometrical and kinematical machining conditions developed theoretically (Goglia et al, 2003). In such machining conditions the value of feed per tooth f_z and thickness of cut layer g are equal for each circular saw blade tooth (Figure 1a). Besides the value of feed per tooth, rotation is constant for every angle of circular saw and thickness of cut layer changes as shown in Figure 1b.



g – thickness of cut layer (*debljina strugotine*), f_z – feed per tooth (*posmak po zubu*), φ – angle (*kut*)

Figure 1 Theoretical parameters of machining with circular saw: a) cut layers, b) values of parameters of cut layer
Slika 1. Teorijski parametri obrade kružnom pilom: a) površina strugotine, b) vrijednosti parametara površine strugotine

This way of determination of cut layer cross-section is actually insufficient in many cases because the determined cross-sections of cut layers do not take into consideration the fundamental parameters, which influence their values. The determination of these parameters should include errors of cut system e.g. error of ra-

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dial run-out of blade teeth, or the actual number of blade teeth used in the machining area. A detailed analysis of the current conditions of circular saw machining requires the determination of cut layer cross-section in real-life conditions.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The value of cut layer intersection is the result of cutting thickness and shape of the blades. In many cases, when the shape of blade teeth is equal, the analysis of the cut layer intersection could be limited to the analysis of cutting thickness. Additionally, as the circular saw is a multibladed tool, the cut layer could be determined for each blade tooth or for the whole circular saw (every blade tooth actually used in the machining area).

2.1 Cut thickness of circular saw blade teeth
2.1. Debljina reza zuba kružne pile

In real-life conditions of machining there is always an error of radial run-out of tooth blades. Radial run-out is the result of difference between radii of particular tooth blades of circular saw versus its axis of rotation. The radial run-out of the saw may be caused by manufacturing errors of the saw (Wasielewski and Orłowski, 2005), errors resulting from mounting on the spindle and errors of the spindle itself.

The value of radial run-out for particular tooth blades can be described as:

– radial run-out, determined by difference between radii of given tooth blade and first tooth blade taken as reference basis

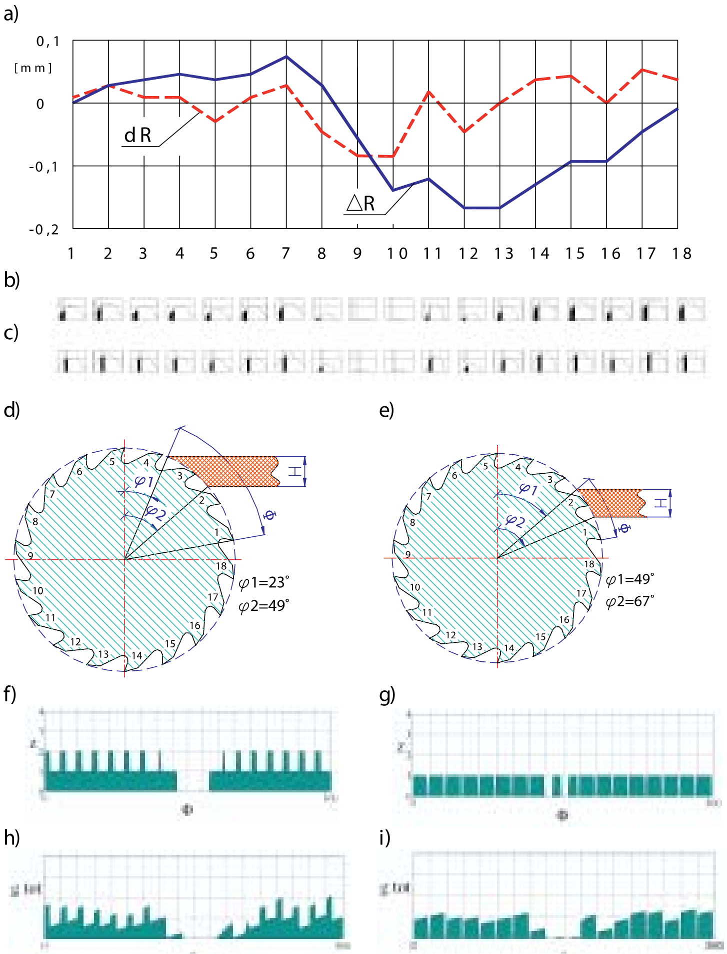
$$\Delta R = R_i - R_1 \tag{1}$$

– an increment of radial run-out, described as difference between radius of given tooth blade and previous tooth blade

$$dR = R_i - R_{i-1} \tag{2}$$

Determination of thickness of cut layers for particular tooth blades for any distribution of radial run-out is a complex task requiring the analysis of movement trajectory for all tooth blades in relation to the machined material. For this purpose special software application was developed. The software application determines changes of thickness of cut layers by tooth blades based on distribution of radial run-out on particular tooth blades of the saw.

An example of calculation of results in real-life conditions of machining by saw with $D = 400$ mm diameter including 18 straight tooth blades is shown in Fi-



a) measured radial run-out of circular saw (*izmjereni ispon reznih bridova*); b) cut layer thickness for each circular saw blade tooth under conditions shown in Figure 2d (*debljina strugotine za svaki zub kružne pile prema uvjetima prikazanim na slici 2.d);* c) cut layer thickness for each circular saw blade tooth under conditions shown in Figure 2e (*debljina strugotine za svaki zub kružne pile prema uvjetima prikazanim na slici* 2.e); f), g) number of tooth blades having contact with the material at the actual moment when conditions shown in Figure 2d and Figure 2e are met (*broj oštrica u dodiru s materijalom u trenutku kad se steknu uvjeti prikazani na slikama 2.d i 2.e);* h), i) total thickness of cut layer of the saw when conditions shown in Figure 2d and Figure 2e are met (*ukupna debljina strugotine u uvjetima prikazanim na slikama 2.d i 2.e)*

Figure 2 Machining thickness of the sample of circular saw blade tooth
Slika 2. Debljina strugotine pri piljenju kružnom pilom

gure 2 (Wasielewski and Walkowiak, 2005). Distribution of radial run-out ΔR achieved from measurements and increment of radial run-out dR of tooth blade is presented in Figure 2a. In this example the saw with large errors of radial run-out is presented in order to show the influence of radial run-out on thickness change of the cut layer.

The calculation of the cut layer thickness for each blade tooth was made using the mean value of feed per tooth $f_z = 0.1$ mm. The calculation results for each blade tooth in the form of graphs presenting changes of cut layer thickness depending on circular saw rotation angle (contrary to Figure 1b) are shown in Figure 2b and Figure 2c. In Figure 2b the calculation results are presented for the case shown in Figure 2d and in Figure 2c for the case shown in Figure 2e.

2.2 Total machining thickness of circular saw
2.2. Ukupna debljina strugotine

In addition to changes of cut layer thickness for each blade tooth, changes of total cut layer thickness gtot are fundamental for the whole saw, because they decide about the changes of the saw operating conditions. This layer is the sum of the cut layer thickness for blades which are cutting the material at a specific moment. Changes of total cut layer thickness g_{tot} in a saw operating cycle are the result of changes of number of tooth blades having contact with the cut material and radial run-out of circular saw blade teeth.

For the examples of machining shown in Figure 2d and Figure 2e, the changes of blade number Z, which are in contact with the machined material, are presented in Figure 2f and Figure 2g. The changes of total cut layer thickness g_{tot} in the saw operating cycle are shown in Figure 2h and Figure 2i.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The analysis of the cut layer thickness for each blade tooth in machining under the above conditions show that radial run-out of circular saw blade teeth have a significant impact on the cut layer thickness. Additionally it can be noticed that the size of changes of cut layer thickness depends on the increment of radial run-out and not on the total value of radial run-out. Under the above machining conditions, blades No. 9 and 10 do not have contact with the cut material, during machining as shown in Figure 2d blades No. 8, 11 and 12 work in unfavourable conditions, because the minimum value of their cut layer thickness is equal to zero, which favour material kneading.

The working cycle of a circular saw is a full rotation of the saw Φ starting from the moment when the blade No. 1 comes into the material ($\Phi = 0°$). It can be seen in the described example that for specific values of rotation angle no saw blade teeth have contact with the machining material. This changeable number of blades, which have contact with the machined material, and radial run-out of circular saw blade tooth cause the change of total cut layer thickness g_{tot}. Comparison of examples under different sawing conditions related to different position of the cut material in relation to the saw (Figure 2d and Figure 2e) shows considerable influence of this parameter on the changes of the cut layer thickness for each blade tooth, as well as changes of total cut layer thickness in the operating cycle of the circular saw.

4 CONCLUSION
4. ZAKLJUČAK

In real-life conditions of machining there is always an error of radial run-out of tooth blades. In most cases it results in considerable changes of the cut layer intersection for each tooth blade and considerable changes of total cut layer intersection in circular saw operating cycle. The developed software application allows the delimitation of these changes under specific machining conditions.

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