THE EFFECT OF THE SHAPE OF THE COMPENSATING SLOTS IN THE BODY OF A CIRCULAR SAW BLADE ON NOISE LEVEL OF A CIRCULAR SAW IN THE CUTTING PROCESS

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Abstract: In most cases, the cutting of wood is proceeded at high feed speed and high cutting speed of the circular saw blades. The circular saw blades teeth rotate in outer ambient and thus are source of noise with unadvisable effects on working environment. The results of the measuring the noise level of three structurally different circular saw blades are presented in this paper. The types of the circular saw blades are: with six compensating slots in radial direction, with six compensating slots in tangential direction and with six sigmoid compensating slots. The diameters of the circular saw blades were 350 mm. The measurements of the noise level were performed in the cutting process using the standard equipments. The circular saw blades with compensating slots emitted high cutting noise level but their noise level was different. The circular saw blade with sigmoid compensating slots had the lowest noise levels in the range of (2 ÷ 4) dB (A) as compared with the others saw blades.

1 Introduction

The cutting process using the circular saws is the most commonly used in woodworking industry. The cutting tools are circular saw blades. The vibration and noise of a circular saw blades are fundamental problems of tool instability in cutting process. The decrease of the amplitude of oscillation is inevitable for the surface quality enhancement, the cutting accuracy, the extension of the tool endurance, but also for the noise reduction. Especially the noise emission can be affected directly by the shape of a circular saw blade. The noise level emitted by a circular saw blade depends mostly on increase of the cutting speed and also whether it’s idling or cutting. The circular saw blades sometime emit higher noise levels during idling than during cutting. This noise is intensive resonant noise, known as „the whistling of a circular saw blades“. It’s very important to detect and eliminate this phenomenon mainly for the circular saws for lateral cutting.

The asymmetric circular saw blade with the compensating slots made in its body is the most commonly used tool in woodworking industry. The effects of length and number of the slots and the copper corks on noise level of the circular saw blades were examined in many scientific works. We can present some of them (Leu a Mote, 1979; Dugdale, 1977; Plester, 1985; Miklaszewski a Grobelny, 1995; Svoreň a Naščák, 1999; Goglia, 1999; Svoreň, 2004; Orłowski, 2005; Svoreň, 2006; Svoreň, 2007). The producers of a circular saws use for the decrease of the noise emission varied damping methods. These methods are divided into three groups:
1. **Glued circular saw blades** – according to (Westkämper, 1990) the decrease of the noise level during idling is by 10 dB (A), during cutting by (6 ÷ 8) dB (A).

2. **The body of the circular saw blade made of high damping materials** – according to (Hattori, 1987; 2001) the decrease of the noise level during idling is by 11 dB (A).

3. **Laser cutting of the compensating slots into the body of the circular saw blade** – according to (Westkämper, 1994) the decrease of the noise level during idling and cutting is from 2 to 8 dB (A). The laser cutting brings some advantages as accuracy, fastness and ability to do individual applications.

## 2 Material and methods

There were used three circular saw blades within the research. The first one (CSB1) had a compensating slots in its body made by a laser in radial direction, copper corks and unbalanced pitch of teeth (Figure 1a). The second one (CSB2) had a compensating slots in tangential direction, copper corks and unbalanced pitch of teeth (Figure 1b). The third one (CSB3) had a sigmoid compensating slots, copper corks and unbalanced pitch of teeth (Figure 1c). The teeth of circular saw blades have plates of hard alloy and are altered sideward ground. The diameter of clamping flanges was $d_f = 110$ mm. Constructional differences of used circular saw blades are figured on Figure 1.

### Figure 1. Used circular saw blades

![Used circular saw blades](image)

### Table 1. Fundamental parameters of used circular saw blades

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CSB1</th>
<th>CSB2</th>
<th>CSB3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of circular saw blade, mm</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Diameter of clamping hole, mm</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Number of teeth</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Thickness of circular saw blade, mm</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Width of cutting edge, mm</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Tooth height, mm</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Pitch of teeth</td>
<td>unbalanced pitch of teeth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geometry of tooth</td>
<td>$\alpha_r = 15^\circ$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tooth type</td>
<td>WZ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The operating speed of circular saw blades were determined upon the calculation of resonant (critical) frequencies according to the equation:

\[
n_{r,k} = \frac{60 \cdot f_{(n=0)}}{\sqrt{k-Z^2-\lambda}} \quad [\text{min}^{-1}]
\]

\(f_{(n=0)}\) – natural frequency of non-rotating circular saw blade \([\text{Hz}]\)

\(k\) – number of nodal diameters \([-\] \)

\(Z\) – harmonic number, \((Z = 0;1;2;3;4;\ldots,)\) \([-\] \)

\(\lambda\) - centrifugal force coefficient \([-\] \)

The natural frequencies of non-rotating circular saw blades were experimentally determined on measuring equipment which is described in (Svoreň, 2000) for \(k = 1;2;3\). The centrifugal force coefficients \(\lambda\) were experimentally determined on measuring equipment in the laboratories of KDSZ TU in Zvolen, which is described in (Svoreň a Danko, 2004). Upon the analysis of calculated resonant (critical) speed the operating speed were chosen for experimental measuring of noise level as follows: \(n_1 = 3400 \text{min}^{-1}; n_2 = 3425 \text{min}^{-1}; n_3 = 3450 \text{min}^{-1}; n_4 = 3475 \text{min}^{-1}\) and \(n_5 = 3500 \text{min}^{-1}\).

The spruce planks used at experimental measuring of noise level had following parameters: length - 1500mm, width - 250mm, thickness - 25mm and 40mm, plank moisture \(w = 12\%\), feed speed \(v_{f1} = 12 \text{m.min}^{-1}\) and \(v_{f2} = 17 \text{m.min}^{-1}\).

The frequencies that are audible for man are in range of 20 - 20 000Hz. This range is marked as the range of acoustic frequencies. At lower frequencies, the vibrations cause appreciable shivering of the body of man, which is rather felt than heard. The upper limit of audibility differs from man to man and it decreases with growing age. The level of acoustic pressure \(L\) is used in practice and is given as:

\[
L = 20 \log_{10} \left( \frac{p}{p_0} \right) \quad [\text{dB}]
\]

\(p\) – acoustic pressure in spotted point in Pascals

\(p_0\) – internationally agreed reference value of acoustic pressure, \(p_0 = 2.10^{-5} \text{ Pa}\)

The measurement of the acoustic pressure levels of the circular saw was realized on measuring equipment, which block schema is seen on Figure2. The microphone was placed in the distance of 1m from the machine bay and in an amount of 1,5m above the ground. The sound-level meter Norsonic 118 that is seen on Figure 3, was set on electric wave filter „A“ and time – weight filter „F“ in the range to 120dB. The whole measuring chain was calibrated before the measurement using the calibration equipment Norsonic 1251 that emits noise level \(L = 113,8\text{dB}\) at frequency \(f = 1000\text{Hz}\) for condenser 1/2” microphone.
Figure 2. Block schema of equipments for measuring the noise level of a circular saw
1 – frequency transducer, 2 – electromotor, 3 – belt gear, 4 – circular saw bay, 5 – circular saw blade, 6 – non-contact speedometer, 7 – circular saw shaft, 8 – condenser microphone 1/2”, 9 – sound-level meter Norsonic 118, 10 – personal computer (PC)

Figure 3. Sound-level meter Norsonic 118
3 Conclusions of measurement and discussion

The values of noise levels recorded and stored in the sound-level meter Norsonic 118 were transformed to PC using the special software bought together with the sound-level meter Norsonic 118. They were then processed and graphically evaluated. The graphic figuration of the measurement conclusions is on Figure 4., Figure 5., Figure 6., Figure 7., of which we found out these informations:

- with increasing feed speed $v_f$ the circular saw blade noise level increases at other similar parameters (Figure 4. and Figure 5.)
- the modified circular saw blade CSB3 allocated averaged noise levels $L_A$ by $(3 \pm 4)$dB lower than the modified circular saw blades (CSB1 and CSB2) at all cutting conditions
- the modified circular saw blades (CSB1 and CSB2) allocated just a slight difference of the noise level $L_A$ from 1 to 2,5 dB at all cutting conditions
- the Figure 6. figures time map line of the noise level of several circular saw blades, figure shows the noise level during idling, onset and cutting
- the Figure 7. figures 1/3 octave frequency analysis that confirms speed frequency $f_k$ of max. noise level that is the part of the all-pass noise:

$$f_k = i \cdot n \cdot z \quad [\text{Hz}]$$

(i – basic harmonic, $i = 1, 2, 3, \ldots$ [-])

$$n \quad [\text{s}^{-1}]$$

$$z \quad \text{number of teeth of circular saw blade} \quad [-]$$

![Figure 4.](image)

**Figure 4.** The dependance of the circular saw blade noise level $L_A$ on speed
Figure 5. The dependance of the circular saw blade noise level $L_A$ on speed

Figure 6. The dependance of the circular saw blade noise level $L_A$ on time
Figure 7. The dependance of the circular saw blade noise level $L_A$ on frequency, $h_{_\text{numb}} = 40\,\text{mm}$, $v_f = 12\,\text{m}\,\text{min}^{-1}$, $n = 3450\,\text{min}^{-1}$

4 Closure

Marked decrease of the circular saw blade noise level in the cutting process was achieved using the structural modifications of the body of the circular saw blades CSB1, CSB2 and CSB3. The compensating slots and the copper corks in the body, as well as the unbalanced pitch of the teeth of the circular saw blades don’t ensure the similar decrease of the circular saw noise level at coincident operating speed and different cutting conditions. The obtained knowledge corresponds and in some cases exceeds the mentioned values in guidebookish sources of the firms (LIETZ, FREUD, AKE, OMAS etc). The manufacturing of modified circular saw blades like these must be a standard for every producer. In the case of users it is the increasing of the working environment quality in terms of noise and thus health protection of people at work.

Acknowledgements

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References


