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INFLUENCE OF THE PROCESSED MATERIAL ON THE SOUND PRESSURE LEVEL GENERATED BY SLIDING TABLE CIRCULAR SAW

Pavlin Vitchev – Dimitar Angelski – Vladimir Mihailov

ABSTRACT

The aim of the current study is to investigate the changes in the sound pressure level generated at the operator's position of sliding table circular saw depending on the type of the processed material, the cutting height (*h)* and the tool overhang effect (T) (T_1 = 7; T_2 = 14; T_3 = 21 mm). The experiments were performed with specimens from chipboard oriented strand board (OSB) and plywood with cutting height of 15, 30, 45 mm. The generated sound pressure level was measured using the method of "sound free field" taking into account the influence of the background noise and the characteristics of the sound field. The measurement of the *A*-weighted sound pressure level was performed using precise digital sound level meter CEL-620B1 (CASELLA, United Kingdom). The obtained results showed that the sound pressure level is influenced by the type of the processed material and it is changed at the cutting height of 15 mm as follows: plywood – 89.5 dB(A); OSB – 88 dB(A) and chipboard – 86.5 dB(A). An increase in the tool overhang effect from 7 mm to 14 mm resulted in an increase in the sound pressure level by 3÷4 dB(A) on average for all three types of processed material.

Key words: sound pressure level (SPL), noise, circular saw machine, chipboard, oriented strand boards (OSB), plywood.

INTRODUCTION

The woodworking and furniture industry is notorious for the high noise emissions generated by the used machinery and equipment. The high level of noise emission is one of the main risk factors with a negative impact on the human health, including noise-induced hearing loss and other disorders (BREZIN 1992, BADIDA *et al*. 2010, BREZIN *et al*. 2015, ANTOV *et al*. 2017). According to the European Directive 2003/10/EO, the upper limit for a workplace noise exposure based on the eight-hour working day is determined to be $L_{EX,\,8h}$ = 85 dB(A).

The circular saw machines used in the woodworking and furniture industry are considered the noisiest after the hammermills and the thicknessers (HSE 2007).

The main factors influencing the noise level generated by the circular saws are generally derived from the characteristics: (i) the processed materials – type, length, thickness, moisture, etc.; (ii) the cutting tool – shape and number of teeth, thickness, cutting angles, presence of different sound absorbing and vibrating cuts on the tool body, etc.; (iii) the cutting mode – feed rate, cutting speed, and others (HSE, 2007; HSE, 2009).

One of the main conditions followed by the woodworking machine producers on the market, is the lower noise level generated by their machines. A number of scientific studies investigate the noise emission levels, generated by woodworking circular saws in relation to the parameters of the tool, the characteristics of the processed material and the cutting mode (CHENG *et al* 1998, GOGLIA 1999, HATTORI 2001, SVOREN *et al*. 2007, VITCHEV *et al*. 2018).

According to BIES (1992) the sound power of an idling sawing machine is highly influenced by the characteristics of the circular saw. In its study, the author concludes that the fluctuating lift forces acting on the teeth account for the increased level of the aerodynamic noise.

Other important factors affecting the noise level of a saw blade are the tooth pitch and the number of the saw blade teeth. KOPECKY *et al*. (2012) measured significantly higher (by 4.1 dB) noise levels generated by the circular saw with irregular tooth pitch when compared to the circular saw with regular tooth pitch. KVIETKOVA *et al.* (2015) investigated the influence of the varying number of saw blade teeth on the generated noise during transverse cutting of beech wood. They showed that the noise values were greater in the case of saw blades with fewer teeth.

Various structural characteristics of the circular saw can also affect the level of the generated noise. A number of studies investigate the influence of the compensating slots in the body of a circular saw blade on the noise level during idling ход (BELJO-LUCIC *et al. 2001*, SVOREN *et al.* 2007, SVOREN *et al.* 2009, KVIIETKOVA *et al.* 2015). In various studies the presence of compensating slots result in a significant decrease of the noise levels by 2 to 6.5 dB.

The construction material of the saw blade teeth is also proven to affect the noise generation. More importantly, properly selected construction material with high internal damping potential, may reduce the noise generation up to 11dB (HATTORI *et al.* 1999, HATTORI *et al.* 2001).

The objectives of the current study were to investigate the changes in the sound pressure level generated at the operator's position of sliding table circular saw, depending on the type of the processed material, the cutting height (*h*) and the tool over-hang effect (*T*).

METHODOLOGY

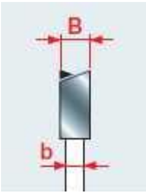
The experiments were carried out using woodworking sliding table circular saw machine WA 6 (Altendorf, Germany) (Fig. 1). The machine was located on a concrete floor in a room with dimensions, length, width and height – $L \times B \times H = 18 \times 6 \times 3.5$ m, respectively.

Fig. 1 Circular saw machine with sliding table, WA6 (Altendorf, Germany).

The main saw blade of the machine is driven through a belt drive, by an electric motor with N = 4 kW power ensuring rotational speed n = 4500 min^{-1} of the circular saw. The scoring saw was not used in the current experiments. In order to limit the background noise level and to measure only the noise generated by the circular saw machine, the aspiration system as well as the other technological equipment did not work.

For the aim of the study, a circular saw blade (Freud, Italy) was used. The technical parameters are presented in Table 1, where: D is the outer diameter; d – bore; B – width of cut; γ – hook angle; β – sharpening angle; z – number of teeth; n_1 – maximum rotation speed, tooth shape W (alternating left and right tilts). The technical characteristics of the machine and the saw blade ensure cutting speed of V_c = 71.65 m.s^{-1}.

Tab. 1 Technical characteristics of the used circular saw.

Teeth shape *W*	*D* mm	*d* mm	*B* mm	γ °	β °	*z* No	n_1 min^{-1}	Material of the teeth
	300	30	3.2	10	65	72	6300	Metal-ceramic hard alloy

The experiments were performed with three different wood based materials at three different cutting heights, as follow:

- Particle boards (without deterioration layer): cutting height 15, 30 (2 × 15) and 45 (3 × 15) mm and density ρ = 660 kg/m^3;
- Oriented strand boards (OSB): cutting height 15, 30 (2 × 15) and 45 (3 × 15) mm and density ρ = 640 kg/m^3;
- Plywood boards (birch wood): cutting height 15, 30 (2 × 15) and 45 (3 × 15) mm and density ρ = 720 kg/m^3.

The length of the processed planes was L = 1500 mm and the width of the processed specimens was 50 mm. In this way the likelihood of the additional noise generated as a result of vibrations in the cut-out material is reduced.

The influence of three different levels of the circular saw over-hang: T_1 = 7 mm; T_2 = 14 mm; T_3 = 21 mm (Fig. 2) was also investigated.

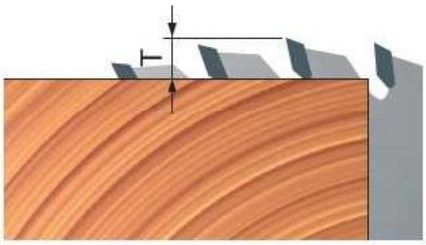


Fig. 2 Schematic representation of the circular saw over-hang effect.

Further, the A-weighted sound pressure level (SPL) depending on the type and the thickness of processed material and the tool over-hang effect was assessed using the method of “sound free field”. The measurements were performed in one point, as described in the

BDS ISO 7960 (Annex A), namely: height from the floor – 1500 mm; 400 mm – forward of the axis of rotation of the saw; 200 mm on the left side of the saw in the direction of feeding (Fig. 3).

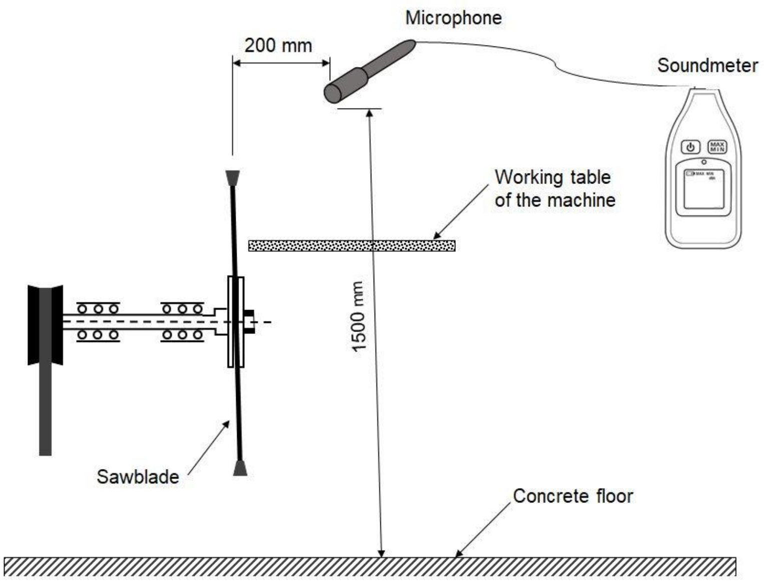


Fig. 3 Schematic representation of the microphone position.

The sound pressure level is measured during idling with mounted circular saw. The height position of the cutting tool over the machine's working plot is equal to the cutting height plus the foreseen overhang (T) of the circular saw over the workpiece.

In the analyses of the results for the sound pressure level, the effects of background noise and sound field characteristics with corresponding correction coefficients K_1 and K_2 were taken into account and the actual sound pressure level was determined using the following equation:

$$L_p = L_p' - K_1 - \mathrm{K}_2 \qquad (1)$$

where:

L_p – the actual sound pressure level, dB;

L_p' – the measured sound pressure level, dB;

K_1 – correction coefficient for the background noise, in the current study $K_1 = 0$, since the difference between the background and the generated noise is more than 15 dB, i.e. $\Delta L > 15$ dB;

K_2 – correction coefficient for the test environment, in the current study $K_2 = 2.1$, i.e. $K_2 < 4$ – the room is suitable for using the method "Measurement in sound-free field".

The measurements were performed using precise digital sound level meter CEL-620B1 (CASELLA, United Kingdom).

Before the initiation of the experiments, the entire measurement track had been calibrated, using a standard sound source from the same company. The measurements were performed in accordance with BDS EN ISO 3744 and BDS ISO 7960.

RESULTS AND DISCUSSION

It is well-known that the noise levels generated during idling differ from those generated during cutting. Therefore, we assessed and analyzed the results obtained from the two different working modes independently. During the cutting mode of the machine, four series of specimens were processed and the mean sound pressure level is taken into account when analyzing the results.

The influence of the tool overhang effect on the sound pressure level in dB(A), generated during idling and cutting mode, is presented in Fig. 4. The results show that during idling with a mounted cutting tool, the sanitary standard of 85 dB(A) is not exceeded only at *T* = 7 mm. For the other two overhang values of the saw, the levels of the noise emission are significantly increased.

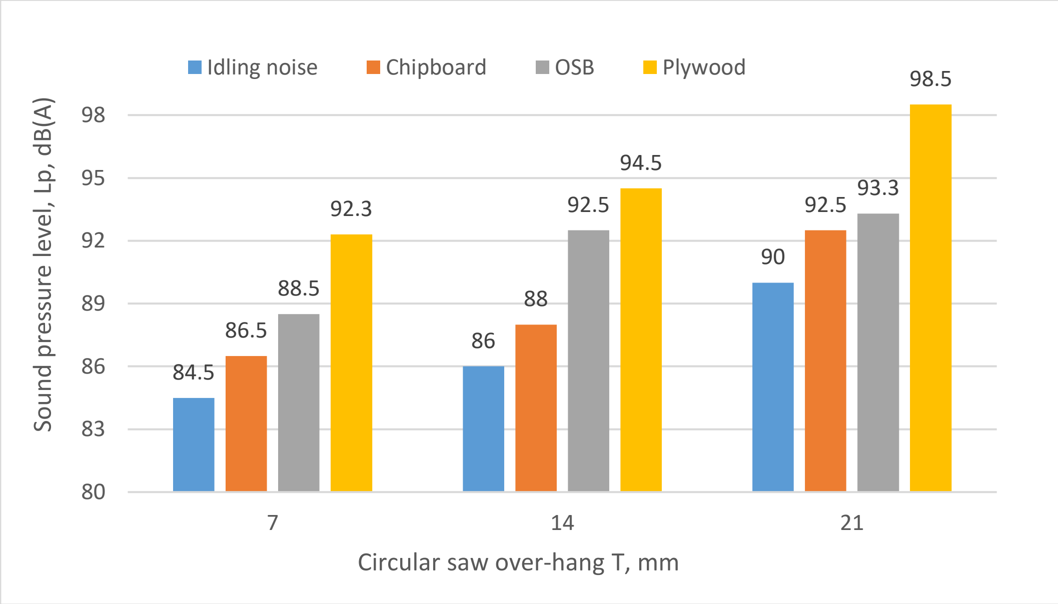


Fig. 4 Changes in the sound pressure level depending on the type of the processed material (height 15 mm) and the tool over-hang effect, measured at rotational speed n = 4500 min^{-1}.

The highest sound pressure levels were measured during processing the specimens from plywood. As shown in Fig. 4, the maximum value of 98.5 dB(A) was achieved at tool overhang *T* = 21 mm, which is by 5 dB(A) higher when compared to 93.5 dB(A), measured at *T* = 7 mm. Regarding the influence of the processed material, the lowest noise levels were measured during processing of specimens from chipboard, followed by OSB and plywood. The measured values at *T* = 7 nm are as follows: for chipboard – 86.5 dB(A), for OSB – 88.5 dB(A) and for plywood – 93.5 dB(A). With the increase of the overhang effect of the circular saw, the air compression and the turbulence generated by the tool rotation increase as well. As a result, the aerodynamic noise increases significantly, which explains the observed higher levels of generated noise. Our results are in good correlation with the observations of other authors (BIES 1992, BELJO-LUCIC *et al. 2001*, SVOREN *et al.* 2007, KOPECKY *et al.* 2012).

The influence of the cutting height on the changes of the sound pressure level is shown in Fig. 5. The results show that the noise levels are not significantly influenced by the cutting height from 15 to 30 mm for the respective processed materials.

An increase in the cutting height from 30 to 45 mm resulted in an increase in the sound pressure level in a similar manner for all three processed materials. The increased sound pressure level, measured at cutting height of 45 mm is by 2 dB(A) higher compared to the cutting height 30 mm for the all three processed materials.

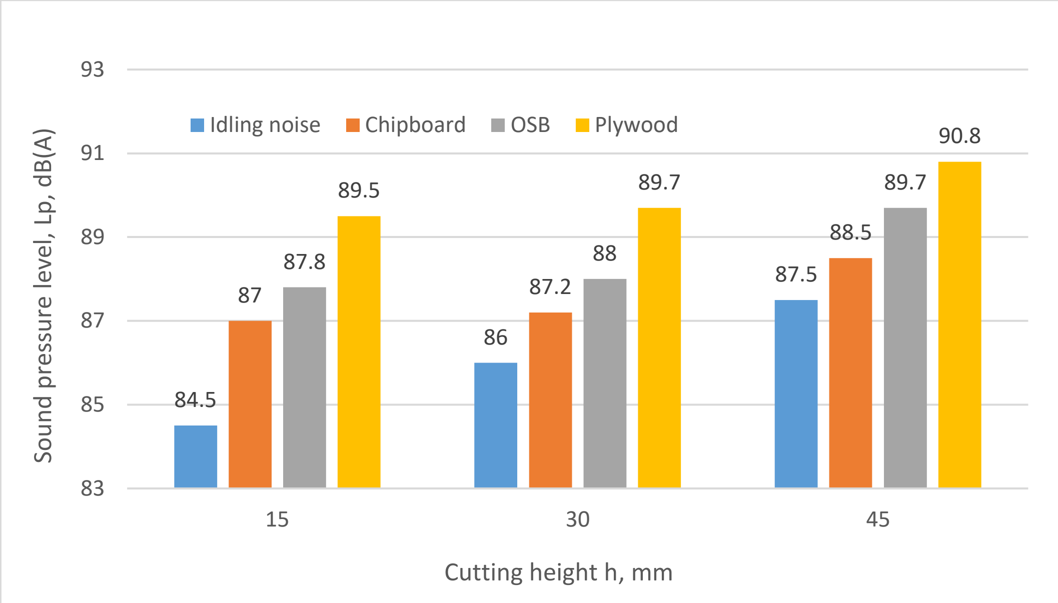


Fig. 5 Changes in the sound pressure level depending on the cutting height, measured at rotational speed of the circular saw n = 4500 min^{-1}.

The obtained results correlate and in some cases surpass the values for sound pressure level provided by different companies and presented in the technical characteristics of the circular saws (LEUCO, FREUD, LEITZ etc.). The difference in the noise levels, generated by processing of the different specimens could also be explained by the different structures of the wood. Significantly higher noise levels measured during processing of the plywood specimens, which also have the highest density (ρ = 720 kg/m^3) compared to the other materials is probably due to, on one hand, the presence of adhesive layers between the individual veneer sheets, and on the other hand – the mutual perpendicular arrangement of the veneer sheets resulting in both longitudinal and transverse cuts of the wood fibers.

During processing of OSB, higher noise levels are measured, when compared to the values measured during chipboard processing. These results can be explained by the relatively chaotic layout of the large-scale particles, as a result of which cavities are formed in the slab which contribute to the production of greater noise during cutting.

The chipboards have relatively homogenous structure in the longitudinal and transverse direction of the three materials used. Those structural characteristics of the material may explain the lowest level of noise generated during cutting.

CONCLUSIONS

The experimental results of this study aimed at investigating the changes in the sound pressure level, generated by woodworking sliding table circular saw and depending on the type of the processed material and the tool overhang effect.

Based on the obtained results

the following conclusions can be drawn:

- During idling with a mounted tool and at tool over-hang T = 7 mm, the generated sound pressure level is under the sanitary standard of 85 dB(A) (see Fig. 4). In practice, these conditions are not realistic because during idling the tool overhang is equal to the thickness of the processed material plus the tool overhang during cutting.

- During cutting mode of the machine, the sanitary standard of 85 dB(A) is increased during processing of the all three wood based materials.
- The overhang of the circular saw above the cutting height influenced significantly the generated sound pressure level. This is due to the increased levels of the aerodynamic noise generated by the rotation of the cutting tool. Therefore, in order to ensure lower noise levels, the tool overhang should be minimal.
- Regarding the processed wood based materials, the highest sound pressure level was generated during cutting of specimens from plywood (89.5 dB(A) followed by OSB (88 dB(A) and chipboard (86.5 dB(A).
- The results from the current study can be used to determine the safe exposure duration for operators of the woodworking sliding table circular saw.

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AUTHORS' ADDRESSES

Chief Assist. Prof. Pavlin Vitchev, PhD
Assoc. Prof. Dimitar Angelski, PhD
Assist. Prof. Vladimir Mihailov
University of Forestry
Faculty of Forest Industry
10 Kliment Ohridski Blvd.
1797 Sofia
Bulgaria
p_vitchev@ltu.bg
d.angelski@ltu.bg
v.mihailov@ltu.bg