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THE INFLUENCE OF CHOSEN FACTORS OF A CIRCULAR SAW BLADE ON THE NOISE LEVEL IN THE PROCESS OF CROSS CUTTING WOOD

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ABSTRACT

Research was focused on evaluation of a circular saw blade tooth spacing on maximum equivalent noise level L_{Aeq} in the process of cross cutting wood. There were used circular saw blades with uniform tooth spacing and a full body and non-uniform tooth spacing with dilatation gaps. The measurements were done on the measuring device which was designed at the Department of Environmental and Forest Technology where it has been modernised. For research, testing samples of three wood species i.e. spruce (*Picea abies*), pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) were used. In the cutting process, two feeding speeds were set up with the same revolutions of circular saw blades and for more precise statistical significance; every measurement was repeated several times. At the research, there was found out that the circular saw blade with uniform tooth spacing has lower equivalent noise level at smaller feeding speed and cutting soft wood species. The circular saw blade with non-uniform tooth spacing has lower equivalent noise level at higher feeding speed.

KEYWORDS: Cross cutting, circular saw blade, equivalent noise level, cutting process.

INTRODUCTION

The most often used wood cutting device for longitudinal and cross cutting wood is a circular saw (Koch 1985, Siklienka and Mišura 2007). In the most cases, high cutting speeds for wood cutting are used, which cause a noise exposition (Chuchala et al. 2014, Kopecký and Rousek 2007, Kováč and Krilek 2011, Kováč and Mikleš 2009).

Noise is a sound and creates unpleasant and disturbing perception which is also very harmful. Noise exposition is caused by running unloaded tool and turbulences of air around a tooth and a dilatation gap (Dado et al. 2013, Kováč et al. 2013). The next reason of this noise is an oscillating circular saw blade when processing material. Noise caused by a processed material is significant especially at wood cutting which is open to oscillation like metals, plastics, etc. (Hargreaves 1989, Kminiak and Gaff 2015, Lučič et al. 2007, Mandic et al. 2015).

Noise is mostly dangerous for operators. To get lower level of noise at cross wood cutting, circular saw blades in different constructional types e.g. dilatation and radiation gaps in the body of a cutting tool, non-uniform tooth spacing etc. are designed. Mentioned modifications ensure lower level of noise but on the other hand they can get worse quality of treated surface (Droba and Svoreň 2012).

The level of noise can be decreased by circular saw blades with cutting inserts made of sintered carbide or using different modifications of a tool body (Prokeš 1985, Siklienka et al. 2013).

According to Barcík (2009), noise of wood cutting machines is in the range of $L_A \approx 90 \div 130$ dB.

Circular saw machines for wood cutting belong to the group of machines with maximum level of noise in the range of $L_A \approx 100 \div 110$ dB as well as rip and edger circular saws and band saws. From physiological noise aspects affecting a human body, long-time work in the working environment with the level of noise in the range of $L_A \approx 85 \div 110$ dB probably makes the people with a hearing impairment (Žiaran 2006, Janoušek 2005, Siklienka and Mišura 2005).

Directive of the European Parliament and Council No. 2003/10/ES regarding to occupational health and safety implemented, three definitions in the Slovak legislation are:

- occupational exposure limit $L_{AEX,\,8h,\,L}$ = 87 dB,
- upper exposure action value $L_{AEX,\,8h,\,a}$ = 85 dB,
- lower exposure action value $L_{AEX,\,8h,\,a}$ = 80 dB.

Exposure action value is a value of noise in the working environment where after overtaking it is necessary to take appropriate measures to decrease the level of noise (Dado and Hnilica 2015). Occupational exposure limit is a value of noise in the working environment which cannot be exceeded in any case even in the case when the ear protection is used. From the analysis where the noise was measured, there is sure that a tool is a primary source of noise (Svoreň and Naščák 1999).

Noise decreasing process of circular saw blades was analysed by Prokeš (1985), Plester (1985), Goglia (1999), Pabiš (1999), Svoreň (2002), Kopecký et al. (2012), Wen-Tung et al. (2012), Siklienka and Šustek (2013), Droba and Svoreň (2012). On the basic of research, they discovered that the main way how to decrease noise level are: Increasing number of teeth on the body of a circular saw blade, decreasing number of revolutions done by a circular saw blade, using radial dilatation gaps in the body of a circular saw blade, using multiple ES curves in the body of a circular saw blade, decreasing diameter of a circular saw blade, increasing diameter of flanges of a circular saw blade and a sandwich construction of a circular saw blade.

Noise measurement of a circular saw blade at the cross wood cutting can be done according to standard STN 49 6150-1997 (wood processing devices, noise of processing machines, methods of measurement, operational conditions and acceptable limits) and STN ISO 7960-1999 (noise of processing machines transferred by air, operational conditions for wood processing machines). Standards define the methods how to define level A of an acoustic performance and equivalent level A of an acoustic pressure at the working position of a machine if it is a machine with a permanent working place or a space for an operator.

MATERIAL AND METHODS

Measuring devices

The process of cross sectional wood cutting was done on the testing device shown in Fig. 1. On the mentioned device, measurements of wood cutting conditions are done. This device was designed and modified at the Department of Forest and Mobile Technology at the Faculty of Environmental and Manufacturing Technology at the Technical University in Zvolen (Slovakia). The measuring device consists of two main parts:

- Feeding part
- Cutting part

Performance and transfer of torque on the tested circular saw blade is done by a cutting part of the device. Fixing and feeding acts of processed material to the place of cutting are done by feeding part of the device.

Fig. 1: Measuring equipment for cross-cutting wood.

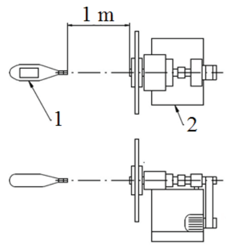

Fig. 2: Scheme for placement of a sound level meter: 1- sound level meter named Brüel&Kjær 2270. 2- measuring device.

The working desk (Fig. 1) consists of a three-phase asynchronous electric motor with performance of 7.5 kW. Torque is transferred further by belt to the safety coupling GIFLEX GFLL – 28, input coupling of a torque sensor HBM T20WN, output coupling of a torque sensor and a spindle headstock of a circular saw blade.

Noise was measured by a sound level meter named Brüel&Kjær 2270. It is a manual noise analyser. It is a two-channel noise analyser which can measure noise in real time according to precision 1 within standard STN EN 61672 - 2014 and dynamic range of 120 dB without switching. The sound level meter is suitable for current measurements indoors and outdoors, verification of noise barriers, binaural measurements with a sound record. Evaluation of a recorded sound is done by software named BZ 5503 - Measurement Partner Suite. (www.bruel.sk).

During the measurement the sound level meter was place 1 m from the source of noise and in height of the spindle headstock axis as it is shown in Fig. 2.

Obtained data were processed with help of software named BZ 5503 - Measurement Partner Suite. The factors affecting noise are wood species at the dimensions of 50x200x1000 mm, feeding speed of 4 and 12 m·min^{-1}, revolutions of a circular saw blade of n = 3000 min^{-1} and a type of a circular saw blade. Circular saw blades differ with tooth spacing because circular saw blade 1 has uniform tooth spacing and circular saw blade 2 has non-uniform one. Circular saw blade 1 has a full body and circular saw blade 2 has dilatation gaps for decreasing tension (in the outer perimeter) and oscillation (in the body of the circular saw blade). There is the same geometry of a cutting edge made of sintered carbide insets.

Testing samples

Measurement was done on the samples of wood species i.e. spruce (*Picea abies*), pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) of the dimensions 50x200x1000 mm. Their dimensions were chosen on the basis of technical parameters of a measuring device.

Moisture of samples

Moisture of samples was measured by gravimetric method. This method belongs to direct methods for a wood moisture definition. The principle of this method is in the definition of wet wood weight and measurement of this wet wood by weighing (Požgaj et al. 1997). Drying process was done at the temperature of 103 ± 2°C in the drying device named MEMMERT UNB 200.

According to the weight of a sample before and after drying, moisture can be calculated using formulas for absolute and relative moisture (Mikleš et al. 2010).

Weighing was done on analytic scales named SARTORIUS – ANALYTIC A200S.

Wood moisture was as follows: spruce 25.60, pine 27.31 and beech 28.22 %.

Circular saw blades

For experimental testing, two types of circular saw blades were used with sintered carbide inserts.

Circular saw blades have different shapes of teeth. The first circular saw blade has uniform tooth spacing and full body (Fig. 3). The second circular saw blade has non-uniform tooth spacing and its body contains dilatation gaps for decreasing tension in the cutting process as well as slots for lower oscillation (Fig. 4). In details it is possible to see different shape of teeth (Figs. 3 and 4). Parameters of circular saw blades are shown in Tab 1.

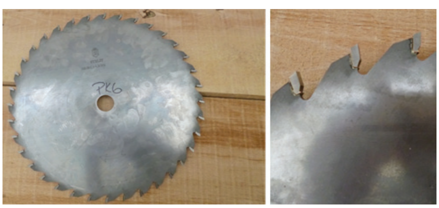

Fig. 3: Circular saw blade 1 with uniform tooth spacing and a full body (Droba and Svoreň 2012).

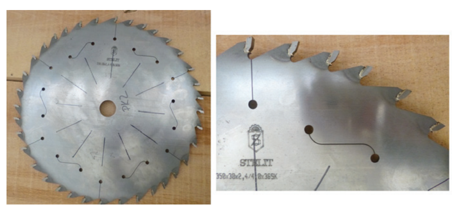

Fig. 4: Circular saw blade 2 with non-uniform tooth spacing and a body with dilatation gaps (Droba and Svoreň 2012).

Tab. 1: Parameters of circular saw blades .

Angle	Angular geometry	Basic dimensions *D·b (mm)*	Tooth spacing t_z *(mm)*	Widening cutting edge to the side *a (mm)*	No. of teeth *z*
Circular saw blade 1					
α	15	350 x 4	uniform	0.8	36
β	65				
γ	10				
Circular saw blade 2					
α	15	350 x 4	non-uniform	0.8	36
β	65				
γ	10				

Method of measurement

The experiment was done with two circular saw blades at two feeding speeds of 4 and 12 m·min^{-1} and revolutions of circular saw blades of 3000 min^{-1}. Every measurement was done several times to get higher statistical importance.

Result of the experiment was noise caused by circular saw blades at the wood cutting process. For result analysis regarding to noise of circular saw blades measured by sound level meter named Brüel&Kjær 2270, software named BZ 5503 - Measurement Partner Suite was used.

RESULTS AND DISCUSSION

The goal of this project was observation and evaluation of noise level at the wood cross cutting process for circular saw blade 1 and 2.

All measured values of maximum equivalent noise level are shown in Tab 2.

Tab. 2: Maximum equivalent noise level $L_A eq$ (dB) for circular saw blade 1 and 2.

Maximum equivalent noise level $L_A e$(dB)			Maximum equivalent noise level $L_A eq$ (dB)		
Wood species	**Circular saw blade**		**Wood species**	**Circular saw blade**	
	1	**2**		**1**	**2**
	Feeding speed v_f (m·min^{-1})			**Feeding speed v_f (m·min^{-1})**	
	4	**4**		**12**	**12**
spruce	90.7	91.2	spruce	93.5	92.0
spruce	91.0	91.8	spruce	93.2	91.9
spruce	91.0	91.5	spruce	93.2	91.8
spruce	90.8	91.4	spruce	93.3	91.8
spruce	90.9	91.4	spruce	93.1	91.7
pine	90.8	92.8	pine	93.3	92.6
pine	91.2	92.4	pine	93.3	92.8
pine	91.2	92.6	pine	93.2	92.4
pine	91.1	92.5	pine	93.3	92.3
pine	90.8	92.5	pine	92.9	92.6
beech	91.4	90.7	beech	90.3	90.3
beech	91.3	90.9	beech	90.7	90.0
beech	91.3	91.0	beech	90.8	90.1
beech	91.35	90.9	beech	90.7	90.2
beech	91.4	90.7	beech	90.9	90.2

In the following graphs (Fig. 5), there is a record of noise at the process of spruce samples cutting at the speed of v_f = 4 m·min^{-1} and revolutions of n = 3000 min^{-1} in both cases of circular saw blades. There are emphasized areas where maximum equivalent noise level $L_A eq$ occurs.

At the beginning of records (Fig. 5), it is possible to observe noise of a circular saw blade without loading. Then there is shown the noise record of a circular saw blade together with feeding part of a machine. After that, there is shown the noise record of a circular saw blade at the process of cutting. The top part is the end of a cutting process with the impact of separated material to the temporary storage. The one before the last part is again the noise of a circular saw blade together with feeding part of the machine and the last part is a noise record of a circular saw blade without loading.

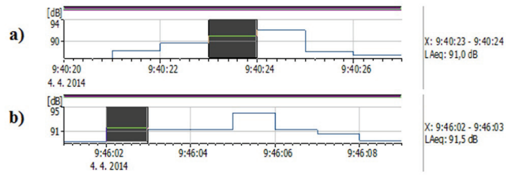

Fig. 5: Graph of the noise course in the cross sectional wood cutting: Feeding speed vf = 4 m·min^{-1}, wood species (spruce), a) circular saw blade 1, b) circular saw blade 2.

In the graph (Fig. 8), there are compared maximum equivalent noise levels $L_A$eq measured at the feeding speed of v_f = 4 m·min^{-1}, at the cross spruce wood cutting process using both circular saw blades. Circular saw blade 1 has lower level of noise. Its maximum value is $L_A$eq = 91 dB. Circular saw blade 2 has level of noise $L_A$eq = 91.8 dB.

The noise record at the pine wood cutting at the feeding speed of v_f = 4 m·min^{-1} and revolutions of n = 3000 min^{-1} using both circular saw blades is shown in Fig. 6. Maximum equivalent noise level $L_A$eq is shown in emphasized part of the graphs.

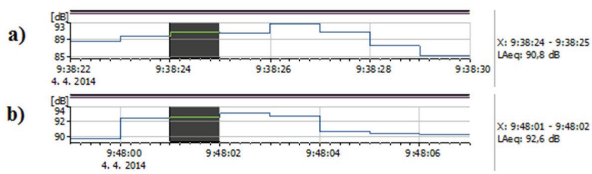

Fig. 6: Graph of the noise course in the cross sectional wood cutting: Feeding speed v_f = 4 m·min^{-1}, wood species (pine), a) circular saw blade 1, b) circular saw blade 2.

Maximum equivalent noise levels $L_A$eq measured at the feeding speed of v_f = 4 m·min^{-1}, cross pine wood cutting process using both circular saw blades are compared in the graphs shown in Fig. 8. Circular saw blade 1 has a lower noise level, its maximum level is $L_A$eq = 91.2 dB and the maximum level of circular saw blade 2 is $L_A$eq = 92.8 dB.

In the record of noise in the graphs shown in Fig. 7, it is possible to observe maximum equivalent noise levels $L_A$eq measured at the feeding speed of v_f = 4 m·min^{-1}, revolutions of the circular saw blades of n = 3000 min^{-1}, cross beech wood cutting process using both circular saw blades. The maximum level is emphasized in the graph.

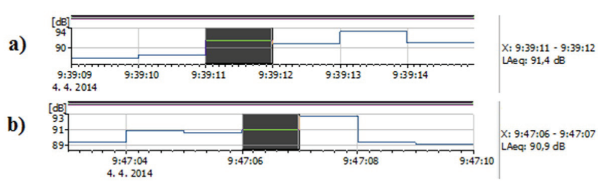

Fig. 7: Graph of the noise course in the cross sectional wood cutting: Feeding speed v_f = 4 m·min^{-1}, wood species (beech), a) circular saw blade 1, b) circular saw blade 2.

In the graph (Fig. 8), there are maximum values of equivalent noise level $L_A$eq measured at the feeding speed of v_f = 4 m·min^{-1}, at the cross beech wood cutting using both circular saw blades. The first circular saw blade (CSB1) has higher noise level, its maximum value is $L_A$eq = 91.4 dB and the maximum value of the second one is $L_A$eq = 90.9 dB.

When it is compared with the previous results, it is possible to say that circular saw blade 2 got lower noise level $L_A$eq at the beech wood cutting and at the feeding speed of v_f = 4 m·min^{-1} and revolutions of a circular saw blade of n = 3000 min^{-1}. Circular saw blade 1 got lower noise level at other wood species i.e. spruce and pine.

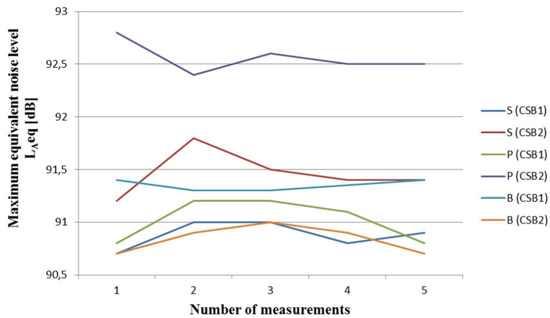

Fig. 8: Comparison of noise level at circular saw blades: feeding speed v_f = 4 m·min^{-1}, S (spruce), P (pine), B (beech), CSB1 – circular saw blade 1, CSB2 – circular saw blade 2 .

In the record of the graphs (Fig. 9), it is possible to observe the course of cutting by both circular saw blades and maximum equivalent noise levels $L_A$eq measured at feeding speed of v_f = 12 m·min^{-1}, revolutions of circular saw blades of n = 3000 min^{-1}, cross spruce wood cutting. The maximum values are emphasized in the graphs.

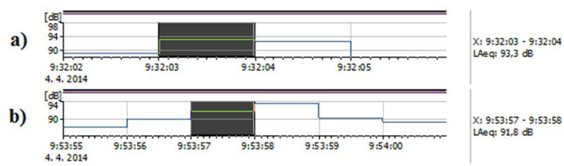

Fig. 9: Graph of the noise course at the cross sectional spruce wood cutting: feeding speed v_f = 12 m·min^{-1}, a) circular saw blade 1, b) circular saw blade 2.

Maximum values of equivalent noise level $L_A$eq measured at cross spruce wood cutting by both circular saw blades with feeding speed of v_f = 12 m·min^{-1} are compared in the graph (Fig. 12). Circular saw blade 1 has higher level of noise with maximum noise level of $L_A$eq = 93.5 dB and the maximum noise level of circular saw blade 2 is $L_A$eq = 92 dB.

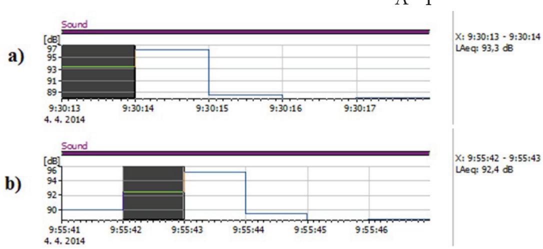

Fig. 10: Graph of the noise course at the cross sectional pine wood cutting: feeding speed v_f = 12 m·min^{-1}, a) circular saw blade 1, b) circular saw blade 2.

The record of noise level at pine wood cutting at the feeding speed of v_f = 12 m·min^{-1} and revolutions of n = 3000 min^{-1} by both circular saw blades is shown in Fig. 10. Maximum equivalent noise level $L_A$eq is shown in emphasized part of the graphs.

Maximum values of equivalent noise level $L_A$eq at the feeding speed of v_f = 12 m·min^{-1}, cross pine wood cutting by circular saw blade 1 and 2 are compared in the graph (Fig. 12). Circular saw blade 2 got lower noise level and its maximum value was $L_A$eq = 92.8dB. Circular saw blade 1 got its maximum value $L_A$eq = 93.3dB.

In the graphs (Fig. 11), there is a record of noise level at the beech wood cutting by circular saw blade 1 and 2 at feeding speed v_f = 12 m·min^{-1} and revolutions of circular saw blades of n = 3000 min^{-1}. There are emphasized areas where the maximum equivalent noise level $L_A$eq occurs.

Fig. 11: Graph of the noise course at the cross sectional beech wood cutting: feeding speed v_f = 12 m·min^{-1}, a) circular saw blade 1, b) circular saw blade 2.

In Fig. 12, there is a graph where noise levels of circular saw blade 1 and 2 are compared at feeding speed of v_f = 12 m·min^{-1} while beech wood cutting. There are compared measured maximum equivalent noise levels $L_A$eq (dB). The difference between circular saw blades is low but circular saw blade 1 (CSB1) got higher noise level and its maximum level was $L_A$eq = 90.9dB. Circular saw blade 2 (CSB2) got maximum value $L_A$eq = 90.3dB.

After comparison of previous results for v_f = 12 m·min^{-1} and at revolutions of circular saw blades of n = 3000 min^{-1}, it is possible to say that circular saw blade 1 got higher noise level $L_A$eq at spruce wood cutting than pine and beech wood cutting.

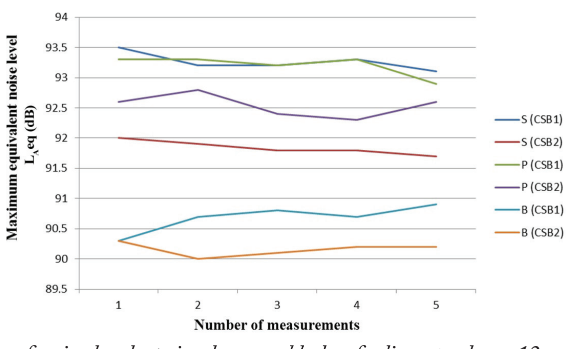

Fig. 12: Comparison of noise level at circular saw blades: feeding speed v_f =12 m·min^{-1}, S (spruce), P (pine), B (beech), CSB1 - circular saw blade 1, CSB2 – circular saw blade 2.

Evaluation of noise level of circular saw blades without loading

Circular saw blade 1 got lower values of equivalent noise level $L_A$eq. Circular saw blade 2 got maximum value $L_A$eq = 89.7 dB, and circular saw blade 1 got maximum value $L_A$eq = 87.4 dB.

The problem was studied by Prokeš 1985, Miklaczewski and Grbleny 1995, Svoreň 2002, Argay 2014 and Kvietková et al. 2015. The measured results were compared with their results. Present time there are circular saw blades with non-uniform tooth spacing where is supposed a lower level of acoustic pressure by minimum 50 %.

Prokeš says that if we decrease tension in the cutting parts of a circular saw blade, the circular saw blade calms down and its vibrations and noise calm down as well. Noise gets down by 3-5 dB at working revolutions (Prokeš 1985).

We discovered that circular saw blade 1 got lower values of equivalent noise level $L_A$eq. Circular saw blade 2 which was modified got maximum value $L_A$eq = 89.7dB and circular saw blade 1 which was not modified got maximum value $L_A$eq = 87.4dB.

Constructional modifications like dilatation gaps have positive influence on equivalent noise level during cutting when the difference between non-modified and modified circular saw blades was 3.4 dB i.e. acoustic pressure was decreased by 50 %. Better results were observed at the circular saw blade with non-uniform tooth spacing. Similar results were observed by foreign research where mentioned difference of modified circular saw blades with non-uniform tooth spacing was by 2-4 dB (Kopecký et al. 2012, Siklienka et al. 2012).

The result of research showed decreasing tendency of acoustic pressure on the modified circular saw blade at the longitudinal wood cutting but not at cross wood cutting where time of cutting is very short and at the beginning of cutting process of wood penetration by a circular saw blade there occur vibrations which increase acoustic pressure and at short cutting process the circular saw blade cannot stabilize properly. Our conclusion is confirmed by Argay (2014) who discovered that the most suitable circular saw blade for cross cutting wood process is a circular saw blade with number of teeth z = 60, which showed the lowest noise level. The influence of number of teeth of a circular saw blade is significant parameter affecting noise in the cutting process.

CONCLUSIONS

The goal of this project was evaluation of noise levels for circular saw blade 1 and 2 at the cross wood cutting process with and without loading.

At feeding speed of $v_f = 4\ m{\cdot}min^{-1}$ and revolutions of circular saw blades of $n = 3000\ min^{-1}$, circular saw blade 2 got lower noise level $L_A$eq at beech wood cutting.

Circular saw blade with uniform tooth spacing got lower noise level $L_A$eq than circular saw blade with non-uniform tooth spacing at cross soft wood (spruce, pine) cutting.

At feeding speed of $v_f = 12\ m{\cdot}min^{-1}$ and revolutions of circular saw blades of $n = 3000\ min^{-1}$, it is possible to say that circular saw blade 1 got higher noise level $L_A$eq (dB) at cross spruce, pine and beech wood cutting.

It means that circular saw blade 2 gets higher noise level at hard (beech) wood cutting and lower feeding speed. Circular saw blade 2 gets lower noise level at cross soft (spruce and pine) wood cutting and lower feeding speed. Circular saw blade 1 gets lower values of equivalent noise level $L_A$eq at wood cutting without loading.

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