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Effect of kerf height on noise emission level in the internal combustion chain saw Stihl MS 211 and the electric chain saw Stihl E 180C during cross cutting of wood

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Abstract: *Effect of kerf height on noise emission level in the internal combustion chain saw Stihl MS 211 and the electric chain saw Stihl E 180C during cross cutting of wood*. The effect of kerf height on noise emission level in the internal combustion and electric chain saws during cross cutting of wood is described. There were investigated the two Stihl chain saw models of similar power and kerb weight. To differentiate cross cutting methods, the lower and upper sides of the guide bar were used. The obtained results of measurements were subjected to statistical analysis; it allowed for precise determination of dependence between the kerf height and noise emitted by investigated chain saws. Significant dependences between investigated features were found for both the chain saws during cross cutting with the lower side of guide bar; therefore, the kerf height affects significantly the level of emitted noise.

Key words: noise, internal combustion chain saw, electric chain saw, wood cross cutting

INTRODUCTION

The one-man internal combustion chain saws for timber harvesting were commonly introduced in Poland in sixties. It enabled to increase the rate of work several times. At present, despite wide application of harvesters, the internal combustion chain saw is still a basic tool in forest operations. A negative effect of chain saw application is undoubtedly exposure of operator to vibrations, noise and exhaust gasses.

There exists an infinite number of surrounding noise sources; it is generated by every machine, device, installations, street traffic etc. However, in internal combustion chain saw the main noise sources are aerodynamic processes proceeded in the engine (suction, combustion, exhaust) and mechanical processes resulted from operation of the piston-crank system [Botwin 1993]. There are also important: friction in bearings, ejection of exhaust gasses [Engel 1993], movement of chain saw over the guide bar [Botwin 1975]. According to Botwin [1975], the sound intensity level generated by a tightened chain saw at 6,000 rpm of engine crank shaft is equal to sound intensity generated by the engine itself. One should also remember that besides the noise generated by machines, the noise is generated also during realization of technological process. In the case of chain saw operation, one can distinguish the two basic noise sources: the wood cutting process and the chain saw vibrations [Botwin 1975]. The level of generated noise is also influenced by power of the chain saw used in timber harvesting. The investigations of Skarżyński et al. [2009] proved that the noise of small-power chain saw (Husqvarna 242) during pine wood cross cutting was lower than that of chain saw Husqvarna 257, in spite of identical acoustic pressure levels declared by manufacturer. Other factors that cause a change in noise emission in engine-machines include also the increased bearing clearances, unbalance of rotary elements and decreased compression pressure [Obliwin and Sokołow 1988]. Deterioration of chain saw technical condition causes significant changes in vibro-acoustic signals of the chain saw. The decreased compression pressure in cylinder had the highest effect on noise emitted by chain saw [Skarżyński 2002].

MATERIAL AND METHODS

The investigations aimed at evaluation and analyzing of noise threat to the operator of internal combustion and electric chain saws during wood cross cutting process. To differentiate cutting conditions, the measurements were carried out at various kerf height and the two cross cutting variants: with the use of lower and upper sides of guide bar (in both cases the cutting plane was set vertically). There were investigated the two Stihl chain saw models of similar power and kerb weight: electric chain saw E 180C and internal combustion chain saw MS 211, of specification presented in Table 1. The internal combustion chain saw was brand new, while the electric chain saw was a second hand device, used previously for vibration and noise measurements.

The scope of work included noise measurements during cross cutting of pine wood and statistical analysis of the obtained results of investigations.

The noise measurements were performed in open air site, away from elements that could cause sound absorbing or resounding. To assure the similar cutting conditions, the wood was cross cut by the same and experienced sawman.

In investigations there was used a well dried pine timber of rectangular cross section (Fig. 1). Cross cutting was executed on four beams of kerf height (H) amounted to 14, 18, 21.5 and 25 cm.

Since the investigated timber was kept for a long time in the dry compartment under the roof, the average wood moisture content was small and amounted to 9.2%. The average graininess of wood was equal to 4.9 grain/cm.

TABLE 1. Specification of chain saws used in investigations

Parameter	Unit	Stihl E 180C	Stihl MS 211
Engine displacement	cm^3	–	35.2
Power	kW	1.8	1.7
Electric power	V	230	–
Weight without chain and guide bar	kg	4.2	4.3
Chain pitch	cal	3/8 picco	3/8 picco
Length of guide bar	cm	35	35
Acoustic pressure level	dB(A)	95	99
Vibration level on front/rear grip	m/s^2	3.7 / 8.7	3.5 / 3.2

Source: Stihl catalogue.

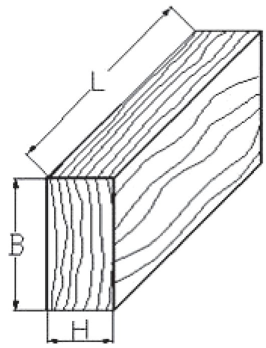

FIGURE 1. Dimensions of timber cross section used in investigations: B – width of kerf, H – height of kerf, L – length of timber

During cross cutting the wood was fixed on a wooden saw-horse (Fig. 2) with the use of belt.

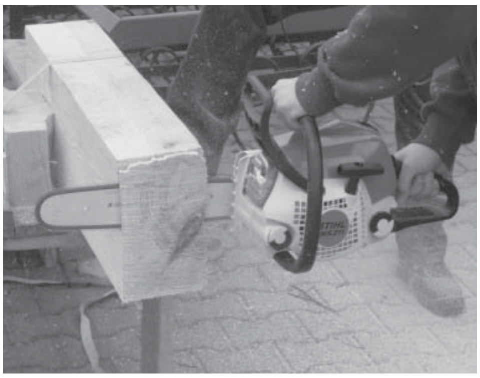

FIGURE 2. Cross cutting of fixed timber with the use of internal combustion chain saw

The noise measurements were carried out with the use of sound level meter of Brüel & Kjær type 2231. Noise was recorded in the range of frequency from 20 Hz to 20 kHz and measuring range from 24 to 130 dB(A). The measurements were recorded at turned on characteristic (filter) „A" and stored in meter's memory.

During measurements the microphone was fixed at the right side of operator's protective helmet and set, according to PN-EN ISO 11201 Standard, 20 cm away from the center of operator head's plane in a straight line with his eyes, parallel to the line of sight (Fig. 3).

FIGURE 3. Microphone fixed to protective helmet during measurements

During execution of wood cross cutting measurements (Fig. 4) the main axis of meter was directed towards the source of sound.

FIGURE 4. Noise measurements during wood cross cutting with internal combustion chain saw

The following noise parameters were measured:
- absolute maximal peak value (MaxP),
- maximal root-mean-square value (MaxL),
- minimal root-mean-square value (MinL),
- equivalent sound level, according to IEC 804 (L_{eq}).

RESULTS AND DISCUSSION

The four noise-characteristic parameters were recorded during measurements, however, in further analysis there were taken the values of equivalent sound level (L_{eq}), since this value best represents the real noise burden of human ear; besides, standard documents are related to this value.

The measurements were carried out during wood cross cutting with the lower and upper sides of the guide bar, at four different kerf heights (14, 18, 21.5 and 25 cm). Therefore, 8 sets of results were obtained for the electric chain saw (Table 2) and 8 sets of results for the internal combustion chain saw (Table 3); they were subjected to statistical analysis to check, whether the sets differ significantly or can be considered together [Elandt 1964].

For every kerf height there were executed 10 measurements. The mean value of noise emitted by electric chain saw varied from 94.2 to 97.2 dB. The maximal value of calculated variance amounted to 0.68 for wood cross cutting at the

TABLE 2. Noise measurement results L_{eq} for electric chain saw

No.	Kerf height [cm], lower (d) or upper (g) side of guide bar							
	14 d [1]	18 d [2]	21.5 d [3]	25 d [4]	14 g [5]	18 g [6]	21.5 g [7]	25 g [8]
1	95.6	95.9	94.6	94.5	96.5	97.7	97.2	96.6
2	95.4	96.0	94.6	94.5	94.9	96.2	96.2	96.7
3	94.9	95.4	94.3	94.7	95.9	97.6	97.3	96.5
4	95.3	95.9	94.8	94.5	96.2	96.6	96.5	95.1
5	94.9	95.3	94.2	93.7	95.6	96.8	97.4	94.9
6	94.8	95.6	94.5	94.3	96.5	97.6	95.9	95.4
7	94.8	95.2	94.6	93.8	95.8	97.0	97.4	94.7
8	95.2	95.3	93.9	93.9	96.4	97.6	96.3	95.9
9	95.2	94.9	94.8	93.9	95.1	97.1	97.2	94.7
10	94.6	95.1	94.1	93.8	96.4	97.8	96.6	94.8
Number [n]	10	10	10	10	10	10	10	10
Sum [$\sum$]	950.7	954.6	944.4	941.6	959.3	972	968	955.3
Mean [$\sum$/n]	95.1	95.5	94.4	94.2	95.9	97.2	96.8	95.5
Variance [s^2]	0.10	0.14	0.09	0.14	0.34	0.30	0.32	0.68
Standard deviation [s]	0.32	0.37	0.30	0.37	0.58	0.54	0.56	0.82

TABLE 3. Noise measurement results L_{eq} for internal combustion chain saw

No.	Kerf height [cm], lower (d) or upper (g) side of guide bar							
	14 d [9]	18 d [10]	21.5 d [11]	25 d [12]	14 g [13]	18 g [14]	21.5 g [15]	25 g [16]
1	102.9	104.0	105.8	104.0	101.6	104.6	104.5	104.3
2	102.4	103.5	104.3	103.6	103.0	103.4	103.9	104.9
3	104.2	103.1	103.8	103.3	103.5	105.1	104.4	105.0
4	103.6	102.7	103.7	103.6	104.0	105.7	105.4	105.3
5	103.7	103.0	103.8	103.9	104.3	105.5	105.2	105.3
6	103.1	103.3	103.5	103.4	103.2	106.0	105.9	105.4
7	102.7	102.5	103.8	104.0	104.4	105.6	106.1	104.0
8	102.7	103.6	103.8	103.8	104.2	105.8	105.6	105.0
9	103.1	103.1	103.5	103.2	103.6	105.6	105.7	104.4
10	103.1	102.6	104.0	103.1	104.4	105.8	105.9	104.7
Number [n]	10	10	10	10	10	10	10	10
Sum [∑]	1031.5	1031.4	1040	1035.9	1036.2	1053.1	1052.6	1048.3
Mean [∑/n]	103.2	103.1	104.0	103.6	103.6	105.3	105.3	104.8
Variance [s^2]	0.29	0.22	0.45	0.11	0.76	0.61	0.56	0.22
Standard deviation [s]	0.54	0.47	0.67	0.33	0.87	0.78	0.75	0.47

kerf height 25 cm, with the use of upper side of guide bar. The minimal standard deviation value amounted to 0.30, the highest value – 0.82.

Using the internal combustion chain saw, for every kerf height there were executed 10 measurements. The variance values ranged from 0.11 to 0.76, while standard deviation value from 0.33 to 0.87.

As it is evident from the presented data (Table 3), the noise values during wood cross cutting with internal combustion chain saw exceed the value for electric chain saw. The mean value of noise emitted by internal combustion chain saw ranges from 103.1 to 105.3 dB, and all values presented in Table 3 exceed 99 dB(A) (declared by manufacturer). Therefore, in the presented investigations there were obtained the higher noise values for both the chain saws, due to different noise measurements methods. The values of acoustic pressure levels declared by manufacturer for the internal combustion chain saw were obtained according to PN-EN ISO 22868 Standard, during “simulated cross cutting” at three different operational states of the machine. The values presented in this paper were obtained only for a single operational state of the chain saw – a real cross cutting of wood.

For both chain saws there was checked, whether the sets of results obtained during cross cutting with lower and upper sides of the guide bar (at various width of kerf) can be considered together or separately; it was also verified that no test was burden with a blunder.

Besides, distribution of statistics was determined and tolerance limit was calculated for particular sets, in order to reject values that were beyond the tolerance limits.

For the electric chain saw (Table 2), none of recorded noise value exceeded the calculated tolerance limit; therefore, all the values were considered in further analysis. For the internal combustion chain saw (Table 3) the bold and underlined values were rejected and not considered in further analysis, since they exceeded the tolerance ranges.

Figures 5 and 6 presents a comparison between the values of noise emitted by the electric and internal combustion chain saws, depending on kerf height and sides of the guide bar used during cross cutting.

In the case of cross cutting with the lower side of guide bar, far smaller noise value were obtained for the electric chain saw. It should be noted that in the case of internal combustion chain saw, the determined trend is ascending; with an increase in height of kerf, the noise emitted by the chain saw increases.

In the case of electric chain saw on the contrary – an increase in the kerf height causes the noise decrease. One may assume that a considerable load of this chain saw causes reduction of engine revolutions, therefore, the reduced noise emitted.

In both cases, the calculated value of correlation coefficient r is higher than the critical value of this coefficient (0.3125 for electric chain saw and 0.3165 for internal combustion chain saw). It testifies for a strong dependence between the investigated features: the kerf height significantly influences the level of emitted noise.

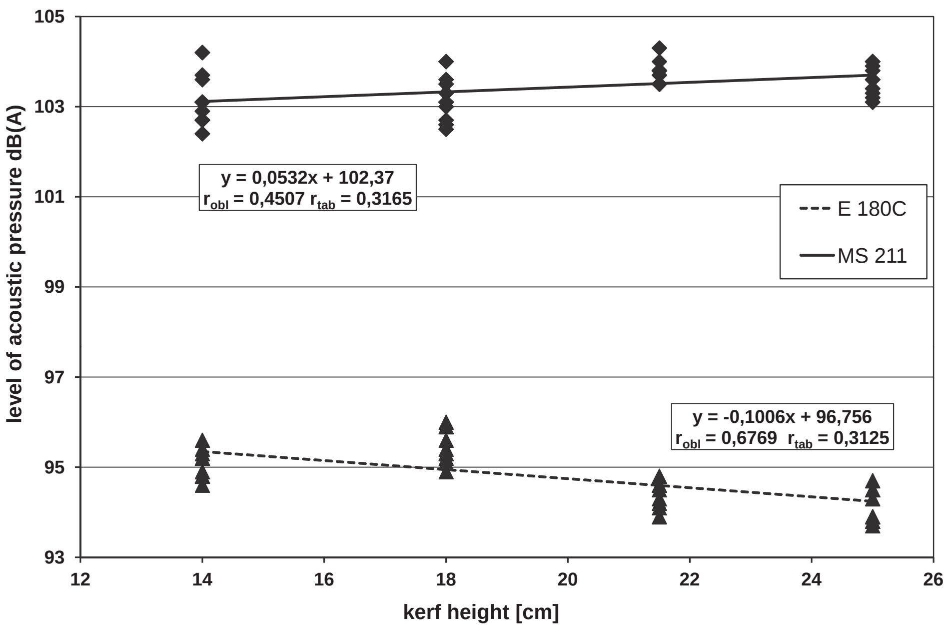

FIGURE 5. Dependence between chain saw noise and kerf height during cross cutting with lower side of guide bar

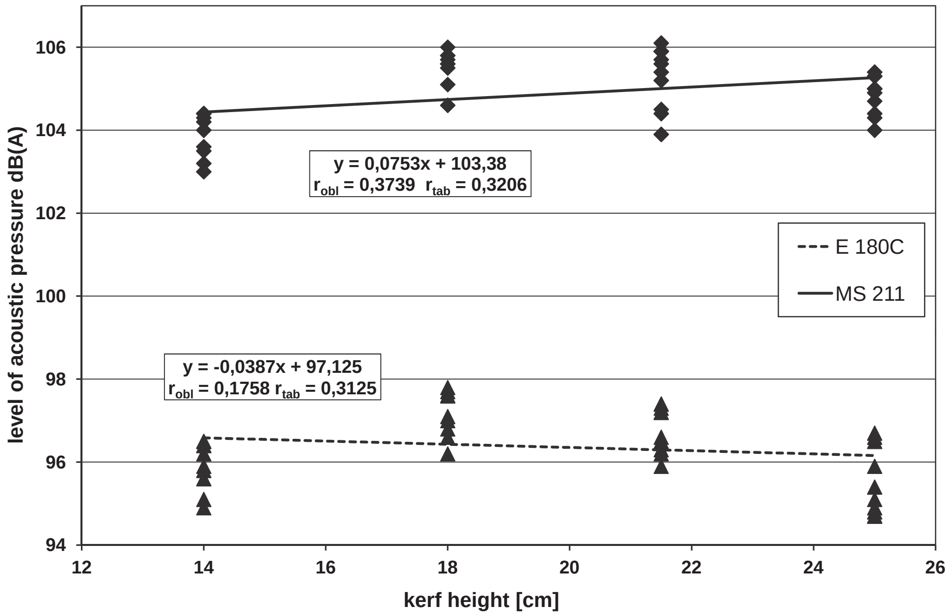

FIGURE 6. Dependence between chain saw noise and kerf height during cross cutting with upper side of guide

Similarly to cross cutting with lower side of the guide bar, the noise emitted by internal combustion chain saw during cross cutting with upper side of guide bar is considerably higher (Fig. 6). The course of trend line is similar to that presented in Figure 5 (the ascending trend for internal combustion chain saw and descending one for electric chain saw).

For internal combustion chain saw, the calculated value of correlation coefficient r is higher than the critical value of this coefficient (0.3206). It testifies for a strong dependence between the investigated features. For electric chain saw the value of this coefficient is lower than the critical value. Therefore, one can find that the kerf height does not influence the level of noise emitted by electric chain saw.

CONCLUSIONS

1. Level of noise emitted by internal combustion chain saw is higher than that emitted by electric chain saw.
2. The higher noise level (for both chain saws) is generated during cross cutting with upper side of the guide bar. One can assume that these differences result from different position of operator during cross cutting with the upper and lower sides of the guide bar.
3. Only during cross cutting with upper side of guide bar of electric chain saw, no dependence between noise and the kerf height was found. For all remaining investigated cases this dependence was found significant.
4. In the case of internal combustion chain saw, an increase in the wood

thickness caused an increase in the emitted noise. The thicker wood, the more cutting teeth are engaged in the kerf, that generate the higher noise.

5. In the case of electric chain saw, an increase in the wood thickness causes a decrease in the emitted noise, presumably because the electric chain saw is more susceptible to changes in engine speed under the influence of variable load. The higher kerf, the lower engine speed; it results in reduction of generated noise.

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PN-EN ISO 11201: Hałas emitowany przez maszyny i urządzenia. Pomiar poziomów ciśnienia akustycznego emisji na stanowiskach pracy i w innych określonych miejscach. Metoda techniczna w warunkach zbliżonych do pola swobodnego nad płaszczyzną odbijającą dźwięk.

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Streszczenie: *Wpływ wysokości rzazu na poziom emisji hałasu pilarki spalinowej Stihl MS 211 i pilarki elektrycznej Stihl E 180C podczas przerzynki drewna.* Dokonano analizy zagrożenia hałasem występującym podczas przerzynki drewna pilarką spalinową i elektryczną. W badaniach wykorzystane zostały dwa modele pilarek firmy Stihl o zbliżonej mocy i masie własnej narzędzia. Przerzynki dokonywano dolną jak i górną stroną prowadnicy. Pomiary hałasu zostały przeprowadzone w warunkach laboratoryjnych, wykorzystując do przerzynki drewno sosnowe o różnych wysokościach rzazu. W przypadku cięcia dolną stroną prowadnicy uzyskano istotne zależności między badanymi cechami dla obydwu pilarek, czyli wysokość rzazu ma istotny wpływ na poziom emitowanego hałasu.

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