NOISE EMISSIONS OF OLDER WOODWORKING MACHINES AT PARALLEL OPERATION PROCESS

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The paper is focused on evaluation of noise emissions of older woodworking machines in specific conditions of individual and parallel operation process. The goal of the paper is monitoring of acoustic pressure of chosen woodworking machines (surfacer and thickenesser) in real woodworking industrial school plant. Next goal is statistical evaluation of measured values and comparing with criteria of legislation (hygienic limits). Experimental measurement conforms to requirements of standard CSN EN ISO 11202, CSN EN ISO 3746 and CSN EN ISO 7960. Measured values of acoustic pressure are compared with requirements of government statute No. 272/2011 col. Our study claim high level of measured sound pressure values and hygienically unsuitable occupational environment.

KEYWORDS

Noise, acoustic pressure, measurement of the noise, woodworking machines

1 INTRODUCTION

Noise is more and more monitored factor of occupational environment. For example [Jena 2018] state that noise pollution is a big problem in the society, starting from household machines to transportation appliances and industries. The main reason it is negative effects on human health. It is the fact, that the long-therm exposition incidence of sound pressure high level causes damage of health condition (e.g. auditory neurome damages or other neurological and psychics disturbances). Wodworking machines are source of high noise level. Especially older types of woodworking machines have no or minimal constructional equipments to noise reduction. [Rech 2017] state that with the increase in performance of machining operations, noise levels have become an occupational health and safety problems.

Higher velocities and accelerations of each machine axis induce higher dynamic loads, which affect the entire machine system, the environment and the peripherals. These loads generally enhance structural vibration amplitudes which affect the production quality negatively and induce a high noise emission during machining. The direct airborne sound is composed of the idling sound of the tool and the impulse sound which results from the contact between tool and workpiece. The second type of sound is generated from the material displacement and chip removal process during machining. Both sounds are emitted directly to the air space of the machine environment [Hesselbach 2010]. For example [Pohl 2016] state that circular saws are precise, efficient and frequently used machine tools for cutting wood, metal, composites or even ceramics. Since the invention of circular saws, technology of saw blades, tooth materials and machines developed with time, but one general problem had never been able to be solved: in machining condition, when the saw blade has contact to the workpiece, it is randomly excited by the contact of the cutting edges. This leads to intense vibration amplitudes of the very lightly damped thin blade disk. But even in the idling condition, when the saw blade is rotating, but does not interact to any workpiece, an aerodynamic excitation is present which may result in high frequency vibration. The vibration amplitudes result in the emission of severe noise, which can excess sound pressure levels of 110 dB(A).

Noisy machines are the main cause of worker noise exposure in industrial halls. In order to reduce this noise pollution, actions to lower noise emission of the source and actions to improve acoustical treatments of the halls are both usable. The acoustical characteristics of industrial sources are often known globally and are often reduced to a single representative: the Sound Pressure Level (SPL) [Chatillon 2007]. [Wiora 2017] state that acoustic insulation of a device from the environment can be enhanced by appropriate control of its casing vibrations and tThe level of noise reduction obtained in such way is considered as the main point for evaluating the performance of the active control system, hence its appropriate measurement constitutes a vital issue. Use of powerful industrial machines raises justified concern about the exposure of operators to noise, which is an important and preventable cause of hearing loss [Dobie 2008]. Other author state that noise-induced hearing loss is still common in the woodworking sector, despite a significant trend for improvement [Johansson and Arlinger 2001]. Noise-induced hearing loss is attributed to unprotected exposures above 95 dB(A), and it becomes clinically apparent in middle age, when age-related threshold shifts are added to prior noise-induced damage [Sliwinska-Kowalska and Davis 2012]. Noise in the workorking environment affects the ability to distinguish sound signals (stimuli) and affects the probability of human error [Kotek 2015]. [Kahraman 2016] state that millions of employees in the World are exposed to noise at work.

The goal of the paper is monitoring of noise emissions of chosen older woodworking machines in specific operational conditions at individual and parallel operational process.

2 MATERIAL AND METHODS

The experimental measuring of noise emissions was carried out under operational conditions in real woodworking industrial school plant during the spring season (March 2017). Industrial school plant is situated in hall building with masonry walls and light acoustic ceiling.

Specification of first machine (planer):

Specification of second machine (thickenesser):

The following characteristics were monitored contemporary with acoustic pressure:

- air temperature (°C),
- air flow velocity (m·s^{-1}),
- air humidity (%),
- distance of measured object (m).

Acoustic level measurement was performed by digital sound-level meter EXTECH HD 600 with technical specifications:

- meet requirements of standards IEC61672-1:2002 category 2; IEC60651:1979 type 2; ANSI S1.4:1983,
- measuring range from 10 to 130 dB,
- accuracy of measurement ± 1,4 dB,
- frequency weighting: function A or C,
- frequency range from 31,5 Hz to 8 kHz,
- microphone diameter 12,7 mm,
- number of possible data records 20000.

Acoustic calibration of digital sound-level meter was performed by Brüel & Kjær 4226 calibrator.

The air temperature and relative humidity were measured using KIMO AMI 300 (France) multifunction equipment. The air velocity and temperature were measured with using a telescopic vane probe type HET 14 (in the range of 0,8 to 25,0 m/s and -20 to 80 °C) featuring the temperature measurement accuracy of ±1 °C. The relative humidity were measured with using a telescopic hygrometry probe SVTH (in the range of 5,0 to 95,0% relative humidity) featuring the measurement accuracy of ±4%.

Conditions of measurement: cloudy conditions, air temperature - exterior (0 °C), interior (20,0 °C), air velocity 0,50 $m \cdot s^{-1}$, relative humidity 55 %.

The distance of the digital sound-level meter from measuring objects was determined using Leica DISTOtm A5 laser EDM (Germany) device (measurement accuracy: ±1,5 mm at a distance between 0.2 and 200 m). Methodology of measuremet is according to requirements of CSN ISO 7960 Airborne noise emitted by machine tools - Operating conditions for woodworking machines; CSN EN ISO 11202 Acoustics – Noise emitted by machinery and equipment – Determination of emission sound pressure levels at a work station and at other specified positions applying approximate environmental corrections; CSN EN ISO 3746 Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane.

Statistical evaluation of measured data sets is performed by STATISTICA v. 12 (StatSoft, Inc.) software. Hypothesis testing procedure is performed at significance level α = 0,05.

Specification of measured machines:

Surfacer B. JOHAN; year of construction: 1957; main dimensions – length 2400 mm, width 425 mm, height 780 mm; electric output of electromotor 3 kW; length of knife shafting 400 mm; diameter of knife shafting 120 mm; number of cutting knives 4; cutting-wedge angle 42°; rated speed of shaft 6000 rpm.

Figure 1: Surfacer B. JOHAN

Thickenesser JAROMA; year of construction 1973; main dimensions – length 1330 mm, width 755 mm, height 1090 mm; electric output of electromotor 10 kW; length of knife shafting 900 mm; diameter of knife shafting 140 mm; number of cutting knives 3; cutting-wedge angle 42°; rated speed of shaft 2930 rpm.

Figure 1: Thickenesser JAROMA

Experimental work is balk from soft wood with moisture level 10 % and dimensions 1000 mm length, 100 mm width and 80 mm thickness.

3 RESULTS AND DISCUSSION

This chapter present main results of our experimental measurement and evaluation of measured values.

3.1 Sound pressure level (A) of surfacer

Determination of correction on background noise K_{1A}

- average sound pressure level (A) operation at machine idling
  $L'_{pA} = 96,3$ dB
- average sound pressure level (A) on-load operation $L'_{pA} = 97,4$ dB
- average sound pressure level (A) background on measuring surface $L_p = 38$ dB
  ΔL = 96,3 – 38,0 = 58,3 dB (operation at machine idling)
  ΔL = 97,4 – 38,0 = 59,4 dB (on-load operation)

Whereas ΔL > 15 dB, standard ČSN EN ISO 11202 does not require correction, therefore $K_{1A} = 0$

Determination of correction on environment K_{2A}

- Surface S = 4,0192 m^2
- $K_{2A} = 10\log(1 + 4 \cdot S / A) = 10\log(1 + 4 \cdot 4{,}0192 / 165{,}06) = 0{,}4$ dB

Requirement $K_{2A} \leq 7\ dB$ for application of standard ČSN EN ISO 11202 is executed.

Determination of correction on environment K_{3A}

Distance of measured point from nearest main source of noise $a = 1$ m

Surface of measured area $S_3 = 2\pi a^2 = 2 \cdot 3{,}14 \cdot 1^2 = 6{,}28\ m^2$

Total bounding surface of the work-room $S_v = 1100{,}4\ m^2$

Medium absorption capacity factor (square room) α = 0,15

Total absorption capacity of the work-room $A = \alpha \cdot S_v = 0,15 \cdot 1100,4 = 165,06\ m^2$

$K_{3A} = 10\log(1 + 4 \cdot S3 / A) = 10\log(1 + 4 \cdot 6,28 / 165,06) = 0,6$ dB

Requirement $K_{3A} \leq 2,5$ *dB* for application of standard ČSN EN ISO 11202 is executed.

Sound pressure level after correction at measuring position

$L_{pA} = L'_{pA} - K_{1A} - K_{3A} = 96,3 - 0 - 0,6 = 95,7$ dB (operation at machine idling)

$L_{pA} = L'_{pA} - K_{1A} - K_{3A} = 97,4 - 0 - 0,6 = 96,8$ dB (on-load operation)

Results of sound pressure level (A) measurement of surfacer at idling with summary statistical evaluation of measured values are presented in Table 1.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	96,12982	96,00000	0,634419	0,659961	0,185888	-0,496984	0,250000
2	96,51563	96,45000	0,567456	0,587942	0,475473	-0,297869	0,080000
3	96,26452	96,30000	0,623725	0,647928	0,024197	-0,676984	0,430000

Table 1: Summary statistical evaluation of data sets for sound pressure level (A) of surfacer at idling

As we can see in Tab. 1, standard deviations are to the 5 %. Hypothesis testing procedure about data layout is performed by Shapiro-Wilke test. Hypothesis h_0 about normal data distribution is confirmed in all cases. Medians of particular data sets have with each other minimal differences. Whereas all of assessed data sets show normal data distribution, ANOVA parametric test is used for statistical significance testing. Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity. The results of these tests are in Tab. 2.

Test	p-value
Leven	0,68
Brown-Forsyth	0,76

Table 2: Results of dispersion homogeneity test for sound pressure level (A) of surfacer at idling

As we can see in Tab. 3 there is statistically significant disparity between first and second measurement.

ANOVA test			
Measurement	1	2	3
1		0,014653	0,589717
2	0,014653		0,240826
3	0,589717	0,240826	

Table 2: Results of statistical significance testing by ANOVA parametric test for sound pressure level (A) of surfacer at idling

Results of sound pressure level (A) measurement of surfacer on-load operation with summary statistical evaluation of measured values are presented in Table 4.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	97,14231	96,80000	0,635719	0,654420	1,781897	4,093620	0,000230
2	97,62319	97,50000	0,700450	0,717504	0,835735	0,718819	0,004100

Table 4: Summary statistical evaluation of data sets for sound pressure level (A) of surfacer on-load operation

Data sets are adjusted at reference value 96,5 dB. The Shapiro-Wilkes test is used for hypothesis of normal data distribution testing. Hypothesis h_0 about normal data distribution is disallowed in all cases as we can see in Tab. 4. Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity. The results of these tests are in Tab. 5.

Test	p-value
Leven	0,5
Brown-Forsyth	0,32

Table 5: Results of dispersion homogeneity test for sound pressure level (A) of surfacer on load operation

Whereas data sets has no normal data distribution there is used non-parametric Mann-Whitney test for statistical significance testing on significance level $\alpha = 0,05$. There are statistically significant differences at second measurement as we can see in Tab. 6 These differences are caused by smaller thickness of experimental work.

Mann-Whitney test		
Measurement	1	2
1		0,000962
2	0,000962	

Table 6: Results of statistical significance test for sound pressure level (A) of surfacer on load operation

3.2 Sound pressure level (A) of thickenesser

Determination of correction on background noise K_{1A}

- average sound pressure level (A) operation at machine idling
  $L'_{pA} = 90,1$ dB
- average sound pressure level (A) on-load operation
  $L'_{pA} = 92,6$ dB
- average sound pressure level (A) background on measuring surface $L_p = 38$ dB
  $\Delta L = 90,1 - 38,0 = 52,1$ dB (operation at machine idling)
  $\Delta L = 92,6 - 38,0 = 54,6$ dB (on-load operation)

Whereas $\Delta L > 15$ dB, standard ČSN EN ISO 11202 does not require correction, therefore $K_{1A} = 0$

Determination of correction on environment K_{2A}

- Surface $S = 6,28\ m^2$
- $K_{2A} = 10\log(1 + 4 \cdot S / A) = 10\log(1 + 4 \cdot 6,28 / 165,06) = 0,6$ dB

Requirement $K_{2A} \leq 7$ *dB* for application of standard ČSN EN ISO 11202 is executed.

Determination of correction on environment K_{3A}

Distance of measured point from nearest main source of noise $a = 1$ m

Surface of measured area $S_3 = 2\pi a^2 = 2 \cdot 3,14 \cdot 1^2 = 6,28\ m^2$

Total bounding surface of the work-room $S_v = 1100,4\ m^2$

Medium absorption capacity factor (square room) $\alpha = 0,15$

Total absorption capacity of the work-room $A = \alpha \cdot S_v = 0,15 \cdot 1100,4 = 165,06\ m^2$

$K_{3A} = 10\log(1 + 4 \cdot S3 / A) = 10\log(1 + 4 \cdot 6,28 / 165,06) = 0,6$ dB

Requirement $K_{3A} \leq 2,5$ *dB* for application of standard ČSN EN ISO 11202 is executed.

Sound pressure level after correction at measuring position

$L_{pA} = L'_{pA} - K_{1A} - K_{3A}$ = 90,1 – 0 – 0,6 = 89,5 dB (operation at machine idling)

$L_{pA} = L'_{pA} - K_{1A} - K_{3A}$ = 92,6 – 0 – 0,6 = 92,0 dB (on-load operation)

Results of sound pressure level (A) measurement of thickenesser at idling with summary statistical evaluation of measured values are presented in Table 7.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	90,31471	90,40000	0,546134	0,604701	-0,086050	0,235107	0,310000
2	90,26774	90,20000	0,396978	0,439778	-0,004235	-0,951648	0,110000
3	89,58485	89,60000	0,523284	0,584121	-0,864244	0,641093	0,050000

Table 7: Summary statistical evaluation of data sets for sound pressure level (A) of thickenesser at idling

As we can see in Tab. 7, standard deviations are to the 0,6 % which indicates low data variability. Hypothesis testing procedure about data layout is performed by Shapiro-Wilke test. Hypothesis h_0 about normal data distribution is confirmed in all cases. Medians of particular data sets have with each other minimal differences. Whereas all of assessed data sets show normal data distribution, ANOVA parametric test is used for statistical significance testing (Tab. 9). Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity. The results of these tests are in Tab. 8.

Test	p-value
Leven	0,41
Brown-Forsyth	0,49

Table 8: Results of dispersion homogeneity test for sound pressure level (A) of thickenesser at idling

The results of statistical significance testing by ANOVA parametric test are in Tab. 9.

ANOVA test			
Measurement	1	2	3
1		0,923019	0,000105
2	0,923019		0,000106
3	0,589717	0,000106	

Table 9: Results of statistical significance testing by ANOVA parametric test for sound pressure level (A) of thickenesser at idling

Results of sound pressure level (A) measurement of thickenesser on-load operation with summary statistical evaluation of measured values are presented in Table 10.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	92,58000	92,70000	1,481680	1,600432	0,041510	-1,07656	0,004000
2	92,64639	92,90000	1,196702	1,291688	-0,280209	-0,49870	0,002000

Table 10: Summary statistical evaluation of data sets for sound pressure level (A) of thickenesser on-load operation

Data sets are adjusted at reference value 90,4 dB. The Shapiro-Wilkes test is used for hypothesis of normal data distribution testing. Hypothesis h_0 about normal data distribution is disallowed in all cases as we can see in Tab. 10. Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity. The results of these tests are in Tab. 11.

Test	p-value
Leven	0,008
Brown-Forsyth	0,01

Table 11: Results of dispersion homogeneity test for sound pressure level (A) of thickenesser on-load operation

Whereas data sets has no normal data distribution there is used non-parametric Mann-Whitney test for statistical significance testing on significance level $\alpha = 0{,}05$. There are not statistically significant differences between measured values as we can see in Tab. 12.

Mann-Whitney test		
Measurement	1	2
1		0,825183
2	0,825183	

Table 12: Results of statistical significance test for sound pressure level (A) of surfacer on-load operation

3.3 Sound pressure level (A) of surfacer and thickenesser at parallel operation process

Determination of correction on background noise K_{1A}

- average sound pressure level (A) operation at machine idling
  L'_{pA} = 90,1 dB (measuring point at surfacer)

  L'_{pA} = 91,4 dB (measuring point at thickenesser)
- average sound pressure level (A) on-load operation L'_{pA} = 99,5 dB (measuring point at surfacer)

  L'_{pA} = 93,2 dB (measuring point at thickenesser)
- average sound pressure level (A) background on measuring surface L_p = 38 dB
  ΔL = 90,1 – 38,0 = 52,1 dB (operation at machine idling, measuring point at surfacer)

  ΔL = 91,4 – 38,0 = 53,4 dB (operation at machine idling, measuring point at thickenesser)
- ΔL = 99,5 – 38,0 = 61,5 dB (on-load operation, measuring point at surfacer)

  ΔL = 93,2 – 38,0 = 55,2 dB (on-load operation, measuring point at thickenesser)

Whereas $\Delta L > 15$ dB, standard ČSN EN ISO 11202 does not require correction, therefore $K_{1A} = 0$

Determination of correction on environment K_{2A}

There is used correction for surfacer and thickenesser

$K_{2A} = 10\log(1 + 4 \cdot S / A) = 10\log(1 + 4 \cdot 6{,}28 / 165{,}06) = 0{,}6$ dB

Requirement $K_{2A} \leq 7$ *dB* for application of standard ČSN EN ISO 11202 is executed.

Determination of correction on environment K_{3A}

K_{3A} = 10log (1 + 4 · S3 / A) = 10log (1 + 4 · 6,28 / 165,06) = 0,6 dB

Requirement $K_{3A} \leq 2,5$ *dB* for application of standard ČSN EN ISO 11202 is executed.

Sound pressure level after correction at measuring position

$L_{pA} = L'_{pA} - K_{1A} - K_{3A}$ = 90,1 – 0 – 0,6 = 89,5 dB (operation at idling in surfacer measuring position)

$L_{pA} = L'_{pA} - K_{1A} - K_{3A}$ = 91,4 – 0 – 0,6 = 90,8 dB (operation at idling in thickenesser measuring position)

$L_{pA} = L'_{pA} - K_{1A} - K_{3A}$ = 99,5 – 0 – 0,6 = 98,9 dB (on-load operation in surfacer measuring position)

$L_{pA} = L'_{pA} - K_{1A} - K_{3A}$ = 93,2 – 0 – 0,6 = 92,6 dB (on-load operation in thickenesser measuring position)

Results of sound pressure level (A) measurement of surfacer and thickenesser at parallel operation at idling in surfacer measuring point with summary statistical evaluation of measured values are presented in Table 13.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	90,31471	90,40000	0,546134	0,604701	-0,086050	0,235107	0,310000
2	90,26774	90,20000	0,396978	0,439778	-0,004235	-0,951648	0,110000
3	89,58485	89,60000	0,523284	0,584121	-0,864244	0,641093	0,050000

Table 13: Summary statistical evaluation of data sets for sound pressure level (A) of surfacer and thickenesser at parallel operation at idling in surfacer measuring position

As we can see in Tab. 13, standard deviations indicate low data variability. Data sets have no normal data distribution so non parametric Kruskal-Wallis test is used. Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity. The results indicate homogeneity of dispersion. Results of these tests are in Tab. 14. ANOVA parametric test is used for statistical significance testing (Tab. 15).

Test	p-value
Leven	0,41
Brown-Forsyth	0,49

Table 14: Results of dispersion homogeneity test for sound pressure level (A) of surfacer and thickenesser at parallel operation at idling in surfacer measuring position

ANOVA test			
Measurement	1	2	3
1		0,923019	0,000105
2	0,923019		0,000106
3	0,000105	0,000106	

Table 15: Results of statistical significance testing by ANOVA parametric test for sound pressure level (A) of surfacer and thickenesser at parallel operation at idling in surfacer measuring position

As we can see in Tab. 15 there is statistically significant disparity between third measurement and first and second measurement.

Results of sound pressure level (A) measurement of surfacer and thickenesser at parallel operation at idling in thickenesser measuring point with summary statistical evaluation of measured values are presented in Table 16.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	91,92667	91,95000	0,401663	0,436939	-0,151008	0,70911	0,350000
2	90,91000	90,90000	0,544154	0,598563	-0,065267	0,47926	0,140000
3	91,39000	91,30000	0,892246	0,976306	-0,027169	-1,36830	0,049000

Table 16: Summary statistical evaluation of data sets for sound pressure level (A) of surfacer and thickenesser at parallel operation at idling in thickeneser measuring position

As we can see in Tab. 16 there is low data variability (coefficient of variation values are to 1 %). Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity (Tab. 17). Data sets 1 and 2 show normal data distribution, data set 3 has not normal data distribution so non parametric Kruskal-Wallis test is used (Tab. 18). Hypothesis testing procedure about data layout is performed by Shapiro-Wilke test.

Test	p-value
Leven	0,000002
Brown-Forsyth	0,000006

Table 17: Results of dispersion homogeneity test for sound pressure level (A) of surfacer and thickenesser at parallel operation at idling in thickenesser measuring position

Kruskal-Wallis test			
Measurement	1	2	3
1		0,000000	0,024595
2	0,000000		0,020609
3	0,024595	0,020609	

Table 18: Results of statistical significance testing by Kruskal Wallis non parametric test for sound pressure level (A) of surfacer and thickenesser at parallel operation at idling in thickenesser measuring position

Results of sound pressure level (A) measurement of surfacer and thickenesser at parallel on-load operation in surfacer measuring point with summary statistical evaluation of measured values are presented in Table 19.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	99,74109	99,90000	0,849872	0,852079	0,590668	1,224510	0,001700
2	99,21608	99,10000	0,851482	0,858209	0,447157	0,198892	0,010000

Table 19: Summary statistical evaluation of data sets for sound pressure level (A) of surfacer and thickenesser at parallel on-load operation in surfacer measuring position

As we can see in Tab. 19, standard deviations indicate low data variability (coefficient of variation values are to 0,86 %). Data sets have not normal data distribution. Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity (Tab. 20).

Test	p-value
Leven	0,11
Brown-Forsyth	0,12

Table 20: Results of dispersion homogeneity test for sound pressure level (A) of surfacer and thickenesser at parallel on load operation in surfacer measuring position

Mann-Whitney test is used for statistical significance testing (Tab. 21). Results of this test indicate that there are statistically significant disparities between evaluated data sets.

Mann-Whitney test

Measurement	1	2
1		0,000047
2	0,000047	

Table 21: Results of statistical significance testing by Mann-Whitney test for sound pressure level (A) of surfacer and thickenesser at parallel on-load operation in surfacer measuring position

Results of sound pressure level (A) measurement of surfacer and thickenesser at parallel on-load operation in thickenesser measuring point with summary statistical evaluation of measured values are presented in Table 22.

	Mean	Median	Standard dev.	Coeff. of variation	Skewness	Kurtosis	S-W
1	93,08175	92,50000	2,372180	2,548491	0,274784	-1,32281	0,000000
2	93,39457	91,50000	3,564195	3,816276	0,405045	-1,41048	0,000000

Table 22: Summary statistical evaluation of data sets for sound pressure level (A) of surfacer and thickenesser at parallel on-load operation in thickenesser measuring position

As we can see in Tab. 22, standard deviations indicate high data variability (coefficient of variation values are about 3,8 %). Data sets have no normal data distribution. Leven and Brown-Forsyth tests are used for testing of dispersion homogeneity (Tab. 23).

Test	p-value
Leven	0,000000
Brown-Forsyth	0,000017

Table 23: Results of dispersion homogeneity test for sound pressure level (A) of surfacer and thickenesser at parallel on-load operation in thickenesser measuring position

Mann-Whitney test is used for statistical significance testing (Tab. 24). Results of this test indicate that there are not statistically significant disparities between evaluated data sets.

Mann-Whitney test		
Measurement	1	2
1		0,772856
2	0,772856	

Table 24: Results of statistical significance testing by Mann-Whitney test for sound pressure level (A) of surfacer and thickenesser at parallel on-load operation in thickenesser measuring position

As we can see medians of data sets has small differences and second measurement has significant variability in comparison with first measurement. Result of the Mann-Whitney test we can consider to relevant.

Similar results are presented in [Hesselbach 2010].

4 CONCLUSIONS

Czech regulation No. 272/2011 col. require permissible exposure limit of steady and variable work noise expressed in equivalent sound pressure level (A) L_{Aeq} = 85 dB. As we can see all of measured old woodworking machines run over of this value at idling and on-load operation too. It is necessary to use personal protection (hearing protection equipments). These machines should be technically modified for noise reduction.

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