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Rate of chainsaw vibrations in laboratory conditions and level of chainsaw noise at different distances

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Abstract

The study is focused on the rate of vibrations and level of noise in the chainsaw model Stihl MS 362 which belongs in the group of the best-selling professional chainsaws in the world with a highly efficient anti-vibration system. Testing cuts to determine the rate of vibrations were made on the stems of two tree species: sessile oak (*Quercus petraea* (Matt.) Liebl.) and Norway spruce (*Picea abies* (L.) H. Karst.). The purpose of noise level measurement was to compare the influence of chainsaw noise on its operator and on the person occurring behind the zone of protection (5 and 10 metres) from the source of noise. Then a distance from the chainsaw was measured where the level of noise reached 80 dB. The measurements were performed according to ČSN EN ISO 22868:2021. At measuring the chainsaw vibrations, the rate of vibrations acting on both operator's hands (front and rear grip) was examined. Vibrations were measured according to ČSN EN ISO 22867 (2012).

It was found out that the rate of vibrations on the rear handle was in both cases of measurements higher than the rate of vibrations on the front handle. At the same time, a higher rate of vibrations was recorded in sessile oak. As to the level of noise, results of measurements indicated that at working with the chainsaw, hearing protectors have to be used at all three measured distances (close proximity, 5 m from the operator, 10 m from the operator) in order to reduce high noise level as the average noise level was higher than permissible in all measurements. The highest possible tolerable level of acoustic noise (80 dB) at which permanent damage of hearing does not happen was measured at a distance of 21 m from the working place of chainsaw operator.

Keywords: chainsaw, Stihl MS 362, vibrations, noise, occupational hygiene, forestry

Introduction

Work in the forest has been always prone to accidents. Statistics classify forest workers as a professional group with a high risk of occupational accidents (Slappendel et al. 1993, Lindroos and Burstrom 2010, Tsioras et al. 2014, Laschi et al. 2016). Even today when occupational health and safety requirements in forestry are high, some forest operations are permanently considered hazardous, namely the motor-manual felling of trees with the chainsaw (Tsioras et al. 2014). Taking into account their relatively low operating costs and a possibility of working in difficult terrains, chainsaws are basic tools for logging (Sztyber 2017). A considerably high number of occupational accidents at working with them is recorded every year. The situation is even worse if the salvage felling is concerned, at which entirely different risk situations happen than in the main felling (Rak 2018).

Apart from accidental risks (fall, slip, etc.), long-term work with chainsaw is a major problem of occupational health and safety due to occupational hygiene and ergonomic stress (Potočnik and Poje 2017). Ergonomics dealing not only with the physical limits of humans but also with their psychological limits in connection with the design of products or whole systems aiming on comfort and safety at work (Abramuszkinová Pavlíková 2020).

Chainsaw with the combustion engine directly expose the operator to considerable vibrations and noise (Neitzel and Yost 2002, Magnusson and Nilsson 2011, Rottensteiner et al. 2012, Rottensteiner and Stampfer 2013, Poje et al. 2018, Dimou et al. 2019). Vibrations arise in the chainsaw due to engine operation and cutting of wood by the saw chain (Rak 2018). Vibrations (oscillation and concussions) are serious harmful phenomena in forestry (Škapa 1987). The vibrations adversely influence the lower part of upper limbs. The most affected parts are fingers, then palms and forearms (Neruda and Černý 2006). The transmission of vibrations depends on the squeezing force applied on the chainsaw handle, on the handle shape, chainsaw weight or lack of training, etc. Another important factor is the position of hand and arm, i.e. angles of wrist, elbow and shoulder joints as well as the direction of vibrations (Teisinger 1953). The negative effects of vibrations on the operator is increasing in the cool and wet environment when hands and particular the fingers become cold and experience insufficient blood circulation. This increases the risk of occupational diseases such as the hand-arm vibration syndromes (Schlaghamersky 1990, Neruda et al. 2015).

The transmission of vibrations onto chainsaw operators is connected with various vascular, neurological and muscoskeletal disorders (Griffin 2004), especially with vasoneurosis, Raynaud syndrome and carpal tunnel syndrome (Neruda and Černý 2006, Rak 2018). Adverse impacts of hand-arm vibrations have been proven also by neurophysiological studies which suggest the worsening of mechanical receptors and nerve endings in the skin of fingers (Bovenzi 2004, Malinowska-Borowska et al. 2012). Vibrations affect internal body organs, too, namely the back, ribs and jaw because if they reach a critical frequency, oscillation of body organs can be considerably harmful to human health (Rónay and Sláma 1989).

The source of chainsaw noise is particularly the engine operation as well as the operation of the cutting mechanism itself. Noise levels range around 105–115 dB at the working engine speed (Neruda and Černý 2006). Optimum volume for human ear is 40–60 dB, unpleasant noise is above 100 dB and pain threshold start at about 140 dB and more (Králová 2009). Exposure to the noise of chainsaw depends to a large extent on the specific operation as well as on the operator's pose (Helander 2006). At full throttle, large volume chainsaws can generate engine noise of up to 113 dB (A), which may worsen the capacity of hearing if the exposure is frequent (Fonseca et al. 2015).

Similarly as most harmful agents, noise cannot be seen, its acts covertly. This means that its impacts cumulate and show only after some time (Kováč 2013).

Moreover, hearing organs have no defence mechanism against excessive noise which unfavourably affects the entire nervous system as well as the mental and physical performance. Heavy noise causes poor concentration of workers, poor quality of work, and increases the rate of accidents. The level of hearing loss induced by noise and frequency depends particularly on the acoustic parameters of noise and length of exposure (Osguthorpe and Klein 1991). Years of working with the chainsaw can unfavourably affect the hearing of loggers (Fonseca et al. 2015) and exposure to high levels of noise in the working environment may result not only in the loss of hearing but can also cause cardio-vascular, psychological and respiratory changes, sleep disorders, immune system dysfunction, irritability and fatigue (Kroemer and Grandjean 2005), and thus impair the worker's performance at work (Massa et al. 2012, Duarte et al. 2015).

Pursuant to Directive 2003/10/EC of the European Parliament and of the Council dated 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (Seventeenth individual Directive within the meaning of Article 16 of Directive 89/391/EEC), action evoking upper values of exposure are: $L_{EX,\,8h}$ = 85 dB(A) and p_{peak} = 140 Pa, and action evoking lower values of exposure are: $L_{EX,\,8h}$ = 80 dB(A) and p_{peak} = 112 Pa, if not specified otherwise. Pursuant to Directive 2002/44/EC of the European Parliament and of the Council dated 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16 of Directive 89/391/EEC) – Joint Statement by the European Parliament and the Council, daily exposure to vibrations evoking an action standardized to a reference time of 8 hours is 2.5 m/s^2 (Nařízení vlády 2011). Based on the assessment of risks mentioned in the two above directives, employers have to introduce and implement a programme of technical or organisational measures determined to reduce the exposure to mechanical vibrations or noise and risks following out from them to minimum in case that the set-up values of exposure are exceeded.

ČSN EN ISO 11681-1 Forest machines – Safety requirements and testing of portable chainsaws – Part 1: Chainsaws for work in the forest, indicates maximum values of vibrations for chainsaws with the engine cylinder capacity of 80 cm^3 and less amounting to 12.5 m/s^2, and for chainsaws with the engine cylinder capacity larger than 80 cm^3 up to 15 m/s^2 (ČSN 11681-1 2012).

The above raises the question of how much vibration affects the operator of a chainsaw via the front and rear handles when cutting different types of wood. Another question is how much noise affects the worker with the chainsaw and those within 5 m and 10 m of the chainsaw. Furthermore, at what distance from the chainsaw will a noise level of 80 dB be reached, which is the critical limit for the use of personal protective equipment in the form of ear defenders. This research can provide answers to these questions.

Material and methods

Our research was focused on the rate of vibrations and noise level in the chainsaw Model Stihl MS 362 which belongs to the group of best-selling professional chainsaws in the world (Unicommerce 2021). This professional chainsaw has an output of 3.5 kW (Table 1) and is equipped with a modern two-stroke combustion engine. In addition, it has a very efficient anti-vibration system and an air filter system with a long service life. The manufacturer claims

Table 1. Technical characteristics of chainsaw MS 362 (Stihl 2020)

Displacement	59.0 cc (3.6 cu. in.)
Engine power	3.5 kW (4.69 bhp)
Powerhead weight	Flush-Cut: 5.6 kg (12.3 lbs.)
Fuel capacity	600 cc (20.3 oz.)
Chain oil capacity	325 cc (11.0 oz.)
Oilomatic® chain	3/8 " RS3
Guide bar lengths	40 cm (16 ") Stihl Rollomatic®
Power source	Petrol

fuel consumption lower by up to 20% and emissions reduced by 50% as compared with conventional two-stroke engines. The saw is particularly suitable for work in forest stands of medium diameters (Stihl 2020).

Testing cuts were made using the Stihl Micro 3 chain with the round profile of guide link (pitch 3/8 ", guide link diameter 1.6 mm, 60 guide links, bar length 40 cm). Prior to each series of measurements, the chain was sharpened by skilled worker using a rasper and a lead.

Cutting with the chainsaw was carried out on tree stems that were fixed to racks. The testing was made when the log was cut in the transverse direction. At cutting, the operator was holding the chainsaw in the classic way, cutting with or without the chainsaw spiked bumper at a ratio of 50 : 50. The rate of vibrations and the level of noise were not affected by external conditions.

Characterization of instruments

Accelerometer:

Accelerometer used for the measurement of vibrations was Datalogger CEM model DT-178 A. The range of this model is 18 G with the resolution of 0.00625 G. It can take records of acceleration in three basic axes and total shaking in G (m/s^2). All values are recorded with a time stamp. The range of time collection is adjustable from 1 second to 24 hours (CEM 2018a). The measurements were taken continually, and sections were selected according to time when the measurements were made. Records were saved on the internal memory of 4 Mbit in capacity allowing to enter up to 85,500 recorded data (CEM 2018a).

Sound level meter:

Noise was measured by the data-logger sound level meter model CEM model DT-8852. This instrument can measure noise from 30–130 dB with accuracy ± 1.4 dB. Registration interval ranges from 125 milliseconds to 1 second (CEM 2018b). The measurement was continual, and values were collected from the data according to time comparison when the saw was in the measuring position (in the cut). Internal integrated memory of this instrument can store up to 32,000 of measured values (CEM 2018b).

Measured quantities

Measurement of chainsaw vibrations

The measurements were based on a comparison of possible vibrations affecting operator's health and comfort at working with the chainsaw. The purpose was to determine the extent to which different tree species can affect the rate of vibrations affecting the chainsaw operator. An important aspect of measurements is the different rate of vibrations acting on each hand because the mounting of engine, construction and handles differs in the two cases. This is why the rate of vibrations on the front handle does not correspond with the rate of vibrations on the rear handle.

During this study, the rate of chainsaw vibrations was measured on both hands of the operator (front and rear handle) when cutting. The CEM DT-178A instrument measuring vibrations was attached to the chainsaw. The instrument was installed at places where the operator holds the chainsaw (at a maximum distance of 20 mm from them). Prior to the beginning of measurements, the saw was set up in line with the recommendations of the manufacturer and warmed up to operating temperature. Testing cuts were made on the stems of two tree species: sessile oak (*Quercus petraea* (Matt.) Liebl.) and Norway spruce (*Picea abies* (L.) H. Karst.). The diameter of stems was 30 cm (± 2 cm) (ČSN 22867 2012). The stems were without knots and the wood bulk density of these two tree species differed by 33% with the density of sessile oak being higher. The measurement was made three times per each sample for 25 seconds (± 4 s).

The procedure consisted of the following steps:

1) attachment of the CEM DT-178A instrument and saw adjustment;
2) warming up of the chainsaw to operating temperature;
3) cutting with a testing measurement;
4) measurement with three repetitions at cutting the hard wood (sessile oak);
5) recording of results;
6) measurement with three repetitions at cutting the soft wood (Norway spruce);
7) recording of results.

Measurement of chainsaw noise

At each site (close vicinity of the chainsaw operator's hearing organs; person present within a radius of 5 m and 10 m), 10 values were measured at a maximum chainsaw loading (to have relevant measured values). Results were mean values from each site. To prevent a possible distortion of results, the measurements were made on a large plain in order to avoid the reflection of sound waves as much as possible.

The purpose of measurements was to compare the level of noise to which a person working with it is exposed as well as a person occurring behind the zone protection at its use. Results of the measurements were to determine whether the limit exceeds 80 dB and could result in the permanent damage to the hearing of some of workers. Noise measurements were recorded using the CEM DT-8852 instrument that has been certified for the given measurements. The meters were installed in a close vicinity of the chainsaw operator's hearing organs and of a person present within a radius of 5 m and 10 m. Then a distance was measured where a noise level of 80 dB was reached. The level of noise was not affected by external factors during the measurement. Factors affecting the level of noise included only the cutting itself, possibly also uneven grip of the chainsaw at individual cuts. Regarding the fact that the measurements were taken for one afternoon (ca. 8 hours), external conditions were identical for all of them. The testing cuts were made on the stems of Norway spruce (*Picea abies* (L.) H. Karst.) the diameter of which was 30 cm (± 2 cm). Sessile oak (*Quercus petraea* (Matt.) Liebl.) was not measured because the relevant standard (ČSN 22868 2021) is not set for the measurement of the species.

The procedure consisted of the following steps:

1) attachment of the CEM DT-8852 instrument for noise measurement to the given position;
2) noise level measurement at Site 1;
3) recording of measurement results;
4) noise level measurement at Site 2;
5) recording of measurement results;
6) noise level measurement at Site 3;
7) recording of measurement results.

The procedure of measuring a guaranteed level of acoustic performance was in line with the Directive No. 2000/14/EC Annex III Section B Item 6 – Portable chainsaws. The measurements were based on the application of standard ČSN EN ISO 22868:2021 (ČSN 22868 2021). Specifics of measurement were determined according to Annex A of the standard. However, the measurements were taken only in two positions according to the standard – on the following coordinates: 1) x, + 5 m, y, 0.00 m z, + 1.76 m, and 2) x, + 10 m, y, 0.00 m z, + 1.76 m. The values were determined so that they corresponded to the distance of the other worker at the nearest permitted safety distance possible (behind the boundary of machine protection zone).

Results

Measurement of chainsaw vibrations

Table 2 presents rates of vibrations affecting the chainsaw operator when cutting spruce and oak timber. The values show that a difference in the rates of vibrations acting on the front chainsaw handle at cutting spruce and oak timber was 10% and that vibrations were greater in oak timber in all measured cuts.

The calculated statistical analysis (Table 3) shows that differences between the values measured in the two sets were not essential and the results were affected by irregular timber structure which is often influenced by the presence of reaction wood and by other external impacts during the tree growth.

Table 2. Rate of vibrations recorded on the front handle

Cut no.	Vibrations at cutting spruce (m/s²)	Vibrations at cutting oak (m/s²)
1	7.360	8.010
2	8.030	8.930
3	8.420	9.110
4	7.770	8.450
5	7.360	7.910
6	7.200	7.630
7	7.800	8.300
8	7.580	8.130
9	7.650	8.280
10	7.630	8.230
Min:	**7.200**	**7.630**
Max:	**8.420**	**9.110**
Average:	**7.680**	**8.298**
Modus:	**7.360**	**-**
Median:	**7.640**	**8.255**
Standard deviation:	**0.338**	**0.424**

Table 3. Statistical evaluation of variances of the basic sets of vibrations acting on the front handle

Two sample *F* test		
	Cut of oak	Cut of spruce
Mean (expected) value	8.255	7.640
Variance	0.199418	0.1268
Observations	10	10
Difference	9	9
F	0.635851	-
P (*F* ≤ = *f*) (1)	0.744702	-
F krit (1)	3.178893	-

Table 4. Rate of vibrations recorded on the rear handle

Cut no.	Vibrations at cutting spruce (m/s²)	Vibrations at cutting oak (m/s²)
1	11.300	12.410
2	11.730	12.910
3	11.580	12.790
4	11.770	12.960
5	12.230	13.430
6	12.390	13.660
7	11.920	12.900
8	12.140	13.160
9	11.830	12.830
10	11.390	12.310
Min:	**11.300**	**12.310**
Max:	**12.390**	**13.660**
Average:	**11.830**	**12.936**
Modus:	**-**	**-**
Median:	**11.800**	**12.905**
Standard deviation:	**0.336**	**0.391**

Comparing the two tree species, the obtained values indicate (Table 4) that the rate of vibrations on the rear handle is by 9.5% higher when cutting oak timber than spruce timber.

Table 5. Statistical evaluation of variances of basic sets

Two sample *F* test		
	Cut of oak	Cut of spruce
Mean (expected) value	12.905	11.VIII
Variance	0.169116	0.125373
Observations	10	10
Difference	9	9
F	0.741347	-
P (*F* ≤ = *f*) (1)	0.668534	-
F krit (1)	3.178893	-

Based on the calculated statistical analysis (Table 5), we can see similar results when measuring the rate of vibrations on the rear handle as in the measurement of the rate of vibrations on the front handle. The results can be attributed to the natural properties of wood, too. Thus, the results were to a considerable extent affected by material amorphousness.

Measurement of chainsaw noise level

The results indicate (Table 6) that an average level of noise at cutting measured in the close vicinity to operator's hearing organs at Site 1 was 108.8 dB, which is very undesirable in respect of sustainable sensitivity of senses. At Site 2, an average level of noise at cutting measured at a distance of 5 m from the chainsaw operator (protection zone) was 97.18 dB. Noise values recorded at a distance of 5 m from the operator ranged from 75.4 dB to 78.5 dB. At Site 3, an average level of noise at cutting measured at a distance of 10 m from the operator (double distance of protection zone) was 85.02 dB, which is much better than in the previous case but still high enough to protect the hearing with recommended elements and aids. Noise values recorded at a distance of 10 m from the idling chainsaw ranged from 64.1 dB to 66.2 dB.

Table 6. Noise level values at cutting

	Noise level (dB)		
Cut no.	Site 1	Site 2	Site 3
1	109.9	98.2	84.4
2	110.9	100.6	84.6
3	111.3	99.9	84.9
4	110.1	99.2	85.1
5	108.5	99.6	85.5
6	108.5	100.1	85.8
7	110.4	99.6	85.6
8	110.1	95.4	85.0
9	100.8	85.3	84.7
10	100.3	93.9	84.6
Min:	**100.300**	**85.300**	**84.400**
Max:	**111.300**	**100.600**	**85.800**
Average:	**108.080**	**97.180**	**85.020**
Modus:	**110.100**	**99.900**	**84.600**
Median:	**110.000**	**99.400**	**84.950**
Standard deviation:	**3.861**	**4.469**	**0.451**

The noise level of 80 dB, at which a human does not have to wear personal protective equipment such as hearing protectors, was measured at a distance of 21 m from the chainsaw operator's post.

Discussion

The issue of vibrations and noise is a very specific theme with a range of variable factors which does not relate only to forestry but also other industries, where chainsaw is used such as arboriculture or woodworking. Therefore, the results measured in this research cannot be compared routinely with the results of other works and can be compared only proportionally.

Vibrations

It can be stated on the basis of obtained results that despite the difference in the wood density of tree species, which amounted to 33%, vibrations measured at cutting sessile oak were by 10% and 9.5% higher on the front and rear handles, respectively. Rottensteiner et al. (2012) found out in their study that wood density affects the rate of transmission of vibrations onto operator's hands at working with the chainsaw, which as the same as in our study. The effect of wood during the process of cutting exhibits significant values, and it can be assumed that vibrations at cutting spruce wood are lower than vibrations at cutting beech wood. The fact results from physical and mechanical characteristics of wood. Softwood absorbs the vibration more readily than hardwood (Kováč et al. 2018).

Comparing the rate of vibrations acting on the front and rear handles of chainsaw Stihl MS 362 it was found out that the rate of vibrations on the rear handle was in both cases of measurement higher than the rate of vibrations acting on the front handle, which was given by different positions of handles and by their attachment to the chainsaw body. The official instructions for use of Stihl MS 362 (Stihl 2020) claim that the vibration value $a_{hv,\,eq}$ represents according to (ČSN 22867 2012) 3.5 m/s^2 for the left handle and 3.5 m/s^2 for the right handle. The instructions further claim that the daily load of vibrations on the left handle A (8) is 2.4 m/s^2 and the daily load of vibrations on the right handle is 2.4 m/s^2 as well. All these values were exceeded in measurements made by us. Staněk et al. (2023) analysed the level of vibrations transmitted to the hands of a logger using the same type of chainsaw that was used in this research. They found an average tree felling vibration of 3.61 m/s^2 at the rear handle and 4.0 m/s^2 at the front handle. These values are lower than the values obtained from this research.

Results of research conducted by Landekić et al. (2020) showed that groups of chainsaw Stihl MS 260 and Stihl MS 440 exhibited the highest measured vibrations most frequently on the front handle while chainsaw Stihl MS 660 had the highest measured vibrations on the rear handle. Another study (Feyzi et al. 2016) performed on the chainsaw Stihl MS 230 arrived at a conclusion that the highest vibrations occurred on the rear handle at idling.

Measurements of vibrations on the chainsaw Stihl MS 362 were performed also by Rak (2018) who used different mixtures of petrol (BA 95 Natura; Shell V-power racing 100) and oil (M2T; HP Ultra) and placed the accelerometer for measuring vibrations on the saw bar. Combining various petrol and oil mixtures, he recorded the following average vibrations in total acceleration [m/ s^2] at chainsaw idling operation range from 4.8 m/s^2 to 5.41 m/ s^2. The author also measured average vibrations when combining various mixtures of petrol and oil in total acceleration [m/ s^2] at chainsaw "half-throttle" and recorded the values from 11.61 m/s^2 to 13.13 m/s^2. These values are consistent with the results of this research.

Rottensteiner et al. (2012) made research on chainsaws of the same performance class as Stihl MS 362 and found out weighted mean values of vibrations to be 5.54 m/ s^2 for Husqvarna 357 XP and 4.26 m/s^2 for Husqvarna 372 XP irrespective of tree species. The values of the authors' research are lower than those recorded in our study.

It is also important to discuss here the battery powered chainsaw. The research made by (Poje et al. 2018) demonstrated that exposure to hand-arm vibrations was lower when working with the battery powered chainsaw as compared with the petrol motor saw. The exposure was on average lower by 1.23 m/s^2. The fact that battery powered chainsaws transmit a lower rate of vibrations on the operator than petrol motor saws has been confirmed also by other studies (Neitzel and Yost 2002, Poje 2011).

In addition to the type of chainsaw engine, there are other factors that can affect the amount of vibration produced. Kováč (2013) maintain that injuries induced by vibrations depend on the amplitude size, frequency of acceleration and number of oscillations. In contrast, Rónay and Sláma (1989) claim that the acting of vibrations and the way of their transmission onto humans depend on the duration of exposure, interruption of vibrations (technological breaks), type of work and human disposition. Rónay and Sláma (1989) and Kováč (2013) agree that the acting of vibrations is not limited to the point of contact only. Vibrations are transmitted not only onto hands in which the operator holds the chainsaw, but also onto the back and head, organs and tissues, in fact onto the whole body of the operator.

The study authors highlight that the key factors to be taken into account as to vibrations affecting the human organism are the type of chainsaw used and work operations performed. The share of performance times plays also a role in the work regime of chainsaws as well as the type of correct saw chain sharpening as Marenče et al. (2017) concluded that the rate of hand-arm vibrations is also affected by the angle of chain sharpening. Mendes (2019) adds that regular maintenance and chainsaw adjustment are necessary in order to reduce vibrations emitted by the chainsaw.

Noise

Similarly as vibrations, noise represents an undesirable phenomenon at working with the chainsaw. This is why our measurements were focused also on the issue of noise during the operation of chainsaw model Stihl MS 362 affecting the chainsaw operator and persons occurring in the vicinity.

Official instructions for use (Stihl 2020) of chainsaw Stihl MS 362 measured by us claim the value of acoustic pressure L_{peq} according to (ČSN 22868 2021) as 106 dB(A) and the level of acoustic performance L_w according to (ČSN 22868 2021) as 117 dB(A). Our measurement records indicated an average value of acoustic noise in the close vicinity of chainsaw operator to be 108.8 dB.

A similar measurement of chainsaw Stihl MS 362 noise was made by Rak (2018) who subjected within his research the chainsaw to the measurement when idling and at increased speed (so-called "half-full throttle"). During the measurement, he used different mixtures of petrol (BA 95 Natura; Shell V-power racing 100) and oil (M2T; HP Ultra) and placed the sound level meter at a distance of 1 meter from the saw bar. The measured average values of noise in dB during the chainsaw idling and with combining different mixtures of petrol and oil were in the range of 88.15 dB to 89.93 dB. The measured average values of noise in dB during the chainsaw "half-full throttle" operation with combining different mixtures of petrol and oil were in the range of 99.3 dB to 101.66 dB. These values represent lower values than those observed in our study.

Similar studies were pursued to assess the risk factor of noise emitted by different chainsaws ranked in the same performance classes as the model Stihl MS 362. For example, in the model Husqvarna 357 XP, the permitted values of noise level were exceeded, too (Malinowska-Borowska et al. 2012, Neri et al. 2018, Poje et al. 2018). Billo et al. (2019) conducted a study with the chainsaw model Stihl MS 361 ranked in the same performance class as Stihl MS 362 and found out that average levels of noise emitted by chainsaws during forest cutting activities were 102.05 dB(A) for felling, 99.20 dB(A) for logging and 95.14 dB(A) for delimbing. It follows that in all assessed activities the noise level was higher than 85 dB(A) which is a maximum permissible value for a work shift lasting 8 hours.

The level of noise emitted from a chainsaw is also different when using a battery powered chainsaw. A research conducted by Poje et al. (2018) demonstrated that exposure to noise is higher when petrol chainsaw is used than with the use of battery powered chainsaw. This holds true for the evaluation of exposures both according to noise indicators and for specific work activities. On average, the noise exposures differ by 13.5 dB(A), and the individual work activities range between 10.1 and 16.0 dB(A). The fact that at working with the petrol motor saw the operator is exposed to the noise level which is higher than at working with the battery powered chainsaw has been demonstrated also by other research studies (Minetti et al. 1998, Neitzel and Yost 2002). Colantoni et al. (2016), whose research results proved the reduced noisiness of battery powered chainsaws (84–96 dB) compared with petrol chainsaws (97–109 dB), is of the same opinion.

Common users of chainsaws find the values of noise in manuals (Instructions for use) which are mandatory part of the package when buying a new chainsaw. In addition, there are also stickers with the symbols of safe use and values of maximum possible noise in dB on the chainsaw frame. It is advised to follow these instructions as Hrnčíř (2006) claims that a noise level up to 70 dB does not cause any injury to hearing even at a longer exposure while noise levels between 120–140 dB cause injuries to hearing organs and acoustic trauma. Ingle et al. (2005) claims that the loss of hearing induced by noise is usually bilateral and exhibits a similar pattern in both ears. Therefore, suitable hearing protectors must be used and work breaks spent in the quiet or less noisy environment (Souza et al. 2015). Although the hearing protectors reduce the level of noise, they cannot protect the chainsaw operator fully from exposure to noise. This is why the breaks for the refreshment of workers are extremely necessary (Billo et al. 2019).

Conclusion

A comparison was made of the rate of vibrations acting on the front and rear handles of the chainsaw model Stihl MS 362. It was found that the rate of vibrations on the rear handle was higher whilst measuring the studied tree species (spruce; oak) than the rate of vibrations on the front handle. The highest vibration values were found on the rear handle when cutting oak and the lowest values were recorded on the front handle whilst cutting spruce.

It can be deduced from the results obtained that when working with the chainsaw, ear protectors have to be used at all three measured distances (operator's hearing organs, 5 m from the operator, 10 m from the operator). This is required to effectively reduce the high levels of noise which could adversely affect the hearing of operators, as well as the hearing of persons in close vicinity who could be exposed to the noise over a long period of time. The highest possible level of acoustic noise at which no permanent injury to hearing should occur is 80 dB. This value was measured to be 21 m from the position where the operator worked with the chainsaw Stihl MS 362.

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