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Effect of chain saw pitch on vibration level on the internal combustion chain saw handles during cross cutting of wood

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Abstract: *Effect of chain saw pitch on vibration level on the internal combustion chain saw handles during cross cutting of wood.* Results of investigations on the efect of chain saw pitch on the vibration level recorded on the internal combustion chain saw handles are presented. The investigations can contribute to learning of factors that intensify vibrations existing during cross cutting of wood with the use of chain saws of different pitch values; they can be also a source of practical instructions for the sawmen-operators of internal combustion chain saws to reduce the hazard of mechanical vibrations. Basing on the results of investigations one can find that the chain saw pitch affects vibration level on the machine handles; it increases along with an increase in the pitch.

Key words: vibrations, internal combustion chain saw, chain saw pitch, cross cutting of wood.

INTRODUCTION

Portable internal combustion chain saws are at present the basic machines for timber harvesting. They are subjected to continuous modification and improvement in respect of design, in order to ensure better working conditions of the chain saw operators and to reduce a risk of accidents.

Diversification of models available on the market in consideration of size and power causes that the chain saws are used not only as professional machines in forestry for timber harvesting, but also in the farms or gardens in preparation of fire wood or cultivation of green plants. This wide application of chain saws brings about a high threat for the operator. Majority of accidents caused by portable chain saws result from direct contact with a moving chains saw. Improper handling often leads to irreversible and serious injuries. Other threats include vibrations emitted by the chain saw, that greatly affect the human health. The chain saw operation lasting for hours and for many years leads to irreversible changes in the organism. This is regarded as professional illness, currently called the vibration illness. The harmful effect of vibrations is sometimes connected to time of exposition and the transferred dose of vibration energy [Żukowski 1996]. Additionally, disadvantageous effect to operator have unfavourable weather conditions and improper position of his body during work. These factors play a key role in development of disorder caused by vibrations.

In respect to both the commonness and hazard of the chain saw operation, there have been introduced rules and standards that determine admissible level of vibrations affecting the operator as well as the maximal time of work at a given level of vibrations. These standards contain all necessary information that enable to reduce the vibration hazard to operator.

Measuring the level of vibrations generated by chain saws significantly affects the search for appropriate constructional solutions that could help to reduce vibrations to the harmless level. Investigations in this field point out at parameters that significantly affect the operator's health disadvantageously. Due such investigations one can give some advice on the chain saw operation in order to reduce the negative effect on the sawman.

VIBRATIONS OF INTERNAL COMBUSTION CHAIN SAWS

One of elements towards improvement of work in forestry was the common introduction of hand operated internal combustion chain saws that were used for felling, debranching and handling. In these chain saws there are mainly used the piston type, two-stroke, single-cylinder engines with spark ignition. Due to their construction one can distinguish the two main groups of units that generate vibrations: vibrations of engine as a whole and torsional vibrations of crankshaft.

The level of vibrations emitted by the chains saw is affected – besides the engine – by working unit elements: drive sprocket, clutch, saw chain with guide bar and nose sprocket. The chain saw consists of cutting teeth (guiding and tying) connected with the use of rivets. Its sectional structure causes that the cutting teeth have freedom of movement during operation and generate vibrations, that are transferred to the chain saw body and handles through the drive sprocket, and then to operator's organism. Another reason for vibrations are variable cutting forces during cutting through particular wood rings [Botwin 1976].

The newer investigations proved that differences in wood hardness between investigated species (aspen, pine, birch, oak) did not affect the level of vibrations, although they were significant [Skarżyński, Wójcik 2008]. Sowa [1998] reported that other factors (related to chain saw operation methods) significantly affected the vibration emission. The author reckoned among these factors the force of guide bar feed in the kerf, lowering of chip thickness limiter in the cutting tooth, rotational speed of engine crankshaft, type of technological operation with internal combustion chain saw, and the use of spiked bumper during cutting or cutting itself with upper or lower side of guide bar. Other researchers [Wójcik, Skarżyński 2008] confirmed that vibration hazard is highest in cross cutting with the lower side of guide bar with the use of spiked bumper, independently of wood diameter, while lowest hazard in wood cutting with the lower side without the spiked bumper.

Wójcik and Skarżyński [2009] found also a linear increase in vibration acceleration on the rear handle of electrical chain saw along with an increase in wood diameter processed.

The saw chain's main parameters (Fig. 1) are: saw chain pitch – half of distance between axes of every third rivet and thickness of the lower part of guiding link, that enters the guide bar groove.

Therefore, it should be checked if saw chain pitch affects somehow the level of vibrations recorded on internal combustion chain saw handles.

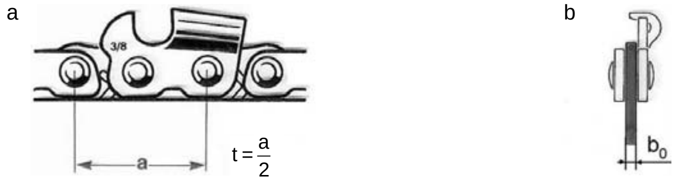

FIGURE 1. Characteristic parameters of saw chain: a) method for pitch determination, b) measurement on guiding link thickness, t – pitch, b_0 – guiding link thickness [Więsik, Kozłowski 2005]

AIM AND SCOPE OF WORK

This paper aimed at determination of the effect of saw chain pitch on vibration level. The measurements and analysis of vibration acceleration on both handles of portable internal combustion chain saw equipped with saw chain of two different pitches, carried out under various operational conditions should answer the question: does the pitch of saw chain affect the vibration intensity on the chain saw handles?

The scope of work included:

- preparation of wood used in investigations,
- preparation of measuring stand,
- preparation of chain saw and the two different cutting systems,
- preparation of measuring equipment,
- measurements on vibration acceleration on both handles during cutting with lower and upper sides of the guide bar.

METHODICS OF INVESTIGATIONS ON VIBRATIONS IN INTERNAL COMBUSTION CHAIN SAW

The vibration measurements were carried out under conditions close to exploitation ones. Prior to measurements the measuring stand and measuring equipment were prepared. The chain saw engine was warmed up according to PN-EN ISO 22867 Standard and producer recommendation. The vibrations were measured by two persons: one of them was executed the wood cross cutting, simultaneously pressing the support with mounted accelerometers to chain saw handle, while the other person was handling the vibration meter. The cross cutting was executed with the upper and lower sides of guide bar, at four kerfs for every measuring variants and both handles. Upon completion of necessary measurements, the chain saw cutting system was dismantled and the

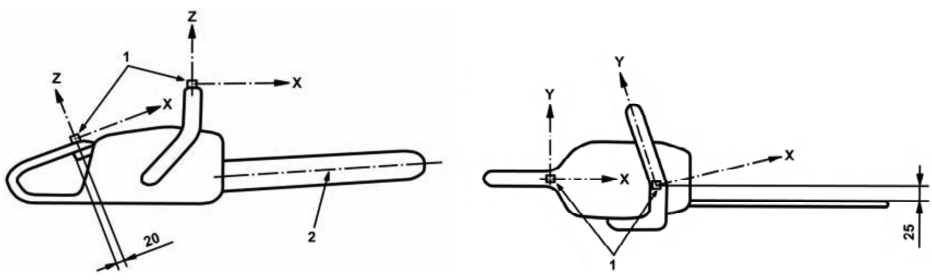

FIGURE 2. Directions of vibration measurements on front and rear handle of chain saw [PN-EN ISO 22867]: 1 – location of vibration sensors, 2 – symmetry axis of guide bar

saw chain of different pitch was mounted (0.325” or 3/8”). Then, upon refilling tanks of oil and fuel, the measurements were carried out as previously, at three directions perpendicular to each other (Fig. 2) according to PN-EN ISO 22867 Standard.

The results of measurements were recorded in vibration meter memory and printed upon completion of investigations for further analysis.

MEASURING EQUIPMENT AND OBJECTS OF INVESTIGATIONS

Vibrations were measured with the use of Danish Brüel & Kjær vibration meter 2231 (Fig. 3) with the 2522 module for evaluation of the effect of vibrations on human organism. Prior to measurements the meter was calibrated and adapted to measurements on chain saw handles. To carry out measurements, the piezoelectric accelerometers were connected to the meter.

The measuring equipment allowed for simultaneous recording and storing in the meter memory the following vibration parameters:

- Maximal peak value (MaxP);

FIGURE 3. Vibration meter Brüel & Kjær of 2231 type with connected piezoelectric accelerometers [own elaboration]

- Maximal root-mean-square value (MaxL);
- Minimal root-mean-square value (MinL);
- Vibration equivalent acceleration (Aeq);
- Vector sum of three directions X, Y and Z (Aeq_{SUM}).

The professional Stihl internal combustion chain saw MS 260 model was investigated. Its technical parameters are presented in Table 1. Two cutting systems

TABLE 1. Basic technical parameters of chain saw Stihl MS 260 [Stihl, Catalog 2009/2010]

Parameter	Unit	Value
Engine displacement	[cm^3]	50.2
Engine power	[kW]	2.6
Mass (without fuel, oil and cutting system)	[kg]	4.8
Vibration acceleration on front/rear handle	[m/s^2]	3.4/4.3
Sound pressure level	[dB(A)]	99.0
Saw chain Oilomatic – pitches	[inch]	0.325 and 3/8
Length of guide bar	[inch/cm]	15/37
Idling speed	[rpm]	2 800
Maximal speed with chain and guide bar	[rpm]	14 000
Capacity of oil tank	[dm^3]	0.29
Capacity of fuel tank	[dm^3]	0.46

were matched to the chain saw, both of the same length of guide bar amounted to 37 cm. Application of two saw chains called for the change of drive sprockets: both sprockets had the same number of teeth that assured the similar linear velocity of the saw chain. The cutting systems of following parameters were investigated:

- Saw chain pitch 0.325 inch, cutting tooth profile of chisel type,
- Saw chain pitch 3/8 inch, cutting tooth profile of chisel type.

Prior to measurements, the chain saw was properly prepared. The saw chain was sharpened and tightened to eliminate the effect of these parameters on vibration level. The oil and fuel tanks were fully filled with appropriate mixtures at every stage of measurements, according to PN-EN ISO 22867 Standard.

The cross cutting was executed on round birch wood of diameter 15.5 cm, fresh and of medium hardness. The moisture content ranged from 45.6 to 81.7% (on the average 65%).

RESULTS OF MEASUREMENTS ON VIBRATIONS ON CHAIN SAW HANDLES

The results of measurements during cross cutting of wood with the use of internal combustion chain saw are presented in Table 2 for all measuring variants.

Four runs were made for each measuring variant. The average vibration levels ranged from 6.63 to 9.08 m/s^2, while the calculated standard deviation for these measurements ranged from 0.190 to 1.387.

The average values of vibration measurement results Aeq_{SUM} [m/s^2] on both chain saw handles during cutting with the lower and upper side of guide bar are presented in Figure 4, together with catalog values given by manufacturer.

Vibration equivalent acceleration values Aeq_{SUM} on the chain saw front handle recorded during cutting with upper and lower side of the guide bar differ significantly from the catalog value. The highest vibration level value (8.83 m/s^2) was found during wood cutting with the upper side of guide bar at chain saw pitch 3/8 inch. The lowest value (8.14 m/s^2) was found during cross cutting with lower side of guide bar at chain saw pitch 0.325 inch.

Besides, vibrations generated by the chain saw during cutting with upper side of guide bar were always higher than vibrations during cutting with the lower side of guide bar.

TABLE 2. Results of vibration measurements Aeq_{sum} on chain saw handles [own elaboration]

No	Chain saw pitch 0.325 inch				Chain saw pitch 3/8 inch			
	Front handle		Rear handle		Front handle		Rear handle	
	Upper side	Low side	Upper side	Low side	Upper side	Low side	Upper side	Low side
1	8.88	9.12	8.60	6.52	7.00	8.80	9.12	6.44
2	8.32	8.20	9.32	6.00	9.32	8.60	9.20	6.92
3	8.12	7.92	7.92	7.00	8.68	8.80	8.80	7.24
4	9.64	7.32	7.76	7.00	10.30	8.20	9.20	7.48
Mean	8.74	8.14	8.40	6.63	8.83	8.60	9.08	7.02
Stand. deviat.	0.681	0.749	0.713	0.477	1.387	0.283	0.190	0.450

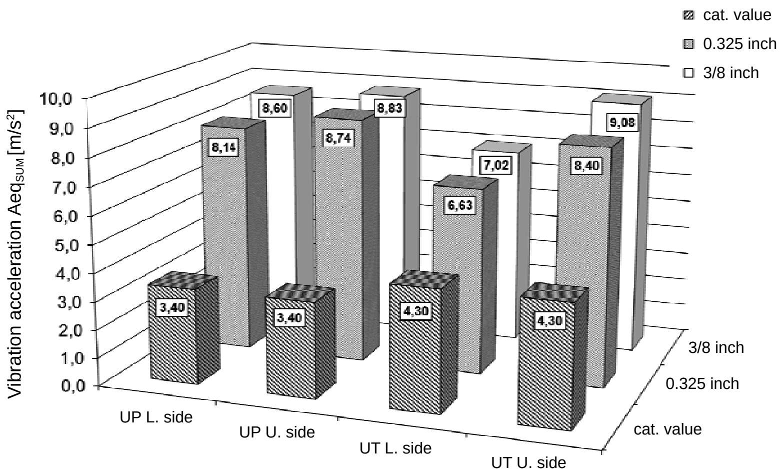

FIGURE 4. Vibrations on chain saw handles during cutting with upper and lower side of guide bar [own elaboration]

The effect of chain saw pitch on vibrations emitted during cross cutting was found also. The vibration equivalent acceleration value Aeq_{SUM} was higher during cutting with the chain saw of pitch 3/8 inch.

The vibration equivalent acceleration values Aeq_{SUM} on chain saw rear handle recorded during cutting with upper and lower side of guide bar differ significantly from the catalog value. The highest vibration level (9.08 m/s^2) was found during wood cutting with the upper side of guide bar of the chain saw of pitch 3/8 inch, while the lowest value (6.63 m/s^2) during cross cutting with lower side of guide bar in the chain saw of pitch 0.325 inch.

Besides, vibrations generated by the chain saw during cutting with upper side of guide bar were always higher than vibrations during cutting with the lower side of guide bar.

The effect of chain saw pitch on vibrations emitted during cross cutting was found also. The vibration equivalent acceleration value Aeq_{SUM} was higher during cutting with the chain saw of higher pitch.

SUMMARY AND CONCLUSIONS

Internal combustion chain saws are the machines that are commonly used in timber harvesting. The main threats to operators during operation of these machines are not only the mechanical hazards like chain saw kickback or downfallen tree, but also threats connected to generated vibrations, noise and exhaust gases. The harmful effect of vibrations on the chain saw and operator's organism was found.

Basing on the obtained investigation results one can draw the following conclusions:

- Chain saw pitch affects the level of vibrations on the chain saw handles;
- Vibrations emitted by chain saw increase along with an increase in saw chain pitch;
- Vibration acceleration Aeq_{SUM} on the front and rear handles of internal

combustion chain saw Stihl MS 260 is bigger, when cross cutting is executed with the upper side of guide bar;
- In majority of cases, the vibration acceleration value in the chain saw is bigger on the front handle;
- To minimize the hazard of unfavourable effects of vibrations on the sawman one should avoid cutting with the upper side of guide bar and also apply the cutting systems equipped with a chain saw of lower pitch value.

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Streszczenie: *Wpływ podziałki piły łańcuchowej na poziom drgań uchwytów pilarki spalinowej podczas przerzynki drewna.* W artykule przedstawiono wyniki badań nad wpływem wielkości podziałki piły łańcuchowej na poziom drgań rejestrowanych na uchwytach pilarki spalinowej. Przedstawione badania mogą przyczynić się do poznania czynników intensyfikujących drgania występujące podczas przerzynki drewna z zastosowaniem pił łańcuchowych o różnych wielkościach podziałek oraz mogą być źródłem praktycznych wskazówek dla drwali operatorów pilarek spalinowych w kwestii zmniejszenia ich narażenia na drgania mechaniczne. Na podstawie wyników badań można stwierdzić, że wielkość podziałki piły łańcuchowej wpływa na poziom drgań na uchwytach pilarki. Wraz ze wzrostem podziałki piły łańcuchowej, drgania emitowane przez pilarkę zwiększają się.

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