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MEASUREMENTS OF NOISE RESULTING FROM CUTTING CHAIN MOVEMENTS ON A CHAIN-SAW BAR, LUBRICATED WITH DIFFERENT OILS

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Abstract. The chain-saw is one of tools commonly used for professional work in the forest and home yards. While working the tool is a source of considerable noise. Experiments on vibration and noise damping abilities of mineral and vegetable oils were carried out at the PIMR – Industrial Institute for Agricultural Machinery in Poznań. The experiments were conducted on a specially constructed measuring stand. The chain saw was running along the bar, while no wood was being cut. Noise was measured with a Bruel & Kjaer meter at a height of the longer symmetry axis of the bar, when the bar plane was vertical and the symmetry axis was horizontal. Measurement results showed that noise levels observed were high and varied with oils used, ranging from 99.6 dB(A) for one of the vegetable oils to 105.2 dB(A) for a mineral oil.

Key words: chain-saw, cutting system, lubricating oil, noise, noise measurement

INTRODUCTION

Solutions eliminating or reducing noise exposure

Respecting noise control Directive no. 98/37/EC [Directive... 2003] stipulates that "a machine has to be designed and manufactured in such a way so that noise exposure is reduced to the lowest level, in accordance with technological progress and applying available means of noise reduction, especially at its sources" [Augustyńska 2005].

There are several solutions eliminating or reducing noise exposure [Kaźmierczak and Kromulski 1995], which need to be applied in the following order:

– noise reduction at the source,
– general noise control measures,
– personal noise control devices.

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Noise reduction at the source

The most effective method to reduce noise at the workplace is the reduction of noise at its source. It should be applied already at the stage of design. Noise control at the source may be realized by:
– using machines with low noise emission levels,
– application of technological processes with low noise emission,
– selection of appropriate machine work operating conditions,
– modernization of machine elements,
– machine maintenance (proper lubrication, balance of machine elements, etc.).

Noise sources

Vibrating surfaces of machine elements are noise sources. The physical parameter responsible for sonic sensations is acoustic pressure p. Amplitude of this pressure is in a direct relation to vibration velocity of medium particles v:

$$p = \rho\, c\, v$$

where: ρ – medium density,
c – speed of sound in the medium,
v – vibration velocity of medium particles.

If we imagine a rigid plate vibrating harmonically e.g. in the air, with velocity v, then acoustic pressure in the vicinity of this model sound source will be $p = \rho\, c\, v$. Power of emitted noise is proportional to vibration velocity of machine element surfaces and to the vibrating area [Cempel 1975]. Sound pressure level (SPL) is measured using relative units, the so-called levels, as:

$$L = 20 \lg\left(\frac{p}{p_0}\right)$$

where: $p_0 = 2 \cdot 10^{-5}$ is reference pressure, Pa.

STUDIES ON NOISE GENERATED BY CHAIN-SAW ELEMENTS

One of machines commonly used for professional purposes as well as by do-it-yourself enthusiasts is a power chain saw. This tool during its operation generates noise of a very high level. According to catalogues of manufacturers [Catalogue... 2006] it may reach 101 dB(A) to 118 dB(A), or even 120 dB(A) [Piszcz 1991]. The Industrial Institute of Agricultural Machines in Poznań, in cooperation with the Department of Forest Machines and Vehicles, the August Cieszkowski Agricultural University of Poznań, conducted laboratory tests at a testing stand on the efficiency of guide bar vibration damping, and thus ambient noise, for selected mineral and vegetable oils applied in the cutting system of the chain saw.

These tests were conducted at a specially prepared testing stand during the movement of a chain saw along a guide bar without cutting wood. This stand consisted of a frame structure welded from angle sections, to which the body of a power chain saw was screwed down. A specially turned shaft, replacing the chain saw crankshaft, was driven by a belt transmission of an electric motor with a power of 950 W, controlled by a "pDrive MX" model basis 22/30 converter. At the other end of the shaft a floating drive wheel was mounted, which set the chain saw in motion along the guide bar. During the operation constant rotational speed of the shaft of approx. 9400 rpm was maintained, i.e. rotational speed similar to actual operating conditions of a chain saw.

Vibrations in the range of acoustic frequencies, generated during the movement of a chain saw along the guide bar, produce noise, which intensity may vary depending on the type of lubricant – oil lubricating the cutting system of the chain saw. Changes in oil viscosity may increase or decrease vibrations, and thus also noise, during the movement of a chain saw over the guide bar [Kromulski 1998].

Sound pressure levels were measured for eleven selected oils.

Noise was measured at the height of the guide bar symmetry axis, when the guide bar is located vertically and the axis parallel to the floor. The distance of the microphone head from the guide bar plane (the axis of the microphone perpendicular to the guide bar plane) was 1.2 m. Recordings and analyses were conducted using a measuring set consisting of the following elements:

– a double channel real-time signal analyzer type 2034 by Brüel & Kjaer,
– a laser vibrometer by Polytec,
– a 0.5 inch condenser microphone with a preamplifier by Brüel & Kjaer,
– a computer with an IEEE-488 measuring interface and PCODS software by Brüel & Kjaer.

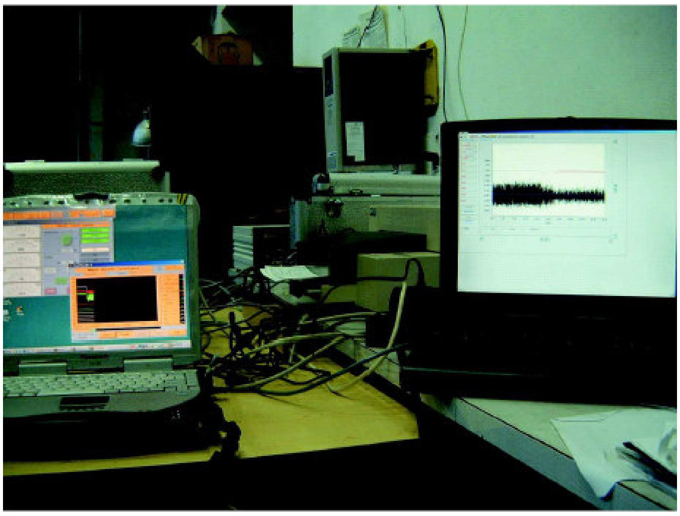


Fig. 1. The measuring stand recording vibrations and temperature of the bar (computer on the right hand side) and the work of the chainsaw engine (computer on the left hand side)
Rys. 1. Stanowisko rejestrujące drgania i temperaturę, do jakiej nagrzewa się prowadnica (komputer z prawej strony), oraz pracę silnika napędowego (komputer z lewej strony)

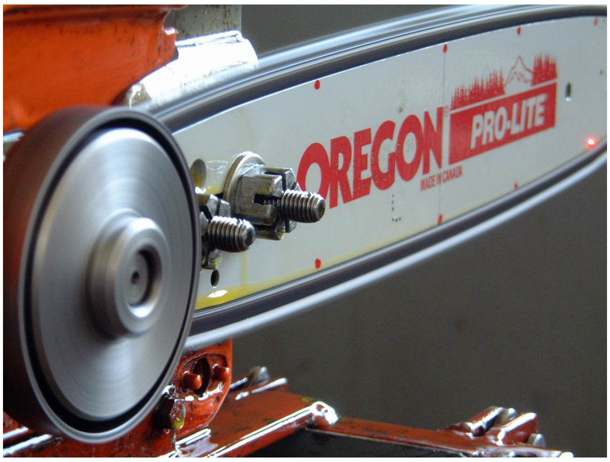


Fig. 2. Measurements of operational vibrations at defined points on the bar. A reflection of a laser beam is visible on the right hand side
Rys. 2. Pomiary eksploatacyjnej postaci drgań w oznaczonych punktach prowadnicy. Z prawej strony widoczne odbicie wiązki laserowej

Analysis of the operational spectrum of guide bar mechanical vibrations in the range of low frequencies indicates that generally vibration components with frequencies of approx. 28, 55 and 83 Hz predominate in the spectrum.

Noise of the chain saw was measured depending on the type of oil lubricating the cutting system of the chain saw. Noise levels were assessed for different, arbitrarily selected oils. They were mineral oils, vegetable oils with different densities, pure rapeseed oil and used engine lubricant.

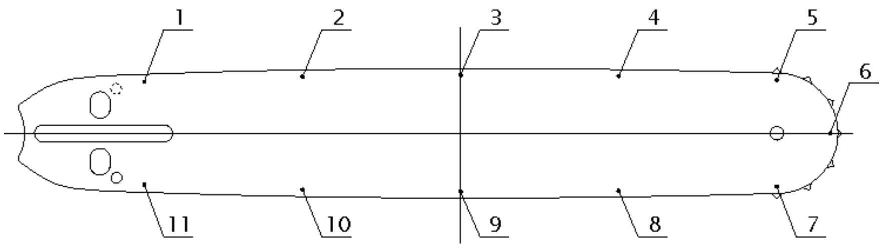
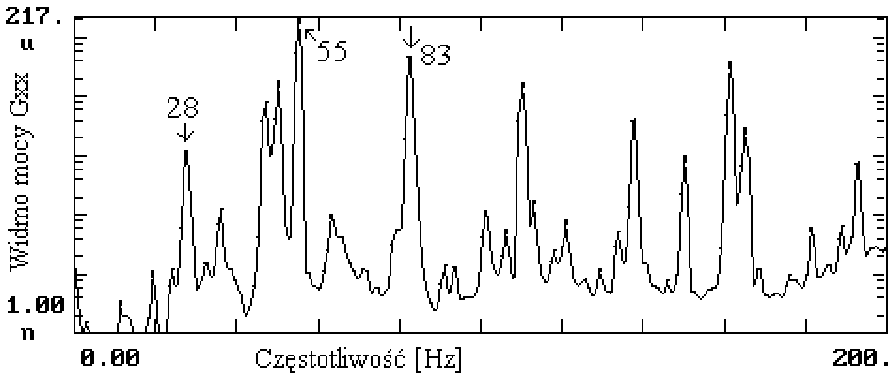


Fig. 3. Measuring points on the bar
Rys. 3. Schemat rozmieszczenia punktów pomiarowych na prowadnicy



Frequency [Hz]

Fig. 4. An example of spectrum of power of mechanical vibration acceleration at the point where the bar was fixed on the measuring stand. An operational shape of vibrations was determined for dominant frequencies in the spectrum
Rys. 4. Przykładowe widmo mocy przyspieszeń drgań mechanicznych wyznaczone w punkcie mocowania prowadnicy do stanowiska. Dla częstotliwości dominujących w widmie została wyznaczona eksploatacyjna postać drgań

RESULTS

On the basis of comparative studies of noise levels the weighted sound pressure level (correction characteristic A in dB(A)) was determined at the measuring point located at the guide bar axis. Measurements were taken during the movement of the chain saw along the guide bar, lubricated with different oils lubricating the cutting system of the chain saw. Testing results are presented in Table 1. Spectral-response characteristics of noise were also determined. Examples of spectra of measured noise are presented in Figs. 5 and 6.

Results show that under identical conditions similar elements of the cutting system, collected from the same unit, may emit different noise levels as a result of application of different oils. The values range from 99.6 dB(A) for vegetable oil I to 105.2 dB(A) for used engine lubricant K.

Elements of the cutting system lubricated with mineral oils D and F, with lower densities, emitted noise levels up to 100.1 dB(A) and 99.8 dB(A), respectively.

Noise caused by elements of the cutting system lubricated with vegetable oils with slightly higher densities did not differ considerably from the above mentioned values. Thus, for oil B it was 99.8 dB(A), for oil A it was 100.2 dB(A), for oil G — 100.6 dB(A), for oil H — 101.1 dB(A) and for pure rapeseed oil L it was 101.4 dB(A), respectively.

A high noise level was recorded for the chain saw lubricated with a water emulsion C (with added oils), specially produced to lubricate the chain-saw cutting system. This noise reached the level of 103.7 dB(A). A higher noise of 105.2 dB(A), was recorded only for used engine lubricant K.

Table 1. Noise level in dB(A) during chain movements along the bar
Tabela 1. Poziom hałasu w dB(A) podczas przemieszczania się piły łańcuchowej po prowadnicy

Type of oil – Rodzaj oleju	Noise level – Poziom hałasu dB(A)
A	100.2
B	99.8
C	103.7
D	100.1
E	102.4
F	99.8
G	100.6
H	101.1
I	99.6
K	105.2
L	101.4

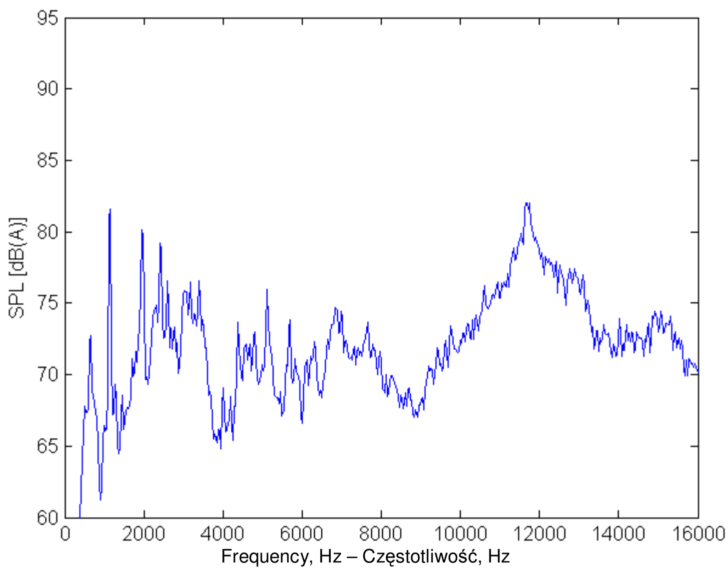


Fig. 5. Frequency spectrum of sound pressure level. The bar lubricated with oil "I"
Rys. 5. Widmo częstotliwościowe poziomu ciśnienia akustycznego. Prowadnica smarowana olejem „I"

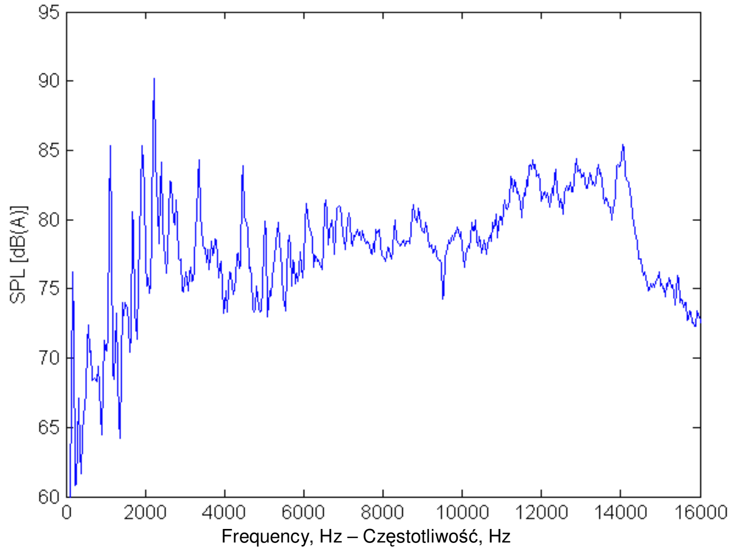


Fig. 6. Frequency spectrum of sound pressure level. The bar lubricated with oil “K”
Rys. 6. Widmo częstotliwościowe poziomu ciśnienia akustycznego. Prowadnica smarowana olejem „K”

It may be stated that relatively low noise levels were recorded for mineral oils in relation to the other analysed lubricants. Measured noise levels recorded for vegetable oils fell within a rather wide range, from the lowest of all recorded values to relatively high ones. This could have resulted from a variety of analyzed vegetable oils and may indicate a wide range of factors, affecting noise damping.

Noise level in the environment of the chain saw is determined by components with medium frequencies of 1500-3000 Hz and high frequencies of 10 000-14 000 Hz.

Studies on mechanical vibrations (operational form of vibrations) of the chain-saw guide bar showed much higher vibrations of a chain saw lubricated with oil “K” than those of the chain saw lubricated with oil “I”. Table 2 presents examples of amplitudes of mechanical vibration velocities recorded for a frequency of 25 Hz in individual chain saw points.

Table 2. Amplitudes of velocity of mechanical vibrations, mm/s, on the bar for an operational frequency of 25 Hz
Tabela 2. Amplitudy prędkości drgań mechanicznych prowadnicy, mm/s, dla częstotliwości eksploatacyjnej 25 Hz

Type of oil Rodzaj oleju	Number of measuring point – Numer punktu pomiarowego											
	1	2	3	4	5	6	7	8	9	10	11	12
I	1.92	2.44	6.33	9.25	15.2	16.1	12.9	8.17	5.01	1.89	1.13	1.89
K	5.15	3.67	13.0	25.5	32.4	24.3	39.1	19.7	16.9	9.41	3.23	2.66

CONCLUSIONS

1. Noise level generated during the movement of a chain saw along the guide bar is very high and varies for tested oils. The application of oils specially composed for lubrication purposes makes it possible to reduce noise generated by the chain saw.

2. Measured noise at the symmetry axis of the chain saw guide bar ranged from 99.6 dB(A) when applying vegetable oil as a lubricant to 105.2 dB(A) in case of lubrication with used engine lubricant.

3. Knowledge on the dynamic characteristics of the man – machine system makes it possible to forecast the behaviour of the system under actual operating conditions. This also makes it possible to undertake studies on the correction of dynamic properties of the system or the modification of exciting forces, leading to the improvement of the operator work safety.

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Catalogue Husqvarna Great experience. 2006. Electrolux Poland.

BADANIA POZIOMU HAŁASU POWSTAJĄCEGO W WYNIKU PRZEMIESZCZANIA SIĘ PIŁY ŁAŃCUCHOWEJ PO PROWADNICY SMAROWANEJ RÓŻNYMI OLEJAMI

Streszczenie. Zgodnie z dyrektywą unijną maszyna musi być tak zaprojektowana i wykonana, aby zagrożenia emitowanym hałasem były zredukowane do najniższego poziomu. Również w wypadku łańcuchowej pilarki spalinowej, powszechnie używanej do celów zawodowych, jak i przydomowych, powinno się maksymalnie ograniczać szkodliwe oddziaływanie na operatora. W Przemysłowym Instytucie Maszyn Rolniczych w Poznaniu we współpracy z Katedrą Techniki Leśnej Akademii Rolniczej im. Augusta Cieszkowskiego w Poznaniu przeprowadzono laboratoryjne badania stanowiskowe skuteczności tłumienia poziomu drgań prowadnicy, a co za tym idzie i hałasu w otoczeniu, dla wybranych olejów mineralnych i roślinnych zastosowanych w układzie tnącym pilarki łańcuchowej. Badania prowadzono na specjalnie przygotowanym stanowisku pomiarowym, podczas przemieszczania się piły łańcuchowej po prowadnicy bez procesu cięcia drewna. Rejestracje i analizy wykonano za pomocą zestawu pomiarowego składającego się z dwukanałowego analizatora sygnałów w czasie rzeczywistym firmy Brüel & Kjaer typ 2034, wibrometru laserowego firmy Polytec, mikrofonu pojemnościowego 0,5 cala z przedwzmacniaczem firmy Brüel & Kjaer, komputera z interfejsem pomiarowym IEEE-488 i oprogramowaniem PCODS firmy Brüel & Kjaer. Badanie hałasu powstającego podczas przemieszczania się po prowadnicy piły łańcuchowej napędzanej kółkiem pozwala stwierdzić, że w tych samych warunkach, podobne pobrane z tej samej partii elementy układu tnącego, w wyniku zastosowania różnych olejów mogą wywoływać różny poziom hałasu. Waha się on od 99,6 dB(A) dla oleju roślinnego I do 105,2 dB(A) dla zużytego oleju silnikowego K.

Słowa kluczowe: piła łańcuchowa, układ tnący, olej smarujący, hałas, pomiar hałasu

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