The Influence of the Cutting Tooth Design and Wear of a Saw Chain on the Vibration Level of a Chainsaw

Wojciech RUKAT
Poznan University of Technology, Faculty of Mechanical Engineering and Management,60-965 Poznan, 3 Piotrowo St, Poland, wojciech.rukat@put.poznan.pl

Bartosz JAKUBEK
Poznan University of Technology, Faculty of Mechanical Engineering and Management,60-965 Poznan, 3 Piotrowo St, Poland, bartosz.jakubek@put.poznan.pl

Abstract

Chainsaws are the most basic mechanical tools used to harvest and pre-treat wood. Unfortunately, these devices emit noise and vibrations exceeding the maximum permissible levels for an 8-hour working day. Many factors influence the level of noise and vibration emitted by chainsaws. Since the conscious choice of the saw chain can significantly contribute to: productivity increase, vibration reduction and the operator's permissible total exposure time extension the influence of the type of a cutting tooth and its wear on the vibration level recorded on the handles of the device has been investigated in this paper.

***Keywords**:* chainsaw, saw chain wear, cutting tooth design, local vibrations

1.Introduction

Currently, a wide range of devices equipped with an independent internal combustion engine is available on the market. A chainsaw is the most basic device in the forest and wood industry. The greatest risk for operators, connected with the use of a chainsaw, are the vibration and acoustic impacts.

One of requirements for admission of a device to EU market is the manufacturer's declaration concerning the intensity of the harmful agents and other hazards. The vibration levels declared by the manufacturers are determined for strictly defined, standardized conditions [1-4]. The level of vibration is determined basing on equation (1). Furthermore, for each of the operating states, a share of 1/3 of the total operating time of the device was assumed. [1,2]

$$a_{\mathrm{hv,eq}} = \sqrt{\frac{1}{3}\left(a^2_{\mathrm{hv,ID}} + a^2_{\mathrm{hv,FL}} + a^2_{\mathrm{hv,RA}}\right)} \tag{1}$$

Where: $a_{\mathrm{hv,eq}}$ – equivalent vibration level, $a_{\mathrm{hv,ID}}$ – vibration level measured while idle speed, $a_{\mathrm{hv,FL}}$ – vibration level measured under full load, $a_{\mathrm{hv,RA}}$ – vibration level measured while racing.

Equal shares of total operating time don’t converge with the real life conditions in which these devices are used. For joint operation of feeling, limbing and buckling shares of the total operating time of the device for idling, working under full load and racing are approximately equal to 10/55/35% [5]. As a consequence, the chainsaw catalog data regarding the intensity of the harmful agents should be treated orientationally. Taking into account the mentioned shares of the total operating time of the device, the equation (1) takes the following form:

$$a_{\mathrm{hv,eq\_R}} = \sqrt{\frac{1}{10}a^2_{\mathrm{hv,ID}} + \frac{11}{20}a^2_{\mathrm{hv,FL}} + \frac{7}{20}a^2_{\mathrm{hv,RA}}} \tag{2}$$

where: $a_{\mathrm{hv,eq\_R}}$ – real equivalent vibration level.

There are a number of factors that influence the level of vibrations emitted by the chainsaws [6-13]. These factors can be broadly divided into three groups:

- the workpiece (grade, size, physical condition, cellular structure, transverse and longitudinal cuts),
- personal traits of the operator (physique, experience, working position),
- the device and the tool (construction and equipment, power, guide length, chain pitch, engine suspension, cutting chain design).

Neither the influence of the type of cutting tooth design (full chisel and semi-chisel chains), nor chain’s wear influence on the vibrations of handles was mentioned in the literature. Because of the adverse health effects of vibration information on this matter is important [14, 15].

2. Measurements

The purpose of the study was to determine the relations between both the wear and the design of the cutting tooth and the level of vibration of the chainsaw. Authors stated a hypothesis that there is a linear, increasing relation between wear and vibration accelerations for each tooth design. In addition, it was assumed that the full chisel chain is favourable (lower acceleration values) for the operator.

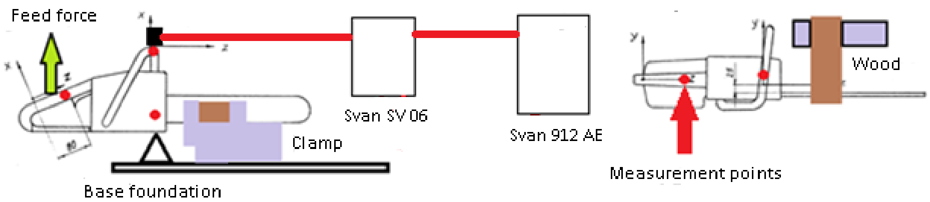

Figure 1. The scheme of the stand and the measurement track

As a part of the study, for both the handles, 9 measurement series were performed. The total recording time of each series was at least 30–second long. Pine beams (90×70 mm) in an air-dry condition were cut. Each of the measurment series was carried out after reaching a specified wear measured by the total cut area (TCA) of 0.5 m^2. As reported by Maciak [10] the efficiency of the cutting process falls by approximately 13% after cutting 3.5 m^2. TCA before the last series was equal 4 m^2. Above in the Figure 1 a scheme of the stand and the measurement track is shown. In the Figure 2 there are photographs of this stand.

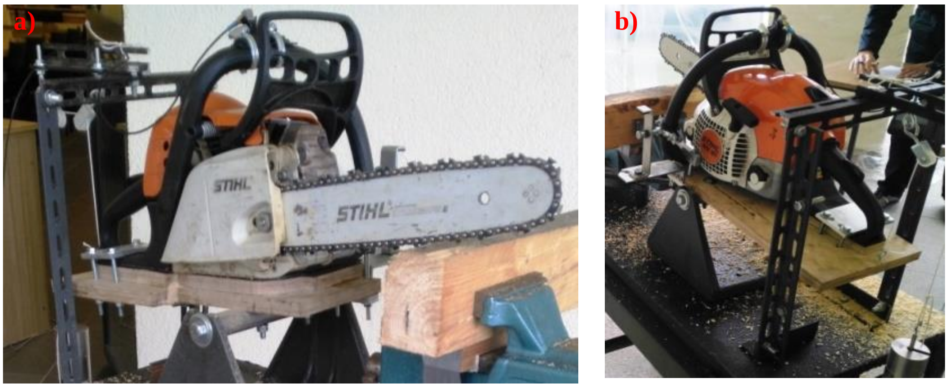

Figure 2. Measurement stand; a) – front view, b) – rear view

The frequency-weighted (correction characteristic Wh) RMS value of the vibration acceleration a_{Wh} was the measured parameter. The STIHL MS 181 chainsaw powered by internal combustion engine (1.5 kW) was used during the tests. Measurements were conducted at the stand that:

- compensated the influence of the individual operator's traits,
- provided a constant run of the force (generated by the mass and set of rollers),
- provided fixation of the cut beam (see Figures 1 and 2).

The three-axial vibration transducer DYTRAN 3023M was used to measure vibration accelerations. The analogue vibration signal has been conditioned and processed in the 4-channel data acquisition module SVAN SV 06 cooperating with the vibration meter SVAN 912 AE. Each of the cutting chains was pre-tensed identically before the measurements. Reference axes have been oriented in accordance with ISO 7505: 1986 and ISO 22867: 2011 [1, 2].

3. Research results

The results of measurements of frequency-weighted RMS values of vibration accelerations a_{Wh} are presented below. The results are shown firstly for the front handle (left hand) while working with the full chisel chain (Fig. 3) and then while working with the semi-chisel chain (Fig. 4). The results for the rear handle (right hand) while working with the same chains (Fig. 5 and 6) are presented next. Additionally the cumulative means of acceleration values of the chainsaw handles measured under full load, while racing and while idle are shown in the Figures 7 and 8.

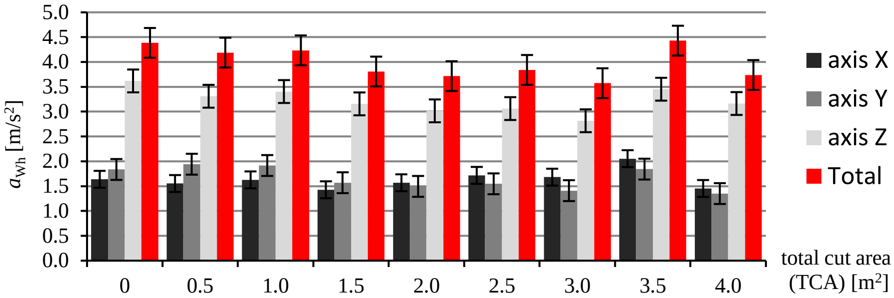

Figure 3. Vibration accelerations of front handle a_{Wh} – full chisel chain

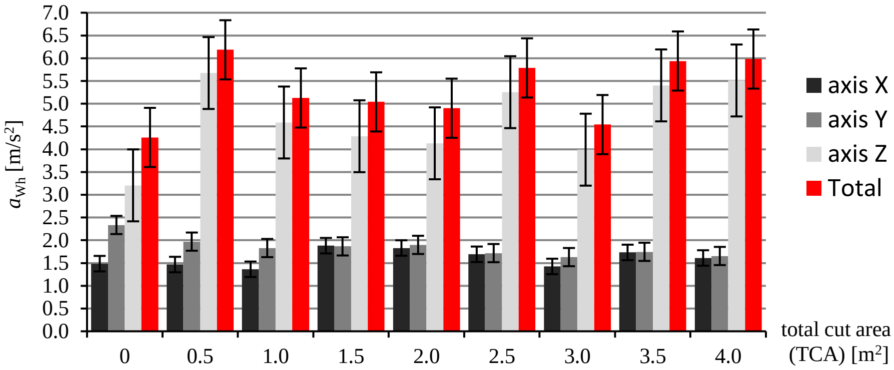

Figure 4. Vibration accelerations of front handle a_{Wh} – semi-chisel chain

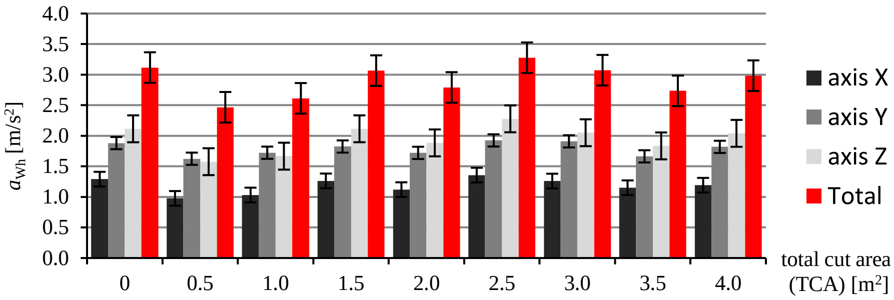

Figure 5. Vibration accelerations of rear handle a_{Wh} – full chisel chain

As it can be seen in the Figures 3 and 4, the wear of the cutting teeth, under measuring conditions specified earlier, does not affect the level of vibrations of the front handle. Although the cutting tooth design itself has a significant influence on the vibration levels, that are, on average, 1.3 m/s^2 higher for the semi-chisel chain. The dominant direction of the vibrations of the front handle of the chainsaw is the Z direction - the longitudinal axis of the chain guide bar.

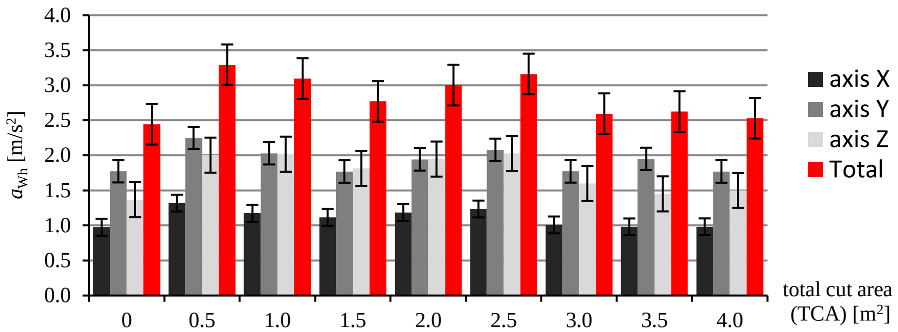

Figure 6. Vibration accelerations of rear handle a_{Wh} – semi-chisel chain

As it can be seen in the Figures 5 and 6, the wear of the cutting teeth, under measuring conditions specified earlier, also does not influence the level of vibrations of the rear handle. On the other hand, in contrast to the front handle, the cutting tooth design itself does not affect the vibrations recorded on the rear handle. The dominant directions of the vibrations of the rear handle of the chainsaw are the Z and Y directions - the longitudinal axis of the guide bar and the direction perpendicular to its plane.

Basing on an analysis of cumulative average of vibration accelerations, the full chisel chain performs better than semi-chisel chain, both for the front and the rear handles, (see Figures 7 and 8). There was no dependence between the wear of the full chisel chain and the level of vibrations noted.

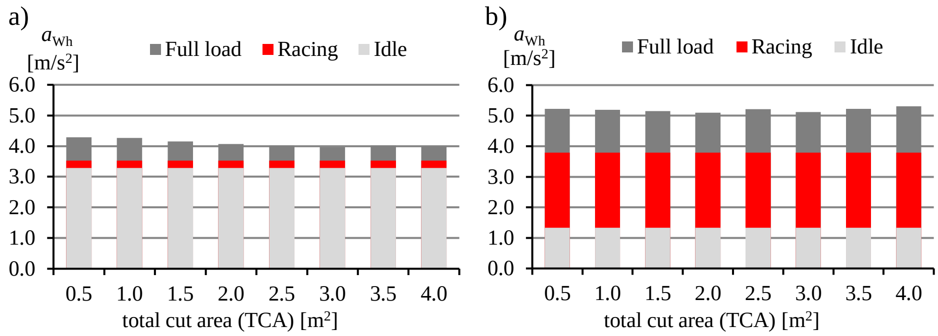

Figure 7. Cumulative averages of vibration accelerations of chainsaw handles
for the full chisel chain, a) front handle, b) rear handle

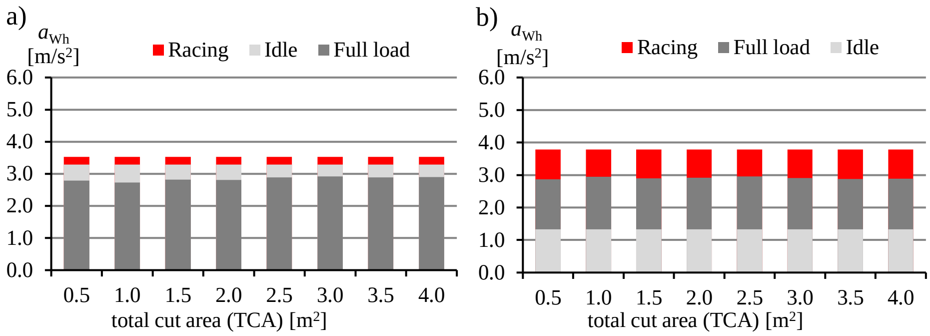

Figure 8. Cumulative averages of vibration accelerations of chainsaw handles for the semi-chisel chain, a) front handle, b) rear handle

The wear of semi-chisel chain has no influence on vibration level of the chainsaw in measuring conditions specified earlier. Comparison of frequency-weighted RMS values of vibration accelerations a_{Wh}, measured for three operation modes, allow us to state that the use of equation (1) in order to evaluate the impact of vibrations on a chainsaw operator lowers the real result. Table 1 shows the equivalent vibration level of the tested chainsaw calculated in accordance to standardized conditions [1,2] (1) and in accordance to real data [5] (2).

Table 1. The equivalent vibration level of the chainsaw STIHL MS 181

shares of the total operation time of the device		$a_{hv,eq}$ [m/s²]	$a_{hv;eq\_R}$ [m/s²]	$\frac{a_{hv,eq\_R} - a_{hv,eq}}{a_{hv,eq\_R}}$
		$\frac{1}{3}, \frac{1}{3}, \frac{1}{3}$, [1,2]	$\frac{1}{10}, \frac{11}{20}, \frac{7}{20}$, [5]	
full chisel chain	front handle	3,61	3,77	4,06%
	rear handle	2,86	3,14	8,79%
semi-chisel chain	front handle	4,14	4,57	9,49%
	rear handle	2,84	3,10	8,51%

The value of $a_{hv,eq}$ calculated according to (1) is on average 7.71% lower than that calculated on the basis of real shares of the total operation time.

Table 2 shows the pictures of the cutting teeth both of designs tested: new and worn (after cutting the total area of 4 m²).

Table 2. The comparison of cutting teeth, new and used ones

	full chisel chain		semi-chisel chain	
	undamaged	used (TCA = 4 m^2)	undamaged	used (TCA = 4 m^2)
right tooth				
left tooth				

As a result of the visual evaluation of the wear the full chisel chain looks better. In its case, the wear occurs mainly in the form of blunting the nose. On the other hand, the semi-chisel teeth wear on the entire length of the front cutting edge.

3. Conclusions

Basing on the experiment, the results of the measurements and observations, it was found that the full chisel chain provides up to 50% more cutting efficiency under the same conditions than the semi-chisel chain.

The design of a tooth has a significant influence on the level of vibrations of the front handle. The vibration levels measured for the semi-chisel chain was on average 30% higher than the vibration levels measured for the full chisel chain. Higher vibration levels were recorded on the front handle for both of the cutting tooth designs used. The greatest influence on the vibration levels among all variables on the testing stand was the structure of the cut beam (knots, cracks e.g.).

During the measurements, no clear signs of wear of the full chisel chain were noticed. In case of semi-chisel chain a significant cutting edge damage was observed, which is contrary to the data provided by the manufacturer.

No relation between the wear of the cutting teeth measured by TCA and the vibrations recorded on both handles was noted for both of full chisel and semi-chisel chains. Therefore, the assumptions were not confirmed. The chosen measurement methodology does not provide clear and precise possibilities of determining the influence of the cutting tooth design as well as its wear on the vibration level of the chainsaw handles. It is necessary to apply more advanced methods of the vibration signal analysis e.g. time-frequency analysis.

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