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FACTORS INFLUENCING VARIABILITY OF THE ADMISSIBLE TIME OF EXPOSURE TO VIBRATIONS OF CHAIN SAWS

The first reports of negative influence of local vibrations were made in 1911 with reference to miners. It was manifested as the so-called Raynaud's symptom, in which fingers became paroxysmally pale. It was also noticed that local vibrations cause negative changes in blood vessels, the nervous system and in the osseous and joint system. Since the 1960s, these symptoms have been widely known among foresters using chain saws.

The present study is an attempt at analysis and synthesis of selected achievements concerning minimalization of the threats caused by mechanical vibrations produced during the use of the chain saw. The study presents results of research, construction solutions, factors which influence the level of emitted vibrations, methods of assessment and prognosis of threats from mechanical vibrations which occur in the process of timber harvesting in the manual and mechanical technology.

Keywords: vibrations of chain saws, factors, forest utilization, ergonomics, technological processes

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Чинники, що впливають на рівень вібрації ланцюгових пил

Перші висновки про негативний вплив місцевих вібрацій з посиланням на гірників були зроблені в 1911 році. Це викликало, так званий, симптом Райнауда, що супроводжується побілінням пальців. Також було відмічено, що місцеві вібрації викликають негативні зміни в кров'яних судинах, нервовій системі, хребті та суглобах. Починаючи з 1960-х ці симптоми широко відомі і в працівників лісового господарства, що працюють з ланцюговими пилами.

Дана робота є спробою аналізу та синтезу вибраних досліджень щодо зменшення впливу механічних вібрацій, викликаних роботою ланцюгової пили. В статті представлені результати, конструктивні рішення, чинники, які впливають на рівень вібрацій, методи виявлення та прогнозування загрози механічних вібрацій, що виникають в процесі лісозаготівлі.

Ключові слова: вібрації ланцюгових пил, чинники, лісоексплуатація, ергономіка, технологічні процеси

In the middle of XX century physicians have found out negative influence of mechanical vibrations on workers which work with chain saws. Local vibrations have caused negative changes in blood vessels, nervous system, a backbone and joints, and also, a so-called syndrome, pale fingers. The various Polish and foreign researches which have been which have been carried out during last years, have found out that, despite of progress in humanization works of operators of chain saws, all of them still suffer from negative influence of vibrations.

The given research is attempt of the analysis and synthesis of the elected researches concerning reduction of influence of the mechanical vibrations caused by work of a chain saw. In research results, constructive decisions, factors which influence a level of vibrations, methods of revealing and forecasting of threat of mechanical vibrations which arise during timber cutting are submitted.

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1. Introduction

Vibrations which occur in the working environment can be divided into the following two kinds: general vibrations transferred by legs, pelvis, back and sides, and local vibrations transferred by the upper limbs. The first reports of the negative influence of local vibrations were made in 1911 with reference to miners [4]. It was manifested as the so-called Raynaud's symptom, in which fingers became paroxysmally pale. It was also noticed that local vibrations cause negative changes in blood vessels, the nervous system and in the osseous and joint system. Since the 1960s, these symptoms have been widely known among foresters using chain saws. Epidemiological research conducted by [2] showed a strong dependence between professional experience and the syndrom of pale fingers observed in chain saw operators. Numerous Polish and foreign studies, conducted for several years, reveal that, despite much progress in the humanization of the work of chain saw operators, they are still threatened with exposure to negative vibrations in their working environment.

2. Aim and scope of research

The present study is an attempt at analysis and synthesis of selected achievements concerning minimalization of the threats caused by mechanical vibrations produced during the use of the chain saw. The study presents research results, construction solutions, factors which influence the level of emitted vibrations, methods of assessment and prognosis of threats from mechanical vibrations which occur in the process of timber harvesting in the manual and mechanical technology.

3. Factors which influence the level of emitted vibrations

The development of the construction of chain saws and the introduction of the anti-vibration system (AV) allowed for a reduction of the level of vibrations from 17 m/s^2 for saws produced in the 1960s and 70s to $3\text{--}4 \text{ m/s}^2$ for modern ones. In the same period, their weight has been reduced and the rotation speed of their engines has been increased [15]. The increase in rotation speed from 2000 to 14000 rotations per minute allowed for shifting the frequency of vibrations in chain saws to medium and high frequency ranges, which reduced the vibration threat to chain saw operators [14].

Analysis of variability of the level of mechanical vibrations emitted by chain saws in the function of time [10] showed that the function runs according to the Lorenz curve, described as the U curve (the curve of use). Therefore the level of vibration threat to operators is not constant in the function of the chain saw operation time. Analyses of chain saws available on the market [5, 6] reveal that these devices still emit vibrations which are higher than admissible (2.8 m/s^2).

Research results show that the complexity of technological operations of timber harvesting has an impact on the level of threat from mechanical vibrations. However, statistical analyses carried out by Sowa [10, 11] did not show any statistically significant differences between distributions of the values of the admissible time of exposure to vibrations during the treatment of softwood or hardwood. It can therefore be stated that the kind of timber does not significantly affect the vibration

threat. However, as was shown in research, it is the technique of cutting by means of the chain saw that has a main influence on the level of vibration threat to operators.

Numerous studies indicate that the differentiation of the level of threat from mechanical vibrations is related to a technological operation that is being performed. The greatest threat occurs during the cross-cutting of timber and the smallest during the delimbing [7, 10, 11]. The distribution of probability of the value of the admissible exposure time, expressed in relative units as a share in the nominal working shift (480 min), is presented in figure 1. Analysis of this distribution in particular operations performed on timber indicated their right-sided asymmetry. This means that the operation of the chain saw more often requires shorter admissible exposure times (higher values of acceleration of vibrations).

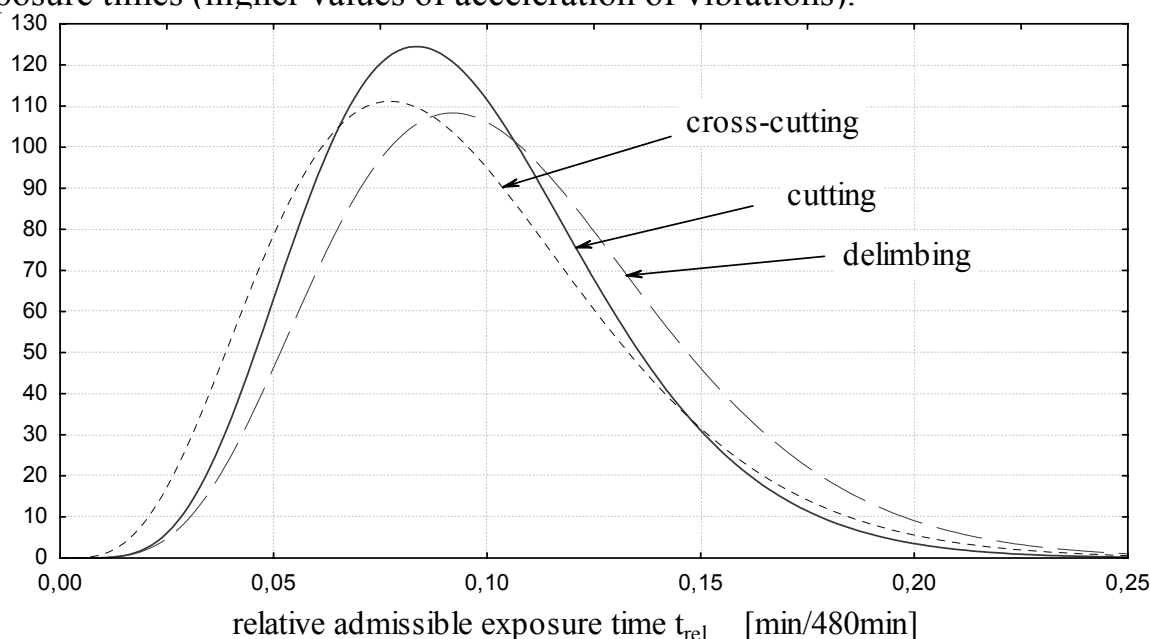


Figure 1. The estimated function of the laws of probability of the relative admissible exposure time t_{rel} for technological operations (source: Leszczyski 2003)

Research carried out by Sowa [11] showed that it is the condition of the cutting system in the chain saw that has the biggest influence on the level of emitted vibrations. For example, increasing the height of the chip limiter from 0.5 mm to 1.0 mm results in a decrease of value of the admissible exposure time from 53 min to 36 min (figure 2). Using the chain saw with a blunt chain blade makes the operator use force when cutting wood. Increasing the force feed of the chain saw in the curf results in multiplication of the level of the emitted accelerations of mechanical vibrations, which requires a reduction of the admissible operation time even to a few minutes (figure 3).

The dose of vibrations absorbed by the operator depends both on acceleration and on time of exposure to vibrations. Time of exposure is variable and depends on e.g. timber harvesting system, technological level, work organization or stand conditions. German standards [20] assume that the chain saw operation time amounts to 46 % of the effective worktime per 1 m³ of the raw material. The conclusion is that an increase in the effectiveness of work in timber harvesting, expected by employers and employees, will result in an increase of harmful exposure of chain saw operators to mechanical vibrations.

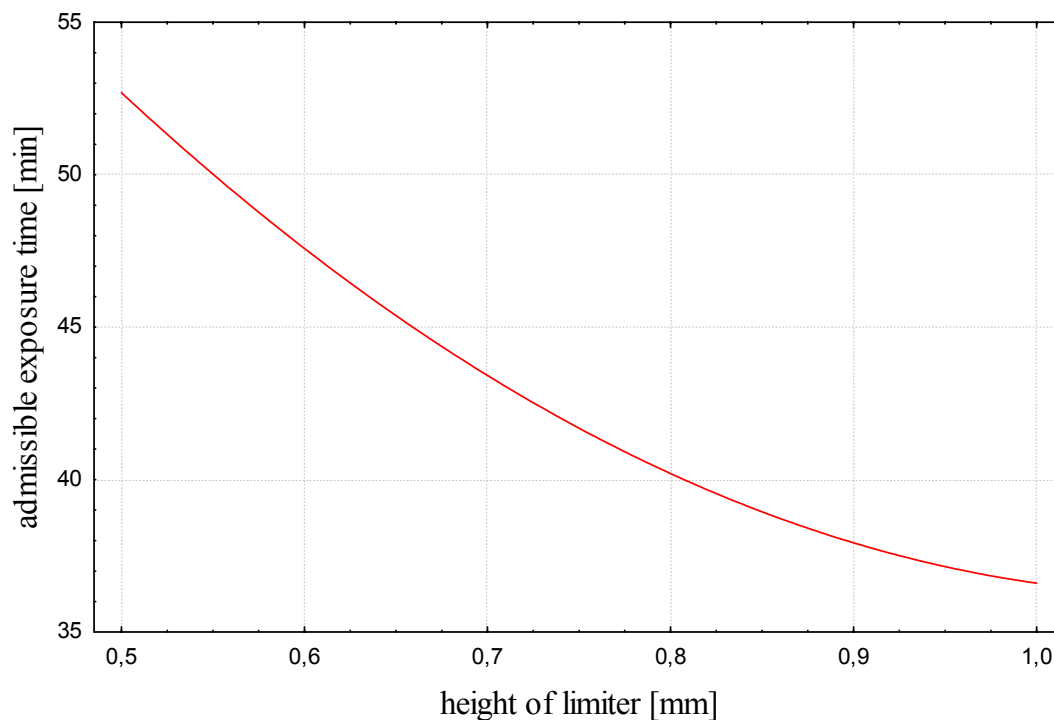


Figure 2. Influence of the height of the chip limiter in the PS-180 chain saw on admissible exposure time (source: Sowa 1995)

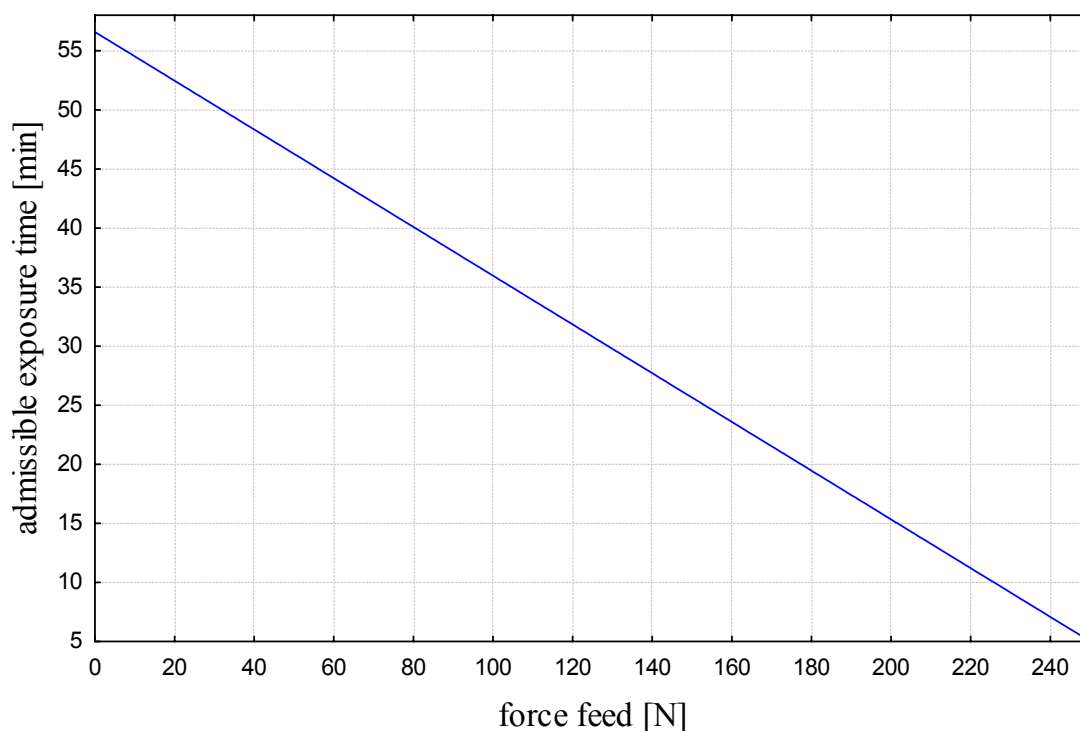


Figure 3. Influence of the force feed on the value of admissible exposure time (source: Sowa 1995)

4. Estimation and modelling of the level of vibration threat

Estimation of exposure to mechanical vibrations can be performed by various means:

- The spectral method, consisting in analysis of effective values of vibration accelerations in 1/3-octave frequency ranges;
- The weighed method, consisting in determination of the effective value of the acceleration of mechanical vibrations weighed in the domain of frequency;
- The dosemetric method, consisting in determination of a dose of vibrations.

Because of the complexity of factors which affect the vibration threat, Sowa [11] tried to determine function models of the condition of vibration threat in the process of timber harvesting. Statistical analyses of distributions of the relative admissible time of exposure to mechanical vibrations indicate statistically significant differences in comparison with the normal distribution [12]. For the purpose of model description of vibration phenomena in the process of timber harvesting, Sowa [10, 11] proposes the use of the beta distribution, which is a good approximation of the achieved empirical distributions.

On the basis of the interpretation of the distribution function of the probability function $F(t)$, where t symbolizes the relative admissible exposure time, it can be assumed that the measure of the admissible threat W_{bz} is the area limited by the function of lack of threat $F_{bz}=1-F(t)$ (the cumulated probability of lack of threat) and by the axes of the coordinate system $OX OY$ (Figure 4).

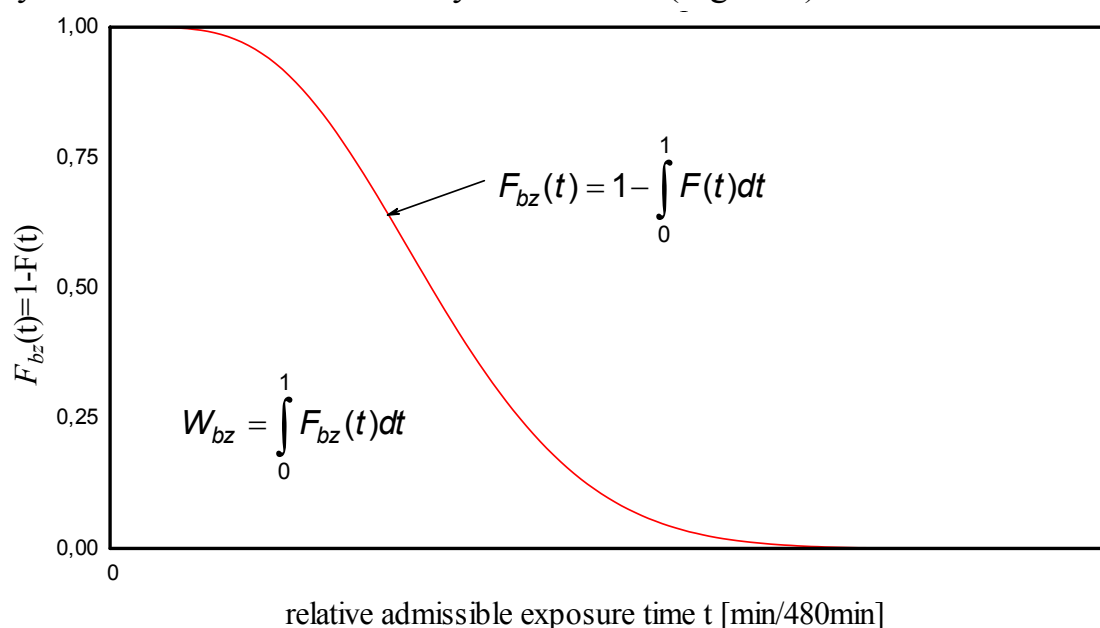


Figure 4. Illustration of the function of lack of threat and of the index of admissible period of threat

The mixture of probability functions (formula 1) allows for determination of the level of vibration threat, taking into consideration the variability of e.g. technological operations performed by means of the chain saw [7].

$$F_w(t) = \int_0^{\infty} F(t, v) u(v) dv \quad (1)$$

where: F is the distribution function of the relative admissible exposure time t dependent on the parameter v , e.g. of the period of a technological operation, u is its probability density.

Instead of integrating relative to the density u , we can sum relative to the discrete probability distribution:

$$F_w(t) = \sum_k F(t, v_k) p_k \quad (2)$$

if v_1, v_2, v_k are selected and $p_k \geq 0, \sum p_k = 1$

Using the method of probabilistic modelling allows for the determination of the admissible time of exposure to mechanical vibrations for different variants of organization of manual and mechanical timber harvesting [11]. At the same time, on the basis of the probabilistic interpretation of the course of the function of lack of threat from mechanical vibrations, it is possible to determine changes of the level of this threat [7]. Analyses carried out by the authors show the universal character of the method presented in this study because it can be applied both for the estimation of the existing state of threat and for its predicting and programming.

5. Summing up and conclusions

The results of many years of research as well as instructions concerning the modernization of techniques and technologies of forest work have been put into practice for a number of years. The application of e.g. the antivibrational system has resulted in a decrease in the number of paroxysmal contractions of blood vessels and sensory and nervous disorders in upper limbs, observed in chain saw operators since the late 1970s. Recent research carried out by the Central Institute of Labour Protection in Warsaw has not shown any differences between an increase in bone changes in the workers exposed to vibrations and in those who performed hard physical labour without exposure to vibrations [4]. However, ten years of exposure of the chain saw operators to noise and mechanical vibrations generated by the chain saw results in permanent partial loss of hearing in 30 % of operators and symptoms of the vibrational disease syndrome in 60 % of them [9]. Chain saws produced serially are more and more often equipped with devices which increase their operational reliability and facilitate their use [19].

Humanization of work may be improved by proper planning of worktime in a shift and by using modern multioperational methods [8, 16]. Comprehensive ergonomic research on forest machines and tools indicates, however, that in order to protect the operator's health from noise and vibrations it is often necessary to take into consideration a reduction of worktime [1, 3, 13, 18]. Despite great efforts on the side of both forest science and practice, it has not been possible, however, to eliminate the existing threat.

An interesting approach to the planning of the timber harvesting process has been presented by Styranivsky and Bybliuk of Lvov University [17]. The authors presented methods of applying the geographical information system (GIS) to elaborate the technology of utilization of the Carpathian forest stands. On the basis of the methods of computer simulation and visualization they showed a possibility of assessment of the effectiveness of technologies and of the ecological aspects of their application. It can be assumed that the collected data may be useful for complex assessment of the strenuousness of forest work in differentiated mountainous stands.

The analyses presented in this study allow for the formulation of the following conclusions:

- Despite considerable achievements in the construction of chain saws, these devices still emit vibrations above the admissible level.
- Organizational and technological suggestions presented here allow for a reduction of operators' exposure to vibrations. However, the level of this reduction must still be considered to be insufficient.

- We still cannot effectively protect chain saw operators from mechanical vibrations. The effect is common qualification of operators for disability pensions. This fact should inspire further efforts in limiting the negative effect of using chain saws on their operators.
- The methods of exposure assessment presented here allow for prediction and assessment of operators' exposure to vibrations in various technological and organizational variants.
- The most promising direction of reducing threat from factors of work in executi-onal posts in forestry is modernization of technological processes by means of introducing modern multioperational machines.

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