# HUMAN VIBRATION IN WOOD CUTTING PROCESS

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## Abstract
*The paper contains an example of experimental identification of physical reasons of really harmful, human vibration generated in wood cutting process. The application of computer methods for processing and analysis of all measurements signals enabled to identify the two main phenomena significantly affecting the harmfulness of portable electric chain saw machine vibrations: forced vibration resulted from dynamic condition of co-operation between the saw chain and gear wheel and low-frequency (19-65 Hz), probably self-excited vibrations.*

**Key words:** *mechanical vibration, chain saw, self-excited vibration*

## INTRODUCTION

Scientific investigations on vibrations generated during woodworking process have been carried out since many years.Generally (from practical as well as from theoretical point of view) it is very useful to understand the physical reasons of vibration in cutting process. It is the only way to really effective minimize this harmful phenomenon. One of the most harmful vibration is human vibration, which is defined as the effect of mechanical vibration on the human body. The typical example of above problem may be hand-arm vibration produced by portable electric chain saw (very popular hand-tool). The main aim of this paper was as follows: to attempt to set an example of experimental identification of physical reasons of really harmful, human vibration generated in wood cutting process. Therefore the analysis of chain saw vibration were presented.

## THEORETICAL BACKGROUND

Extremely important is understanding the discrimination between three basic kinds of vibrations: free, forced and self-exited vibration. The best, formal illustrations of this discrimination problem are the most simple equations of motion for above different kind of vibration which can be written as follows:

$mx''(t) + hx'(t) + kx(t) = 0$ $\omega = \omega_0$ free vibration
$mx''(t) + hx'(t) + kx(t) = F(t)$ $\omega = \omega_F$ forced vibration
$mx''(t) + hx'(t) + kx(t) = F[x(t)]$ $\omega = \omega_0$ self-exited vibration

where:
m – mass of dynamic system [kg],
h – dumping coefficient of dynamic system [Ns/m],
k – coefficient of stiffness of dynamic system [N/m],
F – force [N],
t – time [s],
x – displacement of dynamic system [m],
x' – velocity [m/s],
x" – acceleration [m/s$^2$],
ω – frequency of vibration [rad/s],
$\omega_0$ – natural frequency of the dynamic system ($\omega_0^2$ = k/m) [rad/s],
$\omega_F$ – frequency of the force F [rad/s].

In free vibration (with natural frequency) there is no exciting force. In forced vibration the external exciting force F(t) is independent of the oscillation of the dynamic system. In self-excited vibration the dynamic system generates exciting force F[x(t)] by its own oscillation. In the other words: the force that maintains the self exited vibration is conditioned only by oscillation of the system with its own natural frequency.
The most specific features (e.g. the most useful in discrimination problem) of different kind of vibration generated during cutting are as follows:

- free vibration - frequency is the natural frequency of the dynamic system and amplitude tends towards zero;
- forced vibration - frequency is the frequency of the concrete external, periodic force;
- self-excited vibration - frequency is the natural frequency of the dynamic system but amplitude does not tend to zero.

## MATERIALS AND METHODS

The investigation covered the sawing (cross-cutting) of unbarked round logs (birch wood, diameter about 160 mm, moisture content about 50%) by means of standard (produced in series) electric chain saw (power - 1600 W). The elements being cut were fixed with the use of rigid steel post. The operator's body position was quite normal (Fig. 1).

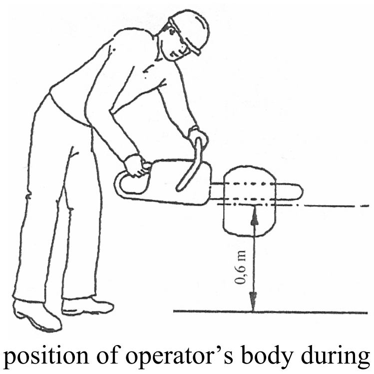


Fig. 1. The position of operator's body during experiments

During the cross-cutting the vertical (in direction “x“ - according to Fig. 2) vibration of the front grip of chain saw was measured by means of piezoelectric accelerometer (Kistler 8141A121). Moreover the rotational speed of chain saw driving wheel was monitored by means of special photo-electric sensor [Górski 1999]. All analog measurements signals were converted to digital signals and recorded then in the computer memory. In analysis of vibration signals a digital corrective filtering was applied according to ISO 8041 recommendation [Górski, Staroszczyk 1998]. The correction filter, defined in standards, reflects the characteristics of physiological sensitivity of human organism to vibrations of various frequencies (Fig. 2). Moreover FFT (Fast Fourier Transform) of vibration signal (after corrective filtering) was used.

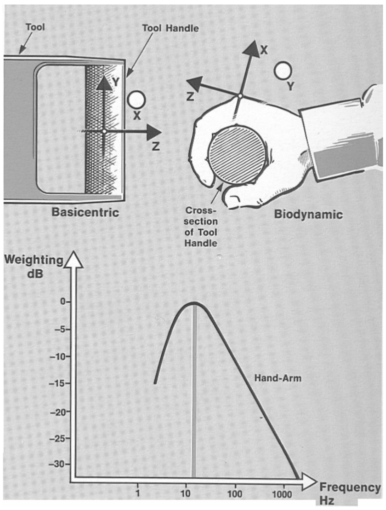


Fig. 2. Standard rules of measuring and filtering of hand-arm vibration signal [N.N. 1988]

## RESULTS AND CONCLUSIONS

Analysis of vibration signals showed that amplitude of its particular spectrum components varied substantially (typical shape of frequency spectrum is shown in Fig. 3.) The basic reason was occurrence of so called broad-band noise of cutting (result of random factors distinctly influencing course of cutting).

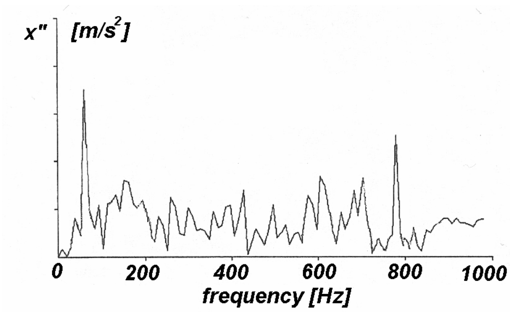


Fig.3. The typical frequency spectrum of vibration signal

However, in spite of all difficulties, it was possible to make some important generalization. The application of computer methods for processing and analysis of all measurements signals enabled to identify the two main phenomena significantly affecting the harmfulness of portable electric chain saw machine vibrations:

- forced vibration resulted from dynamic condition of co-operation between the saw chain and gear wheel,
- low-frequency vibrations occurring in the spectrum from 19 to 65 Hz (mechanism of creation is not clear).

It is possible that second type of vibration are not forced vibration but self-excited vibration. Basic arguments supporting above hypothesis, based on theoretical background (presented in earlier part of this paper) are as follows:

- the range 19-65 Hz is very close to the natural frequency of human hand-arm system [Gierke, Goldman 1976; Żukowski 1996],
- it seems that there is no external, periodic force in this range of frequency [Górski 2002].

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