

Impulsiveness of vibration as an additional factor in the hazards associated with hand-arm vibration

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STARCK J, PYYKKÖ I. Impulsiveness of vibration as an additional factor in the hazards associated with hand-arm vibration. *Scand J Work Environ Health* 12 (1986) 323–326. Impulsiveness is defined as the difference between peak and root-mean-square signals. As the difference varies in time, the cumulative distribution function has been used to describe the probability of achieving a certain value of impulsiveness. To make numerical comparison of different vibration signals possible, an impulse index has been selected from the cumulative distribution function. Symptoms of vibration-induced white finger were observed and compared to those expected on the basis of measurements taken according to guidelines of the International Organization for Standardization (ISO). Agreement was found for chain-saw vibration. In the case of pedestal grinding, the ISO draft underestimated the hazardous effects of vibration. Stone workers using pneumatic hammers were exposed to highly impulsive but asymmetrical vibration. The corresponding asymmetry was not, however, observed between the symptoms of the left and right hands, a finding which indicates that coupling between the tool and the hand is important for impulse vibration. The results suggest that the impulse character of vibration increases the risk of vibration-induced pathology. The analysis of high-impulse acceleration peaks obtained by the method presented in this study could provide additional data necessary to improve risk assessment.

Key terms: asymmetrical vibration, chain saw, impulse vibration, pedestal grinding, pneumatic hammer, risk assessment.

Measurement of root-mean-square (rms) acceleration does not take into consideration short, high peak values of the vibratory signal, which may be more hazardous in the development of the vibration syndrome than is generally thought (1, 9).

The purpose of the present report is to measure and analyze the high peak level of impulse vibration from different tools and occupations and to relate the results to the observed prevalence and latency data from exposed workers.

Subjects and methods

Definition of impulsiveness

The primary quantity used to describe the magnitude of vibration is rms acceleration. If the vibration signal contains impulses, the time-averaged energy level (L_{rms}) remains low in comparison with the peak level of individual impulses (L_{peak}). The shorter the impulse, the greater the difference between the peak and rms level. This phenomenon led to the assessment of impulsiveness on the basis of the difference between the peak and rms signals in decibels (4, 7). The difference, called I , also known as the crest factor of the signal, can be expressed as

$$I = L_{peak} - L_{rms}.$$

The definition is suitable for the continuous analysis of randomly varying signals. The function computed

is the cumulative distribution function (CDF) for difference I (6). From the cumulative distribution function the impulse index I_1 is selected to compare the impulsiveness of different vibration signals. This impulse index indicates the difference between peak and rms signals in decibels that corresponds to the 1 percentile value.

Subjects

This study comprised three different groups of workers exposed to vibration from different types of tools. A longitudinal study among professional forest workers was conducted from 1972 ($N = 118$) to 1980 ($N = 217$) on persons who had used chain saws for at least three consecutive years for a minimum of 500 h a year (5). Sixteen professional stone workers who used pneumatic hammers were examined in a cross-sectional study, as well as 12 pedestal grinders (6, 8).

Tools

The vibration measurements comprised three different generations of chain saws. The first-generation chain saw was a Homelite Zip manufactured in 1958. It represented the chain saws used in the 1960s and was not supplied with any antivibration elements. In the late 1960s the first so-called antivibrating chain saws replaced the first-generation saws. A Partner R22 was selected to represent this second generation. The vibration of chain saws was reduced further in the 1970s, and a Raket R420 was selected to represent this generation. The operation time increased from 2 h to about 5 h daily during the follow-up period (5).

The pneumatic hammer was used by stone workers.

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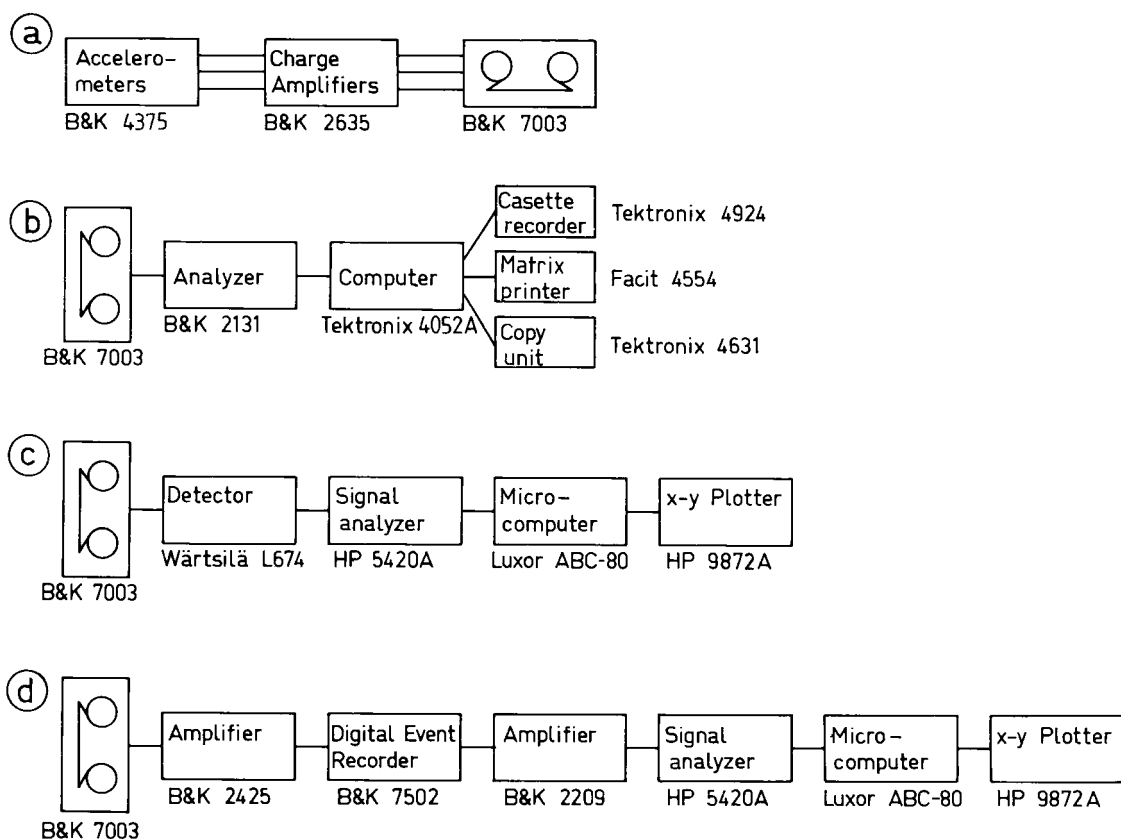
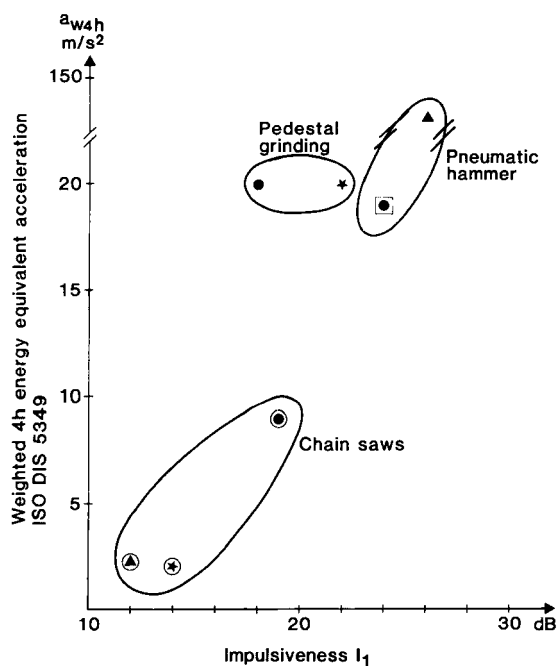


Figure 1. Block diagram of the equipment used in the measurements and laboratory analyses in the field (a); in the laboratory, according to ISO/DIS 5349.2 (3) (b); in the laboratory, for the analyses of impulsiveness (c); and in the laboratory, for the analyses of time history (d). (B & K = Brüel & Kjaer, HP = Hewlett Packard)



The left hand was in contact with the chisel head, and the right hand with the barrel.

Pedestal grinding was used in a foundry for cleaning small castings by hand. The vibration of two different types of grinding wheels was measured, one being made of corundum and the other of zirconium corundum. The corundum wheel had not caused vibration-induced white finger (VWF) in any of the grinders, whereas the zirconium corundum wheel proved to be very hazardous in that all the workers had contracted the syndrome within one year of changing to this wheel (8).

Equipment for the recordings and analyses

A lightweight accelerometer was attached to a mechanical filter, which in turn was mounted rigidly by a screw

Figure 2. Weighted 4-h energy equivalent acceleration (a_{w4h}) and impulsiveness (I_1) of vibration for pedestal grinding with a corundum wheel (circle), pedestal grinding with a zirconium corundum wheel (star), a Homelite ZIP 1958 chain saw (encircled circle), a Partner R22 1972 chain saw (encircled star), a Raket R 420 1982 chain saw (encircled triangle), the chisel head of a pneumatic hammer (triangle), and the barrel of a pneumatic hammer (circle in a square).

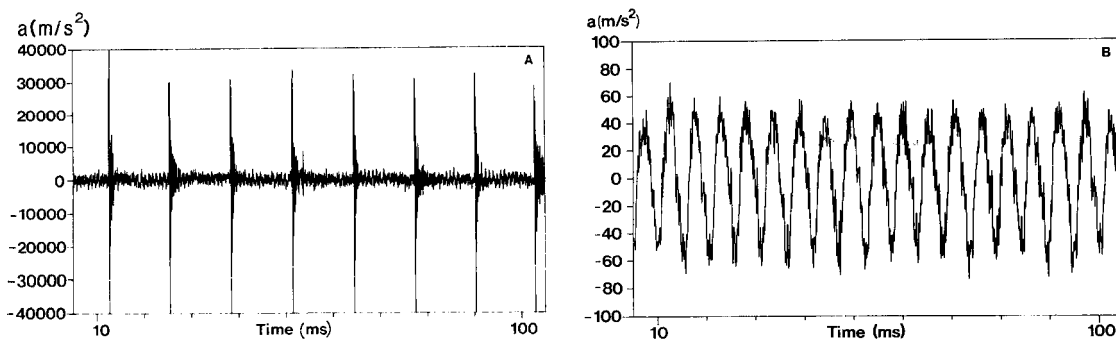


Figure 3. Transient recordings of vibration for the chisel head of a pneumatic hammer (A) and the most up-to-date chain saw (B).

Table 1. Expected latency period and prevalence of vibration-induced white finger (VWF) assessed according to ISO/DIS 5349.2 (3) in comparison with the observed latency and prevalence. (a_{w4h} = frequency-weighted 4-h energy equivalent acceleration, I_1 = impulse index for the percentage value of 1)

Tool ^a	a_{w4h} (m/s ²)	I_1 (dB)	VWF			
			Expected latency period (years)		Observed latency period (years)	Observed prevalence (%)
			Prevalence 10 %	Prevalence 50 %		
Pedestal grinding						
Corundum wheel	20	18	1.3	3.2	>5	not known
Zirconium wheel	20	21	1.3	3.2	<1	100
Chain saw						
Homelite ZIP 1958	9	19	3.3	7.5	<5	40
Partner R22 1972	2	14	15.0	33	<10	16
Raket R420 1982	2	12	13.7	30.5	not known	<7
Pneumatic hammer						
Chisel head	130	26	0.2	0.5	6	75
Barrel	19	22	1.6	3.5	9	50

to the measuring point. Acceleration was recorded in the frequency range from 2 Hz to 10 kHz, and in this range the frequency response was linear within 1 dB.

The total and frequency-weighted acceleration was calculated from the average one-third octave spectrum according to the guidelines of the International Organization for Standardization (ISO) (3). This spectrum was formed from 20 to 50 spectra, each time-averaged 0.5 s and sampled at intervals of 0.5 s.

The probability distribution function was generated by a fast Fourier transform analyzer after rms and peak detectors were first employed. The cumulative distribution function was calculated by a microcomputer, which also showed the selected impulse index.

A detailed time history analysis was carried out with a transient recorder and a microcomputer for signals of 100-ms duration, which were constructed by the joining of recurrent 10-ms samples analyzed with a bandwidth of 12.8 kHz.

Results

The frequency-weighted 4-h equivalent acceleration and the impulsiveness of the vibration are presented

for each tool in figure 2. The pneumatic hammer and, especially, the chisel head generated weighted-equivalent acceleration and impulsiveness. The corundum and zirconium corundum grinding wheels produced the same frequency-weighted acceleration, but the impulsiveness of the vibration generated by the zirconium corundum wheel was higher than that generated by the corundum wheel. Of the different chain saws, the oldest type of saw generated vibration with the highest weighted acceleration and impulsiveness. The most up-to-date chain saw generated the lowest impulsiveness.

Transient analyses were performed in an attempt to find an explanation for these results.

The chisel head generated short peaks that occurred regularly at intervals of 12 ms. The most up-to-date chain saw produced vibration with the least impulsiveness, and transient analysis showed that it contained no peaks.

Discussion

The risk assessment of VWF was done according to the ISO method. Both 10 and 50 percentiles were eval-

uated. The expected values were compared with the observed ones for different tools. Agreement was found for the chain saws. In the case of pedestal grinding, the ISO guidelines underestimated the hazardous effects of the vibration. According to it the prevalence of VWF among the grinders should have required a weighted acceleration of about 55 m/s^2 , but in this study it was about 20 m/s^2 .

The stone workers using pneumatic hammers were exposed to highly impulsive vibration. Their left hand was in contact with the chisel head where the frequency-weighted 4-h acceleration was about seven times greater than in the barrel of the pneumatic hammer held by the right hand. A corresponding asymmetry in the symptoms was not observed (2). The finding suggests that nonlinear transmission from the vibrating tool to the wrist occurs when impulse vibration is being generated. In the case of chisel head vibration the explanation might be the short duration of the high peak values in the vibration signal.

Conclusions

The present results suggest that conventional methods of measuring vibration do not reveal all its hazardous characteristics. High impact components were observed in the tools regarded to be the most hazardous. An additional problem in the measurement of vibration for risk assessment purposes is related to the amplitude-dependent transmission of vibration within the body. The analysis of high-impulse acceleration by the method presented in this study could provide ad-

ditional data necessary to improve the assessment of the risk involved in exposure to hazardous hand-transmitted vibration.

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