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IMPULSIVE VIBRATION AND EXPOSURE LIMIT

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ABSTRACT

Several cases of exposure to hand-transmitted shocks in two different factories were studied with an intention to improve our knowledge about the influence of the impulsive components of vibration on human being. Two types of shocks affecting the workers could be distinguished, i.e., shocks having small amount of energy at frequencies higher than 100 Hz and shocks having relatively high frequency components up to 1000 Hz. An exposure to the hand-arm shocks of both types was measured and assessed in accordance with the international standard ISO 5349. Health condition of workers was examined. Carpal tunnel syndrome was found among the workers of the workshop in wood industry, who work with staple gun. The investigation of the health condition of about 60 forge workers up to now did not confirm the severity of hand-arm shocks as it had been assessed according to the Annex A of the ISO 5349. The exposure to hand-arm shocks in the forge leads to the incidence of occupational diseases and disorders, which however, differ from the diseases normally reported as a consequence of the hand-arm vibration and shocks. It seems obvious that for the assessment of shock exposure, the ISO 5349 is not quite suitable in its present form.

Key Words: Hand-arm vibration, Shock, Assessment, Exposure

INTRODUCTION

Many authors considered the impulse type vibrations and shocks.[1,2,4)] The basic questions have not been, however, answered yet. Similarly the effects of shocks and vibrations on the locomotive apparatus of the hand and arm has not been explained and documented satisfactory.[2,4)]

In practice we frequently meet a combined exposure to vibrations, shocks, noise and long-term, unilateral and excess loading of upper extremities. In the mentioned combination of factors eventual findings in the locomotive apparatus are usually explained as the consequence of the influence of one-sided, long-term and excess loading of the upper extremities at work. Doubt are usually cast upon simultaneous effects of vibration and shocks on the development of these changes. In the case of blacksmiths the overloading of the organism as a whole obviously could occur.

The international standard ISO 5349[5)] on the measurement and assessment of hand-arm vibration admits that it may be provisionally also applied to repeated shock type excitation.

In the older literature[1)] we frequently encountered that the exposure of the hand and arm to repeated shocks at frequencies below 1800/min is discussed as an exposure to the "low-frequency vibrations", which is assumed to be in connection with the damage of the locomotive apparatus of the hand and arm.

The authors of the presented work believe that reason for the possible contribution of shocks

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and vibrations to the damage of the locomotive apparatus of the hand and arm[2,4,9] should be particularly searched for in the fact that these are impulse vibrations. The time history and not only the frequency domain is of importance. Furthermore, the hand-arm shocks with the relatively high content of lower frequencies, like shock transmitted onto the smith and smith helper when working with the power hammer can have consequences in the health condition of the locomotive apparatus of the whole body.[2]

For the above described reasons we decided to study in details the exposure of two groups of workers to repeated shocks. The first group of 23 workers in wood industry is exposed to hand-arm shocks in the work with staple or nail guns.[9] The second group of 60 workers is exposed to hand-arm shocks in the work at power hammer or with hand hammer in a forge. The health condition of both groups of workers was examined and followed since 1981. At the same time the health condition in a control group of workers (hardeners) was studied. The study includes a relevant ergonomic examinations.

METHODS

The measurements of the time history and of the frequency spectrum were carried out with the Brüel & Kjaer Portable FFT and Digital Real Time Frequency Analyzer in the frequency range 0.3 — 1600 Hz. The transducer were fastened to the standard mount placed between the source of vibration and the hand. The exposures were measured with the Brüel & Kjaer Human Vibration Meter.

The clinical examination included the general health examination and cold provocation test. In workers with some positive findings, the examination was completed by the neurologic examination (including EMG), laboratory examination for precluding the possible effects of metabolic disturbances, rheumatologic examination, examination for glycaemia and by the orthopaedic examination.

RESULTS

The exposure time per one shock is in the case of staple gun about 20 to 30 ms. Thus, for the total number of about 3000 shocks per shift, it is possible to assume that the net time of the exposure to shocks lasts only 60 to 90 s per shift. The actual time of the exposure to the work with the nail or staple air gun is of course longer. The worker provide about 2 to 3 shocks per second. Thus, it is possible to estimate that the total time of the work with the gun per shift is of about 30 minutes.

When starting the work at risk working places, the workers in our country are submitted to preventive medical examinations, where usually at least 10% persons are eliminated. Thus, the time of the latency for 10% of the population should mean the time up to the occurrence of the first sporadic manifestations of the vessels or the neurologic disease due to the vibrations. The relevant calculation was performed in accordance to the Annex A of the international standard ISO 5349[5] (see Table 1).

All the workers reported pains in the spine, arms and hands. They have been clinically examined since 1981. In this period, in 7 workers a suspect possibility of the occupational damage to the health was considered. These were the carpal tunnel syndrome (5 workers), cervico-brachial syndrome (1 worker) and last the nerve disease due to the vibration (1 worker). Out of the mentioned number of 7 workers, the occupational disease was recognized only in two workers with the diagnosis the carpal tunnel syndrome and disease of vessels and nerves due to vibra-

Table 1. Results of the measurements of shocks exposure in the work with the nail or staple gun

Direction of vibration	Calculated total weighted rms acceleration value $a_{w,4h}$ [$m.s^{-2}$]	Latency period F_{10} [years]	Median of lat. period F_{50} [years]
x_h	1,18	25	$\geq$ 30
y_h	1,06	28	$\geq$ 30
z_h	1,44	21	$\geq$ 30

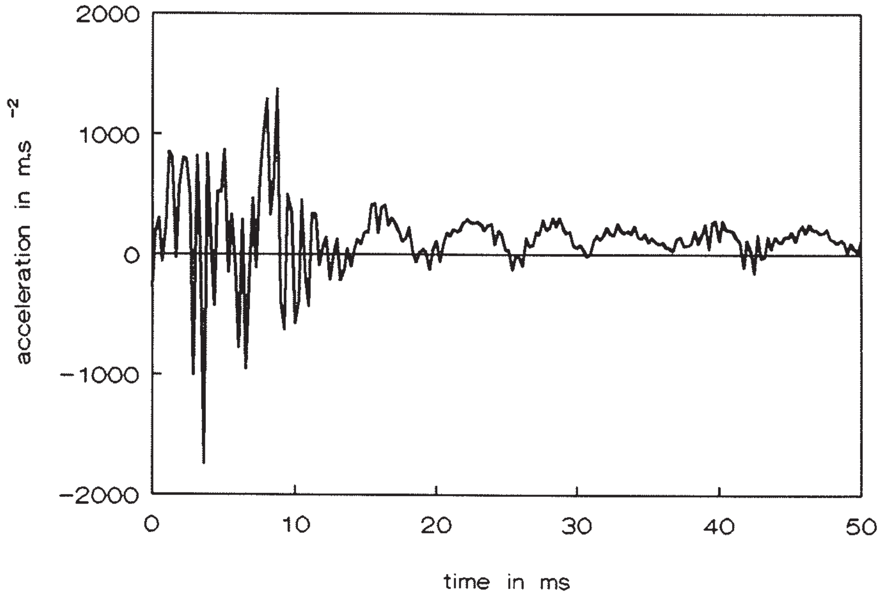

Fig. 1 Hand-arm shocks in hot forging. Right hand, direction z_h

tions. In the remaining 5 cases with the diagnosis carpal tunnel syndrome and cervico-brachial syndrome, the disease was not recognized as an occupational disease. Results of vibrotactile examination[7,10)] carried out later corresponded fully to the findings mentioned.

Typical time history of a shock in the hot forging is shown in Fig. 1. Neither the shock duration nor the intensity of the shocks differ very much from the shocks transferred on the hand during the work with the staple gun. In the reality are, however, these shocks very different. Blacksmiths and smith-helpers must exert much more force in work and the energy of shocks transmitted to the hands and arms and to the body as a whole is much greater. Very frequent and typical operation in hot forging is the forging of turbine blades (see Table 2).

In the blades production the hot forging is followed by the straightening of the blades, i.e., by the cold forging. This operation presents another frequent, but hand operation in the forge. The shocks transferred from the hand hammer are not so intensive like the shocks transferred in the work with power hammer. However, the shock exposure of helpers is completely different. These shocks are characterized by the vibration of metal obstacle kept in the hands of helper. These vibrations are induced by shocks and are characterized by a long decay (see Fig. 2). The

Table 2. Results of the measurements of hand-arm shock exposure in the hot forging of tubine blades with power hammer

Operation	Vibratory acceleration level L_{aw}, [dB//1μm.s^{-2}]					Hand	Exp. time per operation
	Magnitude	Direction z_h	Direction y_h	Direction x_h	Vect. sum		
Blade forging/ smith	$L_{aw\ eq}$	137,3	137,6	139,4	143,0	Right	3 min 22 s
	$L_{aw\ Peak}$	169,2	172,8	174,5			
	$L_{aw\ max}$	152,4	155,6	155,9			
	$L_{aw\ min}$		< 100				
Blade forging/ smith	$L_{aw\ eq}$	144,7	137,8	141,9	147,1	Left	1 min 47 s
	$L_{aw\ Peak}$	171,9	171,9	170,0			
	$L_{aw\ max}$	156,0	151,4	151,7			
	$L_{aw\ min}$	122,4	122,5	123,0			
Blade forging/ smith	$L_{aw\ eq}$	145,6	144,2	143,5	149,3	Right	0 min 49 s
	$L_{aw\ Peak}$	176,3	174,6	174,5			
	$L_{aw\ max}$	159,6	159,0	158,3			
	$L_{aw\ min}$	122,1	122,0	120,2			
Blade forging/ helper	$L_{aw\ eq}$	134,6	133,2	137,3	140,2	Right	3 min 44 s
	$L_{aw\ Peak}$	163,3	163,4	166,2			
	$L_{aw\ max}$	142,6	143,2	147,4			
	$L_{aw\ min}$		< 120				

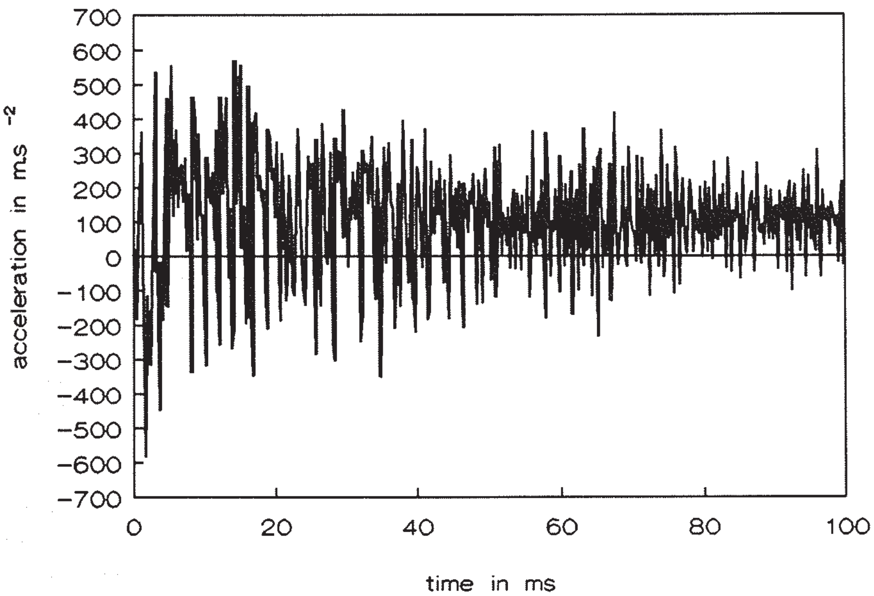

Fig. 2 Hand-arm shocks in cold forging. Left hand, direction y_h

exposure to this shocks remains rather the exposure to hand-arm vibration. The exposure data from the straightening of blades are given in the table 3.

The equivalent root-mean-square (rms) value of acceleration in hot forging for the time of operation is, as can be seen in the tables, about 10 m/s^2 ($L_{aw,eq}$ = 140 dB). One forging operation is normally lasting from one up to about 4 minutes. In the mean the duration of one operation is about 2 minutes. The pure daily exposure to such shocks lasts from 30 up to about 200 minutes. In the mean it lasts about 120 minutes. The equivalent rms value of acceleration for 4 hours is $a_{w,4h} = 7.1$ m/s^2 ($L_{aw,4h}$ = 137 dB).

According to the Annex of ISO 5349[3,5] 10% of population of exposed people in the forge should have health problems due to vibration exposure after about 4 years of exposure. In the reality the reported occupational diseases due to the work in the forge occur after more than 20 years of exposure. Obviously these are another types of damage than that followed by the authors of the ISO 5349 Annex A. In the forge workers group no positive findings was estimated in the cold provocation test. One typical Vibration induced White Finger (VWF) disease was reported in the forge worker group. This was, however, the case of worker exposed to shocks similar to that presented in Fig. 2.

In the forge all together about 200 forge were working until 1990. Nowadays about 60 blacksmiths are occupied in the forge. As a control group, 25 hardeners from the same factory were examined. In the Tables 4 and 5 are shown the first results of health investigation of both groups. In the results the data from prospective study of 25 smiths and 15 hardeners are presented. The mean age of blacksmiths was 44 ± 7.3 years and of hardeners 48 ± 8.3 years. The last three diagnosis from the Table 5 present reported occupational diseases. The overview about the incidence of occupational diseases since 1981 is given in the Table 6.

Table 3 Results of the measurements of hand-arm shock exposure in the cold straightening of turbine blades

Operation	Vibratory acceleration level L_{aw}, [dB//1μm.s^{-2}]					Hand	Exp. time per operation
	Magnitude	Direction z_h	y_h	x_h	Vect. sum		
Blade straigh-tening	$L_{aw\ eq}$	129,8	129,1	131,9	135,2	Left	3 min 28 s
	$L_{aw\ Peak}$	159,6	154,3	161,3			
	$L_{aw\ max}$	141,0	136,1	139,9			
	$L_{aw\ min}$	121,9	122,2	121,4			
Blade straigh-tening	$L_{aw\ eq}$	131,7	132,0	132,0	136,7	Right	3 min 28 s
	$L_{aw\ Peak}$	166,3	163,8	163,8			
	$L_{aw\ max}$	147,3	143,2	145,5			
	$L_{aw\ min}$	120,7	122,2	121,3			

Table 4. Incidence of the subjective complaints in the blacksmiths and hardeners group of worker

Symptoms	Smiths n = 25	Hardeners n = 15
Paresthesia	4	0
Noctural paresthesia	8	0
Low-back pain	13	4
Pain in wrist and hands	9	0
Pain, cramps and oedema in upper extremities	12	3
Noctural pains in upper extremities	9	0
Pains in lower extremities	3	1
Pains in cervico-brachial spine	13	0

Table 5 Incidenc of the diseases and syndromes in the blacksmiths and hardeners groups of workers

Diagnosis	Smiths n = 25	Hardeners n = 15
Arthritis	2	3
Arthroses	4	1
Cervico-brachial syndrome	13	0
Low-back syndrom	8	4
Varices cruris	3	3
Epicondylitis	6	0
Other (trophic) changes	6	0
Carpal tunnel syndrom	12	0
Vasoneurosis (VWF)	6	0
Damage in locomotor system (joints etc.)	2	0

Table 6 Incidence of occupational diseases in smiths since 1980

Time period	1981–85	1986–90	1991–93
Number of new occup. diseases	6	6	9

DISCUSSION

With respect to the common criteria, it was impossible to consider the damage observed in staple gun workers as an occupational disease. The limit values of vibrations were not exceeded and as far as the long-term, one-sided and excess load of the upper extremities, particularly the condition of the unilateral nature of the load, was not adhered, too. It seems obvious, however, that the carpal tunnel syndrome is one possible damage induced by shocks transferred to hands.[7]

In the forge the violation of vibration limits was found in all work places. The occupational diseases occur in this case after a long time (>20 years) of exposure and with an exception of one case, the found disorders have quite different character than disorders followed by epidemiological studies dealing as a base for Annex A of ISO 5349.

It is quite obvious that ISO 5349 standard is not suitable for the evaluation of shocks similar to that in the forge. However, it was not our aim to pose this standard in doubt. We only wanted to help in finding of more precise text of some paragraphs.

This concerns the scope of the standard which should be somewhat more difinite. It should be completed, e.g., in a similar way like it was done in the related international standard ISO 2631,[6] since it considered, that shocks can be assessed according to the standard "...in so far as the energy in question is contained within the frequency range followed."

Furthermore the coupling of the hand, i.e., the amount of the energy transferred into the hand and arm, should play more important role in the assessment of hand-arm shocks and vibration. The shocks in the forge and the shocks in the work with staple gun are completely different in the reality, but the physical characteristics of the motion are very similar. At the time being this can be probably done by indirect way only, e.g., by the incorporation of applied and grip forces into the assessment.

There was no cold affecting the hands and arms in hot forging and it could explain the absence of typical disorders in the blood-vessels in the forge worker. It seems to us that the cold and other co-factors are underestimated in the present standard.[11,12]

With the growing amount of energy of shocks transferred in the region of frequencies below 10 Hz, the part of the body subjected to shocks is increasing. In case of very intensive shock with a big amount of energy in the very low frequencies, the problems of the exposure to hand-arm shocks is becoming the problem of whole-body shocks with quite different consequences for the health of exposed people.[2] In the connections described above, it would be also suitable to reinvestigate the proposal of Kuhn and Scheffler,[8] who proposed to measure the transferred force as a basis for the assessment of the effect of vibrations on the hands and arms.

The knowledge of the influence of shocks and vibration on locomotive system is not satisfactory at present.[2,4,9,11] On the other hand it is quite clear that the damage in locomotive apparatus occurs if intensive shocks are present in the exposure. In this consequence the findings presented in former publications[1] are somewhat covering the reality. The presence of intensive shocks in the exposure leads namely automatically to the presence of lower frequencies.[9]

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