TEMPORARY CHANGES IN VIBROTACTILE PERCEPTION DURING OPERATION OF IMPACT POWER TOOLS: A PRELIMINARY REPORT

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1. INTRODUCTION

The measurement and evaluation of human exposure to hand-transmitted vibration have been codified in an international standard, where exposures are characterized by daily, eight-hour, energy-averaged, frequency-weighted, RMS component accelerations, $a_{w,RMS(8)}$.[1] The exposure metric assumes: 1) a relationship between the relative hazard presented by vibration at different frequencies, which is introduced by frequency weighting the acceleration-time history, $a_w(t)$, and; 2) temporal summation by means of energy averaging throughout the duration of a work day (specified as eight hours), $T_{(8)}$, as described in Ref. 2, i.e., for each (uniaxial) component:

$$a_{w,RMS(8)} = \left[\frac{1}{T_{(8)}} \int_0^{T_{(8)}} a_w(t)^2 dt \right]^{1/2} \tag{1}$$

The metric is broadly accepted for predicting the chronic vascular disturbances associated with the hand-arm vibration syndrome (HAVS) from exposure to near-continuous vibration, but its applicability to exposures involving repeated mechanical shocks, such as during operation of impact power tools (e.g., pneumatic chippers and hammers) has been repeatedly questioned.[3] While some information on the suitability of the metric can be obtained from the results of epidemiological studies of working populations, the results of studies of acute responses to vibration exposure provide another source of information.

A laboratory experiment has been devised for determining changes in vibrotactile perception threshold (VPT) at the fingertip in response to a mechanical stimulus consisting either of continuous vibration or a repeated, transient, damped sinusoidal shock, with the same carrier frequency. The repetition rate of the transient stimulus is chosen to be characteristic of common impact power tools, and to fall within the range of frequencies at which the VPT is known to be mediated by a single mechanoreceptor population.[4] The stimuli are applied to a handle gripped by a subject with a constant static force. The magnitudes of the stimuli are adjusted to yield equal exposures according to eqn. 1, i.e., equal values of $a_{w,RMS(8)}$.

2. METHOD

2.1 Vibration stimulus

Exponentially decaying sinusoidal waveforms were generated digitally to simulate power tool acceleration-time histories. The algorithm contained the decay rate, the sinusoidal carrier frequency, and the repetition rate of the "impacts". Combinations of these parameters were selected to be comparable with real tools and with the stimuli employed in a previous laboratory experiment.[5] A single waveform decay rate, which corresponds approximately to that observed on bucking bars (a device held behind the work piece during riveting), was employed.

The repetition rates for the waveforms were 4, 16, and 32 per second. The rate of 4 shocks per second is consistent with that produced by pneumatic nailers, and the rate of 16 per second with that produced by riveters, while the rate of 32 shocks per second is in the range produced by scalers and needle guns (typically 30-40 impacts per second). The sinusoidal carrier frequency was 125 Hz, which also served as a non-shock stimulus.

The waveforms were applied to an electro-dynamic vibration exciter (Bruel & Kjaer 4805, with 4811 exciter head), after reducing the low-frequency roll-off in its electromechanical transfer function. The uniaxial stimuli were coupled to the hand through a rigid handle. The hand gripped a tube with an elevated strip mounted along its length, to which was attached a strain gauge bridge for monitoring grip force. An accelerometer was attached to the inside of the tube at its mid point, to record the vibration at a surface in contact with the hand. The frequency-weighted, RMS component acceleration was monitored and was adjusted to provide a constant value of $a_{w,RMS(8)}$, as each exposure was of the same duration.

An example of an acceleration waveform recorded at the inside of the tube during an experiment is shown in Fig. 1. It is evident that the desired stimulus acceleration-time history has been achieved for this the most difficult case, involving a 4 Hz repetition rate. As this waveform was recorded under the palm it may be taken to reflect the stimulus experienced by the skin in contact with the handle.

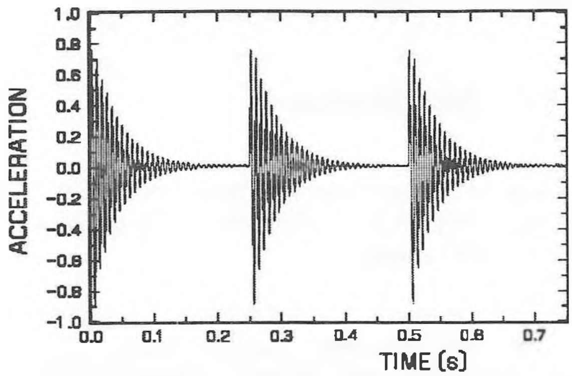

Figure 1: Shock waveform stimulus with 4 per second.

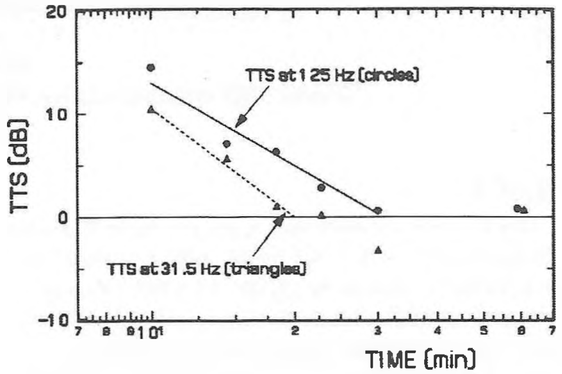

Figure 2: TTS after exposure to continuous vibration for subject #1.

2.2 Determination of vibrotactile thresholds

Vibrotactile thresholds were determined at the fingertip using the tactometer, in a manner analogous to the determination of the threshold of hearing by an audiometer.[6] The tactometer consists of a vibration stimulator and sensor with a probe attached to contact the skin that are lowered onto a fingertip, and a means to support the hand and arm with the palm facing upwards, together with signal conditioning circuits under computer control.

Thresholds were determined sequentially at a fingertip, at three frequencies (4, 31.5, and 125 Hz), commencing as soon as possible after completion of an exposure. Measurements were conducted repeatedly, at predetermined time intervals. The un-adapted threshold was determined before commencing an exposure, and served as the basis for calculating any temporary threshold shift (TTS) occurring as a result of the exposure. A control experiment was performed in which the subject gripped the handle for the duration of the exposures (8 min), but with no vibration stimulus. Fingertip skin temperatures were also recorded.

3. RESULTS AND DISCUSSION

Results are considered here for three subjects and two repetition rates - 4, and 32 Hz, and for continuous vibration. The frequency-weighted, RMS acceleration of each uniaxial stimulus was 2.0 ms^{-2}.

A stimulus-response function for VPTs at 32 and 125 Hz is shown for one subject in Fig. 2, where the responses are to the continuous stimulus at 125 Hz. In this diagram the TTS has been plotted as a function of the time elapsed from determining the initial pre-exposure VPT. The results are the average of three exposures to each stimulus, the order of presentation having been randomised.

It can be seen that in this case the recovery follows a logarithmic time dependence after the termination of exposure (at a time of 9 min), reaching the un-adapted threshold recorded prior to the stimulus (i.e., TTS = 0) after about 20 min for TTS at 125 Hz, and 10 min for TTS at 31.5 Hz. There was no TTS at 4 Hz recorded by this subject. Substantial differences in response were observed between subjects, both in the magnitude of the TTS and in the form and rate of the recovery function. These will be described elsewhere, as well as results from other subjects.

The mean maximum TTS recorded by the three subjects is presented in Table 1, and leads to several observations. Firstly, there appears to be, on average, little or no TTS at 4 Hz in response to any of these stimuli. Secondly, the TTS at 31.5 Hz seems to be, on average, little affected by the nature of the stimuli in contrast to that at 125 Hz, which is substantially less for the slower shock rate. The pattern of these results suggests that the primary influence on TTS is related to the frequency-weighting function used to form $a_w(t)$, rather than to the procedure for summing shocks.

4. REFERENCES

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Table 1: Mean TTS of three subjects for stimuli with the same energy-averaged, frequency-weighted, RMS acceleration

Stimulus	Mean maximum TTS (dB)		
	4 Hz	31.5 Hz	125 Hz
shock, 4 repetitions per second, 125 Hz carrier	1.7	6.7	8.7
shock, 32 repetitions per second, 125 Hz carrier	-2.7	5.8	14
Continuous, 125 Hz	0	4.7	15