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THE USE OF A PORTABLE COMPUTER FOR THE RECORDING AND ANALYSIS OF HAND-TRANSMITTED VIBRATION

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SUMMARY

It is well-established that hand-transmitted vibration causes various physiological disorders. However, it is not known with any certainty which characteristics of the vibration are primarily responsible for each disorder. Current standards define means of reporting the sensitivity of hand-transmitted vibration and may imply that simple meters which conform to the standards are sufficient for investigation. It is suggested that it is highly desirable to determine the spectral, axial and temporal characteristics of vibration exposures in more detail than given by simple meters. This will contribute to the growing understanding of human response and make it possible for measurements to be reanalysed as evaluation methods are improved. Since the measurement of tool vibration is not always simple or reliable this additional analysis also provides a valuable opportunity to inspect the measurements and check their validity. A newly developed portable computer system provides appropriate comprehensive analysis facilities and can also be used to obtain measurements conforming to current standards.

INTRODUCTION

Standards for the assessment of hand-transmitted vibration define how to obtain a single value of vibration severity for comparison with either a vibration limit or dose-effect data. The method of obtaining the single value assumes that it is known how severity depends on the magnitude, frequency, direction and duration of vibration exposure. Using these assumptions it may appear possible to employ simple vibration meters to assess tool vibration. However there are several reasons why additional analysis is desirable.

Currently available data from experimental and epidemiological studies are not sufficient to give any certainty to the form of current frequency weightings, time weightings or the relative severity of vibration in different axes. It is therefore highly desirable that reports of measurements also provide information on the frequency content, variations with time and distribution across axes of the vibration exposure. This requires that the vibration time history in each axis is available for analysis.

ANALYSIS OF HAND-TRANSMITTED VIBRATION

Frequency weighting

British Standard 6841 (1987) and International Standard 5349 (1986) employ the same frequency weighting for the assessment of hand-transmitted vibration. In British Standard 6841 this is called weighting W_h so as to be compatible with weightings W_b to W_g used for whole-body vibration in British Standard 6841. Realisable weightings are defined mathematically in a form familiar to filter designers so that they can be easily implemented by analogue or digital means. For the convenience of others they are also given as asymptotic approximations (straight lines). This approximation corresponds to an acceleration weighting which is independent of frequency below 16 Hz and an acceleration weighting which falls at 6dB per octave above 16 Hz (i.e. a velocity weighting which is independent of frequency). The frequency band is limited by a high pass filter at 6.3 Hz and a low pass filter at 1250 Hz.

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The form of the frequency weighting arises from international compromise after consideration of some data concerned with subjective and biodynamic responses of the hand to vibration. Although some epidemiological data may be consistent with some parts of the weighting they are not sufficient to expect that vibration exposures consisting of different frequencies but having the same frequency weighted acceleration will always cause the same type, severity or extent of disorders. Consequently, although the standardised frequency weighting may be used to report and compare vibration from different tools it may not always provide the best indication of possible problems. It follows that when reporting vibration exposures it is highly desirable to also report the vibration spectra so that when other weightings are evolved they can be applied retrospectively. No report of epidemiological research involving measurement of tool vibration is complete without documentation of the vibration spectra. Reports from such studies should eventually provide the information necessary to improve the weighting.

Some research has suggested that vibration at frequencies far greater than 1250 Hz can have a detrimental effect – particularly on neurological function. The use of a meter with a 6.3 to 1250 Hz band-pass filter defined according to current standards will not be useful for assessing vibration at these higher frequencies.

Clearly, the need for frequency analysis means that measurement should involve analysis beyond the scope of simple meters incorporating single frequency-weighting networks.

Duration

For practical convenience the current standards assume that the severity of hand-transmitted vibration can be assessed from the 'energy-equivalent' frequency-weighted acceleration. In British Standard 6842 it is suggested that an 8h energy-equivalent frequency-weighted acceleration is reported:

$$(a_{h,w})_{eq(8)} = \left[\frac{1}{T_8} \int_0^T [a_{h,w}(t)]^2 \, dt \right]^{\frac{1}{2}}$$

where

$(a_{h,w})_{eq(8)}$ is the 8h energy-equivalent acceleration in $m.s^{-2}$;

T_8 is the duration of 8h;

T is the total duration of the working day in hours;

$a_{h,w}(t)$ is the instantaneous value of the weighted acceleration in $m.s^{-2}$.

Again, this simple method of reporting vibration severity makes many assumptions and it is highly desirable that the duration of individual exposure periods and rest periods is reported. It may be desirable to determine the difference in magnitudes between different periods of exposure as the job varies (e.g. from one type of operation to another during the day). This will allow the job involving the greatest exposure to be identified. Also, since the method of summation over time is not well established, it will help to accumulate knowledge of the influence of different exposure patterns.

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The current use of an 'energy time-dependency' can have a large effect on the apparent importance of shocks in the waveform. Since it is sometimes considered that these have a characteristic effect on the body it may be desirable to separately report the detailed form and composition of shocks.

Vibration direction

Current standards differ in how they advocate that the severity of hand-transmitted vibration occurring in more than one axis should be assessed. Irrespective of whether vibration severity is assessed by reference to only the worst axis, or the vector sum of vibration occurring in three axes, it remains desirable to report the spectra in all axes. If this information is available it is possible to consider retrospectively the possibility that vibration effects are different in each axis and that there may need to be different frequency weightings for each axis.

Other considerations

One of the most severe and well-known problems in the measurement of hand-transmitted vibration is caused by the shocks sometimes occurring on hand tools. These can result in intermittent d.c. shifts in the acceleration time history and consequent elevation of the spectra at low frequencies. It is possible to minimise the probability of d.c. shifts by appropriate choice of accelerometers and signal conditioning and the use of a mechanical filter. However, it currently appears highly desirable to be able to check whether the signal being analysed contains errors due to this problem.

The occurrence of d.c. shifts cannot be detected by instrumentation which only indicates the frequency-weighted acceleration. The problem can be detected if the acceleration time history is available for inspection, although this can be difficult and time consuming. Alternatively, a frequency analysis of the vibration will often indicate the problem at low frequencies. The acceleration spectra on hand tools should show decreasing acceleration with decreasing frequency. A spectrum which rises with decrease in frequency is a good sign of a problem from d.c. shifts.

PORTABLE INSTRUMENTATION FOR EVALUATING HAND-TRANSMITTED VIBRATION

It is apparent that simple meters incorporating a single frequency-weighting are not a sufficient means of evaluation of all forms of hand-transmitted vibration. (Such meters may be useful for some simple measurements but they will not always be reliable and they will not be sufficient for research purposes).

Until recently the alternative to simple portable meters has been the use of tape recorders and subsequent laboratory analysis using, for example, large digital computers. The facilities required can be expensive and their use has proved time-consuming.

Compact, portable and low cost computers now make it possible to undertake digital recording and analysis in the field. Mathematical operations (including spectral analysis, frequency-weighting and linear integration) can be performed on the digitised time histories. The time histories can also be stored so as to provide an archive of tool vibration. The measurements from different tools obtained on different occasions may be easily compared. Later, the measurements can be reanalysed using methods which were not defined when the measurements were originally obtained.

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HVLab Computer System

A portable, battery powered personal computer system for evaluating all human exposures to vibration has been developed in the Human Factors Research Unit of the Institute of Sound and Vibration Research. The system (called HVLab) consists of one of several commercially available digital computers (IBM-PC compatable), one or more specially developed interface boards and an extensive library of time-series analysis software.

The interface boards perform analogue-to-digital conversion and contain on-board software controlled anti-aliase filters. The basic system has four channels of analogue-to-digital conversion but this can be extended in multiples of four up to sixteen. Digital-to-analogue conversion is also available.

The software has been specially written so as to provide the analysis needed for a wide range of human response to vibration problems (including hand-transmitted vibration, building vibration, motion sickness, the evaluation of seat transmissibility). It is also being used for the analysis of other types of vibration, noise and physiological measurements.

All frequency weighting for human response to vibration in relevant British and International Standards can be implimented using digital procedures in HVLab. Time histories, spectral analysis, coherencies, transfer functions etc. can be displayed graphically and plotted. The values can also be printed and stored on a disc.

The HVLab system has been described elsewhere [5, 6]. The application of the system to hand-transmitted vibration will be illustrated and demonstrated during the meeting.

2.0 REFERENCES

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