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PROBLEMS IN INTERPRETING THE BRITISH AND ISO STANDARDS FOR ASSESSING HAND TRANSMITTED VIBRATION EXPOSURE

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1. INTRODUCTION

International and British Standards for assessing human exposure to hand transmitted vibration, ISO 5349: 1986 [1] and BS 6842: 1987 [2], define a basicentric measurement coordinate system 'originating, for example, in a vibrating appliance, workpiece handle or control device gripped by the hand'. The three axes of measurement should approximately relate to an anatomically based coordinate system also defined in the Standards. Both Standards apply equal importance to each vibration axis. However in assessing the injury potential of tools from the frequency weighted acceleration the British Standard suggests that 'dominant axis' data can be used but does not define dominance and the ISO Standard suggests highest axis data can be used.

Experience in measuring hand transmitted vibration exposure has shown that 'dominant axis' based measurements of vibration exposure are not applicable to the vast majority of tools and processes producing hand transmitted vibration. There are many cases where an operator's hand is constantly changing grip and position either on the handle of powered hand tools or on the work piece. In these cases the anatomical coordinate system is constantly changing with respect to the basicentric coordinate system during vibration measurements. Further, very few tools or processes exhibit a truly dominant axis of hand transmitted vibration.

In cases where the dominant vibration axis is indeterminate the vector sum of the three vibration axes has been used by the Research and Laboratory Services Division of the Health and Safety Executive (HSE) to provide an indication of the true vibration exposure.

2. COMPARISON OF DOMINANT AXIS AND VECTOR SUM

In the ideal measurement situation the dominant vibration axis of a tool will exactly match one of the measurement axes. In such cases it is clear that a dominant axis measurement represents the vibration energy entering the hand. However, in practice this situation is the exception rather than the rule: the hand orientation may be randomly aligned with the measurement axis, the vibrational axis of the tool may not be aligned with a measurement axis or the vibrational axis may be moving with respect to the measurement axes. If it is assumed that the quantity of interest is the total vibration energy entering the hand, and not the energy entering the hand along any one of the three anatomical axes, then the vector sum will in general give a better representation of the vibration exposure than the dominant axis measurement.

The results of triaxial vibration measurements made by the HSE for a number of tools of various types are given in Table 1 and shown graphically in Figure 1 as ranges of rms weighted vibration magnitudes, comparing both dominant axis and vector sum measurements. Where data were also available from published papers this has been included in Figure 1; it has been assumed that these data are based on dominant axis measurements. The range of measured weighted acceleration magnitudes for some tools/processes is wide. Although it might be expected that the vector sum values would be higher than dominant axis this is not clearly shown by this form of presentation.

Therefore the results of individual vibration measurements made by the HSE have been reviewed and the dominant axis measurement compared to the vector sum in each case (Table 2 and Figure 2). It should be noted that if the vibrational axis is at 45 degrees to all measurement axes then a dominant axis measurement will be 58% of the vector sum and thus this represents the lowest percentage which could be found. It can be seen from Figure 2 that the dominant axis measurement often produces a significantly lower estimate of vibration magnitudes than the vector sum. The only exception is for measurements on chipping hammers with non-captive chisels, where the 'handle' of the chisel is the chisel body. For these chisels the chipping axis is aligned with the y axis of the basicentric coordinate system and there is relatively little contribution to the overall vibration from the x and z axes.

3. DISCUSSION

Both the British and International Standards for the assessment of hand transmitted vibration exposure [1,2] suggest that it is sufficient to derive the vibration exposure levels from dominant or highest axis measurements. Therefore hand transmitted vibration exposure assessments made according to either Standard may underestimate the true vibration exposure level.

It has been shown above that by simply using the dominant axis measurement as the basis for daily exposure assessment large errors can be introduced. In the worst cases the dominant axis measurement may only be 60% of the true vibration magnitude.

The use of the vector sum improves the estimate of total vibration magnitude. It does, of course, add to the difficulties involved in measuring a daily dose figure. However, it may not always be necessary to determine the vector sum. If the vibration magnitudes in the two non-dominant axes are both less than half of the dominant axis then the dominant axis must be at least 82% of the vector sum. If the two non-dominant axes are both less than one third of the dominant axis then the dominant axis must be at least 90% of the vector sum. Thus it is possible to set specific criteria describing when it is appropriate to use dominant axis data to assess vibration dose.

These differences between assessments become significant when daily exposures are considered relative to proposals for 'action levels' for reducing vibration exposure. Several European countries are considering action levels equivalent to around 3 ms^{-2} for an 8 hour day. Table 3 compares the highest axis with the vector sum weighted vibration exposures normalised to an 8 hour day for examples of several tools. These data have been taken randomly from the HSE data presented in Figure 1. The highest axis data for chainsaws, pedestal grinders and angle grinders are close to 3 ms^{-2} and might be judged 'acceptable' allowing for measurement accuracy. However if the judgement was made on vector sum data all could be assessed as 'unacceptable' and if the tools could not be modified (or replaced), to reduce exposure daily, usage might have to be restricted by 20 - 40%. Such restrictions might have major impact on users of the tool. Clearly the interpretation of the Standards in respect of dominant axis or vector sum has great significance when applied in the context of 'action levels'.

It should be noted that the data presented in Figures 1 and 2 (Tables 1 and 2) are the rms weighted accelerations determined for a short period of tool usage. There can be very large differences between these rms values and daily exposure normalised to 8 hours. Figure 3 illustrates this.

Examination of the references cited in the British and International Standards for assessing hand transmitted vibration exposure does not clearly establish if the dose-response relationship given in their appendices has been developed from solely highest axis data or vector sum data. Neither does it indicate whether, if single axis data have been used, the data relates to a particular axis of either the basicentric coordinate system on the tool or the anatomical system based on the hand. In general it appears that the data are inconsistent in respect of highest axis, vector sum and coordinate system. Thus it cannot simply be assumed that it is more correct to use dominant axis data than vector sum data in assessing the effects of a particular exposure according to the appendices in the Standards.

4. CONCLUSIONS

The vector sum method for determining hand transmitted vibration exposure will always provide a good measure of the total vibration magnitude. If the relative importance of the non-dominant axes is assessed to be small, then the dominant axis will be a good estimate of the vector sum.

With European action levels for hand transmitted vibration exposure being discussed it is important that the Standards for measurement of vibration provide for accurate and unambiguous measurement of exposure levels. It is therefore important that the issue of 'dominant axis' measurement should be clarified.

The views presented in this paper are those of the authors and not those of the Health and Safety Executive.

5. REFERENCES

[1] INTERNATIONAL STANDARDS ORGANISATION, 'Mechanical vibration - Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration', ISO 5349 1986.

[2] BRITISH STANDARDS INSTITUTE, 'British Standard Guide to Measurement and evaluation of human exposure to vibration transmitted to the hand' BS 6842 1987.

Table 1. Values of rms weighted acceleration (in ms^{-2}) included in Figure 1

	Highest axis	Vector sum	External data
Pedestal grinder	3.1 - 34.9	3.9 - 38.1	2.0 - 7.5
Angle grinder	1.1 - 30.9	1.6 - 37.6	0.3 - 13.2
Pneumatic grinder	1.1 - 6.8	1.1 - 7.9	-------
Electric grinder	1.2 - 2.2	1.8 - 2.9	5.0 - 8.0
Angle sander	0.8 - 2.2	1.1 - 2.6	1.5 - 2.7
Chipping hammer	35.3 - 87.0	35.6 - 87.3	-------
Chipping hammer (non-captive chisel)	22.9 - 39.1	24.7 - 47.7	1.0 - 47.3
Pounding machine	5.9 - 17.3	8.9 - 23.1	-------

Table 2. Ratio of highest axis weighted rms acceleration to vector sum (values included in Figure 2)

	Highest axis : vector sum range (%)
Pedestal grinder	66 - 96
Angle grinder	63 - 95
Pneumatic grinder	62 - 90
Electric grinder	67 - 76
Angle sander	73 - 88
Chipping hammers	74 - 93
Chipping hammers (non-captive chisel)	99.1 - 99.7
Pounding machine	61 - 75

Table 3. Highest axis and Vector sum data samples
Figures are weighted vibration normalised to 8 hours

	Highest axis (ms^{-2})	Vector sum (ms^{-2})
Chain saw (Rear handle)	2.4	3.6
Pedestal grinder	3.4	5.2
Angle grinder	3.7	5.0
Pneumatic grinder	1.6	2.3
Angle sander	4.0	5.8
Chipping hammer	10.8	14.6
Chipping hammer (non-captive chisel)	68.8	69.1
Pounding machine	0.7	1.1

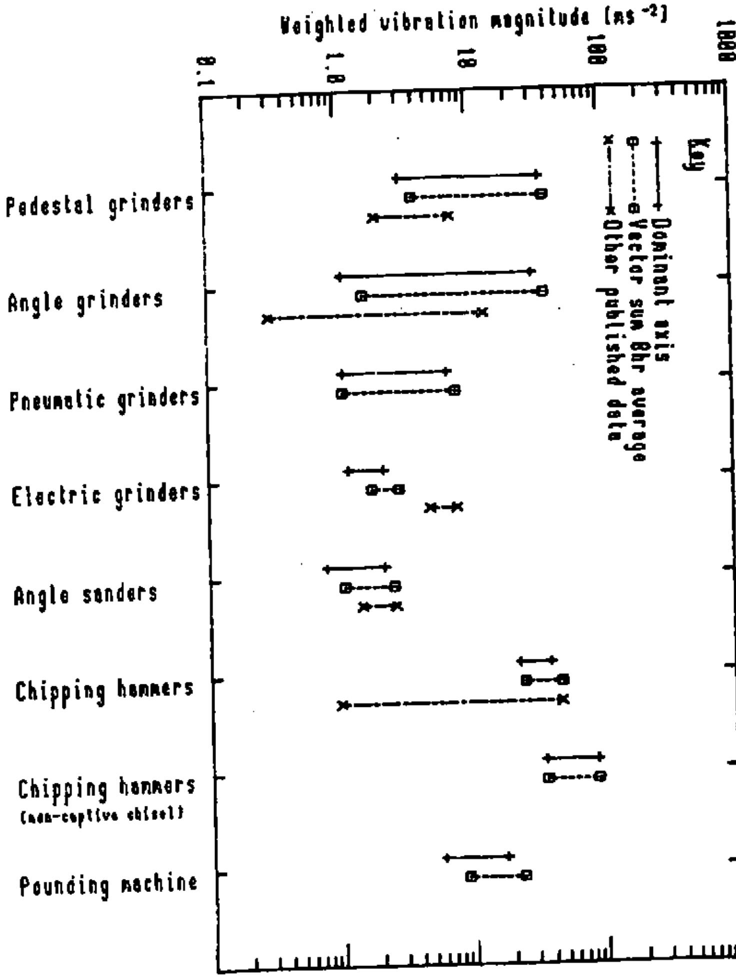

Figure 1 Range of rms weighted vibration

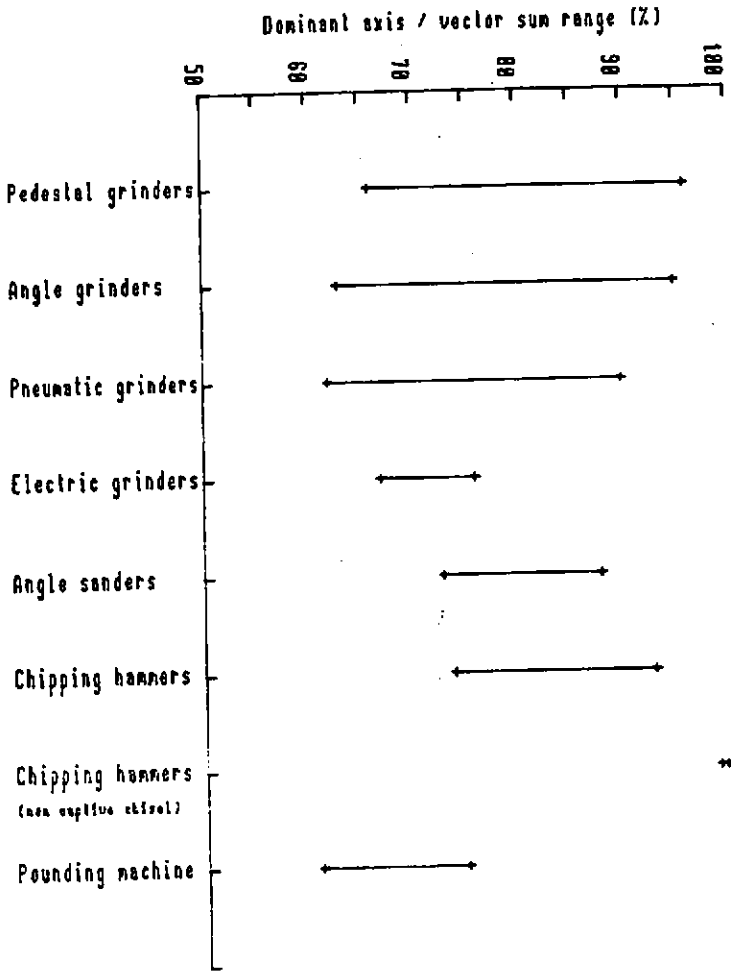

Figure 2 Ratios of dominant axis to vector sum weighted vibration levels

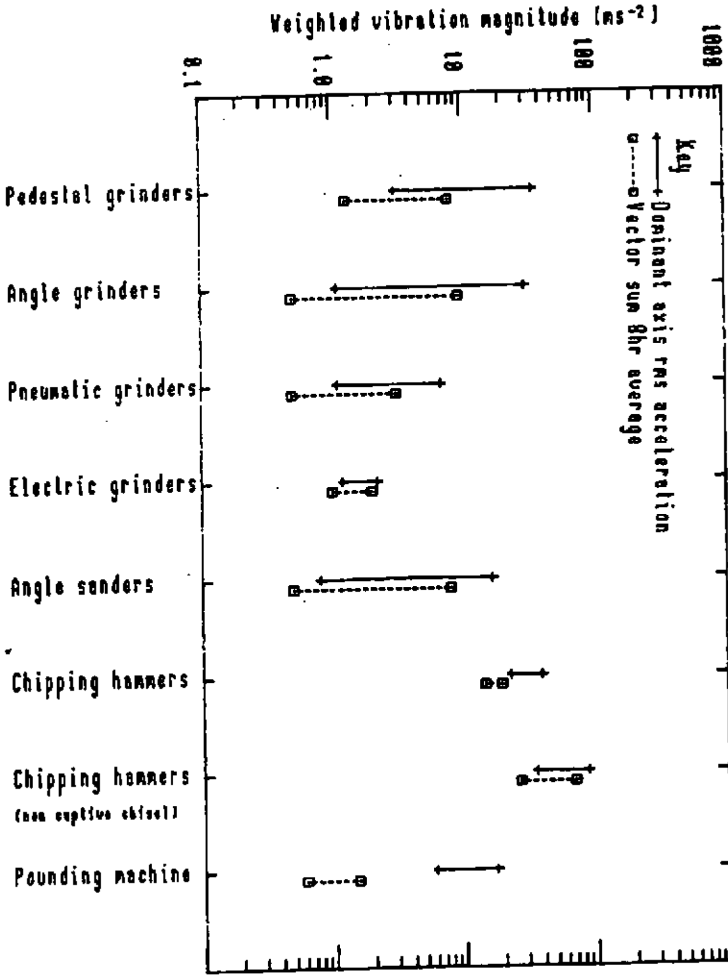

Figure 3 Comparison of rms and 8 hr average vibration magnitudes