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FREQUENCY ANALYSIS FOR HAND-ARM VIBRATION MEASUREMENTS

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1. INTRODUCTION

Driven by new legislation and research hand-arm vibration assessments will be carried out over the next few years by a variety of individuals with varying levels of training and with access to different types of equipment. The simplest approach involves the use of a simple vibration meter with a hand-arm frequency weighting built in. Apart from cost, this has the advantage of requiring a minimum of operator training, and also a minimum of post-measurement calculation. One disadvantage may be the costs and staff time involved in acquiring and maintaining an instrument which has one function and may therefore be used infrequently.

Where frequency analysis equipment is used for hand-arm vibration measurements there are benefits arising from the more detailed information which is stored. These benefits are to be set against possibly greater requirements in terms of staff training, while the added cost of the equipment may for some organisations be justified by its greater flexibility.

Vibration spectra measured at the handles of a number of hand-held woodworking tools are here examined from a vibration dose management perspective.

2. HAND-HELD WOODWORKING TOOLS

Many of the types of hand-held tools used in DIY also find applications in industry. Professional tools are intended for continuous use and tend to have a more robust design which will have an effect on vibration levels, but tools mainly intended for the domestic market may also appear in a workplace situation. While woodworkers do not normally figure in lists of those who are most at risk from VWF, many of those working with wood have reported numbness and/or tingling and in some cases difficulty carrying out fine work after prolonged use of this type of tool. The measurements used here were originally made by a former joiner interested in the correlation between these subjective effects of vibration exposure and the daily vibration doses thought to lead to VWF. The tools selected for the study were those where these effects were reported to be particularly noticeable and consisted of;

- orbital sanders
- jigsaws
- belt sanders

In the first two of the above cases, the mode of operation of the tool is such that high vibration levels are to be expected. In the case of belt sanders on the other hand it is less obvious that high vibration levels will be encountered, and in fact a belt sander might be suggested in some circumstances as a lower vibration alternative to an orbital sander. Similarly, there is an expectation that the vertical axis (relative to the tool) will be the dominant one in the case of a jig-saw and that the two horizontal axes will both be significant in the case of the orbital sander.

The tools used for this study were ones which had been used for various periods as it was felt that results from these would be more useful than those from new tools. The downside of this is that manufacturers test data was not available, and that few of the tools were currently available models. Availability of individual models varies rapidly with time, and, despite the international nature of the manufacturing companies, between countries.

3. MEASUREMENT PROCEDURES

Measurements were made using an accelerometer attached to a V-shaped aluminium block cable-tied to the handle of the tool. The measurement axes were so far as possible aligned with those of BS 6842 (BSI, 1987). A pre-amplifier fed the signal to a Norsonic 830 frequency analyser. The sanders were all equipped with two handles, and measurements were made on both handles under a variety of operating conditions. For example different grades of sanding sheet were used and were applied to different materials, although the pressure applied was so far as possible kept constant in all cases.

4. RESULTS

4.1. Orbital Sanders

The orbital sander results shows a predictable frequency dependence. One frequency is dominant, and this can be deduced to some extent from the rotation speed which is normally quoted by the manufacturer as a range (eg 10,000 - 20,000 rpm ≡ 167 - 333 Hz), the exact frequency depending on loading. The significance of the 2nd and 3rd harmonics of the dominant frequency varies between individual tools. Vibration amplitudes along the x- and y- axes (essentially the horizontal axes) are markedly different, and often change over between the front and rear handles. This will reflect the position of the two handles relative to the centres of mass and of rotation. z-axis amplitudes are also surprisingly high for these tools. Some tools consistently show higher overall vibration amplitudes at the front handle than at the rear one, a point of some importance when interpreting manufacturers' vibration data.

Spectra presented here (figs 1, 2) are for the two handles of one tool using 80 grit sheets on plywood.

Data for a number of orbital sander measurements is summarised here, showing first the hand-arm weighted acceleration levels calculated from the whole spectrum, and secondly the hand-arm weighted level calculated by ignoring all but the 160 Hz band;

		H-A weighted acceleration/ms^{-2} (overall)		H-A weighted acceleration/ms^{-2} (160 Hz band only)	
Tool #	Grit	Rear	Front	Rear	Front
1	80	15.8	17.3	15.5	16.5
1	120	15.4	15.4	15.1	14.7
2	80	10.5	19.2	9.2	17.8
2	120	9.8	25.8	8.9	24.2

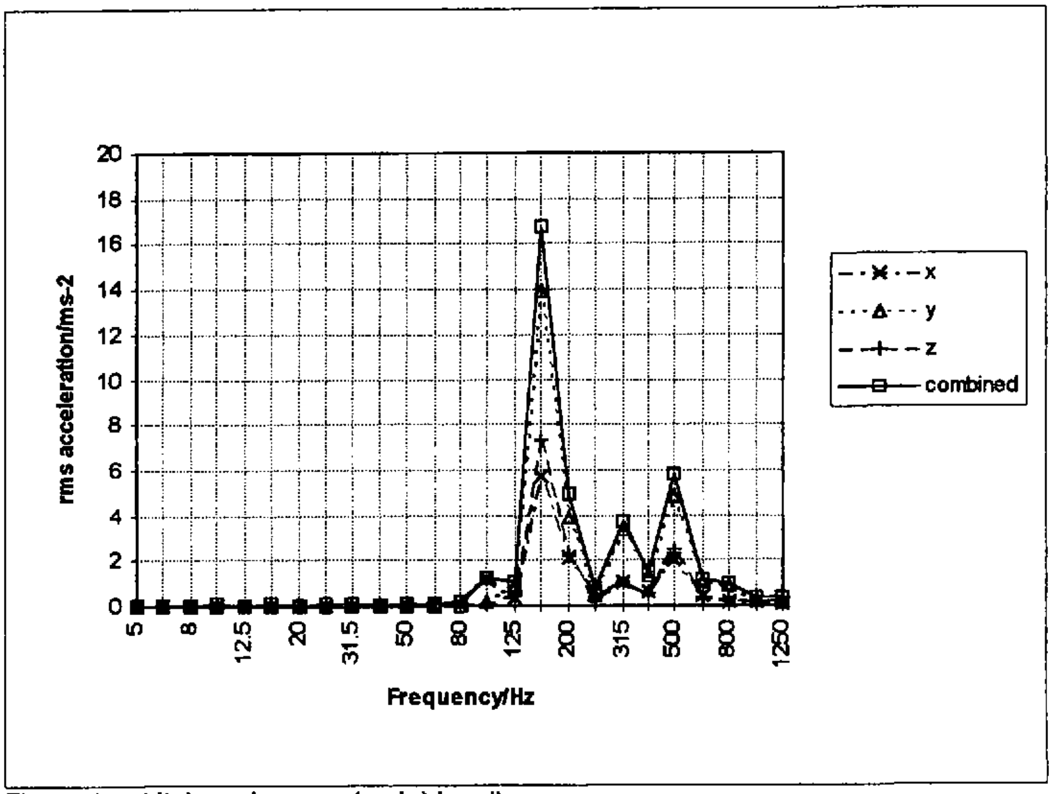

Figure 1; orbital sander, rear (main) handle

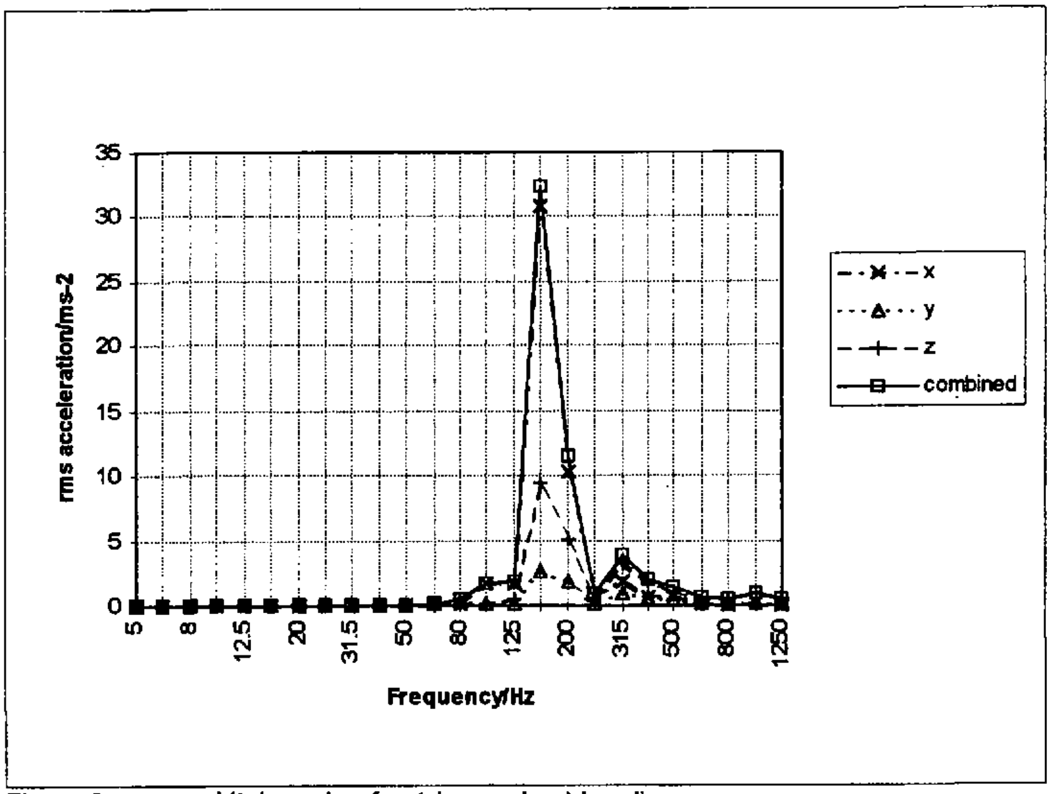

Figure 2; same orbital sander, front (secondary) handle

4.2. Belt Sanders

The sources of vibration within a belt sander are more varied, and spectra from different machines have peaks which are less prominent and occur in various bands which, however, tend to be at higher frequencies than those from orbital sanders.

Hand-arm weighted levels measured under various circumstances are as follows;

		H-A weighted acceleration/ms^{-2} (overall)	
Tool #	Grit	Rear	Front
1	60	1.58	1.02
1	100	1.85	1.36
2	80	2.26	2.21
2	150	2.15	1.86

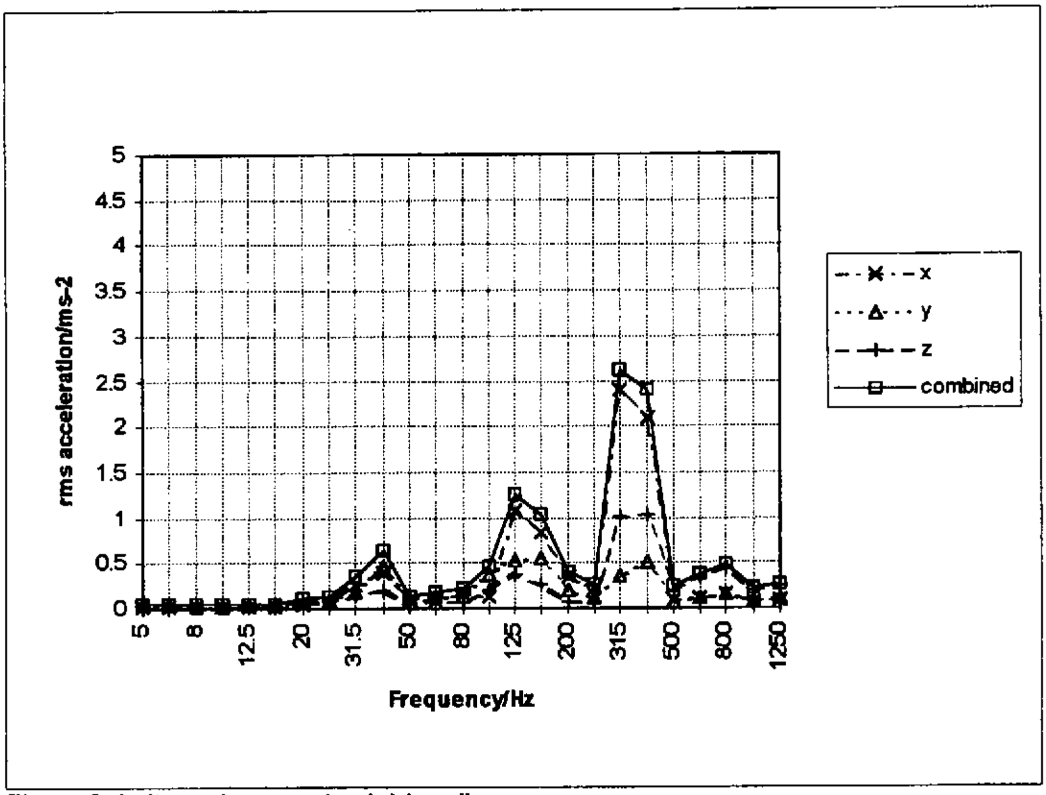

Figure 3; belt sander, rear (main) handle

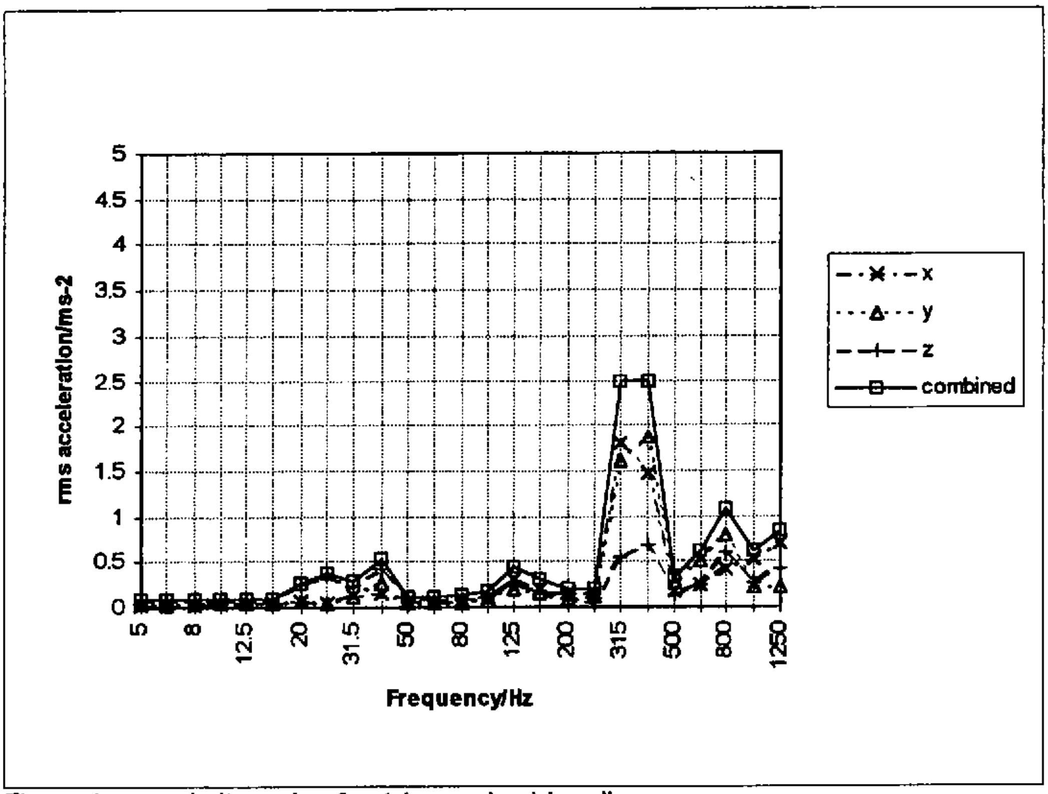

Figure 4; same belt sander, front (secondary) handle

4.3. Jig Saws

The vibration energy at the handle of a jigsaw can be assumed to derive partly from the reciprocating motion of the blade, and partly from the impact of the teeth with the workpiece. No attempt has been made here to identify the source of each peak in the spectrum. Figs 5 and 6 show that compared with the sanders, the energy is concentrated in lower frequency bands, and there is normally more than one peak. All the measurements here were made on single speed tools; variable speed jigsaws will pose additional measurement and assessment problems.

Combined axis hand-arm weighted levels measured when cutting a variety of materials are summarised here;

	Weighted acceleration levels using tool #		
Material	1	2	3
Hardwood cross cut	8.0	6.9	19.5
Hard wood rip cut	7.6	7.5	26.2
Softwood cross cut	5.5	4.5	21.5
Softwood rip cut	5.4	5.3	24.4
Blockboard cross cut	6.3	4.3	26.2
Blockboard rip cut	5.8	5.2	24.0
17 mm sheathing ply	6.2	5.0	20.1
4 mm plywood	6.0	3.8	23.9
12 mm chipboard	5.6	3.5	24.0

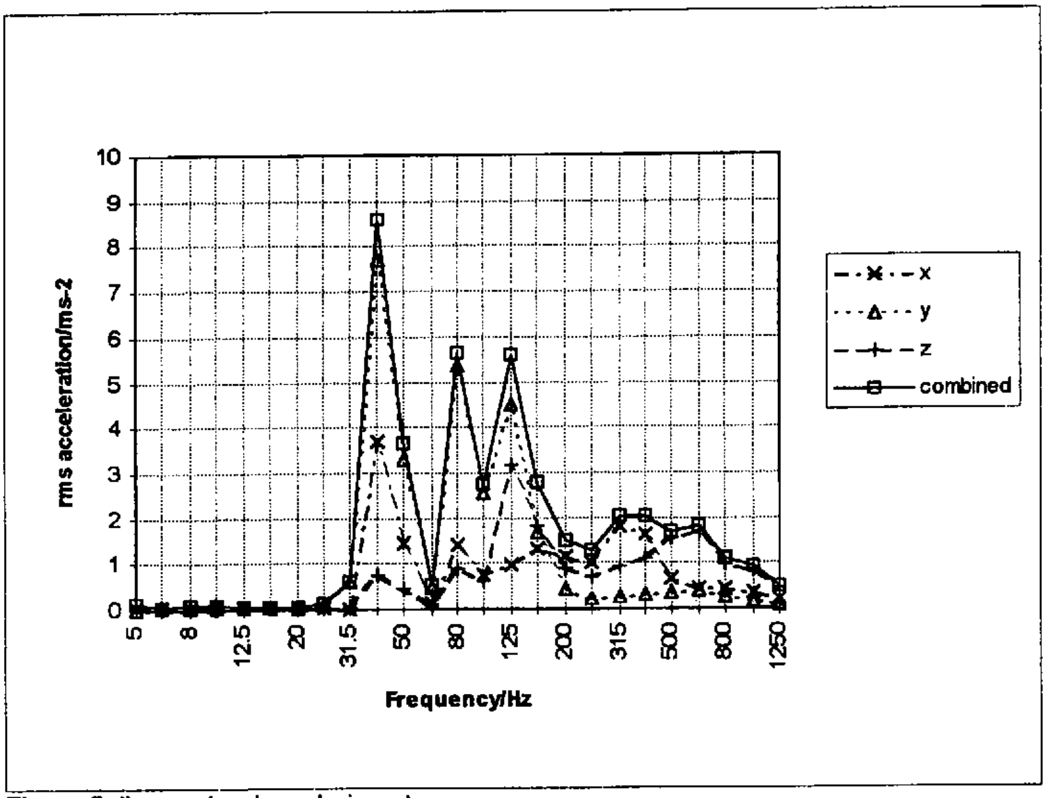

Figure 5; jigsaw, hardwood, rip cut

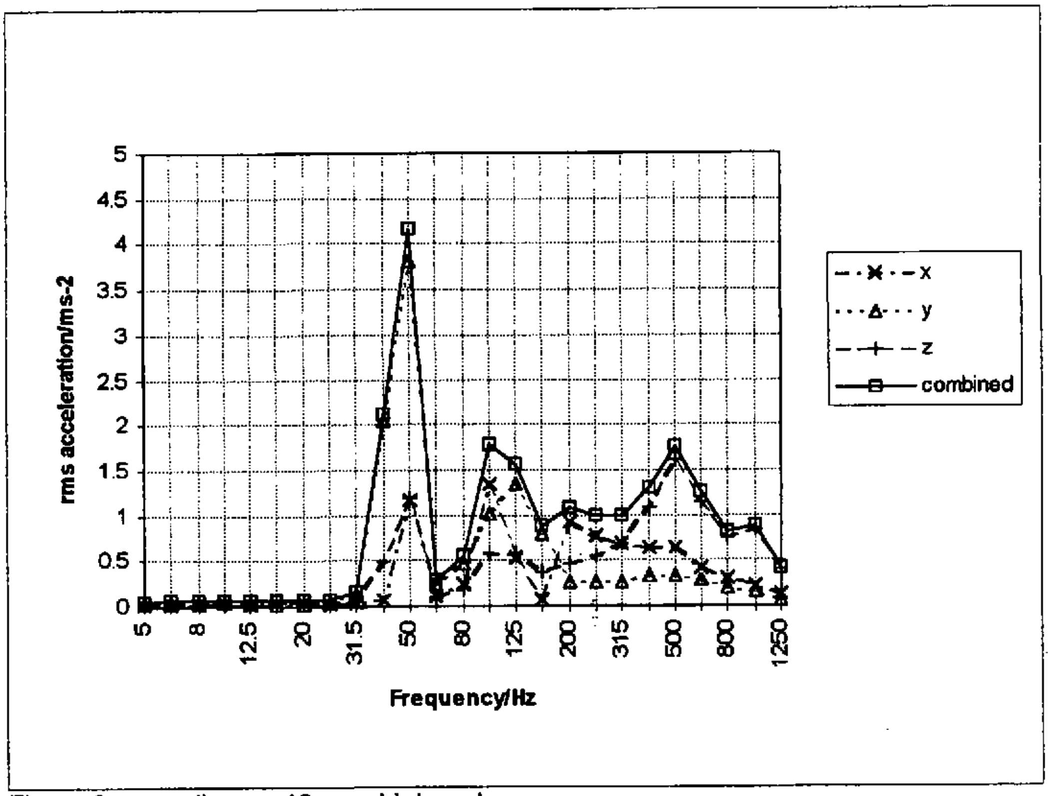

Figure 6; same jigsaw, 12mm chipboard

5. DISCUSSION

To justify the extra expense in equipment and staff time involved in frequency analysis of hand-transmitted vibration, there need to be quantifiable benefits. These could include;

- a greater understanding of the relationship between short-term/subjective effects of vibration and the likelihood of long-term vascular damage
- ability to update existing measurements if and when recommended frequency weightings are changed
- the possibility of identifying the sources and transmission paths of vibrational energy within tools with a view to modifying existing tools, informing future purchasing decisions, or planning maintenance programmes.

The tools investigated here show spectral characteristics which are different from many of those implicated in VWF. The orbital sanders, in particular, exhibit very prominent peaks in one 1/3 octave frequency band, which contain typically 80 - 90% of the vibrational energy present. Tools such as grinders are characterised by a broader range of frequencies (Griffin, 1990). While these were woodworking tools, similar devices are used in engineering and they have advantages in terms of their lightness and manoeuvrability over the belt sanders.

The current frequency weighting used to assess hand-arm vibration exposure was originally derived from measurements of subjective response to vibration and has been criticised as attaching to much weight to frequencies below 20 Hz as opposed to the range from 20 - 250 Hz. Future changes to the existing weighting, or the introduction of additional weightings would require repeated measurements in cases where only a weighted measurement has been made. Frequency data such as that presented here, however, can easily be re-worked to generate alternatively weighted figures. Where a sharp peak exists, the resulting assessments may be particularly sensitive to the details of any weighting eventually adopted.

If it is generally true that the type of tools investigated here give rise to short term and subjective effects in their users' hands more frequently that they give rise to VWF, then there is a case for investigating further the reasons for this. It may be that the nature of the work done with these tools is such that they are used infrequently but are operated then for extended periods (compared with other tools whose use may be more uniform). Alternatively, the vibration present may have characteristics (such as the shape of the spectrum) which produce these short term effects more readily. Some employers may be concerned at short term effects which limit their employees' ability to perform delicate tasks or to easily assess the finish quality achieved after the use of these tools.

6. CONCLUSIONS

1. The dominant frequency(s) present in the vibration spectrum from these hand tools proved easy to predict.

2. The relative importance of the different axes was much less predictable.

3. As expected, belt sanders gave rise to lower levels of vibration than orbital sanders. Nevertheless belt sander use, on these figures, would require a dose assessment to be made.

4. Where a tool has two handles, vibration levels must be assessed at both.

5. Where the equipment and expertise are available to record vibration frequency spectra, this data can be a powerful tool for the management of hand-arm vibration doses. It can enable;

- the updating of assessments to take account of future changes to frequency weightings

- the updating of assessments in the light of research on non-VWF effects of vibration exposure
- the setting of criteria for tool maintenance and acquisition programmes.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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