Hand-Arm Monitoring - Is anyone doing the right thing?

Overview

There is now a legal requirement for employers to ensure that all reasonable steps are taken to protect the workforce against vibration induced medical conditions. The relevant Directive specifies measuring and monitoring techniques defined in EN standards written over 20 years ago. It is argued that these techniques do not provide adequate protection and that recent advances in technology offer an opportunity for a significantly improved monitoring regime to be established. However, the standards as currently written specifically hinder any progress towards this ideal.

Background

The ‘Physical Agents’ Directive requires (amongst other things) employers to take steps to minimise the level of vibration delivered to the hands of operators of hand help equipment. This is to ensure that employees do not suffer vibration levels that may affect their health. This requirement became mandatory in 2005. One of the consequences of this requirement is the need to record the vibration dosage experienced by each operator and to ensure that they do not exceed a specified maximum value in any 24 hour period. The relevant standards (EN ISO 5349 and EN ISO 8041) were originally developed and published in the 1990’s and were based on a considerable weight of research into the connection between White Finger (Reynauds Syndrome) and vibration. This led to the establishment of an absolute maximum ‘daily’ vibration dose limit known as A(8) m/s^2 To make assessments easier to understand the dose is converted to ‘HSE points’ which have the advantage that if you double the length of time that a tool is used, you double the points, and they can be added together when an operator uses two or more tools in one day. The maximum allowable daily does is 400 HSE points, ($5m/s^2$ (A8)), and an action level of 100 points ($2.5m/s^2$ (A8)). This action level defined a figure above which steps should be taken to reduce the vibration dose to a lower level wherever practicable. (HSE points are defined in H & SE ‘The Control of Vibration at Work Regulations 2005, Guidance on Regulations, para 135).

Methodology

The standards also defined the methods by which the vibration dose should be measured. The instrumentation is defined in ISO 5349. Obviously, this was based on the technologies that were current at that time. There were no techniques available that could measure the actual vibration dose transferred from the tool to the hand, so an alternative strategy was adopted. This involved a ‘risk assessment’. For each type/model of tool, the vibration level was measured in laboratory conditions by attaching a tri-axial accelerometer to the tool, ideally close to the handle, and measuring the vibration level with a suitable instrument. The standard defined the characteristics of this vibration measuring instrument in detail. These included a frequency weighting function that matched the human response to vibration. This response has a peak at a frequency of 11.4Hz, in other words, vibration at this frequency has the most damaging effect on the hand. At frequencies above and below this peak, the potential for damage gradually reduces. The end result of these laboratory measurements is a figure for the vibration level of each tool. From this, the expected vibration dose per minute (or hour) of operation can be calculated. For example, a tool might have a vibration level that would give a dose of 66 HSE points per hour, so the maximum usage per day in order not to exceed the action level would be 1.5 hours (assuming no other tools were used during that day).

This strategy has become a common practice. In order to improve the accuracy of the dose calculation, ‘timers’ have been developed which can be attached to each tool and/or operator. These measure the duration of use of the tool and can be embedded with the tool vibration level information. This enables the timers to calculate the vibration dose in HSE points. Whilst this approach offers a relatively low cost and simple solution, it raises the question of whether the results are meaningful.

Limitations

It is well known that the actual vibration level experienced by the operator is dependent on many factors which are not taken into account by this ‘common practice’. These include ….

- Age, wear and tear of the tool;
- Condition of the machine;
- The hardness and other factors of the material being worked;
- The way in which the tool is gripped by the hand;
- The stance of the operator;
- The effect of the rubber cushioning on the handle;
- The effect of any anti-vibration gloves.

These factors have a very substantial effect on the vibration dose inflicted on the operator’s hand. For instance, it might be thought that the way in which the tool is gripped would not cause significant variations, but we have observed extremely wide variations in dosage entirely due to this one factor. One recent situation that was reported to us, an operator recorded a vibration dosage several times higher than the manufacturer’s figures, whilst another operator using the same tool recorded dosage in line with the expected value based on time of operation. Investigation proved that this abnormal result was due to the way in which the tool was held. The first operator was subsequently re-trained in the correct use of the tool and a potential health issue was avoided. Surely, this kind of situation is precisely what any vibration monitoring regime should address.

The use of time of operation is simply blind to this circumstance.

Can we do better?

The sensible alternative would be to measure the actual vibration level transferred to the hand during normal operation. The Control of Vibration at Work Regulations 2005, Regulation 5 (2c) relating to the assessment of daily exposure to vibration states, ‘if necessary, measurement of the magnitude of vibration to which the employees are exposed’. His means actual measurements on the operator. No laboratory measurements, no assumptions, no calculations, no timing, just simple measurement of the actual dose. There is no doubt that if suitable technologies were available at the time that the standard was written, this would be the adopted method. Some 20 years later, however, technology has moved on and techniques are now available to perform this measurement of actual vibration dose experienced by the hand. These advances include ….

- Miniature tri-axial accelerometers;;
- High speed data processing chips;
- Miniature digital memory chips;
- Small high capacity batteries;
- Miniaturisation of electronic assemblies.

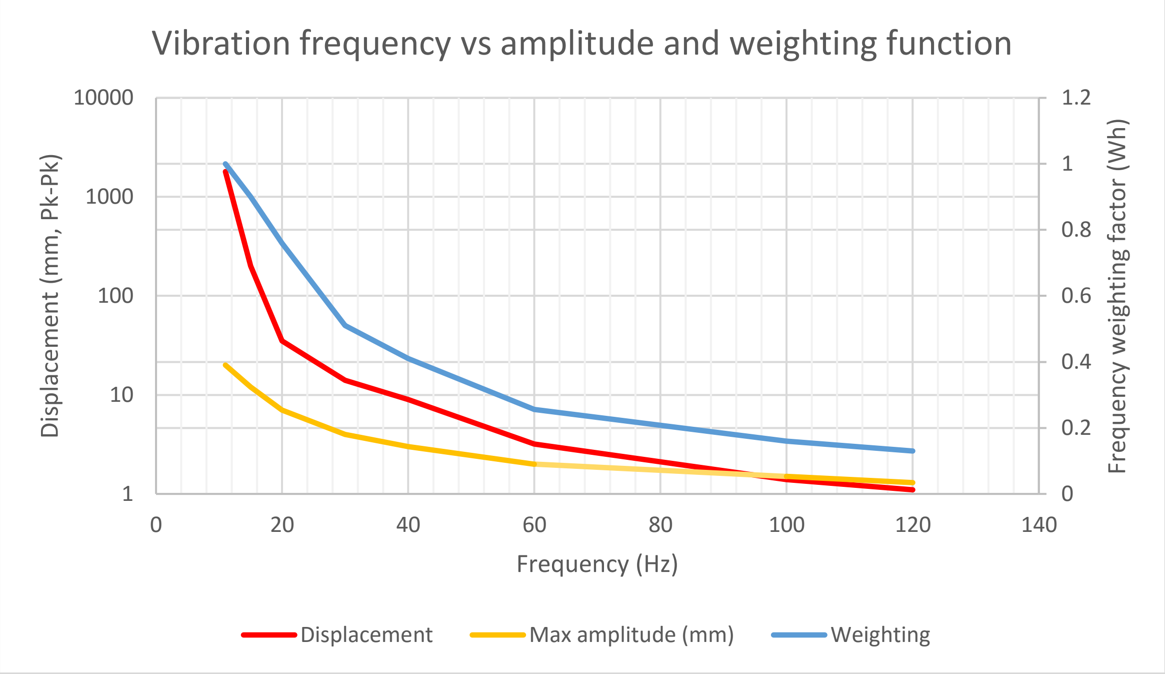
These enable the manufacture of a dosimeter that can be worn inside the work glove, measure the vibration level transmitted to the hand, apply the specified frequency weighting, process the three axes of vibration data, compute the HSE points, process any overloads, store this data every second, and continue these processes for at least 12 hours. At the end of the shift, the whole record can be downloaded automatically to a PC for archiving and display. This provides an ideal solution, namely an accurate record of the dose suffered by the hand, rather than an estimate based on the vibration level of the tool under artificial laboratory conditions.

The Compromises

1. Solutions available today include relatively low cost accelerometers based on MEMS techniques (MicroElectroMechanical Systems) which offer very small size, low power

consumption and high accuracy. This makes them an ideal component for use in vibration dosimeters. Their limitation relates to the maximum level of acceleration they can measure, typically 18g (180mm/s^2), whilst the conventional transducers can measure to significantly higher levels. The MEMS devices do however have an advantage over the conventional more expensive and heavier piezo-electric types that are conventionally used in a lab. These suffer from a saturated state when overloaded, an issue that is recognised in the standard. In this state they become unresponsive for a period of time whilst they recover. MEMS devices do not suffer this effect, but the consequences of a maximum limit of 18g needs to be assessed.

Figure 1 shows the relationship between frequency, amplitude and the weighting function (Wh).



The amplitudes are plotted against the left hand axis and show the values for an 18g acceleration situation. The red line is the amplitude necessary to give the 18g result. This shows that at low frequencies, the necessary amplitudes become very high, for example at 11Hz the required amplitude would have to be 1.4 metres pk-pk. Clearly this is not achievable in reality. The yellow line is the maximum amplitude that can reasonably be expected. The two lines cross around 100Hz at an amplitude of 1.5mm. Above this frequency a level of 18g may be experienced in extreme circumstances. However, at 100Hz the weighting function as shown by the blue line, is 0.16 and diminishing further as frequency increases, so the overall effect on the dose level is relatively small. Where the limitation of 18g may give concern is with tools that deliver high transient (shock) loads. These transients may involve levels well over 18g, but ‘conventional’ accelerometers, especially if bolted directly to the tool, may also suffer overloads, with the added problem of saturation as mentioned earlier. An additional mitigation which favours the ‘new’ approach is that the cushioning of the handle and the work glove tends to become more significant as frequency increases, thus attenuating these high level transients, which by definition, have dominant high frequency components.

2. Clamping. When we are measuring the vibration of the tool, it is important that the accelerometer is firmly clamped to it. However, if we are measuring the vibration induced into the hand or finger, it makes sense to locate the sensor (tri-axial accelerometer) inside the work glove, held between the fingers such that the operator’s grip holds it against the tool handle. This means that the sensor will no longer be firmly clamped to the tool. . However, it

will be subject to the same vibration levels as the fingers. This is precisely what we need to measure as regards white finger risk.

The Directive

Which is more important? Meeting the requirements of a standard, (written before suitable technologies became available), or meeting the intent of the Directive, thus providing better protection for the workforce?

It is clear to the author that this latter strategy provides a far better solution to the requirement for measuring/monitoring the vibration dose 'suffered' by the operator. It offers a solution which fully meets the purpose of the Directive, even though it uses a methodology not defined in the relevant standard.

EN ISO 5349 includes some additional requirements, stated as guidelines….

- Condition of the tool to be recorded. It adds that the characteristics of a vibrating tool can be highly variable.
- The positions and orientations of the operator's hands should be reported. The operator's posture should be described.
- The contact forces between the hand and the griping zone are likely to affect the vibration energy transferred to the hand.

This shows that the standard recognises the shortcoming in it's approach. Are any of the above variables actually recorded in the real world? I suspect we all know the answer to that query.

Clearly, recording actual vibration input to the hand overcomes much of the issues related to these guidelines.

Also desirable…

- Three axes measured and reported separately.
- Time histories to be recorded and retained.

A system such as supplied by HAVSCo provides all these requirements, and the 'real' measurement of the vibration dose suffered by the operator.

Maybe it is time for the standards to be revised such that the recent advances in technology can be utilised to then benefit of our workforce?