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Necessity of Wearable Personal Vibration Exposure Meters for Preventing Hand-Arm Vibration Syndrome

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Abstract

The purpose of this paper is to clarify the limitations of 2002/44/EC Directive, ISO 5349-1 standard, and the Japanese Guidelines and to give some new solutions for preventing hand-arm vibration syndrome.

1. Introduction

The EU Directive 2002/44/EC [1] of the Physical Agent Directive (Vibration) defined three things to employers. For preventing hand-arm vibration syndrome (HAVS) among workers, employers must take the following measures: ① choose appropriate working equipment producing the least possible vibration, ②assess probable magnitude of the vibration, based on the daily exposure value normalized to an eight-hour reference period A(8) (5), and ③if possible, measure the levels of mechanical vibration to which workers are exposed at the worksite, to assess whether the health and safety of each worker is ensured. Among them, ① and ② are defined by new dispatched guidelines of the Ministry of Health, Labor and Welfare of Japan on July 10, 2009 [2]-[5], and many guidelines in the world. However, ③ has not been introduced to the new guideline at this moment, although the ISO/TC108/WG33 is considering to make the Personal Vibration Exposure Meter’s standard. The Digital Revolution and the changing face of work the HSE in UK is reporting that the wearable health and safety as a device can indicate potential health and safety risks [6].

The purpose of this paper is to clarify the limitations of existing standards and the special equipment of Wearable Personal Vibration Exposure Meter from Reactec Company in UK.

2. EU Directive: 2002/44/EC

In July 2002, the European Union published the Directive 2002/44/EC the Physical Agents Directive (Vibration) (PAD (V)). It outlines new guidelines for exposure to vibration in the workplace. It sets action and limit values for vibration exposure, and it describes the employer's obligations to manage the risks from exposure to vibration. This chapter is intended as a guide for the employer who has employees using vibrating hand-held power tools. We also give practical tips regarding what can be done to reduce vibration exposure from hand-held power tools. The Physical Agents (Vibration) Directive was developed from an original proposal made by the European Commission in 1993. This proposal was revised, amended and eventually agreed to by Member States and the European Parliament and came into force on 6 July 2002. The Directive lays down the minimum standards for the health and safety of workers exposed to hand-arm vibration and supports the general requirements for improving health and safety that are outlined in the Framework Directive (89/391 /EEC)[7].

For preventing HAVS, the A (8) is considering the introduction of risk assessment. The A (8) consists of the vibration total value of frequency-weighted r.m.s. acceleration and the daily exposure times. In the work place, managers of the vibration tool users must consider the risk to employees of using of the 'tool work tasks' before considering 'real work tasks' according to A(8). So, managers need the vibration total value of frequency-weighted r.m.s. acceleration of the individual tool. According to the EU Directive, the manufacturers have to declare the magnitude of the individual tool according to the test protocols or to the field measurements for preventing the HAVS in the workplace.

On 2002/44.EC Directive, human exposure to hand-arm vibration should be evaluated using the method defined in European Standard EN ISO 5349-1:2001[8] and the detailed practical guidance on using the method for measurement of vibration at the workplace is given EN ISO 5349-2:2001[9]. The vibration magnitude is expressed in terms of the frequency-weighted acceleration of the surface of the tool-handle or workpiece that is in contact with the hand it is expressed in units of meters per second (m/s^2).

Typically, vibration arises when a body oscillates due to external and internal forces. In the case of hand-arm vibration, the handle of a machine of the surface of a work piece vibrations rapidly, and this motion is transmitted into the human hand and arm. But, the EN ISO 5349-1:2001 standard is assumed that vibration in each of the three direction defined by the orthogonal axis is equally detrimental, and that the same frequency weighting may be used for each axis. The injury potential of hand-transmitted vibration is therefore estimated from the vibration total value, a_{hv}. formed from the three frequency-weighted component (single-axis) accelerations at the surface in contact with the hand as defined in this part of EN ISO 5349-1.

The EU Directive 2002/44/EC of the Physical Agent Directive (Vibration) defined three things to employers. For preventing hand-arm vibration syndrome (HAVS) among workers, employers must take the following measures: ① choose appropriate working equipment producing the least possible vibration, ②assess probable magnitude of the vibration, based on the daily exposure value normalized to an eight-hour reference period A(8) (5), and ③if possible, measure the levels of mechanical vibration to which workers are exposed at the worksite, to assess whether the health and safety of each worker is ensured. Among them, ① and ② are defined by EN ISO 5349-1 standard. As mention on the EN ISO 5349-1, annex D, the effects of human exposure to hand-transmitted vibration in working conditions may also be influenced by many factors. On 2002/44/EC, although the employers have to the following thing: ③if possible, measure the levels of mechanical vibration to which workers are exposed at the worksite, to assess whether the health and safety of each worker is ensured, at the moment, this ③ can't perform yet in the world. Although we are measuring the vibration magnitude of the tool handles, we can't measure the hand-transmitted vibration to human hand and arm for preventing the hand-arm vibration syndrome of each worker. Many researchers and many standards have been considered that the vibration magnitude on the tool handle assumed the hand-transmitted vibration into human hand and arm.

3. Dispatched guidelines of the Ministry of Health, Labor and Welfare of Japan

In March of 2006, the Ministry of Health, Labour and Welfare appointed a special committee to examine work management for the prevention of hand-arm vibration syndrome. This committee recommended adopting the EU Directive of MSD and PAD (Vibration) principles in the committee's final report in 2007. On 10th of July 2009, the Ministry of Health, Labour and Welfare published the following 4 guidelines [2]-[5]:.

1: LSB (Labour Standards Bureau) Issue No.0710-1[2]

Guidelines for Handling Chain Saws

2: LSB (Labour Standards Bureau) Issue No.0710-2[3]

Guidelines for Preventive Measures against Vibration Hazards in Work with Vibratory Tools other than Chain Saws

3: LSB (Labour Standards Bureau) Issue No.0710-3[4]

Management and Indication of Vibration Total Value of Frequency-Weighted r.m.s. Acceleration" of the individual tools

4: LSB (Labour Standards Bureau) Issue No.0710-5 [5]

Promotion of Comprehensive Measures against Vibration Hazards

The purpose of this section of the paper is to describe the implementation of the new Japanese Guidelines for preventing Hand-Arm Vibration Syndrome that was published on 10th July 2009 from the Ministry of Health Labour and Welfare.

Procedures of Work Management for Preventing Hand-Arm Vibration Syndrome (The responsibility of the employers and the workers)

The management method for preventing the hand-arm vibration syndrome based on the Daily Vibration Exposure A(8) as shown the following procedures.

Procedure 1. Evaluating the vibration total value of frequency-weighted r.m.s. acceleration of the individual tool

Employers must obtain the vibration total value of frequency-weighted r.m.s. acceleration of the individual tool.

Procedure 2: Calculation method of the Daily Vibration Exposure A(8)

In Procedure 2 calculations are made of on the amount of Daily Vibration Exposure A(8) consistent with the equivalent vibration acceleration value (Daily Vibration Exposure A(8)) from "the vibration total value of frequency-weighted r.m.s. acceleration" of the vibration tool which employers obtained through Procedure 1 and "the exposure time (the tool usage time)".

Procedure 1: Understanding the vibration total value of frequency-weighted r.m.s. acceleration of the individual tool

Employers must monitor the hazards of the vibration from the usage of the vibration tool in the workplace, and specify the hazards (the vibration total value of frequency-weighted r.m.s. acceleration of the individual tool) of vibration tool.

Procedure 2: Calculation of Daily Personal Vibration Exposure (A(8))

Employers must calculate the A(8) from the vibration total value of frequency-weighted r.m.s. acceleration from Procedure 1 and the Daily Vibration Exposure Times.

Procedure 3: Evaluating the necessity of a Vibration reduction plan according to the Daily Vibration Exposure A(8)

① In cases when A (8)>5.0 (Above the exposure limit value)

Take immediate action to bring exposure below the exposure limit value. In addition, management should implement controls on vibration exposure times and increase the utilization of low vibration tools.

② In cases of 2.5 < A (8)≦ 5.0 (Above the exposure action value, but the exposure limit value is not exceeded)

Implement a program of measures to reduce exposure and risks to a minimum. In addition, management should implement controls on vibration exposure times and increase the utilization of low vibration tools.

Procedure 4: Design and implementation of concrete vibration reduction plans according to Daily Vibration Exposure A(8)

The measures for limiting the daily amount A (8) of the vibration exposure is examined and implemented.

How to calculate daily vibration exposure A(8)

Daily vibration exposure A(8) is calculated from the declared values of "the vibration total value of frequency-weighted r.m.s. acceleration" that are provided by manufacturers, importers and employers, and the exposure time. Daily vibration exposure A(8) (an 8-hour energy equivalent frequency-weighted r.m.s. acceleration value) are found by Equation (3) using the vibration total value of frequency-weighted r.m.s. acceleration and the daily vibration exposure time. Therefore, easy comparisons can be made with the different daily vibration exposure times.

The daily vibration exposure $A(8) = a \times \sqrt{\frac{T}{8}}$ $[m/s^2]$ (3)

Where, a $[m/s^2]$ is the vibration total value of frequency-weighted r.m.s. acceleration.
T [time] is the daily vibration exposure time.

And, when the same worker uses more than one vibration tool on the same day, employers have to calculate the daily vibration exposure A(8) of the worker concerned by the Equation (4) from " The vibration total value of frequency-weighted r.m.s. acceleration" for each and every tool.

$$a_{hv(rms)} = \sqrt{\frac{1}{T_v}\sum_{i=1}^{n}(a_{hv(rms)i}^2 T_i)} \quad [m/s^2]$$

The daily vibration exposure

$$A(8) = a_{hv(rms)}\sqrt{\frac{Tv}{8}} \quad [m/s^2] \quad \cdot\cdot\cdot \quad (4)$$

Where, $a_{hv\,(rms)\,i}$ is the vibration total value of frequency-weighted r.m.s. acceleration of the work of the i turn; Ti is the tool usage time (vibration exposure time) of the work of the i turn; n is the total amount of work (number of jobs), Tv is the total vibration exposure time of the work of the n individual.

Procedure 3: Evaluating the necessity of a Vibration reduction plan according to the Daily Vibration Exposure A(8)

The employers must evaluate the necessity of decreasing the worker's vibration exposure from the daily vibration exposure A(8) obtained through Procedure 2 when daily vibration exposure A(8) exceeds the vibration exposure limit value 5.0 (m/s^2).

The employers must evaluate the necessity to decrease the vibration exposure to the worker when it exceeds 2.5 (m/s^2) even if the daily vibration exposure A(8) is less than 5.0 (m/s^2).

Procedure 4: Design and implementation of concrete vibration reduction plans according to Daily Vibration Exposure A(8)

(1) When the daily vibration exposure A(8) exceeds 5.0 (m/s^2):

When the daily vibration exposure A(8) exceeds 5.0 (m/s^2), the employers must investigate the cause, and depending on that cause, may need to limit exposure times and increase the use of low vibration tools.

(2) When daily vibration exposure A(8) exceeds 2.5 (m/s^2).

When the daily vibration exposure A(8) exceeds 2.5 (m/s^2), even if it is less than 5.0 (m/s^2), employers investigate the cause, and depending on that cause, may need to limit exposure times and increase the use of low vibration tools.

Among them, ① and ② of 2002/44/EC Directive are defined by new dispatched guidelines of the Ministry of Health, Labor and Welfare of Japan on July 10, 2009. These Japanese guidelines are using the vibration magnitude of the tool handles. These ideas are following the 2002/44/EC and the ISO 5349-1 standard. So, these guidelines are focusing to the vibration magnitude of the tool handle. These things are assuming that when the different worker will use the same vibration magnitude tool, the human response to vibration effects is the same. But, the effect from the vibration exposure is different. It can be understood that hand-arm vibration syndrome cannot prevented only with the vibration tool management. So, this means that we have to measure the hand-transmitted vibration to human hand and arm for preventing the hand-arm vibration syndrome of each worker.

4. Progress of ISO/TC108/WG33

Now ISO/TC108/WG33 is considering making the following standard:

Draft for ISO 8041-2 [10]
Human response to vibration — Measuring instrumentation —
Part 2: Personal vibration exposure meters

This part of ISO 8041 specifies minimum additional requirements for personal vibration exposure meters (PVEM) beyond those specified in ISO 8041-1. It is therefore intended to be used in combination with ISO 8041-1. This part of ISO 8041 is applicable to instruments designed for measurements of whole-body vibration (in accordance with ISO 2631-1 [11]) and/or hand-arm vibration (in accordance with ISO 5349-1). This part of ISO 8041 provides specified design goals and permitted tolerances that define the minimum performance capabilities and functional requirements of instruments designed to measure personal daily vibration exposure. Instruments meeting the requirements of this part of ISO 8041 are required to have logging capabilities. Additional information is provided on how instruments might use the logged data for post processing, e.g. to identify measurement artefacts so that they can be excluded from personal vibration exposure values and the assessment of accurate vibration exposure times. This part of ISO 8041 is not intended to apply to instruments designed to measure or log exposure times without also performing human vibration measurement. The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies.

ISO 5349-1, Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1 General requirements

Special characteristics for hand-arm vibration measurement

For instruments designed for hand-arm vibration, the PVEM shall measure vibration at the interface between the machine and the operator hand (in accordance with ISO 5349-1). The considering equipment of ISO/TC108/WG33 is still following the ISO 5349-1 standard to measure the vibration of tool handle. So, this means that the vibration measurement is on the handle. This measurement does not measure the hand-transmitted vibration to human hand and arm. So, this committee standard has to reconsider the measurement of the hand-transmitted vibration considerations.

5. Considerations of Wearable Personal Vibration Exposure Meter (HAVwear) [12]

Within this section the suitability of one wearable personal vibration exposure meter for use in the effective management and reduction of vibration exposure will be examined. Compliance with ISO 5349-1 & ISO 8041 is not claimed by the manufacturer and therefor this paper does not seek to demonstrate absolute equivalence, rather it merely seeks to demonstrate the relevance of data acquired from such a device in the effective management of risk.

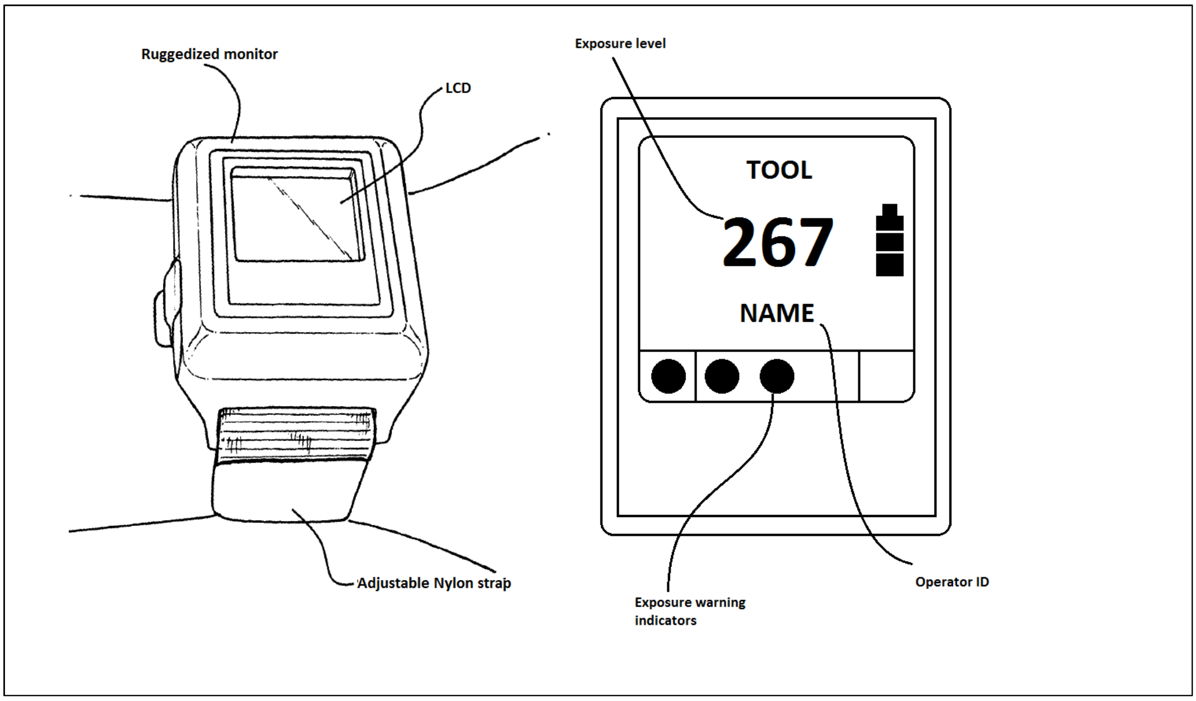


Figure 1 Wearable Personal Vibration Exposure Meter of HAVwear system (Reactec Ltd).

The HAVwear system (Reactec Ltd) combines a number of emerging technologies to provide the user with real time vibration exposure data pertinent to their work activities via an LCD and audible warnings in addition to a suite of analytics tools to enable the design out of harmful vibration. A ruggedized wearable device for data acquisition is coupled with an IOT enabled docking station to upload vibration data to a cloud based analytics platform.

The wearable device mounts to an operators wrist by way of an adjustable nylon webbing strap and comprises a 3 – axis linear MEMS accelerometer sampling at 1.6kHz for 0.66 seconds every 1.5 seconds. A frequency range from 3Hz to 650Hz is captured. Acceleration data from each axis is converted independently from time domain to frequency domain through 1024 point Fourier analysis incorporating a Hanning window function to generate 512 discrete magnitude values for each axis. The corresponding frequency point magnitude values for each axis are then combined to create an overall magnitude value for each point on the spectrum. A proprietary transfer function is then applied to each value across the spectrum to calculate the instantaneous magnitude detected at the wrist. This transfer function compensates for attenuation of the biomechanical structures of the hand and is designed to provide parity with measurements taken on the tool in accordance with ISO 5349-1. Overall exposure is calculated by means of a rolling RMS for the duration of the trigger time. Parity with measurements taken in accordance with existing ISO standards is desirable for calculating exposure as all current research and knowledge on the pathogenesis and progression of the disease is based on exposure calculated to these standards.

ISO 5349 specifies the optimal frequency range for measuring harmful vibration in relation to Hand Arm Vibration Syndrome as 6.3Hz-1250Hz, however in practice the dominant contribution to overall dose received as calculated in accordance with the frequency weighting curve is generated in the lower third of the spectrum. Fig 2 illustrates the average weighted vibration contribution by octave band as a

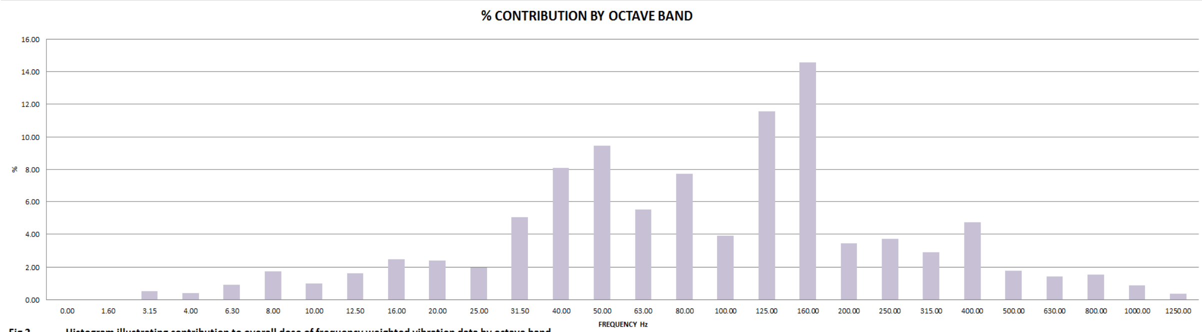


Fig 2 Histogram illustrating contribution to overall dose of frequency weighted vibration data by octave band

percentage of overall vibration magnitude across 27 commonly used vibrating tools of different action, mass operating speed and input power source. Vibration at frequencies greater than 650 Hz make up less than 3% of the overall weighted vibration, therefor the reduction in spectral range employed by the wearable device to conserve battery life does not have a material influence on the validity of data acquired.

To establish a relative effectiveness of the signal processing being employed, the sampling and Fourier transform parameters of the wearable device were modeled against those outlined in ISO 8041 using a MATLAB simulation package. Raw accelerometer data from a number of mechanized tools was acquired using a Bruel & Kjaer Photon + instrument before being processed by the simulation package. The relative performance of the different sampling methods is shown in the lower right matrix of Table 1A. The purpose of this simulation is to assess the relative effectiveness of the signal processing employed by the two methods rather than the effectiveness of the transfer function therefor the raw data collected on the tool has been used and the ISO weighting curve applied to sets of output data

Table 1 Relative performance of the different sampling methods

	First spectral peak (Hz)	Activity	Simulated HAVwear signal processing	Simulated ISO 8041 signal processing	% delta between sampling methods
Drill	19.7	Continuous	4.9	5.2	-5.6%
Drill	19.7	On / Off	3.7	3.9	-5.6%
Jig Saw	49	Continuous	6.2	6.7	-7.1%
Jig Saw	49	On / Off	4.4	4.8	-9.1%
Strimmer	75	Continuous	19.1	20.4	-6.3%
Strimmer	75	On / Off	12.2	13.1	-6.7%

In addition to the simulations, live testing was undertaken concurrently using the wearable device mounted on an operators wrist and a Bruel & Kjaer Photon + instrument configured in accordance with

ISO 8041 specifications mounted on the tool in accordance with ISO 5349-1. Data acquired using the Bruel & Kjaer was then post processed with the frequency weighting curve detailed in ISO 5349-1 and plotted against that from the wearable device employing the proprietary transfer function as shown in Fig 3. Memory restrictions on the wearable device preclude storing Fourier transform data for the entire frequency spectrum however correlation in both frequency and amplitude axis within the range of data captured is strong.

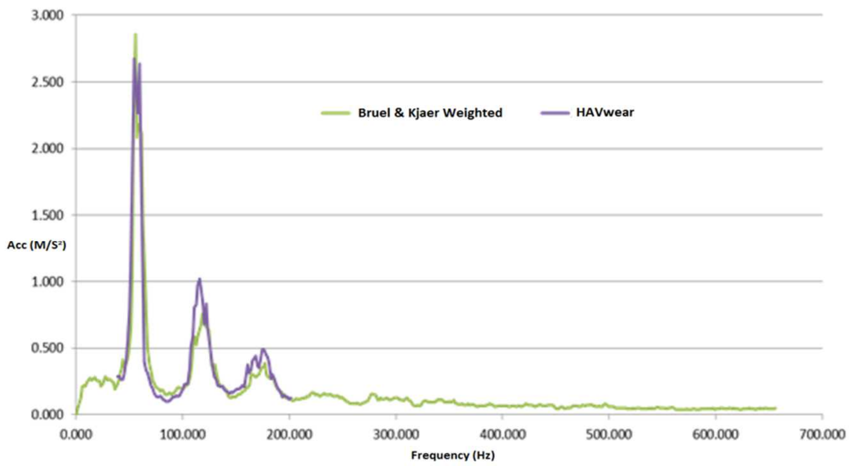


Fig 3 Correlation of frequency domain acceleration data from Bruel & Kjaer Photon + and Reactec HAVwear device

Further live testing was conducted to assess the effectiveness of the transfer function employed by the wearable device against a wide range of tools. Measurements were taken concurrently using Bruel & Kjaer Photon + instrumentation with ISO 5349-1 weighting post applied, ISO compliant Svantek 106 instrumentation and the HAVwear device. A total of 27 separate tool configurations where tested comprising of different tool types, actions, tool masses, power sources, consumable and substrates types. Each tool configuration test consisted of 3 X 1 minute measurements with the average result for the complete test being calculated. Figure 4 illustrates that the average vibration magnitude as measured by all three device with the wearable device showing generally strong correlation with the two reference instruments.

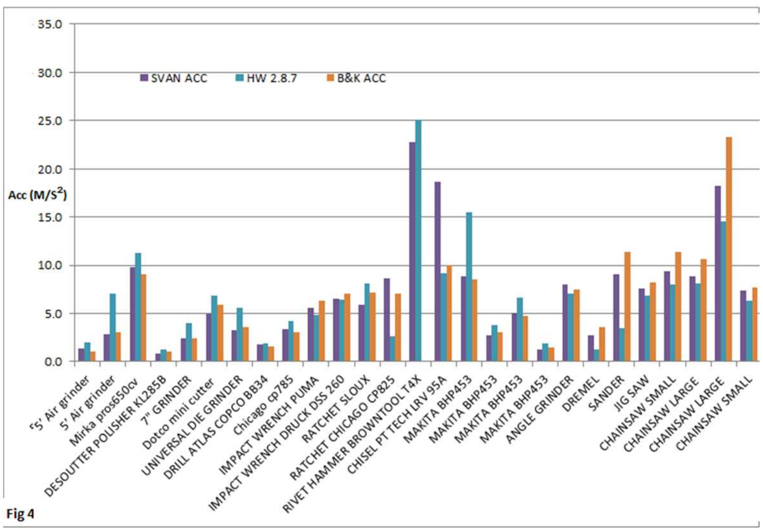


Figure 4. Calculated total exposure in HSE HAV exposure points

The true value of the wearable device comes from its ability to capture the variance in exposure and deviation from the anticipated risk. The current approach of task based assessment relies on tool performance, substrate consistency, operator proficiency and vibrating tool work load allocation all remaining constant which in practice rarely happens. Additionally it has been found that there is no typical working environment across many industries including manufacturing as tool use fluctuates from day to day and month to month. A risk assessment will be required to take this into consideration but will be open to error when relying on sampled data as the resulting average exposure estimation is based on a limited timeframe which can never hope to capture all conceivable fluctuations in activity and behavior present within a real world environment. Continuous monitoring reduces the margin of error associated with this estimation (insert reference to white paper).

To illustrate the variability from tasks a detailed risk assessment exercise was carried out on the work of 14 tool operators in multimen teams, each excavating the same size hole within the same grade of road surface. Each operator used the same tool type for which the duty holder had determined a vibration magnitude of 12 m/s^2. Note this was well in excess of the tool vibration data declared by the manufacturer of 4.2m/s^2. The duty holder had determined that was inappropriate for the type of road surface under test. A mix of site teams were used per excavation which consisted of between two and four man operator teams.

Figure 5 displays the calculated total exposure risk in A(8) m/s^2 each excavation broekn down by the contribution to each excavation by each operator. Each team accomplished the same task within different time durations. The colours within each excavation shows the relative contribution from each team member of each excavation. Clearly a wide range whereby even if the most extreme results are disregarded the exposure per excavation ranged +/- 40% on the mean value.

A task based assesment of these excavations would potentially determine the average exposure per excavation to be an A(8) of 4.2m/s^2 and therefore if work evenly shared a two man team would be exposed to an A(8) of 2.9m/s^2 and a three man team exposed to an A(8) of 2.4 m/s^2. A task based assessment will typically only account for an average exposure risk per task, not the actual exposure of individual operators.

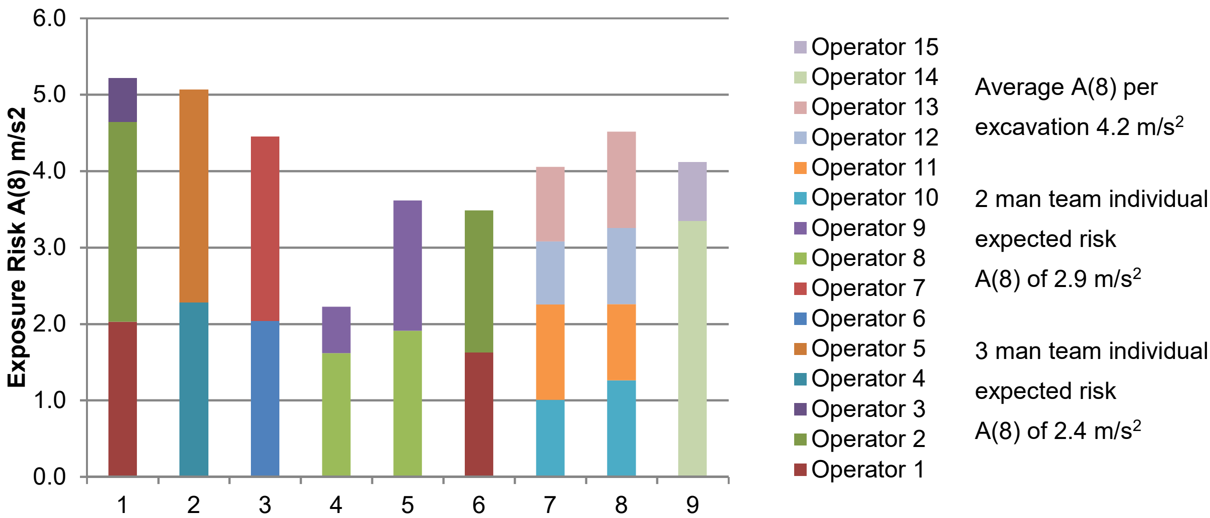


Figure 5 Calculated total exposure in A(8) m/s^2 for each excavation

The assessment also included live tool vibration testing which took place during these excavations. Two methods were used to determine the vibration level.

1. An ISO5349-1 measurement using a reference instrument involving a skilled technician
2. Data collected on a HAVwear worn by the tool operator during tool use.

The data from both is depicted below in Figure 6 which shows the numerical average of the RMS vibration level determined by the two devices. Strong correlation can be seen between the HAVwear and ISO5349 compliant reference instrument Larson Davis with an overall average for the reference instrument of 11.1m/s2 and the HAVwear 11.9m/s2.

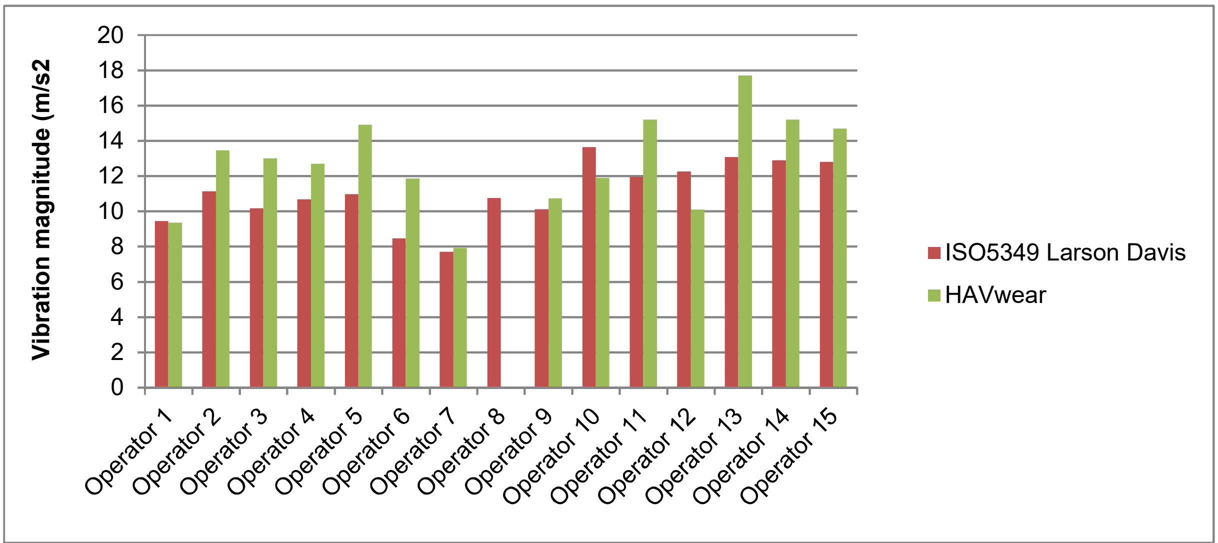
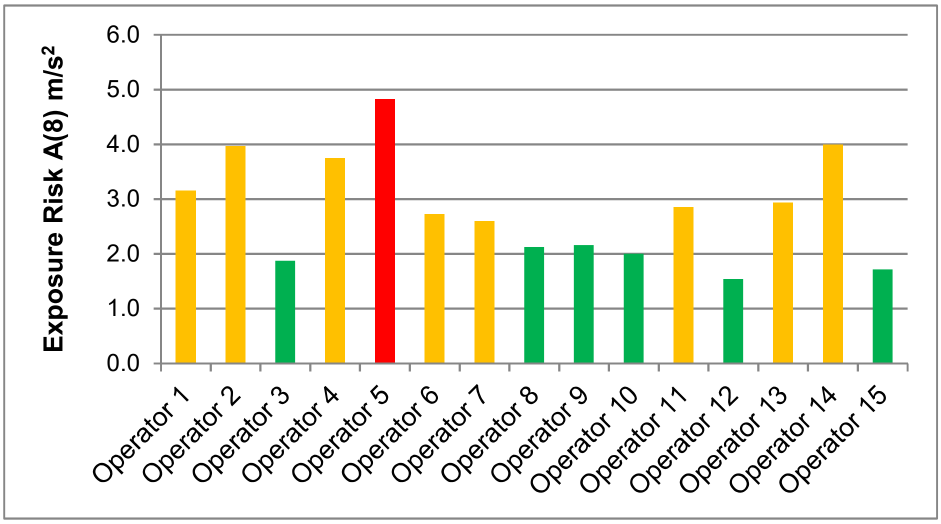


Figure 6 The data from both companies, such as Larson Davis and HAVwear.

Figure 7 below depicts the calculated maximum HAV risk exposure for each individual when excavating just one hole from the actual trigger time and real-time vibration data of HAVwear. Based on a task based assessment with a minimum two operator team the expected max risk would be an A(8) of 2.9m/s^2. In reality 5 out of the 14 operators exceeded this level. The conclusion is that job rotation is unlikely to be as expected without monitoring and each operator is unique in technique and physicality which can lend itself to a high level of variability in exposure risk. Operator 5's exposure was close to the limit exposure level of 5m/s^2 and 6 times that of some other operators tasked with the same duties.



Average A(8) per excavation 4.2 m/s^2

2 man team individual expected risk A(8) of 2.9 m/s^2

3 man team individual expected risk A(8) of 2.4 m/s^2

Figure 7 the calculated maximum HAV risk exposure for each individual for one excavation

The UK HSE acknowledges the existence of variability within real world application and advises the use of caution when selecting vibration data for extrapolated exposure calculations to ensure it is truly representative of the actual exposure.

Combing the wearable technology with IOT data transmission and cloud based analytics has for the first time allowed for the collection and review of truly "Big Data" regarding vibration exposure. Analysis of this data suggests that there is a significant delta between perceived exposure levels and actual exposure. The HAVwear system operates in two modes, one which senses the true vibration and one that calculates exposure from a pre-programed RFID tag attached to the tool in use. By analyzing the data from selected heavily used tools we can plot the manufacturers declared vibration level and the average assumed value used in risk assessments from the RFID tag against a histogram of actual vibration values recorded on the wearable device. Figure 8 illustrates the delta between the average vibration value used during risk assessments of one specific tool used and the histogram of actual vibration recorded by the wearable device.

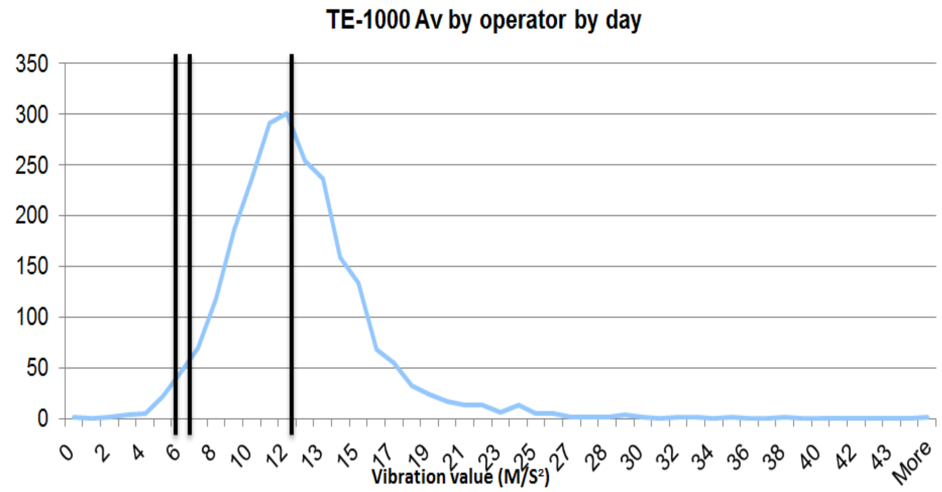


Figure 8 Data between the average vibration value used during risk assessments of one specific tool used and the histogram

For the tool shown a tool testing exercise had been conducted on a live demolition site. A series of 30 one minute trigger tests compliant to ISO5349-1 yielded an average vibration level of 11.9m/s^2 while a monitor worn during testing averaged 13.8m/s^2.

Beyond ensuring exposure is kept within working limits in the short term, the ability to have real time continuous monitoring data which is traceable to tools, tasks and operator can aid significantly in the process of designing out exposure through identifying the source. Targeted procurement, process optimisation, improved tool maintenance and operator training are enabled through access to this data and can lead to significant reduction in exposure. The very nature of a wearable device that provides real time feedback to the operator can also facilitate behavioral change and a level of awareness that are not possible through periodic interventions.

The Control of Vibration at Work Regulations of 2005 stipulates that simply keeping exposure below the action and limit values is not sufficient. To ensure compliance, employers must reduce exposure levels to lowest practicable levels. The process of reducing exposure and also providing evidence of this is greatly aided with the advent of real time exposure monitoring and associated analytical tools. Figure

9 illustrates the progress made by a major global construction organisation in reducing exposure to hazardous hand arm vibrations through the use of real time monitory and illustrates how leveraging the power of analytical data to drive decision making within the organisation can have significant and measureable impact.

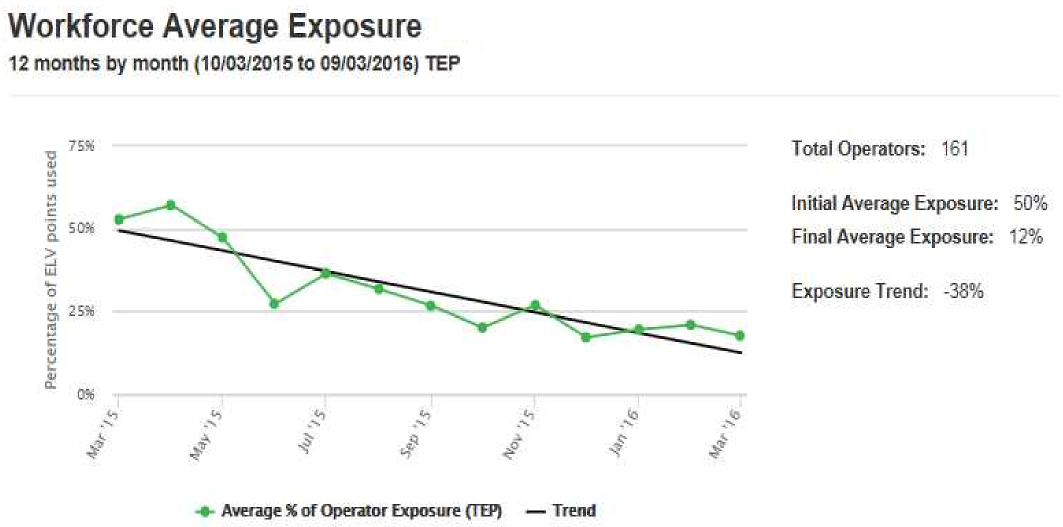


Figure 9 – Progress made by a major construction organisation in reducing operator exposure

6. Conclusions

The ISO 5349-1 standard, 2002/44/EC directive, and Japanese guidelines are focusing to the vibration magnitude of the tool handle. This vibration magnitude evaluation is assuming that when the different worker will use the same vibration magnitude tool, this means that the human response to vibration effects is the same

In this paper, we showed the data between the average vibration value used during risk assessments of one specific tool used and the histogram (Figure 8). These results are showing the factors likely to influence the effects of human exposure to hand-transmitted vibration in workplace conditions of Annex D of ISO 5349-1, Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1 General requirements. And also, these results might be shown the following effect of ISO/CD 15230 "Mechanical vibration and shock -- Coupling forces at the man--machine interface for hand-transmitted vibration" standard [13].

Therefore, from these results, the human response to vibration effects from the vibration magnitude of the tool handle is not the same. It can be understood that hand-arm vibration syndrome cannot prevented only with the vibration tool management.

This paper also showed that the vibration measurement of the hand-transmitted vibration to human hand and arm for preventing the hand-arm vibration syndrome of each worker must take the factors likely to influence the effects of human exposure to hand-transmitted vibration in workplace conditions of Annex D of ISO 5349-1 and ISO/CD 15230 standards into the Wearable Personal Vibration Exposure Meter.

From now, it will be necessary to collect a lot of field measurement data, in order to get the relationship between the data from this HAVwear equipment and the hand arm vibration syndromes.

7. References

[1] Directive 2002/44/EC (2002) Official Journal of the European Communities.

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