ASSESSMENT OF WHOLE-BODY VIBRATION EXPOSURE AND OTHER ERGONOMIC FACTORS ASSOCIATED WITH BACK PAIN

A M Darby Health and Safety Laboratory, Buxton, Derbyshire, UK, SK17 9JN

1 INTRODUCTION

Exposure to high levels of whole-body vibration may cause or exacerbate injury or pain in the lower back. The risks are greatest when the vibration contains significant shocks and jolts, as can occur in off-road work such as mining, quarrying and construction.

The European Physical Agents (Vibration) Directive has been implemented in the UK as the Control of Vibration at Work Regulation 2005. The Directive permits member states to quantify occupational exposure to whole-body vibration either in terms of average (r.m.s.) vibration magnitudes over the working day or in terms of cumulative shock (Vibration Dose Value or VDV) for the working day. The UK has chosen to use the r.m.s. metric for assessing vibration exposure rather than VDV, although the Vibration Regulations still require consideration of the risks from shocks and jolts.

To comply with the Regulations an employer must assess the risks to his employees from vibration and plan for their control. The Regulations contain exposure action and limit values (EAV and ELV respectively) for whole-body vibration of 0.5 m/s² A(8) and 1.15 m/s² A(8) respectively.

This paper describes the process of assessing occupational exposure to whole-body vibration, including suggested minimum sampling times. The assessment of other ergonomic factors associated with back pain is also considered.

2 DETERMINING DAILY VIBRATION EXPOSURE

Human exposure to whole-body vibration should be evaluated using the method given in International Standard ISO 2631-1:1997.

To assess the daily whole-body vibration exposure of a driver it is necessary to estimate both the time for which the driver is exposed to vibration, T_{exp}, and the average vibration magnitude over the period of exposure $(ka_w)_{max}$.

$(ka_w)_{max}$ is the highest of the three values: $1.4a_{wx}$, $1.4a_{wy}$ and a_{wx} where a_{wx}, a_{wy} and a_{wz} are the frequency weighted vibration magnitudes in the three directions x, y and z shown in Figure 1. The frequency weightings applicable to each axis are given in ISO 2631-1:1997: W_d for the x and y directions and W_k for the z direction.

The daily vibration exposure (A(8)) is then calculated from
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$$A(8) = (ka_w)_{max}\sqrt{\frac{T_{exp}}{8}} \text{ m/s}^2$$

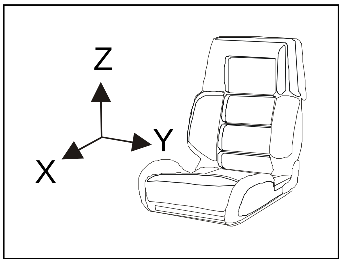


Figure 1. Measurement axes

3 ASSESSMENT OF EXPOSURE TIME

The assessment of exposure time needs to be based on the type of work activity. For example, where driving in urban areas is being assessed, measuring the average vibration magnitude over an hour of representative driving is sufficient, as brief stops at traffic lights and junctions will be allowed for. It is then only necessary to determine how long the driver spends driving in urban areas. Where work is cyclic, for example a dump truck transferring material from a quarry face to a crusher, measuring over a number of operational cycles will give the average vibration magnitude per cycle. In this way the time spent waiting at the quarry face or at the crusher is allowed for. It is then only necessary to determine how long the driver spends on this activity per day, allowing for lunch and other breaks.

4 SOURCES OF VIBRATION DATA

There are a number of sources of vibration data available including:

- Vehicle suppliers
- Trade associations
- Databases available on the internet

  Two European websites that hold manufacturer's standard vibration emission data plus some "in use" values are:

  http://vibration.arbetslivsinstitutet.se/eng/wbvhome.lasso

  http://www.las-bb.de/karla/index_.htm

- Measurement

It will not normally be necessary to measure the vibration magnitude, but care should be taken to select data that is applicable to the vehicle and situation being considered. Factors to be taken into account include:

- Type of equipment
- Size of machine
- Power source
- Task
- Speed
- Type of road surface
- Characteristics of a suspension seat (if provided).

If possible vibration data for the make and model of machine the vibration assessment is for should be used. However if this is not available then information relating to a similar piece of equipment will need be used.

5 MEASURING VIBRATION MAGNITUDES

It will be necessary to measure the vibration magnitude if, after taking actions to reduce exposures, this is the only way to establish whether the whole-body vibration exposure action or limit values continue to be exceeded.

Human exposure to whole-body vibration should be evaluated according to ISO 2631-1:1997. The vibration is measured in the three orthogonal directions specified in the Standard and shown in Figure 1: i.e. the vertical, transverse and fore-aft directions.

The vibration is measured using a tri-axial accelerometer placed either on the seat for a seated person or by the feet of the operator for a standing person. The signals from the accelerometer are fed either to a hand held meter or alternatively to a multi-channel analysis or recording system. The advantage of using a hand-held meter is that it is quick and simple to set up, and takes little time to put on the vehicle. Disadvantages of a multi-channel analysis or recording system are that it can require more setting up time, and where space is at a premium it may be difficult to fit the system into the cab. However, a multi-channel recording system allows the vibration signals on and below the seat (in three directions) to be recorded. This permits the vibration signals to be examined prior to analysis, and any erroneous data to be excluded from subsequent analyses. It should be stressed that measuring vibration is a complex and difficult task, and it is vital to ensure that any measurements made are valid.

Measuring the vibration at the seat base allows the vibration isolation provided by the seat to be investigated. This can be extremely useful information as suspension seats can amplify the vibration exposure of the driver if wrongly selected, incorrectly installed, maintained or adjusted. Knowledge of the seat base acceleration spectrum can be used to help identify a suitable suspension seat.

5.1 Sampling times

The aim of measuring the magnitude of the vibration signal is to obtain a representative vibration level that can be used to estimate the vibration exposure of the operator. Vibration exposures can only ever be estimated as even if vibration signals are recorded for the whole working day, the vibration signals for the previous or next days will differ to some (unknown) degree. As there is a cost involved in making measurements, it is necessary to select sufficiently, but not excessively, long sampling times.

The graphs in Figure 2 illustrate the effect of sampling time on the vibration magnitude measured on a variety of vehicles. They have been obtained by assuming that the value measured for the entire time history is the ‘true’ vibration level. In each case the vibration level obtained by analysing the first n times 60 seconds of the time history, (n = 1 to length of time history / 60), has been compared with the ‘true’ value and the percentage difference in the two vibration levels plotted. The second set of graphs show the error in the estimated time to the exposure limit value. These graphs confirm what is expected intuitively: for short sample times the error can be substantial, particularly where the surface over which the vehicle is traveling is rough. The one exception to this in Figure 2 is the track maintenance vehicle, where the work task was repeated over a short period.

Figure 3 shows the equivalent error in the time to the exposure limit value for different time histories.

Since the error for short sample times can be substantial, HSL normally samples whole-body vibration levels for a minimum of 10 minutes, although 30 minutes to 1 hour sample times are more usual.

Figure 2. ‘”Error” in RMS value with increasing sample time.

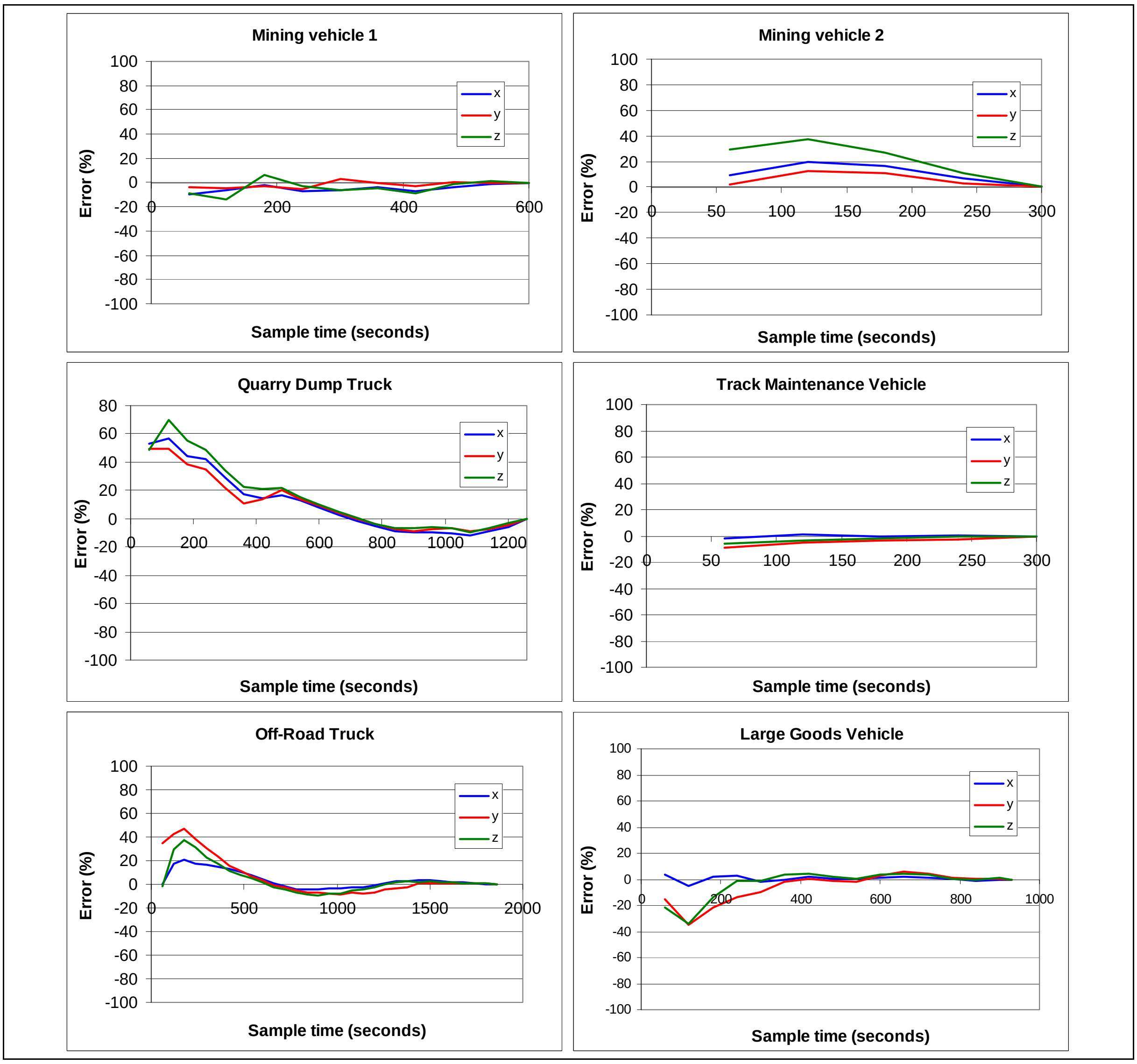
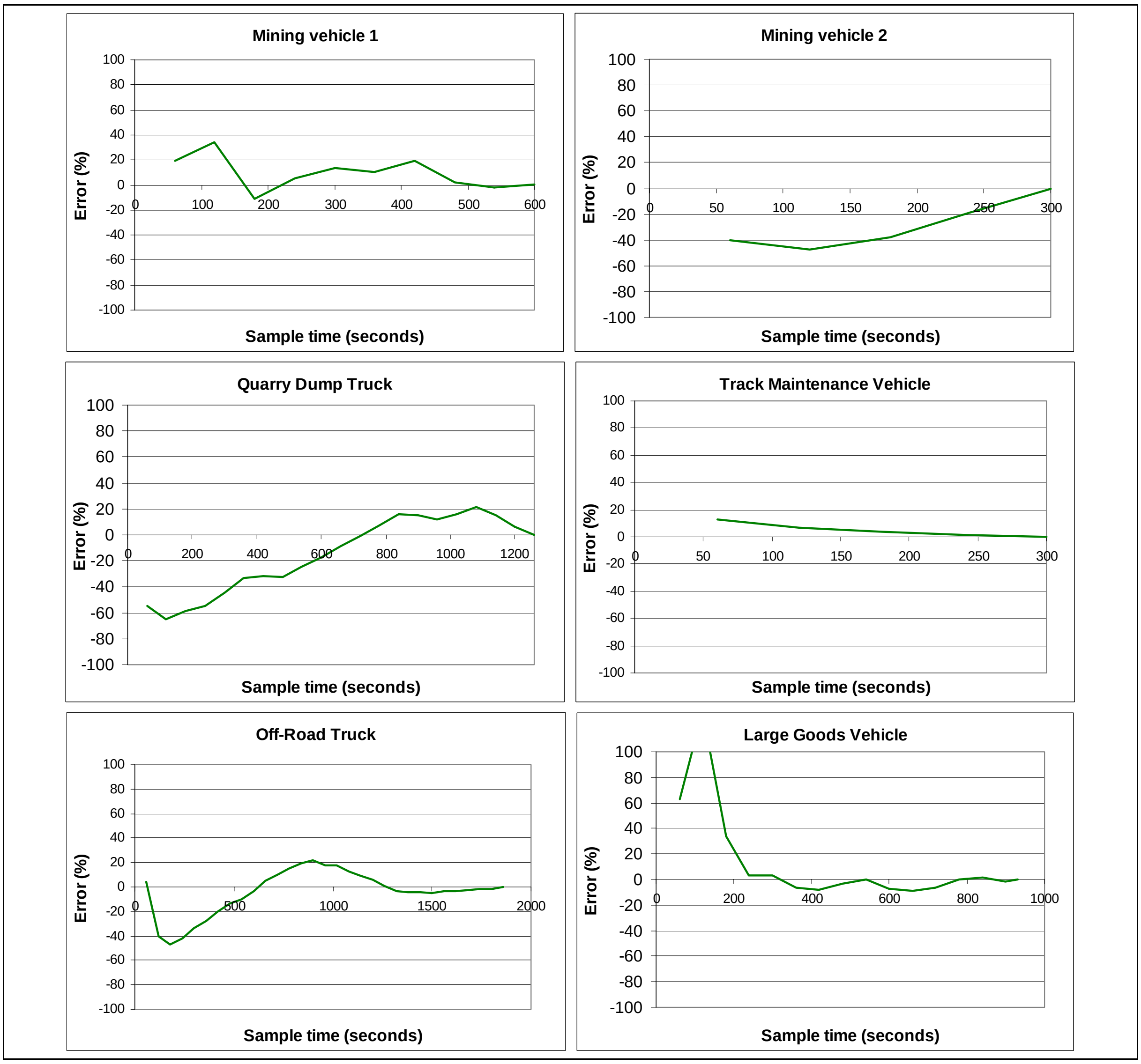
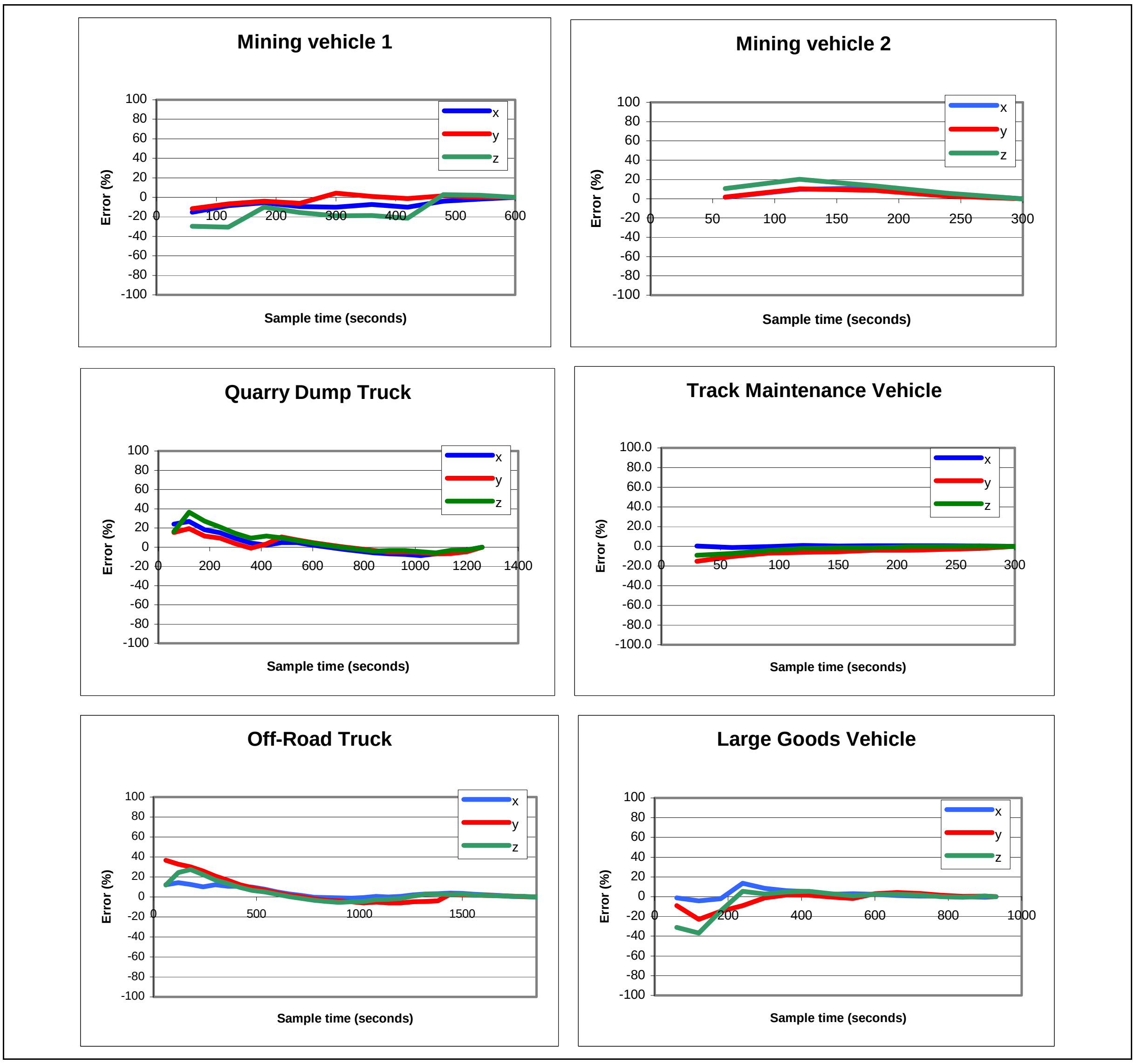


Figure 3. "Error" in time to reach exposure limit value with increasing sample time.



A comparative set of graphs showing the effect of sampling time on VDVs for the working day are shown in Figure 4. However it should be remembered that for a vibration signal containing just a few, severe shocks the daily VDV level may be reached very quickly if those shocks occur at the start of the working day. Conversely almost the entire VDV for the working day may occur close to the end of the day.

Figure 4. ‘”Error” in VDV with increasing sample time.



6 OTHER FACTORS TO CONSIDER

Whole-body vibration is not the only cause of back pain and injury, and it rarely occurs in isolation. Other factors, which may contribute to the development of lower back injuries, such as poor ergonomic design or manual handling, are almost always present in the working environment to a greater or lesser degree. The presence of these additional factors may well reduce the body’s capacity to tolerate a given level of exposure to whole body vibration. Consequently it is essential to consider other possible causes and contributors to back injuries when presented with complaints of back disorders in the presence of whole body vibration exposure. This holistic approach has been implemented in the Health and Safety Laboratory by the development of a whole body vibration and human factors tool kit. The tool kit considers manual handling, posture and cab design.

Manual handling activities are assessed by HSL using HSE’s Manual Handling Assessment (MAC) tool which is available on HSE’s website:

http://www.hse.gov.uk/msd/mac/index.htm

Video taken as part of the whole body vibration assessment is used to identify any postures needed to carry out the job that may be associated with an increased risk of musculoskeletal injury.

To make the 'cab fit' assessment, details of the instructor's cab layout (seat, auxiliary pedals, etc.) are recorded and used to assess the population range accommodated by the cab. Standard sets of measurements are taken in each vehicle using a pro-forma, along with additional dimensions where appropriate. Figure 5 shows dimensions a and h, which are

Figure 5. Postural assessment

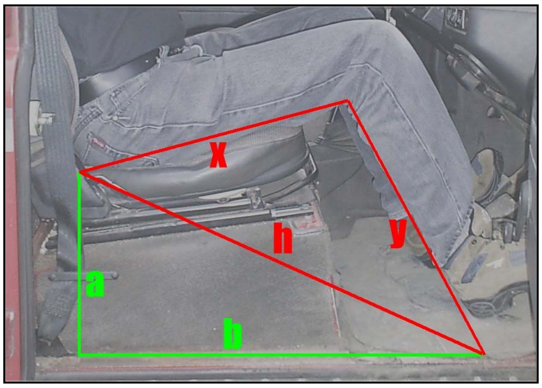


Figure 6. Cab-fit assessment

7 REFERENCES

1. DIRECTIVE 2002/44/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) 6.7.2002 L 177/13 Official Journal of the European Communities
2. ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements