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Managing Vibration Exposure

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Abstract

Whole-body vibration exposure is found to be associated with low back injuries and spinal disorders. Muscular fatigue and stiffness may lead to re-occurring pain. Hand-arm vibration exposure can lead to injuries to wrist and arm joints as well as vascular problems, including vibration white finger. Vibration exposure is an emerging issue for Australian mines and needs to be managed properly with full knowledge of all controls available.

The current Australian Standard for whole-body vibration describes measurement and assessment methods and provides exposure limiting guidelines. The assessment of jolts and jars is addressed for the first time. The EC has also released exposure limits and action levels. There are still no fully supported exposure criteria for health risks due to vibration and mining companies are left to comply with vague Standards while trying to maintain production.

There are a number of solutions available for reducing vibration exposure. Ideally these solutions should start with control at source, but this is not always possible. Vibration exposure can be reduced using a combination of methods, including modifying vehicles, work procedures and operator training. These methods can also have productivity benefits. Correct seating design is important and depends on the character of the vibration exposure. Expensive air ride suspension seats are not always the best control method and can sometimes even exacerbate the problem.

This paper will discuss a workable and managed approach to assessing and controlling whole-body vibration exposure in mines.

Introduction

Whole-Body Vibration (WBV) is an emerging issue for the mining industry and has been found to contribute to low back pain and spinal degeneration. Mine workers are exposed to both ‘steady state’ vibration and shocks (jolts and jars) from equipment such as dozers, scrapers, shovels, haul trucks, man hauls, loaders, load haul dump vehicles and most other earthmoving plant. Back pain symptoms have been found to be more prevalent in operators who are exposed to jolts and jars in vehicles (Mansfield & Marshall).

Until recently, shock type vibration was underestimated by measurement and analysis methods used in the Australian Standard, but newer standards have introduced methods that can more accurately predict health effects. However, the newer standards are often vague and have disputed exposure guidelines, action levels and exposure limits. Mining companies are left to comply with these standards while trying to maintain production. driver’s. It should also be noted that to date a direct dose response relationship between WBV exposure and back pain or injury has not been established due to other confounding factors associated with back pain such as prolonged sitting, manual handling and poor posture.

More recent Standards for WBV exposure

British Standard, BS 6840:1987

The British Standard, (*BS 6840:1987, Guide to measurement and evaluation of human exposure to whole body mechanical vibration and repeated shock*), addressed the issue of jolts and jars by using a Vibration Dose Value or VDV for assessment. Vibration Dose Value (VDV) is based on fourth power methods rather than the second power methods of the r.m.s. The VDV is sensitive to high peak vibration and therefore gives a better assessment of rides containing jolts and jars than the r.m.s method. It also correlates well with subjective comfort levels and perception of ride roughness. An ‘action level’ of 15 $m/sec^{1.75}$ was recommended in the British Standard, which was based on the subjective reaction of people tested in a laboratory. Vibration at 15 $m/sec^{1.75}$ has been found to cause severe discomfort and it was reasoned that levels above this will be accompanied by increased risk of injury.

International Standard, ISO 2631-1:1997

A new International Standard (*ISO 2631-1:1997, Mechanical vibration and shock-Evaluation of human exposure to whole-body vibration*) was adopted, which used both r.m.s and VDV methods. The standard describes measurement and evaluation methods for health effects, comfort and perception of vibration. Two assessment methods are set out in the standard. The Basic Evaluation Method uses the average r.m.s vibration value and compares it with the Health Guidance Zones shown in Figure 1. The chart gives times for vibration levels to reach the Caution and Likely Health Risk Zones. The chart allows for exposures of more than 8 hours/day.

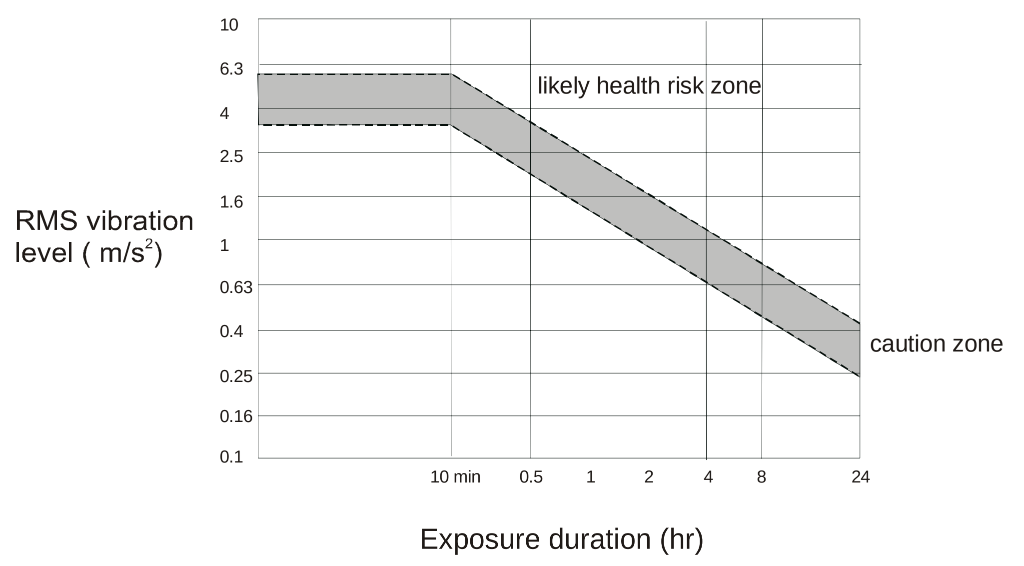

Figure 1. Health Guidance Zones – Basic Method (r.m.s)

For shock type vibration (jolts and jars) two Additional Evaluation methods are described. The most useful is the Vibration Dose Value as described for the British Standard. The severity of peaks is used to decide when to use the Additional (VDV) or the Basic (r.m.s.) Evaluation method.

The Standard provides guidelines for exposure durations. The guidance criteria for VDV are:

Caution Zone: 8.5 m/s$^{1.75}$

Likely Health Risk Zone: 17 m/s$^{1.75}$

The standard states that for exposures below the Caution Zone, health effects have not been clearly documented and / or objectively observed, in the Caution Zone there are potential health risks and above the Caution Zone, health risks are likely.

The VDV is a dose value that accumulates over the shift. The r.m.s is an average value over the shift.

Both measurements require a representative sample of vibration exposure to be taken. The values can then be extrapolated to 8 or 12 hours allowing for breaks.

The application of these two methods requires extensive experience and knowledge of both the analysis and interpretation of the findings. However, there is evidence that many people attempting to measure and interpret WBV exposure findings do not have sufficient understanding of these technicalities and VDV is often ignored.

The standard contains ambiguities and vague statements about the evaluation methods and exposure guidelines.

Australian Standard AS 2670-2001

In 2001, Australia adopted the complete International Standard as the Australian Standard *AS 2670-2001, Evaluation of human exposure to whole-body vibration*.

European Directive 2002

The European Union adopted a Vibration Directive in 2002. The document set an action level and an exposure limit for whole-body vibration for both VDV and r.m.s values.

Action level: r.m.s. of 0.5 m/s^2 or VDV 9.2 $m/s^{1.75}$

Exposure limit: r.m.s. of 1.15 m/s^2 or VDV of 21 $m/s^{1.75}$

Health surveillance is recommended for exposures above the Action Level. Levels should not exceed the Exposure limit. The individual European states can decide whether they use the r.m.s or VDV method and limits.

The measurement and assessment methods described in ISO 2631-1 are prescribed for use.

International Standard ISO 2631.5 -2004

A new addition to ISO 2631 was released in 2004 that gives guidelines for the evaluation of vibration containing multiple shocks (*ISO 2631-5; Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 5: Method for evaluation of vibration containing multiple shocks*). The standard states that the assessment method and related models described in this part of ISO 2631 have not been epidemiologically validated.

The standard uses the sixth power of peak vibration levels to calculate a dose that is thought to be related to lumbar spinal response. Criteria are provided that predict the probability of adverse health effects. The methods used are disputed by other researchers (Seidel H, et al, 2007 and Alem, N, 2005). It appears that more application experience is needed for this standard before it can form the basis of realistic health effect predictions.

Extended shift exposure guidelines

The exposure standards and guidelines described above are based on an 8-hour working day. For a 12-hour shift, a person will receive proportionally more vibration compared to an 8-hour exposure for the same r.m.s level. The exposure standard can be reduced for a 12-hour shift to account for this additional vibration exposure as shown in Tables 1 and 2.

The VDV is a dose so the standard limit need not be lowered, because if a person receives the same VDV in 8 hours as in 12 hours the exposure is equivalent. For example, if a VDV of 15 $m/s^{1.75}$ is reached in 8-hours or 12-hours, the exposure is the same. However, the 12-hour exposure is longer and therefore must be at a lower intensity than that experienced for an 8-hour exposure.

Table 1. Summary of vibration exposure limits and guidelines for 8-hour shift

Standard	Caution Zone or Action Level	Likely Health Risk Zone or Exposure Limit	Comment
British Standard BS 6840:1987	15 $m/s^{1.75}$ (VDV)	-	Only Action Level - no Exposure Limit set
International Standard ISO 2631-1:1997 & Australian Standard AS 2670-2001	0.43 m/s (r.m.s) 8.5 $m/s^{1.75}$ (VDV)	0.86 m/s (r.m.s) 17 $m/s^{1.75}$ (VDV)	Derived from Figure 1
European Directive, 2002	0.5 m/s (r.m.s) 9.2 $m/s^{1.75}$ (VDV)	1.15 m/s (r.m.s) 21 $m/s^{1.75}$ (VDV)	-

Table 2. Summary of vibration exposure limits and guidelines for 12-hour shift

Standard	Caution Zone or Action Level	Likely Health Risk Zone or Exposure Limit	Comment
British Standard BS 6840:1987	15 $m/s^{1.75}$ (VDV)	-	Only Action Level - no Exposure Limit set
International Standard ISO 2631-1:1997 & Australian Standard AS 2670-2001	0.35 m/s (r.m.s) 8.5 $m/s^{1.75}$ (VDV)	0.7 m/s (r.m.s) 17 $m/s^{1.75}$ (VDV)	VDV level remains the same for 12 hours
European Directive, 2002	0.41 m/s (r.m.s) 9.2 $m/s^{1.75}$ (VDV)	0.97 m/s (r.m.s) 21 $m/s^{1.75}$ (VDV)	VDV level remains the same for 12 hours

Which standard to use?

The current exposure standards offer differing Action Levels and Exposure Standards. The Action Level of the EU Directive is similar to the Caution Zone level of the International and Australian Standard for both r.m.s and VDV criteria. There is a greater difference between the Likely Health Risk Zone of the International Standard and the Exposure Standard of the EU Directive. The EU Exposure Standard was originally proposed at a much lower level (0.63 m/s) but changed, because no one could meet the lower limit.

The VDV is likely to be a better indication of whole-body vibration in mines, because it emphasizes the peaks from shock type vibration typically experienced in mining vehicles. Like the r.m.s criteria, the Caution Zone or Action Level tends to be too conservative and it is difficult to achieve compliance. On the other hand, the Likely Health Risk Zone in the International Standard and particularly the Exposure Standard in the EU Directive could be too high to be protective enough. However, compliance is more easily achievable for most mine vehicle rides under this standard.

A reasonable compromise between the upper and lower limits would be an intermediate value in the middle of the Caution Zone of the International Standard and Australian Standard. Selection of this as an initial goal could be partly justified from studies of subjective opinion of ride roughness.

The chart below (Figure 2) shows the correlation found between the measured VDV for a ride and the subjective opinion of ride roughness in an extensive study of WBV exposure in NSW coal mining, carried out in the 1990s (McPhee, Foster & Long).

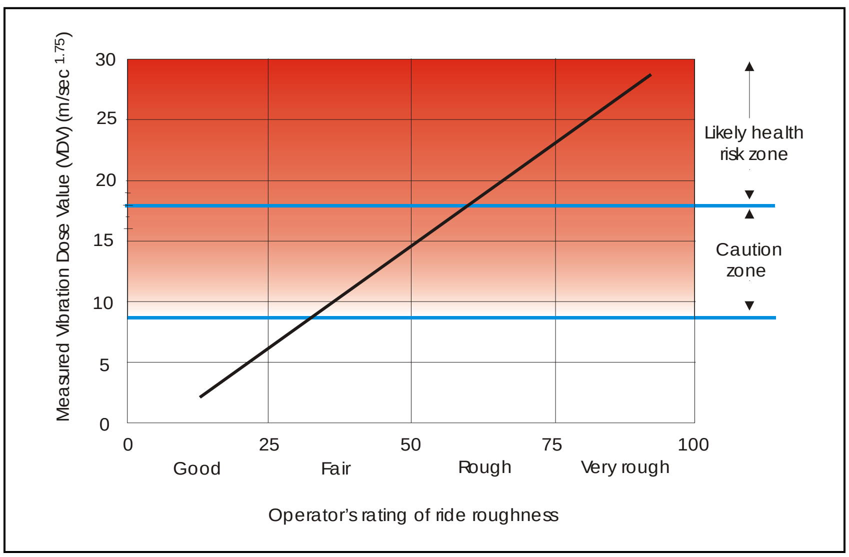

Figure 2. Drivers' subjective ride roughness rating versus measured VDV

Drivers and passengers were asked to assess the ride roughness by placing a cross on a 100 mm line with extremities representing the best and worst rides they have experienced. There were no values on the line when it was marked so the estimations were proportional. The VDV correlated well (r=0.61) with subjective ratings.

It is interesting to note that operators' opinions appeared to move from 'fair' to 'rough' at about 15 m/sec$^{1.75.}$ The VDV procedure appears to yield a good correlation with operators' responses to a ride in a real-world setting. Therefore a VDV of 15 m/sec$^{1.75}$ appears to be a reasonable target for the control of WBV exposure.

This value is just above the mid position in the Caution Zone. If the r.m.s method is used for more steady state vibration, a similar mid Caution Zone action limit seems a reasonable and achievable goal.

Management of whole-body vibration in mines

Employers need to know how their operators' vibration exposures relate to the new standards and guidelines and how to manage vibration issues and reduce injury risk with minimum impact on operating schedules. The following steps are central to managing and reducing vibration exposures:

1. **Assess exposures levels**
   Exposure levels at the mine or work site can be measured from a representative sample of vehicles. The measurement duration must be long enough to get a realistic sample, including any short breaks. Crib times and other longer breaks can be allowed for in calculations. Existing data from past measurements or a library database can be used where applicable.

2. **Compare exposures with Exposure Standards, guidelines and other mining industry data**
   Results should be presented in a clear and concise graphical format, ranking operator exposure according to vehicle type and activity. This provides a comprehensive overview of all exposures in relation to exposure standards and other mining industry data.

3. **Health surveillance for operators exceeding the Action Level or Caution Zone**
   Operators whose vibration exposures fall in the Caution Zone should have particular attention paid to health surveillance. The health surveillance would rely on feedback from operators possibly through questionnaires. It is also important to include observation and rectification of any manual handling problems, poor posture and prolonged sitting, etc. It has been found that, when these problems are present, they can exacerbate the effect of vibration. The physical health and any pre-existing medical conditions of the individual are also important.

4. **Limiting exposure to the lower half of the Caution Zone and not exceeding the Likely Health Risk Zone Limit**
   It is possible to limit the exposure of operators by a combination of methods ranging from improving road conditions, vehicle suspension, cab suspension, seating, improved operating techniques and job rotation to limiting duration of use. Operators must be able to properly adjust seats for maximum efficiency. They must also know how to limit exposure by "operating to conditions" and slowing down or avoiding particular rough sections. This can have a dramatic effect on overall vibration exposure levels.

5. **Training for management and operators**
   There are many ways for operators and management to work together to reduce vibration exposures while sustaining productivity.

Conclusion

Despite the complexity and ambiguity of standards, whole-body vibration exposure can be managed without compromising production. Combined with improvements to manual handling and posture, prolonged seating can not only reduce the risk of back pain symptoms, but may also give other productivity benefits when procedures and rosters are reviewed.

References

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