ROCK-DRILL HANDLE VIBRATION: MEASUREMENT AND HAZARD ASSESSMENT

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Introduction

Despite progress in predicting the risk of developing vibration-induced white fingers (VWF) from exposure to the vibration of power tools, the relative hazard posed by different vibration amplitudes and frequencies remains a subject of debate.[1, 2] The present international standard, ISO 5349 (1986),[3] requires the exposure "intensity" to be derived from orthogonal, component, rms accelerations measured in directions related to the orientation of the third metacarpal, in the frequency range from 5.6 to 1400 Hz. It has been suggested that inaccuracies resulting from application of the ISO procedure are associated with: a) employing a frequency weighting that progressively reduces the contribution to the overall hazard from accelerations at increasing frequencies; b) restricting the frequency range of measurements to an upper limit of 1400 Hz; c) the crest factor of the acceleration waveform; or d) a combination of these factors.

The purpose of this paper is to characterize the handle vibration of a pneumatically-powered jack-leg rock drill commonly used in Canadian mines, and to record its vibration at frequencies above 1400 Hz. The potential health hazard posed by different vibration frequencies may then be explored, by reference to data from medical studies and other types of power tools.

A detailed report of this work will be published elsewhere.

1. Apparatus and Measurements

Three miniature accelerometers (Brüel & Kjær, type 4393), were attached to 10 g weights, and then mounted on a mechanical filter (Brüel & Kjær, type UA 0559). The mechanical filters were, in turn, mounted orthogonally on a prepared steel block welded to the drill handle. By careful positioning of the block, an accelerometer was oriented to record the vibration of the drill along its percussion axis (referred to as "front to rear," or F-R). When drilling horizontally, the handle acceleration was also recorded in the vertical and horizontal directions. The orientation error was less than 15°.

The three vibration components were recorded simultaneously on an FM tape recorder (Brüel & Kjær, type 7006). The frequency limits for the channel recording the F-R acceleration were from 2 Hz to either 1.3 or 10 kHz (± 1 dB). The corresponding frequency limits for the other two channels were 1 Hz, and either 1.6 or 7 kHz.

A retired miner (height 1.70 m, weight 68 kg), drilled horizontal holes (which had been pre-drilled to a depth of ≅ 15 cm) in a near-vertical, exposed rock face of marginally weathered but competent granite. The drill was operated at full throttle, and the penetration time for each 1.2 m of drilling was noted. Some holes were drilled by a second, experienced driller (height 1.83 m, weight 102 kg), to establish whether individual differences in drilling technique influenced the vibration recorded at the drill handles. The effect of hand grip on handle vibration was also explored.

The acceleration waveforms and spectra were monitored during all measurements (Brüel & Kjær, type 2515), to ensure that large-amplitude impacts did not overload the transducers.[4] The apparatus was calibrated both before and after measurements by a portable vibration calibrator (Brüel & Kjær, type 4291). In addition, electronic calibration signals were recorded on each tape. With these precautions, the systematic error of these measurements is believed to be less than 5 %.

The recorded signals were analyzed in the laboratory to yield one-third octave bands (complying with IEC 225-1966 and ANSI S1.11-1966, Class III), by means of a real-time spectrum analyzer. Linear (time) averaging of each signal was performed for 32 s, to accommodate fluctuations in vibration amplitude. Unexplained variations in drill operation that resulted in changes to the percussion frequency of greater than ± 12 % have been excluded from the data analysis.

2. Results

The root mean square one-third octave-band, F-R component acceleration spectrum recorded when drilling with a 1.2 m length drill rod, and the air pressure set to a typical value found within a mine (5.5×10^5 Pa), is shown in figure 1 (expressed in dB re 10^{-6} $m \cdot s^{-2}$). While accelerations of similar magnitude were observed in orthogonal directions at frequencies below 31.5 Hz, it was found that at this, and higher frequencies, the F-R component dominated the handle vibration. Values of the component accelerations frequency-weighted according to the provisions of ISO 5349 (1986) are listed in Table 1, and clearly demonstrate that the F-R component possesses the largest magnitude. The relative magnitudes of the frequency-unweighted acceleration levels, also given in Table 1, suggest this ranking of the handle acceleration components is unlikely to change with hazard weighting schemes that give more emphasis to contributions from higher frequencies.

The spectrum in figure 1 has been constructed from two measurements: one including the complete frequency range, and the other, the range from 5.6 to 1400 Hz. The second measurement was required to detect vibration at low signal levels, which was otherwise lost in tape-recorder noise. Repeated measurement of the F-R component acceleration in this restricted frequency range permitted an estimate of the variation in handle acceleration during normal drilling operations. Below 1400 Hz, values for plus and minus two standard deviations are shown by the dashed lines in the diagram, and are derived from 16 data samples.

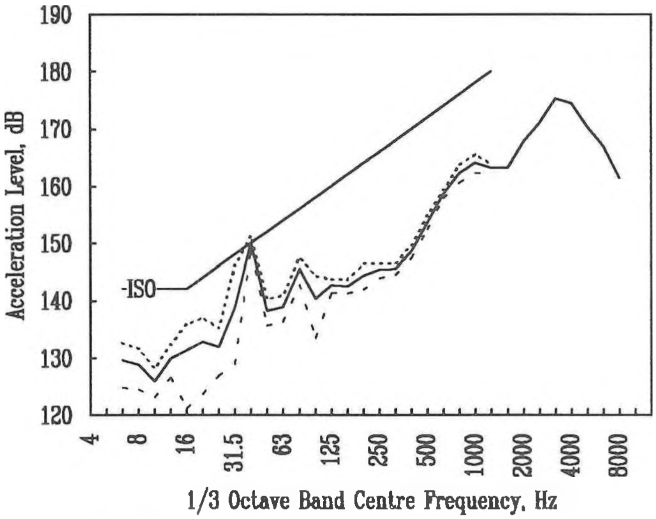

Figure 1: RMS Front to Rear Component Handle Acceleration Level (dB re 10^{-6} $m \cdot s^{-2}$), using 1.2 m Drill Rod. Also shown are: $\pm$ 2 standard deviations (- - -), and ISO weighting.

The F-R component handle acceleration tended to increase at the percussion frequency ($\cong$ 40 Hz) when drilling with a new or re-sharpened bit, and at frequencies between 100 and 400 Hz when drilling with a longer ($\cong$ 2.4 m) drill rod. However, all changes in operating conditions, and operators, led to insignificant variations in handle vibration at frequencies above 400 Hz.

3. Discussion and Conclusions

The insensitivity of handle vibration to changes in drill operating conditions, and driller, at frequencies above 400 Hz, together with the small standard deviations recorded at these frequencies, suggest that the spectrum shown will provide a reasonable first estimate of the dominant acceleration component at all frequencies. Inspection of this diagram reveals the presence of a large acceleration peak at frequencies between 3 and 4 kHz, which is not recorded if handle vibration is measured following the procedure established in the international standard.[1]

Two recent studies of miners in Canada have found that the rate of development of VWF is slower than would be predicted from rock drill handle vibration, when the hazard associated with different frequencies is weighted according to the ISO standard (curve labelled ISO).[5,6] In contrast, the development of VWF in forest workers operating gasoline-powered chain saws with vibration-isolated handles is predicted by the ISO procedure.[7] The handle vibration of such saws is known to decrease with increasing frequency, at frequencies above that corresponding to the engine firing ($\cong$ 150 Hz), which determines the frequency-weighted acceleration. Measurements on the handles of a typical 3 kW saw when cross-cutting wood have recorded unweighted one-third octave-band acceleration levels of 140 dB, or less, at band centre frequencies above 315 Hz.[8] In consequence, the hazard associated with operating jack-leg rock drills relative to that associated with operating chain saws, which is presently overestimated by the ISO procedure,[3] will be additionally overestimated by employing frequency-unweighted accelerations.

Table 1: Mean, RMS Component Frequency - Weighted and Frequency - Unweighted Acceleration Levels (dB re 10^{-6} $m \cdot s^{-2}$)

	Front to Rear	Side to Side	Up and Down
ISO Weighting (5.6 - 1400 Hz)	144.9	141.2	139.3
Unweighted (5.6 - 1400 Hz)	169.4	168.9	164.9
Unweighted (5.6 - 5600 Hz)	180.1	-	-

Furthermore, because of the different spectrum shapes, this overestimate will be increased by increasing the maximum vibration frequency included in the assessment of hazard.

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