MEASUREMENT AND EVALUATION OF VIBRATION EXPOSURE FOR LOCOMOTIVE CREW MEMBERS

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Introduction

The vibration and impact environment for crew members on locomotives has been investigated in a series of studies conducted by Exponent Failure Analysis Associates (Exponent) beginning in 1990. Locomotive cab vibration and impact levels were measured on a variety of locomotive models operating over many different track sections across the Union Pacific, Burlington Northern Santa Fe, CSX, Norfolk Southern, and CONRAIL systems. The comfort and health implications of exposure to the measured locomotive vibration levels were evaluated by comparison with the human vibration exposure boundaries given in the International Standards Organization (ISO) standard 2631-1:1997, the British Standard 6841:1987, European Union (EU) Directive 2002/44/EC, measurements made by Exponent on various commercial and recreational vehicles, and vibration exposure measurement data found in the literature.

Methods

Initially, vibration levels experienced by locomotive crews were measured and recorded at incremental speeds covering the range of normal train operation. In 2003, a method of measuring the vibration exposure continuously by means of a digital recorder was developed, allowing the vibration level over the entire run or crew shift to be analyzed. For each seating location measured, acceleration was recorded on the seat surface beneath the ischial tuberosities (pelvis) of the seated crew member and on the cab floor directly under the seat. At each of the locations, triaxial accelerometers were used to measure the vibration along the longitudinal, lateral, and vertical axes. Since the vibration environment varies throughout the route, and locomotive vibration levels have been found to be primarily speed dependent, a speed sensor was used to continuously measure the speed of the train.

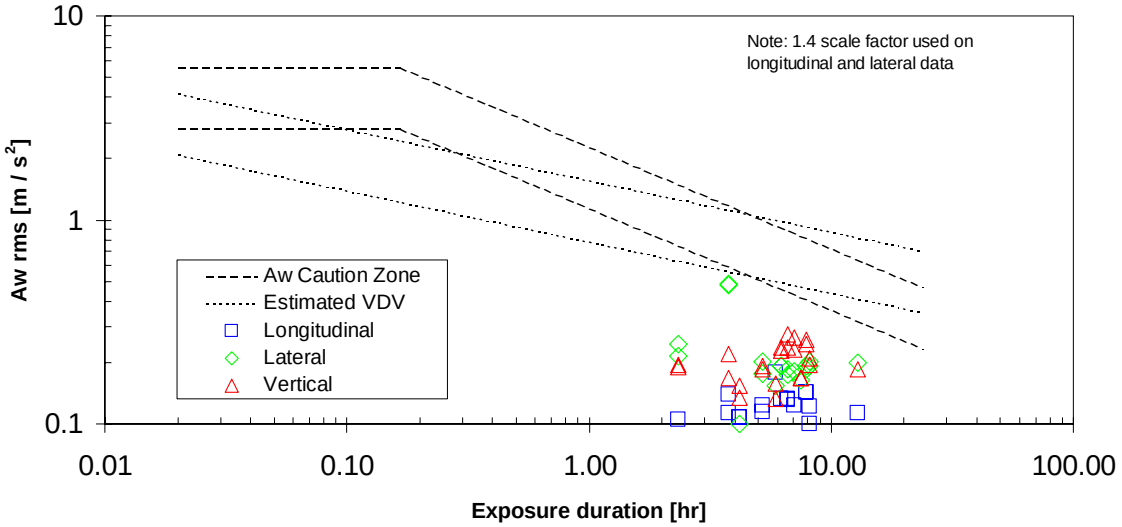
To evaluate the recorded vibrations levels, the data was divided into two-minute segments, which were each processed per the 1997 ISO standard for weighted RMS vibration levels and Vibration Dose Values (VDV). Additionally, PSDs and 1/3 Octave RMS values were calculated to determine the frequency content of the vibration. For each two-minute segment, the average speed of the locomotive was calculated to allow for correlation with the recorded vibration exposure values. The resulting exposure values for the entire run were calculated by combining the data from all of the two-minute segments.

Since introducing the continuous method of recording acceleration, 23 seating locations have been recorded on 11 locomotives traveling 11 different routes across various parts of the United States. One of the routes was a shift of ‘yard work’, traveling back and forth in a rail yard coupling train cars together.

Results

A guide to interpreting weighted acceleration values with respect to health is given in Annex B of the 1997 ISO standard. A health guidance caution zone is defined to indicate the

level of vibration where a health risk could exist. The figure below shows the caution zone from the ISO standard as the area between the dashed lines. The dotted lines represents an alternative caution zone, also defined in the 1997 ISO standard, that is based on an estimated Vibration Dose Value (eVDV) and a health guidance caution zone range of 8.5 to 17 $m/s^{1.75}$. Also shown are the data points representing the exposure levels for all 23 measurements in all three directions. In all cases, the weighted rms accelerations measured were below both caution zones defined in ISO 2631.



To put the locomotive vibration exposure level in perspective, the results were compared to the levels measured on heavy trucks, light and medium duty trucks, a van and a motorcycle. The locomotive vibration levels were also compared to levels reported for various vehicles found in the literature. The vibration environment on locomotives was found to be comparable to commercial on-road vehicles and below many commercial off-road vehicles and recreational vehicles.

To evaluate the effect of transient vibration and shock, a VDV was calculated for all of the measurements. The VDVs calculated for locomotive crew members averaged 4.6 $m \cdot s^{-1.75}$, with the highest value at 6.1 $m \cdot s^{-1.75}$. These values are well below the action level of 15 $m \cdot s^{-1.75}$ defined in the British Standard (BS 6841:1987), the EU Directive 'action value' of 9.1 $m \cdot s^{-1.75}$, and the EU 'exposure limit' of 21 $m \cdot s^{-1.75}$.

Discussion

The vibration exposure experienced during locomotive operation was found to be consistently below the health guidance caution zones defined in the ISO whole body vibration exposure standard. The Vibration Dose Value measure of vibration exposure, which is an additional measure that is more sensitive to occasional shocks, was found to be less than the action levels of the British Standard and the EU Directive.