A CASE STUDY OF WHOLE-BODY VIBRATION EXPOSURES ASSOCIATED WITH ORDINARY PASSENGER AND RECREATIONAL VEHICLES

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Introduction

Measurements and analyses were conducted of whole-body vibration aboard seven commercially available passenger and/or recreational vehicles: sedan; sport-utility vehicle (SUV); pickup truck; moving truck; motorcycle; all-terrain vehicle (ATV); and boat. The purpose of the testing was to measure and assess whole-body vibration exposure in a range of typical vehicle environments in order to gain understanding of typical exposure levels characteristic of activities of daily living.

Vehicle models tested (and model year) were: Ford Taurus (1995); Jeep Cherokee Sport (2000); Toyota Tundra SR5 (2002); Ford F-350 (1997); Harley-Davidson Electra Glide Classic (2004); Yamaha Kodiak 400 4x4; and Steiger Craft Model 21 Montauk. All vehicles were tested with their standard factory-installed seats and were operated under a range of normal operating conditions and speeds typical of intended vehicle use.

Methods

The measurement, processing, analysis, and exposure assessment methods follow the guidance of generally accepted, national and international consensus standards relevant to the evaluation of whole-body vibration, including ISO 2631-1 [1] and ANSI S3.18 [2].

Seats were instrumented with low-mass triaxial accelerometers mounted in seat pads. Accelerometers used in the test are specified to have flat frequency response over the frequency range of 0.5 to 80 Hz, and all accelerometers were recently calibrated traceable to the National Institute of Standards and Technology (NIST). Seat pads were installed following guidance in the relevant standards [1, 2], with sensitive axes of the accelerometers following the standard coordinate system with respect to the seated occupant. (The x-axis represents fore-aft motion; the y-axis represents side-to-side motion; and the z-axis represents vertical motion with respect to the occupant.)

Vibration data processing and analysis, including filtering, sampling, frequency-weighting, averaging, summation, and determination of basic and additional metrics followed procedures in the relevant standards [1, 2]. Digitized time series data were acquired and stored using a PC-based data acquisition system. Whole-body vibration exposure analyses were conducted via post-processing. During data processing, recorded periods of seat acceleration that were identified and verified as resulting from occupant-induced motion rather than vehicle motion were excluded prior to exposure analysis.

The basic evaluation metric for whole-body vibration is the frequency-weighted root-mean-square (r.m.s.) acceleration, a_w. The primary additional evaluation metric is the fourth-power vibration dose value, VDV. The VDV measured for a period of time can be normalized to a standard eight-hour time period using a standardized calculation process.

Testing of on-road vehicles was conducted on public roads. The routes included a variety of road surfaces and features that are typical of road travel in urban, suburban and/or rural areas. Testing of the ATV was conducted off-road, on rural trails. Testing of the boat was conducted in a bay and estuary in calm conditions with waves of less than one foot. The total duration of vibration measurements during vehicle operations ranged from approximately 1½ hours for the ATV and boat to approximately 4½ hours for the SUV.

Results

Results of basic and additional exposure metrics are summarized in the table below. Basic r.m.s. acceleration is expressed in m/s^2. Measured VDV for the duration of the test and VDV normalized to an 8-hour exposure period (VDV_8) are expressed in $m/s^{1.75}$.

Vehicle	a_{wx}	a_{wy}	a_{wz}	VDV_x	VDV_y	VDV_z	VDV_{8x}	VDV_{8y}	VDV_{8z}
Sedan	0.27	0.21	0.38	4.6	3.8	7.4	6.2	5.2	9.9
SUV	0.14	0.20	0.33	2.9	3.9	6.8	3.4	4.6	7.9
Pickup Truck	0.16	0.19	0.30	3.0	3.8	6.3	3.7	4.7	7.8
Moving Truck	0.22	0.21	0.53	3.8	3.5	11.3	5.2	4.8	15.4
Motorcycle	0.23	0.87	0.61	4.8	14.5	13.9	5.9	17.8	17.1
ATV	0.69	0.67	1.02	9.2	8.9	14.2	14.2	13.7	21.7
Boat	0.66	0.47	1.01	10.0	8.2	22.0	15.0	12.3	33.1

Discussion

Measurements and exposure analyses conducted in accordance with consensus standards may be compared with guidance for the assessment of whole-body vibration and impact with respect to health, as published in Annex B of the standards [1, 2], in order to address questions regarding potential health effects of vehicle operation.

It is also instructive to compare whole-body vibration exposures determined for these typical passenger and recreational vehicles with exposures measured in other vehicle types, including those driven by professional operators, and with other occupational exposures to whole-body vibration and impact. Comparisons may also be made with exposure assessments of vehicles measured by other investigators, in accordance with relevant standards, for example, locomotives and road vehicles, e.g., as reported in [3].

References

1. International Organization for Standardization (1997). Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General Requirements, ISO 2631-1:1997.
2. American National Standards Institute (2002). Nationally Adopted International Standard, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General Requirements, ANSI S3.18-2002.
3. Fries, R.H., N.K. Cooperrider, and R.E. Larson (1993). Locomotive and Road Vehicle Ride Quality Assessments, *ASME Rail Transportation*, RTD Vol. 6, pp. 219-227.