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CBM Suspension Seat
Vibration Transfer Test Analysis

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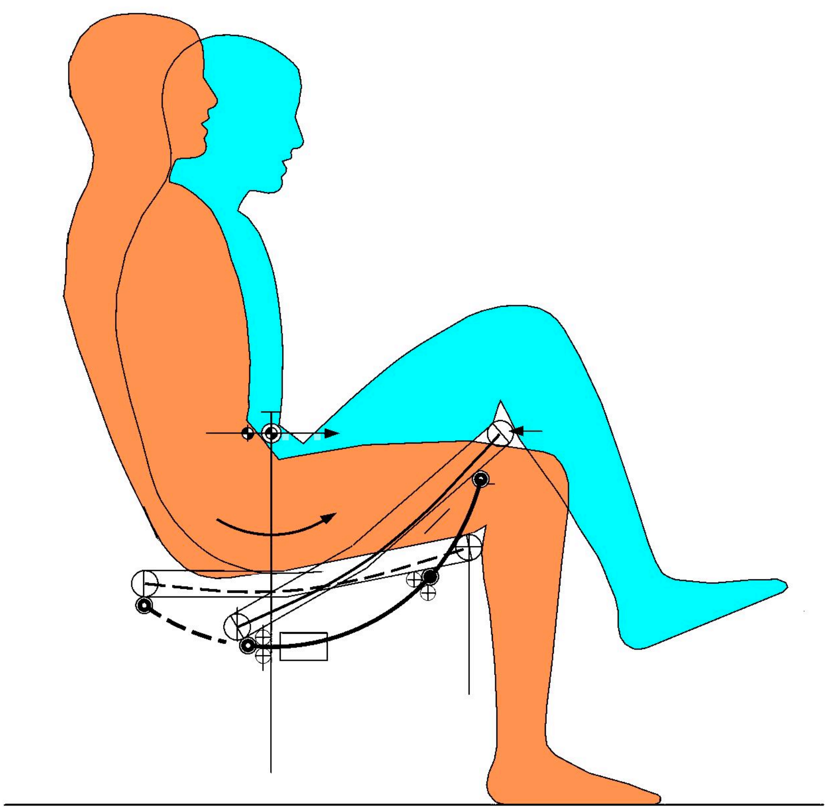
Background

The Counter Balanced Motion (CBM) Seat is designed as a comfort control mechanism with safety advantages. The seat components are mounted on an automatic seat tilting mechanism that dually functions as a comfort tilt adjuster and a safety restraint. The CBM Seat automatically increases the seat's containment angle to restrain the occupant, thus improving crash dynamics by redirecting forces and distributing them over longer periods. For non-impact seating this provides smooth positional transition for the occupant.



Generalized CBM Seat and Occupant Positional Changes in Frontal Impact

The seat cushion tilt angle adjustment is an important feature providing the angular motion isolator. The pendular motion also actuates an integrated backrest mechanism used for front and rear crash safety as well as for increasing seat and backrest support.

Description of Test and Terms

The vibrations test performed on the shake table is a procedure that is valid for testing in aircraft seating, large public transportation, heavy equipment seating, large 4x4 rigs, and RV's and generally, any suspension seat.

Seven vibration tests were performed at MGA Research Corporation, Troy, Michigan. in 2003 on a CBM Seat utilizing sand filled water dummy lap belted to the seat. Results from the tests were provided from the laboratory in the form of percentage of vibration transferred from the table at specific frequencies in frequency steps of 0.2 Hz. Less than 1 indicates dampening while over 1 indicate resonance.

Test 1-3 were performed with the suspension off and preset at low height. It is noted that when the CBM and isolator are considered "Locked" a small amount of movement remains due to mechanical tolerance play. Tests 4-7 were performed with the suspension on and pre run posture was set at mid-range of seat height. It is assumed here that suspension would always be functioning and used and that mid-height is the most common usage, so this report will focus on results for tests 4-7 only, Tests 4 is performed with the rigid seat (CBM locked), test 5 has the linear isolator function on the rigid seat, test 6 is with the CBM function on, and test 7 has the CBM and linear isolator functions on. The frequencies examined are limited in the range of 0-15 Hz; within these frequencies are the primary concerns for musculo-skeletal health effects.

The sand filled dummy was constructed with a solid plastic casing without lower legs and without pelvic, neck or lumbar motion. This produces more limited results than testing with Hybrid III dummies, as will testing with human subjects, due to voluntary and involuntary muscle movements. Therefore, this test was not designed to obtain direct data relating to the reduction of angular vibrations and dynamic forces at the neck, chest, lumbar joints, pelvis, femur, knees or legs due to the CBM automatic seat angle tilting. This could be examined with additional Madymo Modeling, HYGE Sled Crash Simulations and other testing.

Terms used

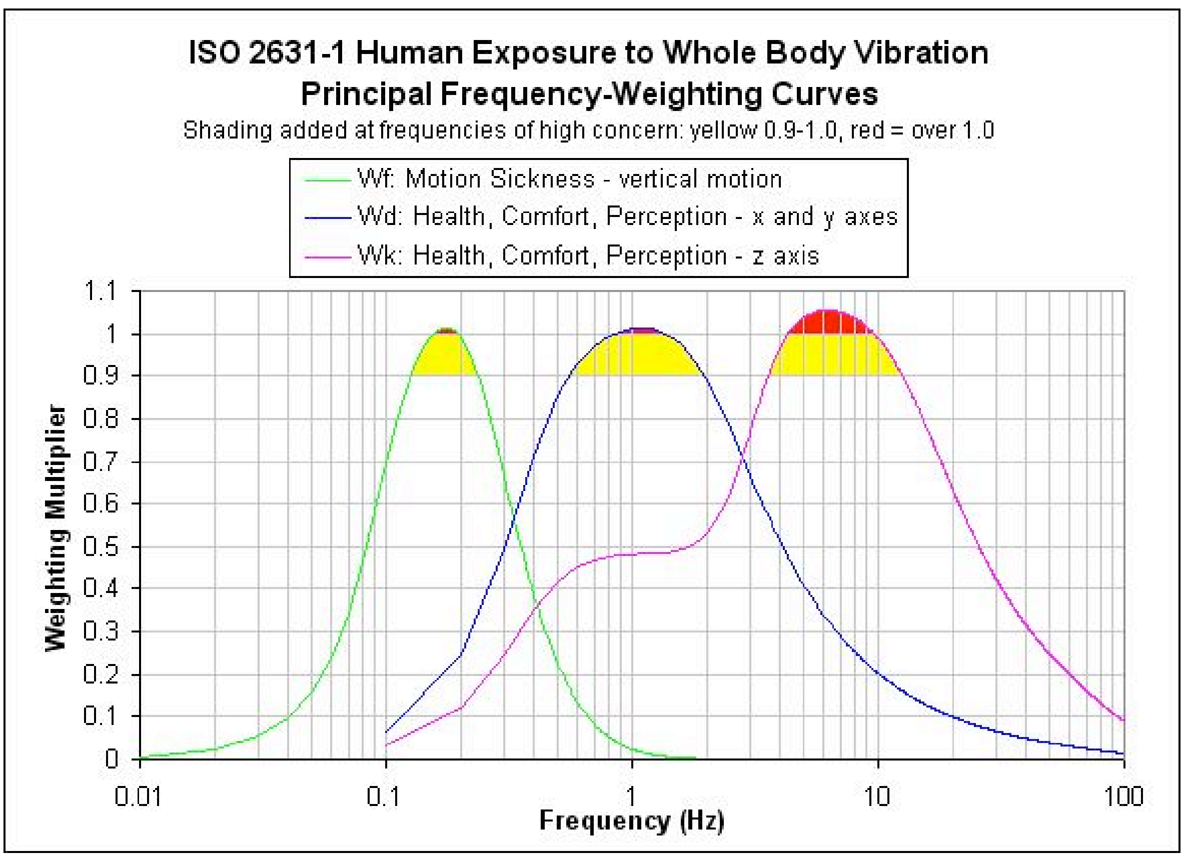
Rigid Seat	A standard seat cushion fixed in a position always parallel to the test table plane. This parallelism can occur with suspension and isolator functions.
Suspension	A standard, air pressure cylinder seat suspension that functions in the vertical (z) direction, up or down over bumps and pot holes, fixed to the test table at the bottom and supporting the seat structure at the top.
Isolator	A horizontally linear motion isolator that works in the forward or backward direction mounted between the Rigid Seat structure and the vibration test table to reduce vibrations motion along the x-axis,
CBM	Counter Balanced Motion is an automatic, angle tilting mechanism that provides instantaneous self-adjustment of the seat cushion while maintaining body equilibrium. It is also a pendular mechanism centered on axis on and about the center of mass of the occupant.

<u>Basic Test Configuration</u>

Sensor attachment at lower front of 87.4 kg (193 lb) sand filled water dummy.

ISO Vibration Standards

ISO standards have been developed to help address concerns of the effects of vibration on the human body. ISO standard 2631-1 provides frequency-based weighting multipliers which highlight principal frequencies ranges of concern for motion sickness, health, comfort, and perception. These standards are shown below in Graph 1.

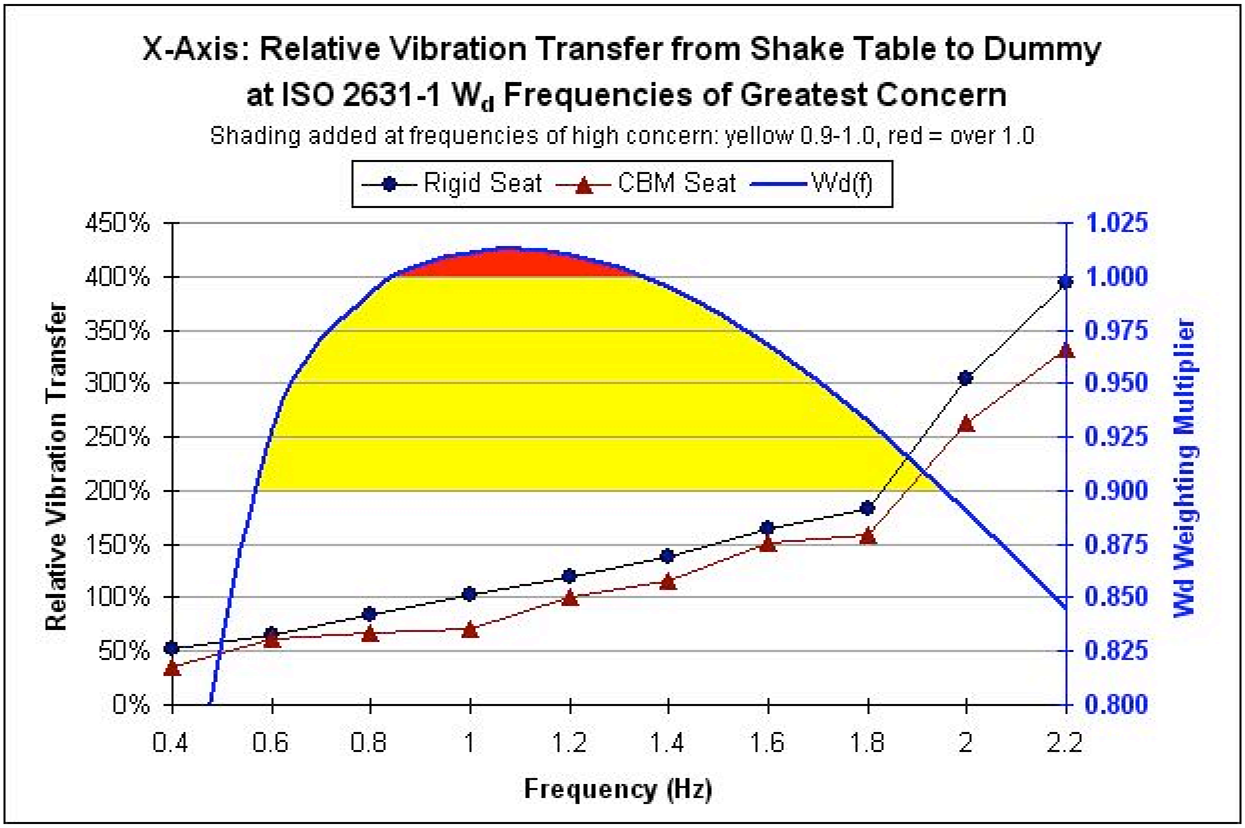


Graph 1: ISO Vibration Standards

Vibration Transmission on X-Axis with Respect to W_d Weighting Curve for Health, Comfort, and Perception

The results of vibration transmission on the x-axis are shown below in Graph 2a and 2b. These results are separated based on the horizontal isolator disabled (graph 2a) or operating (graph 2b). In reviewing these and subsequent graphs, it should be remembered that amplitudes below 1.0 indicate a dampening of table vibrations and values above 1.0 indicate a magnification of table vibrations.

Graph 2a illustrates the differences between a standard rigid seat and the CBM Seat along the x-axis. These tests use suspension however it is noted that rigid seat configuration without suspension is found in such areas as passenger cars, trucks and vans, transit bus and rail seating, and rowed aircraft passenger seating. The test results show that the CBM seat is better at dampening vibrations in this zone of concern. For example: at 1Hz the rigid seat transferred 102% of the vibrations compared to 71% with the CBM Seat.



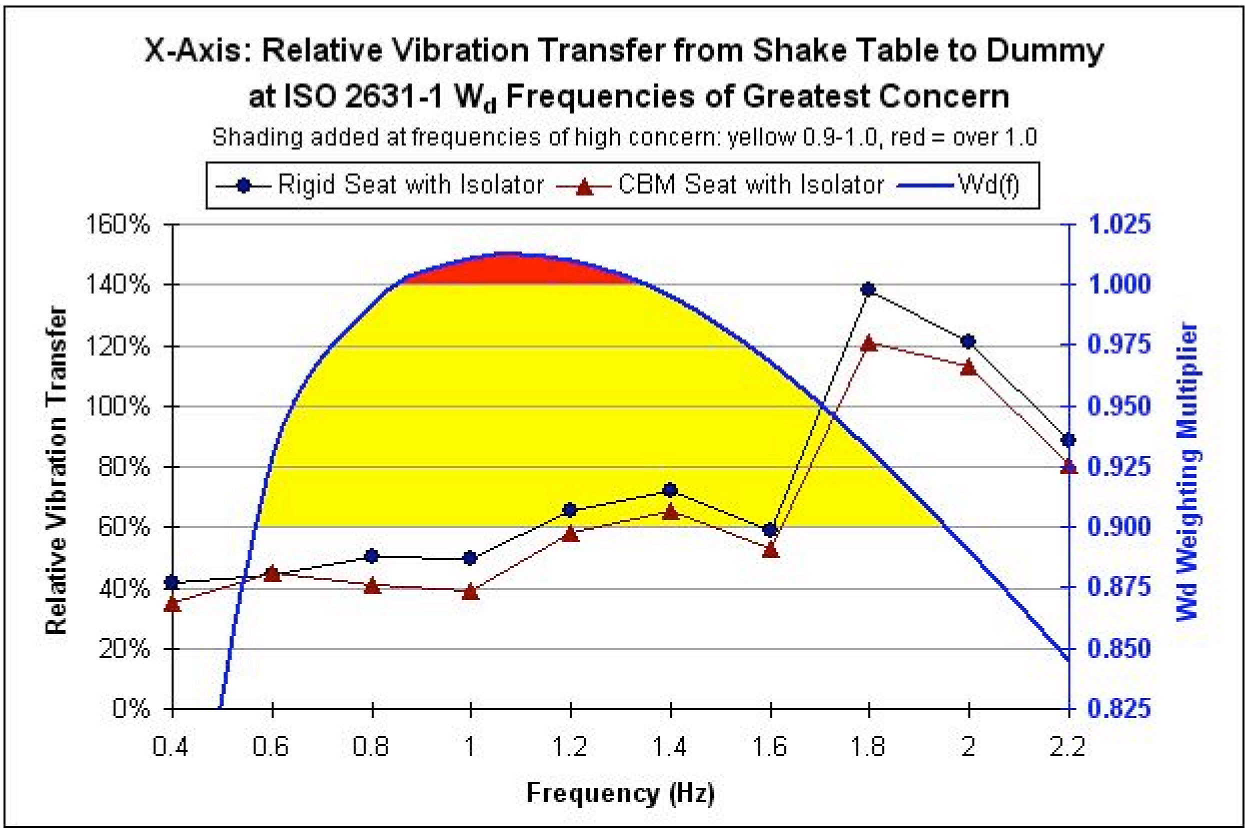
Graph 2a: X-axis vibration at W_d frequencies of greatest concern without horizontal isolator

We note that as the frequencies increase in Graph 2a the vibrations are increasingly magnified. This occurs with all seats because the natural resonant frequencies of the seat are being approached. Seats exhibit this behavior in approximately the same frequency range.

The CBM Seat reduced vibration magnification in the point of peak resonance from 436% to 352% at 2.4 Hz compared to the rigid seat. There was a 2 Hz range of resonance for both tests: 1-3 Hz for the rigid seat and 1.2-3.2 Hz for the CBM Seat.

When considering the resonance ranges with Graph 1, two additional items become apparent. The first is that the lower end of the resonance range is where the resonant frequencies meet ISO 2631-1, frequencies of greatest concerns. In this area, the CBM Seat is clearly more effective rigid seat. The second is that the CBM motion shifts the overall range of resonance away from the ISO concern zone.

Graph 2b illustrates the differences between a standard rigid seat and the CBM Seat along the x-axis when a horizontal vibration isolator is included. The rigid seat configuration is found in such areas as driver seats for transit bus and commercial trucking. The test results also show that inclusion of the CBM Seat provides increased vibration dampening in this zone of concern. For example: at 1Hz the rigid seat transferred 49% of the vibrations compared to 39% with the CBM.



Graph 2b: X-axis vibration at W_d frequencies of greatest concern with horizontal isolator

Graph 2b also shows that when the CBM was added to the isolator motion, the peak vibration transmission dropped further, from 138% to 121% at 1.8 Hz. As with the rigid vs CBM comparison, there is a slight upward step in the range of resonance.

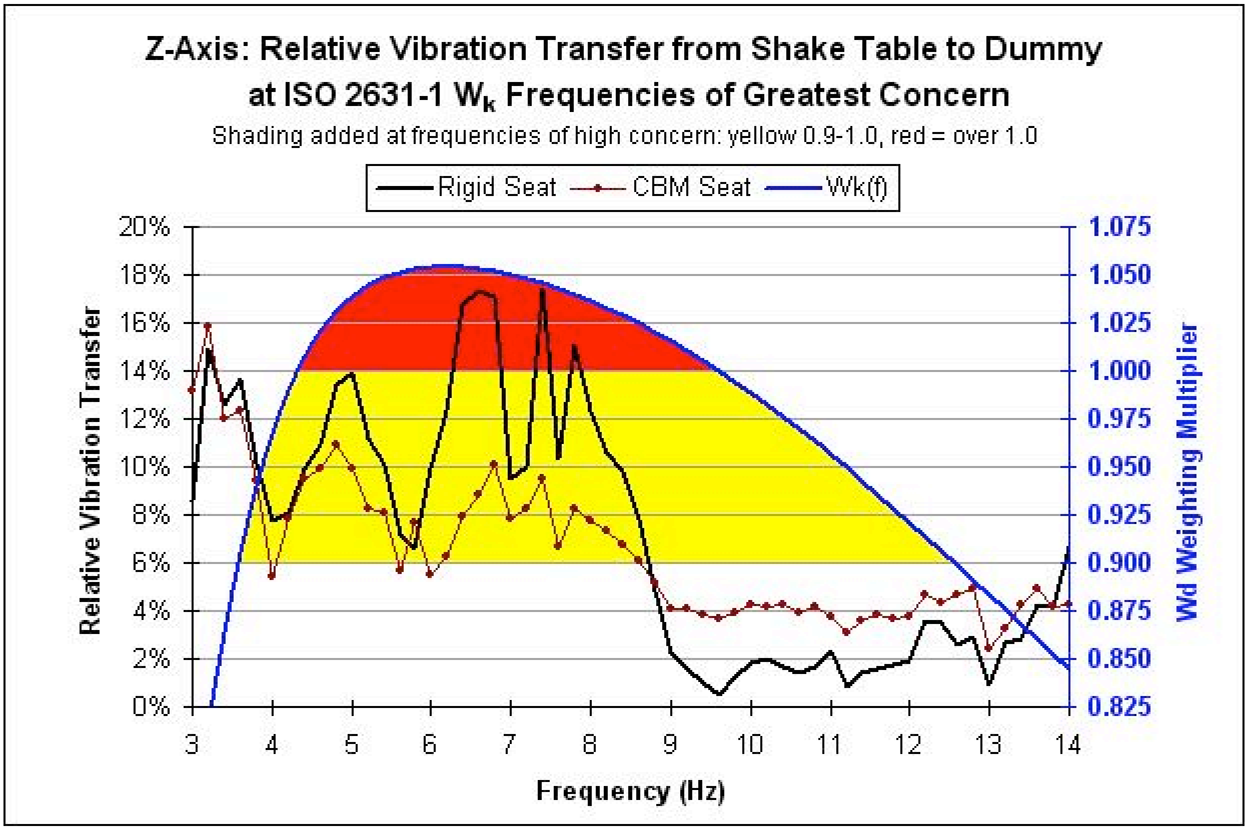
Vibration Transmission on Y-Axis with Respect to W_d Weighting Curve for Health, Comfort, and Perception

While collected, these values are not discussed here because the motion in the y plane was limited and a comparison of the relative transmission of minor motion is considered unnecessary.

Vibration Transmission on Z-Axis with Respect to W_k Weighting Curve for Health, Comfort, and Perception

The results of vibration transmission on the z-axis are shown below in Graph 3a.and 3b. These results are separated based on the horizontal isolator disabled (graph 3a) or operating (graph 3b). In reviewing these and subsequent graphs, it should be remembered that amplitudes below 1.0 indicate a dampening of table vibrations and values above 1.0 indicate a magnification of table vibrations.

Graph 3a illustrates the differences between a standard rigid seat and the CBM Seat along the z-axis. The test results here show the CBM Seat provides superior vibration dampening in the zone of highest concern.

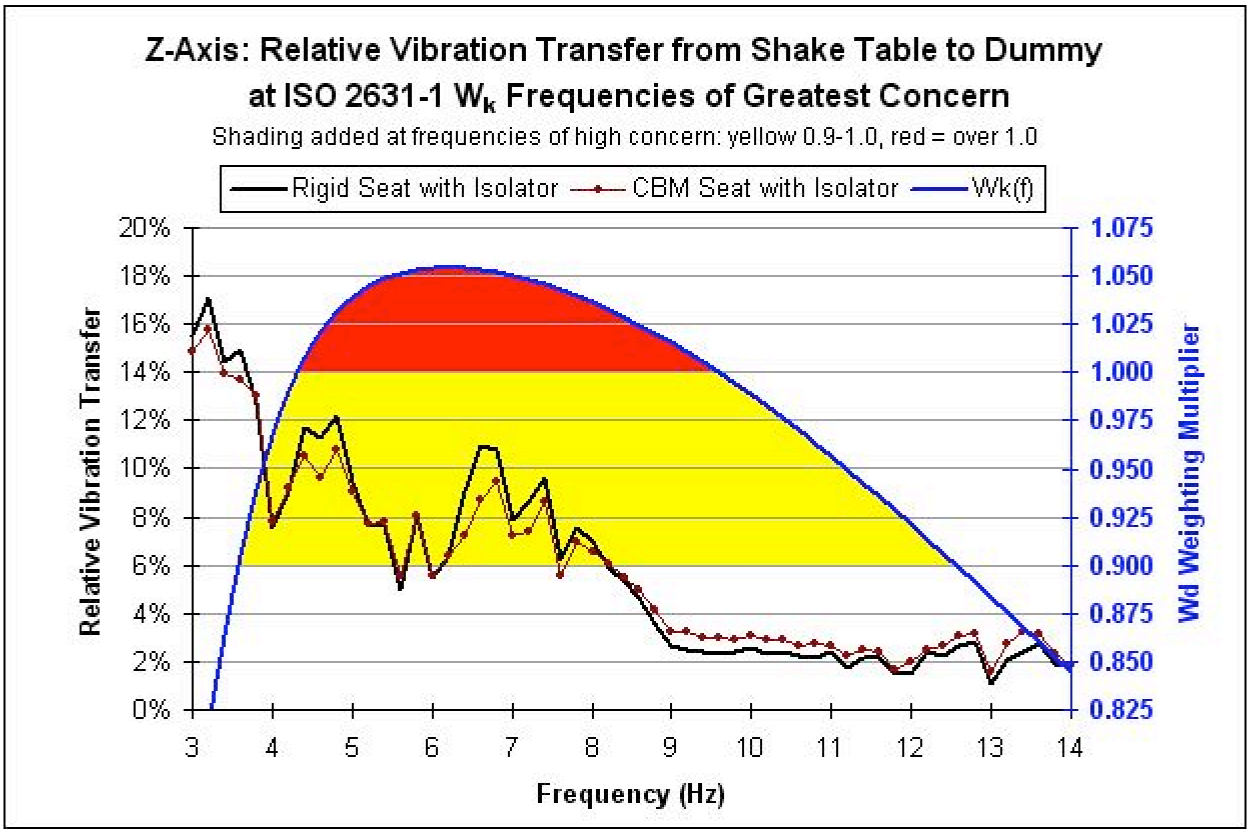


Graph 3a: Z-axis vibration at W_k frequencies of greatest concern without horizontal isolator

As Graph 3a shows, the rigid seat does dampen vibrations more effectively above 9Hz. But, per ISO 2631-1, this range is of increasingly lower importance and the overall vibration transmission is much lower than in the 4-9Hz range. The peak transfer value for the rigid seat was 17.2% at 7.4 Hz (CBM was 9.5% at 7.4Hz). The peak transfer value for the CBM seat was 10.9% at 4.8 Hz (rigid seat was 13.4% at 4.8Hz).

Peak vibration transmission for both seats was at 2.2 and 2.4Hz. At these two frequencies the rigid seat values differed only very slightly with the greatest being 39.5% at 2.2Hz. The CBM Seat displayed similar characteristics with the greatest value being 37.5% at 2.4Hz.

Graph 3b illustrates the differences between a standard rigid seat and the CBM Seat along the z-axis when a horizontal vibration isolator is included. The test results show that inclusion of the CBM Seat provides increased vibration dampening in this zone of concern. The rigid seat does dampen vibrations more effectively above 8.2 Hz but per ISO 2631-1, this range is of increasingly lower importance and the overall vibration transmission is much lower than in the 4-9Hz range. The peak transfer value for the rigid seat was 12.2% at 4.8 Hz. Peak transfer value for the CBM Seat was 10.8% at the same frequency.



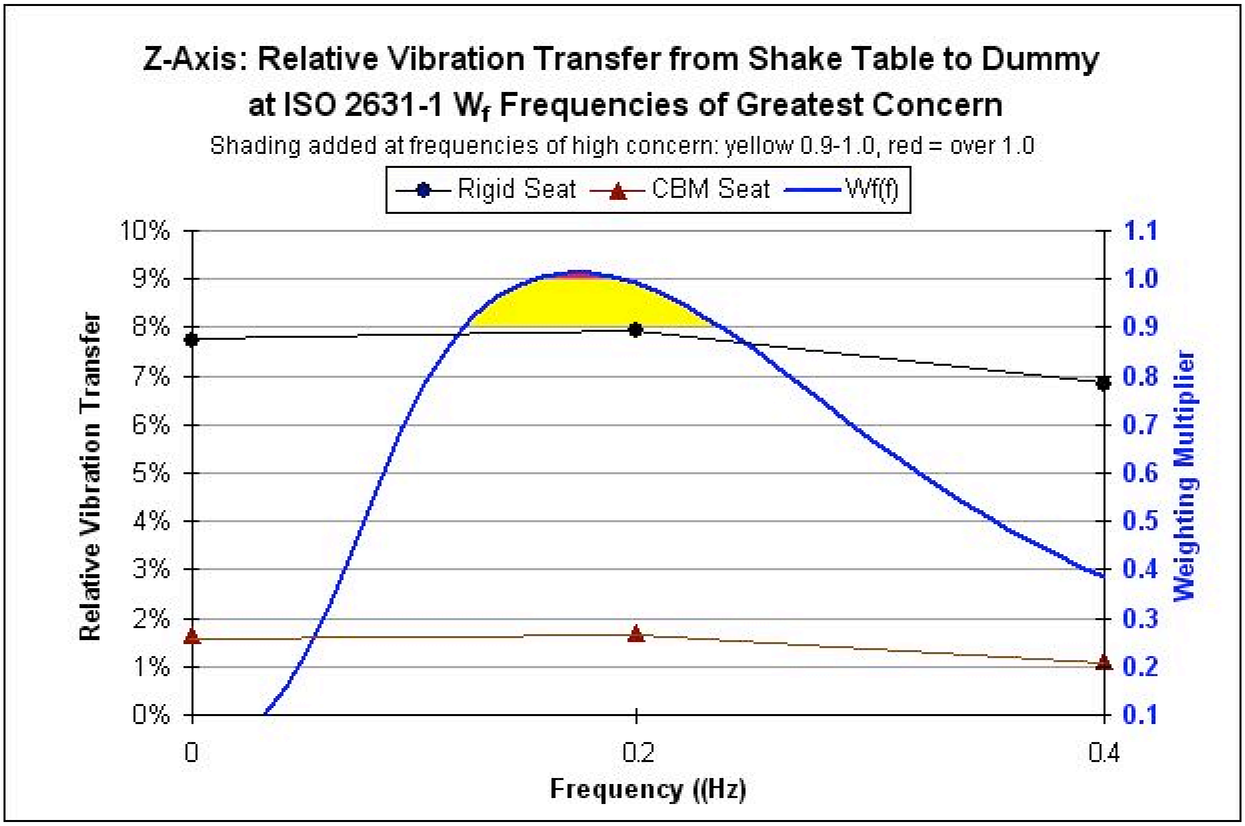
Graph 3b: Z-axis vibration at W_k frequencies of greatest concern with horizontal isolator

Overall peak vibration transmission occurred at 1.8Hz in both cases with the rigid seat at 20.7% and the CBM Seat at 20.8%.

Vibration Transmission on Z-Axis with Respect to W_f Weighting Curve for Motion Sickness

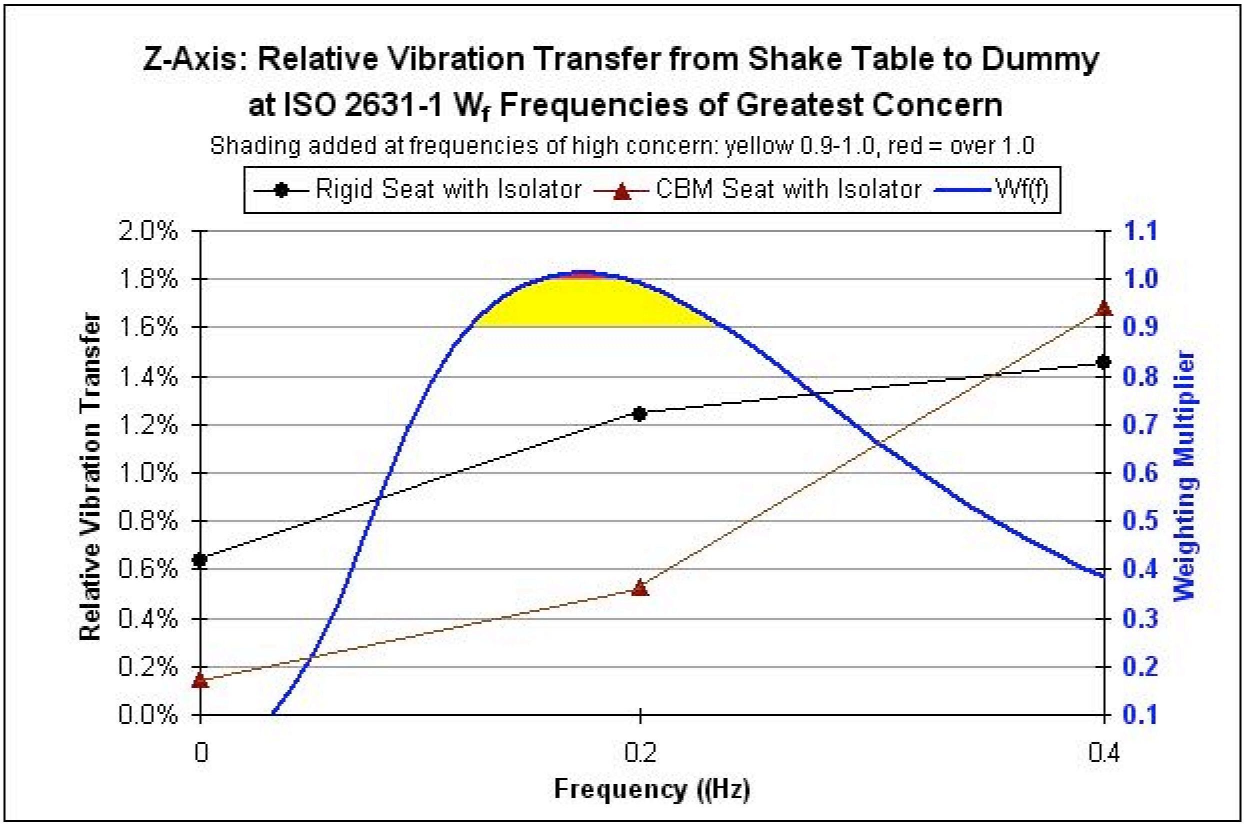
Figure 1 shows that motion sickness occurs at relatively low frequencies in vertical motion (on the z-axis) and is most problematic between 0.16-0.20 Hz. The testing laboratory collected only one data point in this range, at 0.2 Hz.

The results for the rigid seat and the CBM seat are shown in Graph 4a. At 0.2 Hz, the vibration transferred to the occupant by the CBM Seat was substantially (79%) lower than a conventional rigid seat.



Graph 4a: Z-axis vibration at W_f frequencies of greatest concern without horizontal isolator

The results for the rigid seat and the CBM Seat, with the isolator included, are shown in graph 4b. Including a horizontal isolator substantially lowered the vibration transferred in the vertical direction. When the CBM Seat was added to the isolator, vibration transfer was further reduced by 57%.



Graph 4b: Z-axis vibration at W_f frequencies of greatest concern with horizontal isolator

Conclusion

Results show that reductions in vibration transmission occur when a seat incorporates the CBM motion. These reductions occur in the ISO 2631-1 frequencies of greatest concern for human health, comfort, perception, and motion sickness. Overall vibration reductions were independent of the presence of a horizontal isolator.

The external characteristics of a rigid seat can be duplicated in a locked position of a CBM Seat. Therefore, while different rigid seat designs would produce different results, an applicable CBM design would still be expected to reduce vibrations.

Though data was limited, substantial reductions in vibrations related to motion sickness were seen when a rigid seat was compared to a CBM Seat. This could have notable advantages in public transportation such as aircraft, rail or bus passenger seating. Although tests were designed to simulate recorded road vibration for heavy transport trucks, the frequency-based evaluation would still hold.