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Counter Balanced Motion Seat for Automotive Comfort and Safety

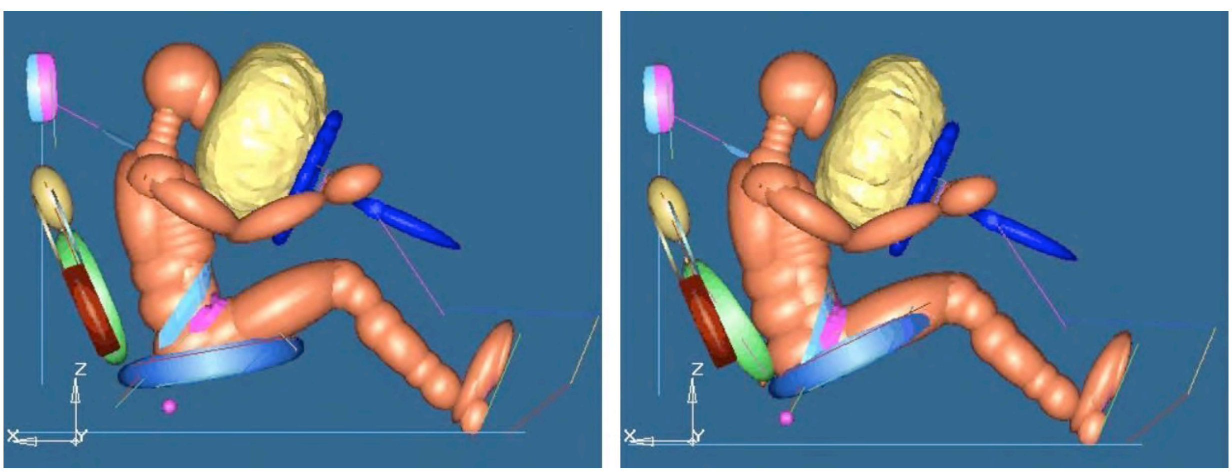
The Counter Balanced Motion (CBM) Seat is an optimized comfort control mechanism with crash safety and cost saving advantages. The main feature of this unique device is the arcuate path of motion of the seat that provides comfort adjustment and also acts as a safety restraint.

For comfort, the CBM Seat passively supports posture change. The movable backrest and lumbar offer continuous back support while driving. The CBM Seat automatically balances seat tilt and lumbar angle with optimal weight distribution, thus reducing driving fatigue. The seat, backrest, headrest and lumbar adjust to the posture and movements of the occupant without hand-activated adjustment.

For frontal crash safety, the CBM Seat utilizes the seat and lumbar cushions as a passive safety, crash restraint. It automatically increases seat containment angle to stop the occupant, redistributing forces and improving crash dynamics. The CBM Seat also actuates a backrest and headrest mechanism that increases rear crash safety.

In a typical frontal impact, the occupant continues forward and is restrained by the belt, often with some contribution by the knee bolster and airbag, with virtually no safety contribution from the seat pan structure (about 50 kN). The traditional late model seat in Figure 1, is compared to the CBM Seat 50 milliseconds into a crash simulation, both beginning at the same starting time at 12 degrees from the horizontal position. The traditional seat shows visible space between the lower backrest and the driver's back.

With the CBM Seat, effective deceleration has already begun. The driver's lower back, pelvis is still in contact with the lumbar support cushion and, more importantly, the face is not yet in contact with the airbag.



Traditional late model seat CBM Seat

Figure 1: Seat containment angles at 50ms into frontal crash simulation.

In Figure 1, (right) the angles the seat pan and bottom cushion make with the horizontal plane are notably different at 50ms. The body is kept in contact with the seat and begins to dissipate upper and lower body impact forces instantaneously, even before the seat belt or airbag can act. This occurs because the CBM Seat moves that quick with an arcuate path located proximate to the occupant's center of mass, (proximate to belly button when seated). The CBM Seat acts as the third occupant restraint, which increases the number of significant restraints and therefore improves the force distribution required to stop the body with an over all 10-60% reductions in Injury loads values recorded in the tests.

Crash simulation of the CBM Seat utilizing a softer airbag and softer belts; yield a reduction in injury loads. All tests have shown that the CBM Seat effectively prevents submarine of the lower body. These advantages are also seen in 25mph, unbelted frontal as well as 35mph offset-frontal impact simulations.

Results and Comparison of Crash Safety Tests

Frontal Belted Impacts (35mph NCAP)

- Current Safety Optimization: 2005 CBM Seat vs. NHTSA NCAP testing of the 2005 Nissan Maxima
- Sled Validation Testing: 2004 CBM Seat vs. NHTSA NCAP crash testing of the 2005 Nissan Maxima
- Current Safety Optimization: 2005 CBM seat vs. Identical seat but with CBM motion disabled (Fixed)

Frontal Unbelted Impacts (25mph)

- 2005 optimization of CBM Seat vs. Identical seat but with CBM motion disabled (Fixed Seat)

Rear Belted Impacts (25mph)

- 2005 optimization of CBM Seat vs. Identical seat but with CBM motion disabled (Fixed seat)

Frontal Belted Impacts

NHTSA's Full-Frontal Impact Star Rating, shown in Figure 2, is based on the combined probability of head and chest injuries for an average adult male. CBM technology alters occupant motion during a crash, reducing key accelerations and lowering the probability of these injuries.

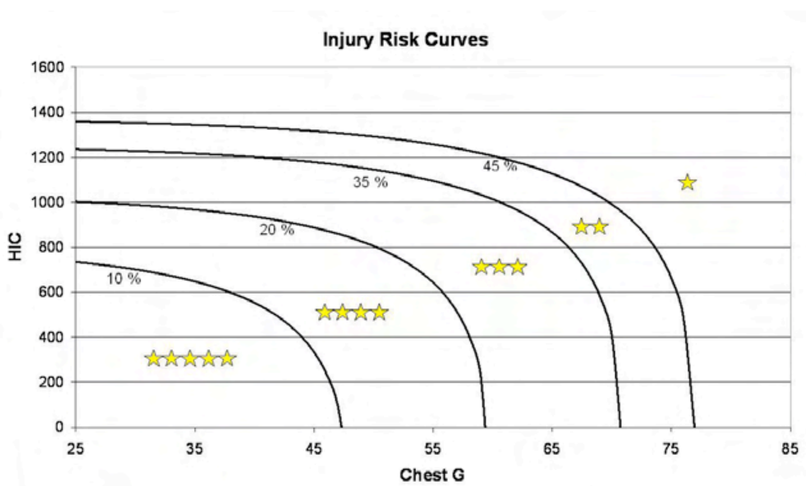


Figure 2: NHTSA Star Curve For Full-Frontal impact

In Figures 3 and 4, TNO Madymo simulations and NHTSA NCAP tests show that when using the CBM Seat the driver and passenger's head and chest acceleration injury levels are reduced by 23-28% compared to the 2005 NHTSA Maxima tested.

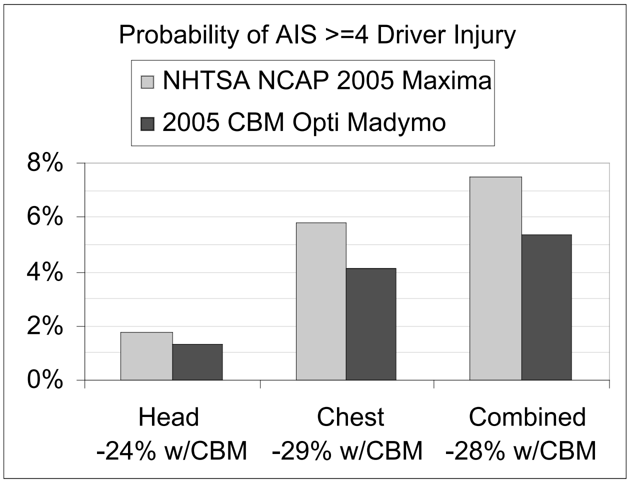


Figure 3: Reductions In Drier Injury Levels

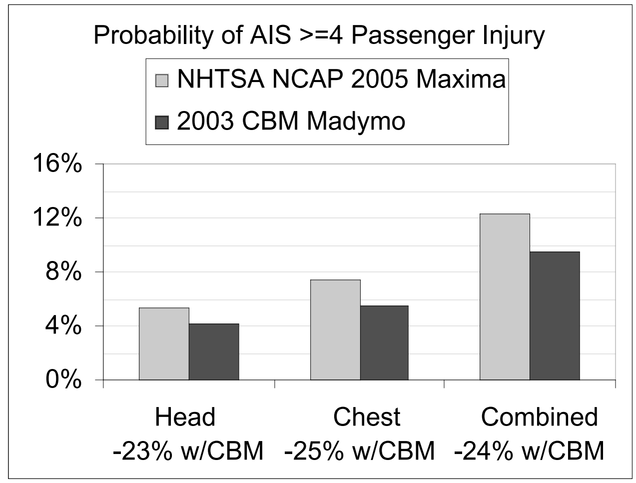


Figure 4: Reductions In Passenger Injury Levels

In the NHTSA NCAP testing, the 2005 Maxima received a 5 Star rating with a driver HIC36 of 282.2 and Chest G's of 39.9. By comparison, a 2005 CBM Opti based on the Maxim's interior produced an improvement of 28.9 % lower driver HIC36 of 201 and Chest G's of 34.6. See Table 1

NHTSA also reported a passenger HIC36 level of 609.1 and 43.7 Chest G's. An earlier 2003 CBM Madymo crash simulation showed that passenger HIC36 are reduced to 532 and Chest G are to 39.2.

When Star Ratings are applied to passenger results, the 2005 Maxima would get only a 4-Star rating but, if fitted with CBM Seats the Maxima would have a 5 Stars rating for both driver and passenger. Though a "6 Star" frontal impact rating is not currently used for the driver, the CBM technology realistically introduces its possibility.

Table 1 shows NHTSA reported compression forces were highest for the Maxima. Left and right femur forces are 84-94% lower with the CBM Seat. From the available data, only the Lower Tibia Indexes are + or - mixed, however the maximum TI values seen are -25.9% lower with the CBM.

The significance of reducing Femur loads from 2699 N down to 147 N while also increasing upper body safety, relates well to recent NHTSA and IIHS reports of higher leg injury and lower body incidents due to better airbags and belts.

Table 1: NCAP 35mph Belted AM50 Driver		NHTSA 2005 Maxima	CBM 2005 Opti.	Change With CBM
HIC36		282.8	201	-28.9%
HIC15		138.4	118.5	-14.4%
Chest g's F res.	g's	40.2	34.6	-13.9%
Chest Deflection	mm	20.7	35.4	41.1%
NIJ-NTE		0.24	0.159	-33.8%
NIJ-NTF		0.19	0.211	11.1%
NIJ-NCE		0.08	0.032	-60.0%
NIJ-NCF		0.07	0.033	-52.9%
Femur Left Comp	N	-1338	-214	-84.0%
Femur Right Comp	N	-2699.1	-147	-94.6%
TI-UL		N/A	0.475	N/A
TI-UR		N/A	0.352	N/A
TI-LL		0.38	0.473	24.5%
TI-LR		0.522	0.387	-25.9%

Sled Validation Testing: *2004 CBM Seat vs. NHTSA NCAP crash testing of the 2005 Nissan Maxima*

In order to validate Madymo simulations, a series of 16 sled tests were performed on a CBM design for the driver and passenger seats.

These sled tests were constrained by the requirements that the cabin envelope, existing interior, airbag and belt system not be modified. While these requirements limited some design features, tests show that even a partially optimized CBM seat still decreased combined injury loads beyond the 2005 NHTSA Maxima test levels.

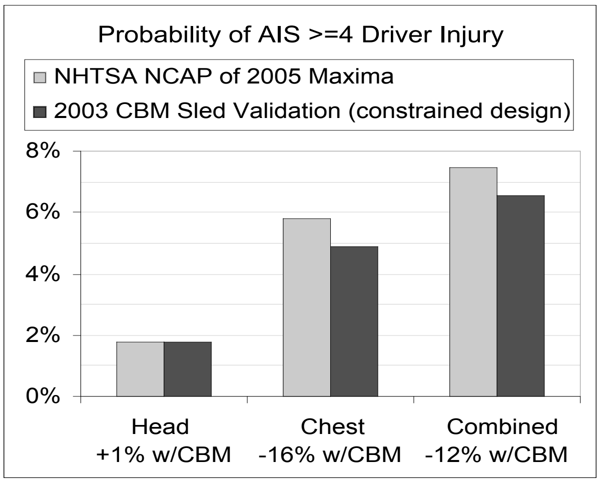


Figure 5: 2003 Sled Validation vs. 2005 NHTSA NCAP

HIC36 levels are slightly higher, 285 vs. 282.2, but Chest G's are 37.2, down from 39.9. The probability of injury is shown in Figure 5.

Current Safety Improvement Optimization: *2005 CBM seat vs. identical seat but with CBM motion disabled (Fixed Seat)*

AEC performed simulations in which a CBM 2005 seat motion is locked and not allowed to function, thus representing a standard seat. These seats are referred to here as "fixed", and are useful as a comparative guide to our current optimized models, whereas the only change between models is the seat motion.

In the CBM Seat optimized interior, NCAP simulations indicate that driver HIC36 levels can be reduced 22% from 271.2 to 201 and that Chest G's can be reduced 16% from 37.2 to 34.6. The effect on injury probability is shown in Figure 6.

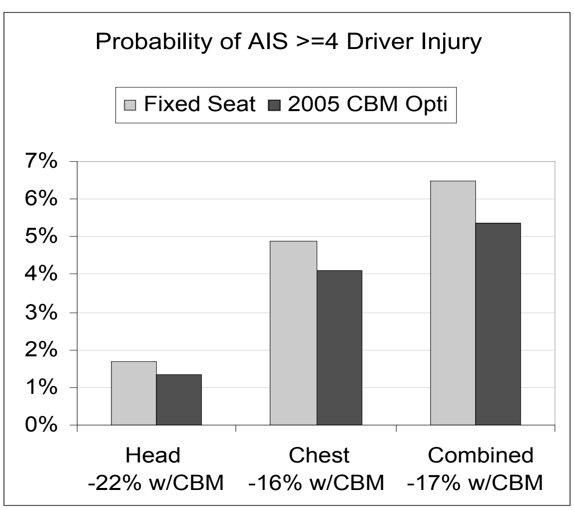


Figure 6: Predicted Injury probability

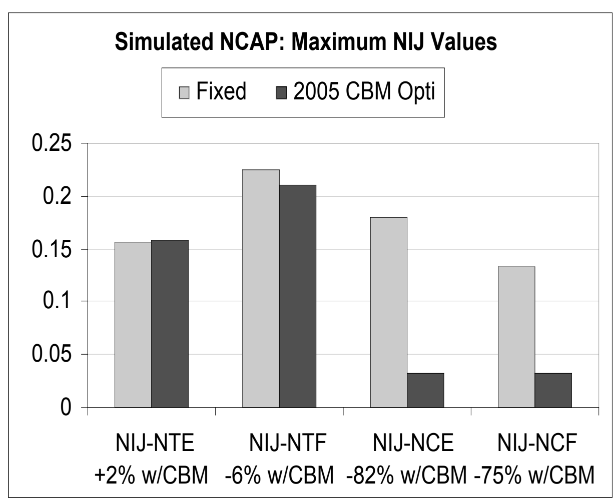


Figure 7: Maximum NIJ values

Based on 16 sled validation tests performed with the CBM seat and how well they compared to NHTSA NCAP reports[1], HIC15 level drop 25.9%, from 159.6 to 118.5. This gives a high degree of confidence in the Madymo modeling. See Table 2

NCAP Madymo simulations show the CBM Seat consistently reduces maximum NIJ values. It also shows that the CBM Seat is especially effective at lowering compressive neck injury loads. See Figure 7

Table 2 shows that the CBM reduces peak neck tension forces by 30%, falling from 1222N to 855N, and neck compression forces fall by 89%

Peak neck shear forces (-)Fx dropped by over 48% and though shear forces (+)Fx increased, the overall maximum neck shear fell 30% with the CBM Seat, from 566 to 397.

Chest deflection dropped by 18.2% from 43.3 to 35.4mm. Peak Femur loads drop by 10-22%.

Tibia Indexes, while mixed and slightly higher than a fixed seat are still less than 1/2 of maximum. Upper and Lower Lumbar loads are also low.

A summary of peak Dummy injury loads for both, frontal belted and unbelted impacts is given in Tables 1, 2.

Table 2: NCAP 35mph Belted AM50 Driver, Madymo		Fixed	2005 CBM Opti	Change CBM
HIC36		271.2	201	-25.9%
HIC15		159.6	118.5	-25.8%
Chest Deflection	mm	43.3	35.4	-18.2%
Chest g's Fres	g's	37.2	34.6	-7.0%
Neck Comp Fz	N	-335	-36	-89.3%
Neck Tension Fz	N	1222	855	-30.0%
Neck Shear Fx(-)	N	-566	-293	-48.2%
Neck Shear Fx +	N	64	397	520.3%
NeckBe My-	Nm	-20	-15	-25.0%
Neck BendMy(+)	Nm	32	35	9.4%
NIJ-NTE		0.156	0.159	1.9%
NIJ-NTF		0.224	0.211	-5.8%
NIJ-NCE		0.18	0.032	-82.2%
NIJ-NCF		0.133	0.033	-75.2%
Femur Left Com	N	-109	-214	50%
Femur L Tension	N	1382	1231	-10.9%
Femur Rig Comp	N	-184	-147	-20.1%
Femur R Tension	N	1368	1061	-22.4%
TI-UL		0.422	0.475	12.6%
TI-UR		0.426	0.352	-17.4%
TI-LL		0.39	0.473	21.3%
TI-LR		0.392	0.387	-1.3%

The CBM Seat, in frontal belted tests, shows a 25.9% reduction in HIC36. Fixed seat tests show an HIC of 271.2 compared to 201 with the CBM seat.

Frontal Unbelted Impacts (25mph)

Crash Simulation: *2005 optimization of CBM Seat vs. Identical seat but with CBM motion disabled (Fixed Seat)*

Unbelted frontal impact simulations show that windshield contact does not occur. A 10.7% drop in HIC36 levels drop, from 109.8 to 98, 10.7% with the CBM Seat. The HIC15 level also dropped 7.2% from 62.3 to 57.8. Chest deflection is reduced 3.7%. See Table 3.

Again, in unbelted cases, the significance of reducing Femur loads from 2594 N down to 1624 N while also increasing upper body safety provides an answer to recent reports of higher leg injury incidents.

[1] Reported NHTSA NCAP Driver HIC36 for the Nissan Maxima are 283 for 2005 (Test #5286) and 272 for 2004, (Test #4719), 3ms Chest G's reported were 39.9 for 2005 and 44.1 for 2004.

Chest deflection and acceleration were both slightly lower than a fixed seat. Maximum NIJ levels are lower in all categories. See Figure 7

The optimized CBM 2005 Seat lowered all Tibia Indexes by 16-22% and Lower Lumbar forces by 24-37%. Peak Femur compression forces show a 37-40% drop in both left and right legs. See Table 3.

Table 3: frontal unbelted Sled Validated Madymo 25 mph AM50 Driver		Fixed	2005 CBM Opti	Change with CBM
HIC36		109.8	98	-10.7%
HIC15		62.3	57.8	-7.2%
Chest Deflection	mm	27.1	26.1	-3.7%
Chest g's Fres	g's	28.2	27.9	-1.1%
Neck Comp Fz	N	-111	-69	-37.8%
Neck Tension Fz	N	402	396	-1.5%
Neck Shear Fx(-)	N	-126	-50	-60.3%
Neck Shear Fx(+)	N	914	949	3.8%
NeckBend My(-)	Nm	-3	-3	0.0%
Neck Bend My(+)	Nm	88	89	1.1%
NIJ-NTE		0.028	0.024	-14.3%
NIJ-NTF		0.28	0.272	-2.9%
NIJ-NCE		0.027	0.006	-77.8%
NIJ-NCF		0.061	0.014	-77.0%
Femur Left Comp	N	-2594	-1624	-37.4%
Femur Rt Comp	N	-2636	-1565	-40.6%
TI-UL		0.368	0.287	-22.0%
TI-UR		0.367	0.286	-22.1%
TI-LL		0.138	0.116	-15.9%
TI-LR		0.139	0.116	-16.5%

Table 4 Rear Impact: Sled Validated Madymo: 19.5 G AM50 Driver		Fixed	2005 CBM Opti	Change with CBM
HIC36		39.7	19.7	-50.4%
HIC15		38.1	16.8	-55.9%
Chest Deflection	mm	12	12.7	5.8%
Chest g's Fres	g's	12.1	10.1	-16.5%
Neck Comp Fz	N	-144	-179	24.3%
Neck Tension Fz	N	305	307	0.7%
Neck Shear Fx(-)	N	-247	-283	14.6%
Neck Shear Fx(+)	N	123	158	28.5%
Neck Bend My(-)	Nm	-7	-21	200.0%
Neck Bendi My(+)	Nm	13	15.68	20.6%
NIJ-NTE		0.055	0.142	158.2%
NIJ-NTF		0.074	0.055	-25.7%
NIJ-NCE		0.054	0.155	187.0%
NIJ-NCF		0.08	0.084	5.0%
Femur Left Comp	N	-811	-776	-4.3%
Femur Rt Comp	N	-820	-775	-5.5%
TI-UL		0.134	0.107	-20.1%
TI-UR		0.097	0.1	3.1%
TI-LL		0.454	0.581	28.0%
TI-LR		0.459	0.58	26.4%

Rear Belted Impacts (25mph)

Crash Simulation: *2005 optimization of CBM Seat vs. identical seat but with CBM motion disabled (Fixed seat)*

A summary of peak Dummy injury loads for belted rear impacts is given in Table 4.

In rear impacts, the CBM motion is reversed. The headrest moves up and forward to restrain the head sooner. HIC values are over 50% lower with the CBM. Neck and NIJ load levels are well below 1 (0.5-15% of maximum). In general, other differences are large but not of significant magnitude.

Vibration Transfer

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, anything that uses a suspension.

The improvement of the CBM Seat for large transport application is to provide an angular motion isolator. This reduces vibrations and stressful forces in the neck, chest, lumbar joints, pelvis, and legs by providing automatic seat angle tilting with instantaneous, self- angular adjustment of the seat cushion. For motion sickness concerns (0 to .5 Hz), tests indicate the CBM reduces vibration transfer by approximately 75%.

Repetitive stress of vibration transmission is reduced with lower magnitude forces acting on the body.

For health, comfort and perception issues ISO 2631-1 (*Mechanical vibration and shock - Evaluation of human exposure to whole body vibration*) is most concerned with z-axis values in the 4.4 - 9.5 Hz range where its frequency weighting factor, W_k is over 1.

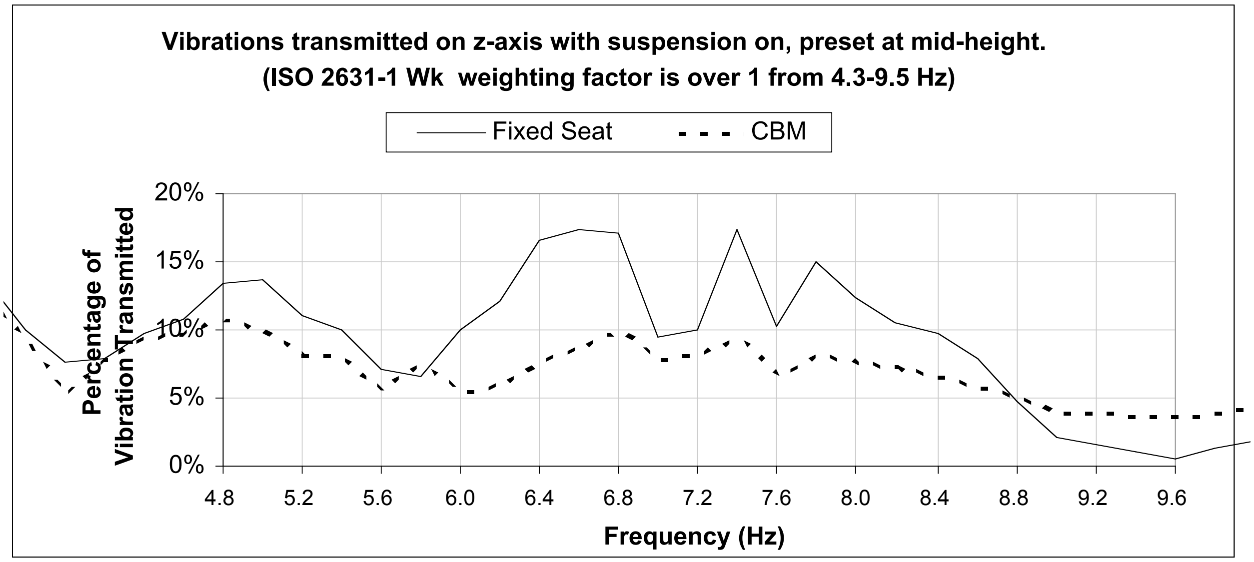


Figure 9: Vibration transmission on z axis

As shown in Figure 9, the CBM Seat, as tested for a truck, reduces vibration transfer in the primary area of concern. This reduction is a significant benefit for extended driving periods, especially for full time drivers. ISO 2631-1 is also most concerned with values on the x and y axes in the 0.9-1.3 Hz range, where its frequency weighing factor, W_d is over 1. As shown in Figure 10, the CBM Seat noticeably reduces vibration transfer in the primary area of concern.

Overall, vibration tests confirm that the CBM Seat enhances performance by reducing the transmission of peak vibrations to the body. The most noticeable improvement appears on the z-axis. Also improved is the x-axis transfer (compression, z and shear loads, x, y)

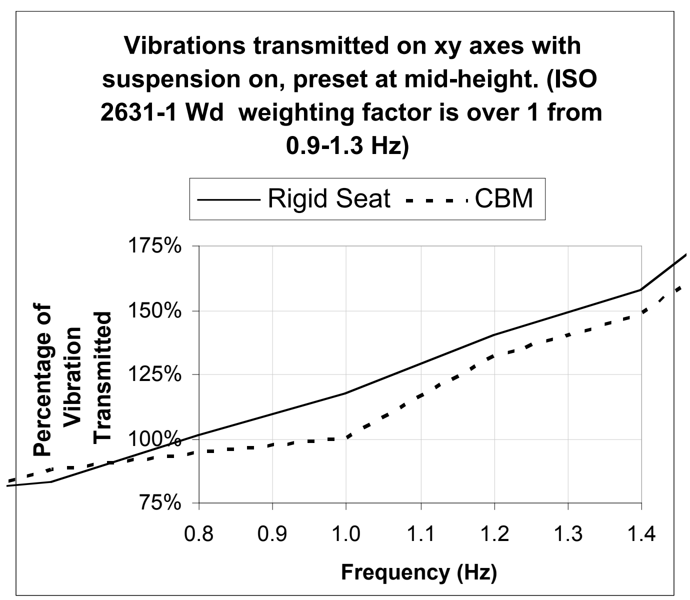


Figure 10: Vibration transmission on x, y axis.

CBM Models and Features

All models include the CBM Seat Pan and Lumbar Auto Tilt Adjuster with continuous support. All Models can provide All-Belts-To-Seat structure.

Model 100

CBM Seat pan and lumbar, auto tilt adjuster with detached upper backrest and side bolsters. CBM-headrest is optional.

Model 200

CBM Seat and 2 piece backrest, auto tilt adjuster with CBM headrest with detached side bolsters.

Shown in normal position and fully deployed.



Model 300

One piece backrest and headrest recliner with detached side bolsters with CBM headrest.

Model 400

Two piece backrest and headrest recliner with integral side bolsters with CBM headrest.




Model 500

One piece CBM backrest and headrest recliner with integral side bolsters.

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Benefits of the Counter Balanced Motion Seat

Comfort Features

- Automatic seat tilt and backrest recline for comfort without complex mechanisms.
- Automatic, self-adjusting lumbar support.
- Seat tilt-lock control with instantaneous release to insure that CBM performs for safety.
- Ease of use.

The seat motion and excellent support actually makes one feel safe. The reaction from people ride-testing the CBM Seat is "I want this seat in my car!" The CBM Seat's passive qualities insures consumer acceptance.

Front Impact Safety

The CBM Seat acts as a passive restraint system to reduce head, chest and lower body injury.

- This allows for the use of lower pressure air bags and softer belt characteristics.

Rear Impact Safety

The CBM Seat in rear impact tests, shows an 18% reduction in HIC values and a 6% reduction in neck loads:

- Reduced head trajectory in both directions, rear impact loading and forward unloading.
- Reduced HIC, neck and chest loading values while absorbing forces of the lower body.

Improved Safety Standards

Results of both, crash testing and computer modeling show significant reduction of injury loads in frontal, offset, unbelted and rear impacts. This presents an outstanding improvement to automotive safety.

Increases safety: The CBM Seat significantly reduces crash forces on the body and can noticeably reduce lower body injuries. It improves the performance of other safety restraints, allowing safe depowering (reducing pressure) of the air bag.

CBM Seat Cost, Savings and Offsets

The CBM Seat mechanism is an efficient and cost effective design to manufacture that provides backrest recline and seat tilt adjustment controls, for comfort and safety. This reduces other restraint modules costs while adding important features.

Cost, Savings

- Motorized Seat Tilt parts, one motor
- Active Head Restraint module
- Knee Airbag Module not required
- All Belts To Seat (ABTS) structure

Added Features

- Seat and Lumbar Auto Tilt Adjuster
- Frontal, offset and rear impact safety
- Simplified, easy adjustment mechanism
- Superior comfort

Confidentiality and Ownership of Data and Test Results.

The following patents and pendings dealing with the CBM Seat technology disclosed in this paper and in CBM Seat prototype, drawings, tests and graphs are owned by:

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Patents and Pendings

Seat Assembly and Method Granted Sept. 14, 1993	No. 5,244,252
Seat Assembly and Method Granted Oct. 24, 1995	No. 5,460,427
Seat and Lumbar Motion Chair, Assembly and Method granted Sept. 24, 1996	No. 5,558,399
Seat Lumbar Motion Chair, Assembly and Method Granted April 7, 1998	No. 5,735,574
Japan Patent No. Granted October 23, 1991	Seat Assembly and Method 3-518615,
Hong Kong Patent Granted May 5, 2000	Seat Assembly and Method 1012313
UK Patent No: Granted Nov. 11/ 2005	Dynamically Balanced Seat Assembly 2406047
Patent Cooperation Treaty (PCT) Publication date Nov. 17, 2005	Seat Assembly with Moveable Seat and Backrest and Method WO 2005/108158 A2
Australian Patent Application Nov. 7, 2005	Dynamically Balanced Seat Assembly 200326181
Dynamically Balanced Seat Assembly Having Independently and Arcuately Movable Seat and Backrest and Method Patent Pending Filed July 18, 2002	No. 10/175,452
Seat Assembly with Movable Seat and Backrest and Method Patent application April 30, 2004 Patent application November 3, 2005	 No. 10/836964 No. 11/276,068

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