A PROPOSED ROLLOVER AND COMPREHENSIVE RATING SYSTEM

Donald Friedman
Center for Injury Research
United States
Raphael Grzebieta
Injury Risk Management Research Centre
University of New South Wales
Australia
Paper Number 09-0515

ABSTRACT

The US, European and Australian New Car Assessment Program (NCAP) [1] and the Insurance Institute for Highway Safety (IIHS) produce ratings of new vehicle performance based on dynamic crash tests in frontal, side and rear crashes; and vehicle handling tests. No dynamic based crashworthiness ratings exist to date in relation to rollover crashes [2]. This study fills that gap and proposes a rating system for new vehicle performance in rollover crashes. Combined with existing rating systems, consumers will then have a complete and balanced picture of occupant protection performance.

A database of more than 40 Jordan Rollover System (JRS) dynamic rollover tests [3], [4], [5] assessing injury potential by roof crush and crush speed has generically validated NHTSA and IIHS statistical data as a function of FMVSS 216 quasi-static, strength to weight ratio (SWR) [6].
There is however a wide disparity between the performance of individual vehicles at the same or similar SWR between the IIHS statistical and JRS dynamic test data. That disparity has been partially investigated in a companion paper in this conference (Vehicle Roof Geometry and its Effect on Rollover Roof Performance [7]).

IIHS data indicated [8], [9] a 50% reduction in incapacitating and fatal injury risk with a fleet average SWR = 4. However, the use of a SWR-based rollover criterion does not provide sufficient crashworthiness fidelity essential for consumers, nor does such a criterion provide industry the opportunity to design cost-efficient rollover crashworthy vehicles based on occupant injury performance. Only a dynamic rollover testing protocol based on injury criteria would provide this information.

INTRODUCTION

NHTSA, in 1973, established a 13 cm (5”) occupant head and neck survival space criterion [10]. In 1995 [11], NHTSA proposed a post-crash negative headroom injury criterion and, in its 2005 [12] and 2007 [13] statistical studies, authenticated [14] that criterion to be five times more likely to result in injury. In 1979, the onset of head and neck injury was determined to be a head impact at 11 km/h (7 mph) as a consensus injury measure [15]. Recently, IIHS, based on its SUV and passenger car rollover crash statistical studies and quasi-static tests, announced that it will provide rollover roof crush crashworthiness ratings for 2010 model year vehicles. Their “good” rating criterion requires a SWR of at least 4. An “acceptable” rating requires a SWR of at least 3.25 and a “marginal” rating of at least 2.5. Vehicles with a lower SWR receive a “poor” rating.

This paper evaluates the generic dynamic JRS injury potential rating for far side occupants by the roof intrusion and intrusion speed criteria and compares it to the FMVSS 216 SWR ratings.
Under the auspices of the Center for Auto Safety and funding by the Santos Family Foundation and State Farm Insurance Company, the Center for Injury Research has completed JRS tests on 5 current model passenger cars and 5 current model light truck vehicles (LTV’s). Our analysis of the 10 JRS tests is the basis for our proposed rollover and comprehensive rating system.

This paper assembles these results and discusses the disparities, which exist as a result of geometry and design techniques that cannot be evaluated in the FMVSS 216 static tests. Details of the geometry and design technique disparities are discussed in a companion paper submitted in this conference entitled “Vehicle Roof Geometry and its Effect on Rollover Roof Performance” [7].

METHODS

Developing a predictive rollover injury potential rating system requires generic correlations with real-world crash injury data, a repeatable dynamic test machine, a representative rollover impact protocol, preliminarily validated experimental injury criteria and appropriate measuring devices. Although the scientific reliability and repeatability of the JRS has been affirmed [16], comparative dynamic results will not be available from a multiplicity of facilities until early next year.

The proposed IIHS rating effort is to quasi-statically test 2010 vehicles and to rate their structural strength according to SWR. The JRS test results are compared here to the SWR rating to assess whether a SWR only based strategy would provide sufficient information to ascertain occupant protection performance. The preliminary data indicates that a SWR only based strategy may not work as well as expected by consumer rating groups, such as IIHS and NCAP. Instead, we propose to supplement JRS results with both geometric data and quasi-static two-sided roof strength tests, with one side conducted at a 10º pitch angle.

Biomechanics Data

Separate papers regarding the biomechanical equivalent measurements and criteria using the Hybrid III dummy data, interpreted to represent real-world injuries, have been published [17], [18]. Work is continuing. NHTSA post-crash headroom is based on cumulative crush data and is not an accurate representation of injury. Head and neck injuries are a function of the impact crush and crush speed in any individual roll. Head injuries are not accumulated; they occur during one roll or another when struck at more than 16 to 19 km/h (10 to 12 mph). Neck bending injuries predominate and are not accumulated; they occur during one roll or another when the head is struck at more than 11 km/h (7 mph) with a maximum dynamic crush of more than 15 cm (6”) and residual crush of more than 10 cm (4”).

JRS Test Device

Figure 1 shows the JRS test device. Descriptions of how the test rig functions are described elsewhere [3], [4], [5]. The ends of the vehicle are mounted on towers on an axis of rotation through its Center-of-Gravity (CG). The vehicle is simultaneously rotated and released as a roadbed moves under it. The test is commenced from an almost vertically-oriented to the road bed position similar to that shown in Figure 1.

Figure 1. JRS Dynamic Rollover Test Device

During the simultaneous rotation and fall, the vehicle strikes the moving roadbed below on the leading side of roll (near side) at the side roof rail at the prescribed roadbed speed, vehicle angular rate, drop height and impact pitch angle. After striking the near side the vehicle continues to roll and strikes the side opposite to the leading side (far side). The vehicle is then captured. The motions of the vehicle and roadway are coordinated so that the touchdown conditions can be controlled and thus repeated within a narrow range that was considered acceptable in other crash test protocols used by IIHS and NCAP.

A 50th percentile Hybrid III Anthropomorphic Test Dummy (ATD) is used to monitor head and neck loads in the driver seat position. String potentiometers are used to measure roof intrusion and intrusion rates, as well as the ATD’s motion. High-speed cameras also record vehicle and ATD motions. The ATD is setup according to the FMVSS 208 protocol.

In the first roll, the vehicle is set at 5º pitch angle whereas in the second roll the vehicle is set at 10º pitch angle. Roll rate at 190º per second, yaw at 10º and roadway speed at 24 km/h (15 mph or 6.7 m/s) are the same for each of the two rolls. The results from a JRS study involving ten newer vehicles tested are shown in Figure 2 and 3.

	2007 VW Jetta		2007 Toyota Camry		2006 Hyundai Sonata		2006 Chrysler 300		2006 Pontiac G6	
	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2
Roof FMVSS 216 SWR	5.1	5.1	4.3	4.3	3.2	3.2	2.5	2.5	2.3	2.3
Road Speed (kph)	24	24	24	24	24	24	24	24	24	24
Pitch Angle at Impact (deg)	5	10	5	10	5	10	5	10	5	10
A-Pillar										
Peak Dynamic Crush (cm)	6.9	16.0	8.6	18.3	11.9	17.5	21.3	26.4	18.0	25.4
Cumulative Residual Crush (cm)	2.5	8.6	4.1	10.9	6.6		14.2	18.8	12.4	17.8
Maximum Crush Speed (kph)	9.2	11.4	8.0	13.2	8.0	--	12.07	17.06	12.07	21.08
B-Pillar										
Peak Dynamic Crush (cm)	3.8	6.1	4.6	10.7	--	6.6	11.2	13.5	9.1	15.0
Cumulative Residual Crush (cm)	1.5	3.3	1.8	5.3	--	2.0	6.9	8.6	6.4	8.6
Maximum Crush Speed (kph)	6.1	5.6	5.1	8.0	--	6.6	8.7	12.23	10.14	14.32
Compressive Neck Load, Fz	5158	5394	4211	2669	4835	3457	5598	1979	2399	1916
Peak Upper, Flexion Moment (N m)	279	318	--	--	--	--	414	155	198	155
Upper Neck, Nij*	0.96	1.08	0.78	0.76	1.63	1.15	1.80	0.40	0.66	0.54
Lower Neck, Nij**	1.17	1.28	--	--	--	--	1.44	0.57	0.68	0.54

*Based on by NHTSA: Compression 6160 N, Flexion 310 Nm, Extension 135 Nm

**Based on values presented in Mertz, et. al, 2003: Compression 6200 N, Flexion 610 Nm, Extension 266 Nm

Volvo XC90 SWR-4.6 IBM-11.3 | Honda CRV SWR=2.6 IBM=18.7 | Honda Ridgeline SWR=2.4 IBM=28.9 | Jeep Grand Cherokee SWR=2.2 IBM=29.4 | Chevrolet Tahoe SWR=2.1 IBM=21.8

	2005 Volvo XC90		2007 Honda CRV		2006 Honda Ridgeline		2007 Jeep Grand Cherokee		2007 Chevrolet Tahoe	
	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2
Roof FMVSS 216 SWR	4.6	4.6	2.6	2.6	2.4	2.4	2.2	2.2	2.1	2.1
Road Speed (kph)	24	24	24	24	24	24	24	24	24	24
Pitch Angle at Impact (deg)	5	10	5	10	5	10	5	10	5	10
A-Pillar		***								
Peak Dynamic Crush (cm)	4.3	8.1	8.6	16.5	19.8	36.6	21.3	30.0	20.1	35.6
Cumulative Residual Crush (cm)	1.3	2.5	4.6	9.1	12.7	27.7	16.5	23.1	14.7	27.7
Maximum Crush Speed (kph)	3.1	5.1	6.4	8.5	13.2	24.1	11.75	13.84	9.8	18.67
B-Pillar										
Peak Dynamic Crush (cm)	3.0	5.3	5.1	8.6	15.2	28.2	18.5	25.7	13.2	24.9
Cumulative Residual Crush (cm)	0.5	1.8	2.0	3.6	8.6	18.8	14.2	19.8	8.9	17.5
Maximum Crush Speed (kph)	2.7	3.5	4.2	5.5	9.0	11.1	12.71	10.46	6.8	11.27
Compressive Neck Load, Fz	2889	3628	5583	3687	10006	4685	9757	6781	6101	3318
Peak Upper, Flexion Moment (N m)	128	259	255	328	492	324	470	396	304	247
Upper Neck, Nij*	0.52	1.05	1.02	1.30	1.64	1.19	1.75	2.07	1.09	0.81
Lower Neck, Nij**	0.62	0.87	1.20	1.10	2.10	1.06	2.00	1.59	1.02	0.87

*Based on by NHTSA: Compression 6160 N, Flexion 310 Nm, Extension 135 Nm

**Based on values presented in Mertz, et. al, 2003: Compression 6200 N, Flexion 610 Nm, Extension 266 Nm

*** Determined through photoanalysis of High Speed Video

Figure 2 and 3. 2-Roll JRS test results for 10 current production vehicles.

Typical graphs of far side roof crush, crush speed, and road load are shown in Figures 4 and 5.

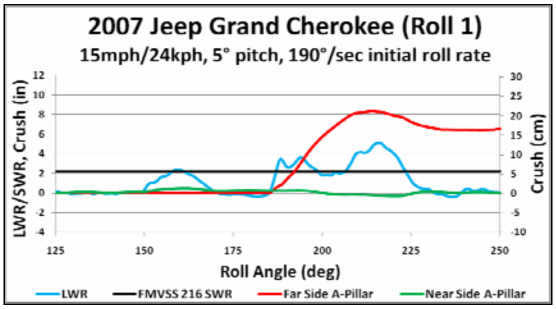

Figure 4. Far Side Crush versus Roll Angle.

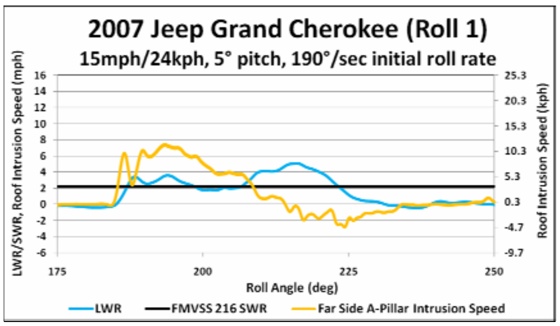

Figure 5. Far Side Intrusion Speed versus Roll Angle.

The main reason that the vehicle is subjected to two rollover events in the JRS is based on observations published by Digges and Eigen [19] [24]. They showed that rollover crashes lasting 8 quarter turns or less (i.e. two full rolls) accounted for more than 90% of all rollover crashes, where a fatal or serious injury experienced by occupants was recorded.
The generic slope composite chart shown in Figure 6 presented by Paver et al [20] and by Friedman [21] that compares injury criteria and injury rates versus SWR from previous papers correlates well with NHTSA and IIHS data versus FMVSS 216. It indicates that an SWR of about 4 would be “good”.

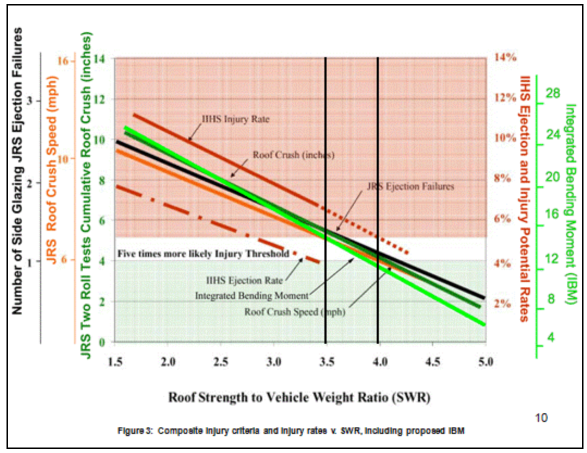

Figure 6. Composite NHTSA, IIHS, and JRS Injury Criteria.

M216 10° of Pitch Quasi-Static Tests

The M216 test machine is shown in Figure 7. It is a fixture with two platens, both oriented with 10° of pitch and one side at 25° of roll and the other at 40° of roll.

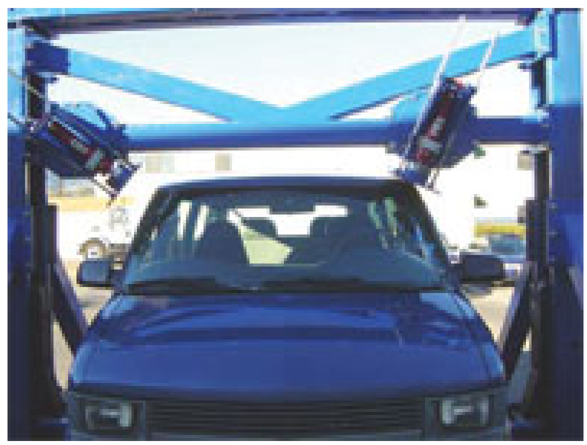

Figure 7. Modified FMVSS 216 Fixture (M216).

Figure 8 indicates the second side SWR performance of some of the 40 vehicles which have been tested.

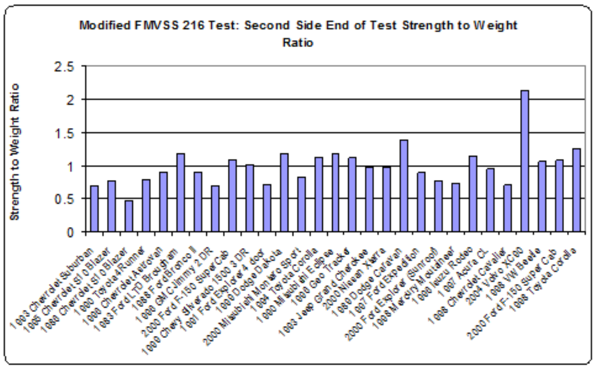

Figure 8. Second Side M216 versus 216 SWR.

Figure 9 describes the relationship between M216 results and FMVSS 216 with confidence limits.

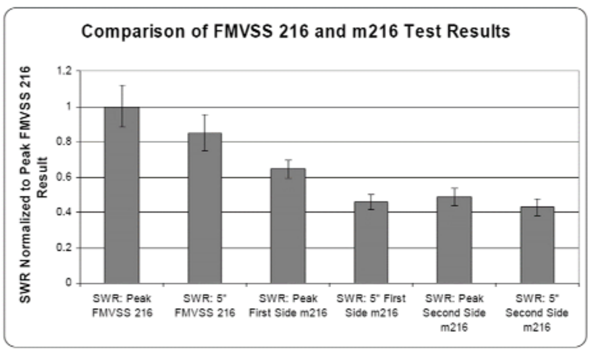

Figure 9. M216 and 216 Relationship with Confidence Limits.

Figure 10 is a scatter plot of the relationship between M216 tests of production vehicles and their SWR. Because serious injuries are strongly related to 10° of pitch crashes in the National Accident Sampling System (NASS) [22], [23] it would seem appropriate to factor a second side quasi-static test performance into a predictive rating. Such a test could also provide an indication of the vehicles structural elasticity, another factor important to its injury potential performance.

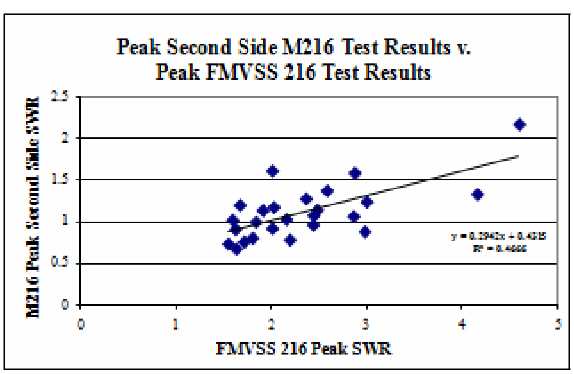

Figure 10. Scatter Plot of M216 and SWR.

Geometric Considerations

Experimental [7] and empirical (NASS) [22] data suggest that geometrical and dimensional vehicle configurations influence how vehicles roll. Front-wheel drive vehicles tend to roll with substantial forward pitch stressing windshield pillars, which are generally weak and undetected by FMVSS 216.

It is estimated that a difference between the major and minor radius of a vehicle (its rollover "roundness") of only a few centimeters (inches) can play an important role in the ability of the roof structure to remain intact. The Honda CRV is the roundest of the 10 JRS-tested vehicles both in transverse section and the longitudinal rake of the windshield and roof as shown in Figure 11.

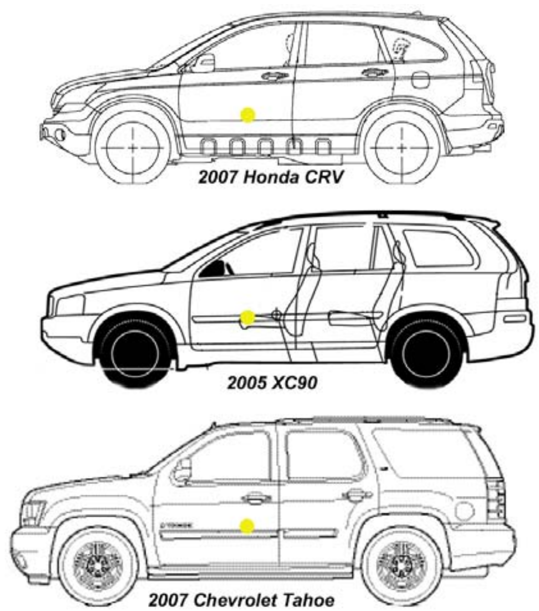

Figure 11. Geometric differences with CG.

Other geometric factors not discernable in static tests, nor yet explored are: the CG position relative to the windshield header, the weight distribution (shifting of the CG), the pitch moment of inertia and the vehicle height-to-width ratio.

RESULTS

Generic Ratings

A rating system requires criteria. For the quasi-static performance, we assumed:

- an SWR of 4 or more is "good",
- more than 3.25 is "acceptable",
- more than 2.5 is "marginal", and
- less than 2.5 is "poor".

We compared the FMVSS SWR to the maximum residual and dynamic intrusion of some 40 vehicles (including the 10 current production vehicles shown in Figure 2 and 3). For the JRS generic data, we used the NHTSA residual crush and the cumulative residual crush criteria. Since 65% of serious injury rollovers are completed in four quarter turns, for residual crush after one roll, we used:

- less than 5 cm (2") per roll to represent "good" performance,
- less than 10 cm (4") to represent "acceptable" performance,
- less than 15 cm (6") to represents "marginal" performance, and
- more than 15 cm (6") to represent "poor" performance.

For cumulative residual crush after two rolls which covers 95% of all serious injury rollover crashes[19], we used:

- less than 10 cm (4") to represent "good" performance,
- less than 15 cm (6") to represent "acceptable,"
- less than 20 cm (8") to represent "marginal," and
- more than 20 cm (8") to represent "poor" performance.

For maximum dynamic crush, we used:

- less than 10 cm (4") to represent "good" performance,
- less than 15 cm (6") to represent "acceptable,"
- less than 20 cm (8") to represent "marginal," and
- more than 20 cm (8") to represent "poor" performance.

Similarly, with respect to intrusion speed, in any roll:

- "good" is represented at less than 10 km/h (6 mph),
- "acceptable" is 10 to 13 km/h (6 to 8 mph),
- "marginal" is 13 to 16 km/h (8 to 10 mph), and
- "poor" is more than 16 km/h (10 mph).

Specifically, each of the scatter charts are ordered by SWR versus JRS dynamic data. The ratings "good", "acceptable" ,"marginal", and "poor" were chosen based on consensus injury measures for crush and intrusion velocity [8-15].

Figure 12 is a scatter plot of the composite of all JRS tests for the first roll by residual crush. All plots are segmented by the criteria for SWR and JRS dynamic tests.

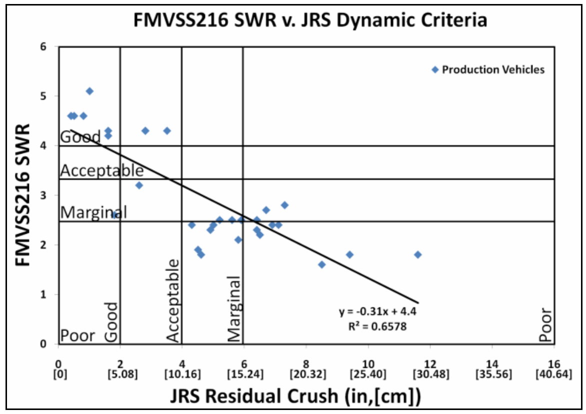

Figure 12. JRS Testing Results for Residual Crush After One Roll.

Figure 13 is the cumulative residual crush from two JRS roll tests.

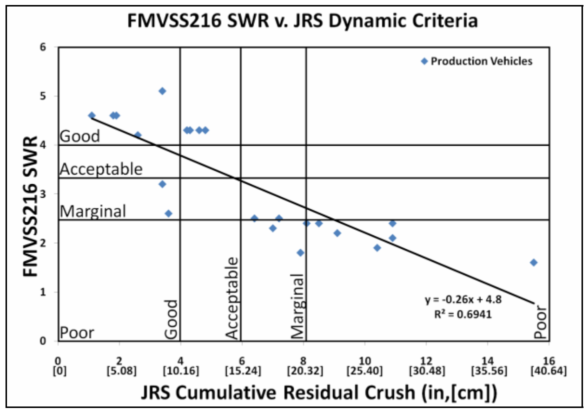

Figure 13. JRS Testing Results for Cumulative Residual Crush After Two Rolls.

Figure 14 is the same scatter plot by maximum intrusion speed.

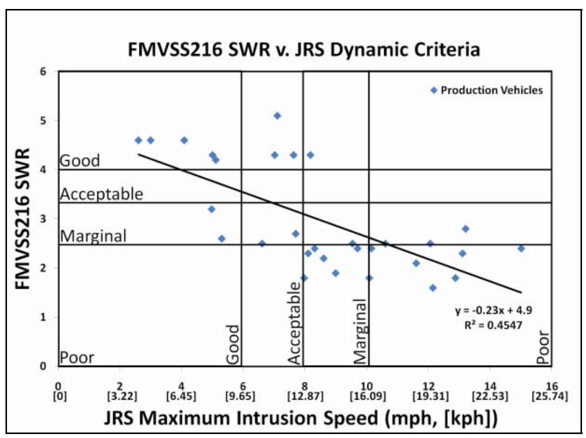

Figure 14. JRS Testing Results for Maximum Intrusion Speed.

Figure 15 is the same scatter plot by maximum dynamic crush.

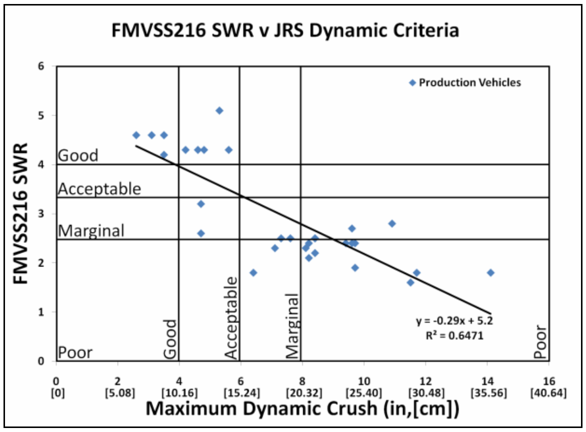

Figure 15. JRS Testing Results Maximum Dynamic Crush.

Current Production Vehicle Testing by SWR versus JRS Ratings

Scatter plots for the 10 vehicle set performed with the same protocol are presented next. Figure 16 and 17 show the disparity between LTV's and passenger cars. This is more specifically identified by residual crush after roll 1 and then cumulative crush after roll 2.

Figure 16 shows the residual crush results after roll 1, where 3 passenger cars and 2 LTV's fall in "acceptable" or "good" in JRS testing and 6 fall below the "acceptable" level. 3 passenger cars and only 1 LTV are better than "acceptable" for SWR.

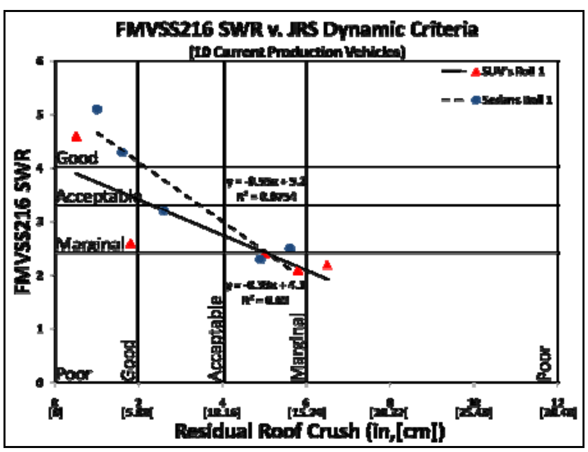

Figure 16. JRS Test Results, Current 10 Vehicles by Residual Crush, by LTV's and Sedans.

Figure 17 examines cumulative residual crush and shows that the disparities are larger when the second roll at 10º of pitch is considered. The sedans held their relative positions, while three of the LTV's fall to a "poor" in JRS testing. Those anomalies are thought to be associated with vehicle parameters discussed in Figure 11 and in the companion geometry paper. [7]

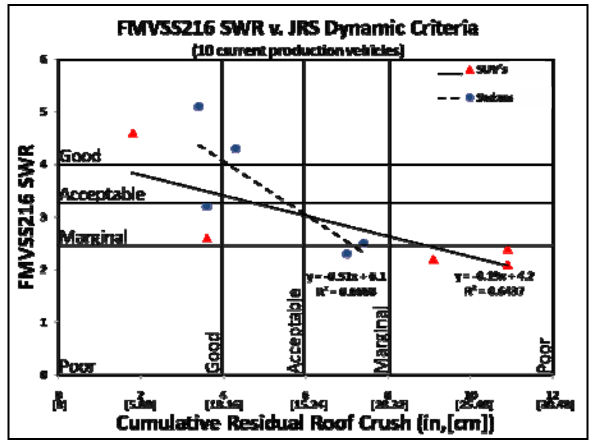

Figure 17. JRS Test Results, Current 10 Vehicles by Cumulative Residual Crush, Post Roll 2.

Figure 18 shows the relationship between maximum intrusion speed in JRS tests and FMVSS 216 SWR. The disparities between the JRS and FMVSS 216 measurements again are significant in the second roll at 10º of pitch. Note how the squares (roll 2) are shifted toward "poor" ratings versus their diamond equivalents for roll 1. Those anomalies demonstrate the shortcomings of FMVSS 216 as a measure of a vehicle's actual dynamic performance in a rollover.

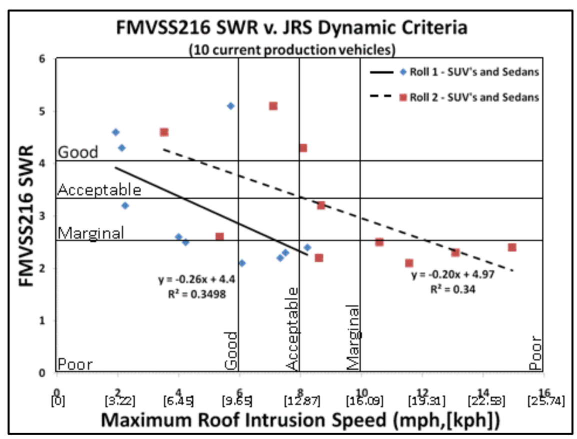

Figure 18. JRS Test Results, Current 10 Vehicles by Maximum Intrusion Speed, Rolls 1 and 2.

Figure 19 shows the amount of maximum dynamic crush in each roll of each vehicle. Note that three of the vehicles move to the left, meaning they had less dynamic crush in the second roll. Vehicles like the Pontiac G6, that crush significantly in roll 1, i.e. 20 cm (8"), cannot crush as much in roll 2. The vehicles that have more than 15 cm (6") of crush in any roll are likely to be seriously injurious. Of the twenty rolls shown, three are likely to be serious injuries and five to be severe injuries.

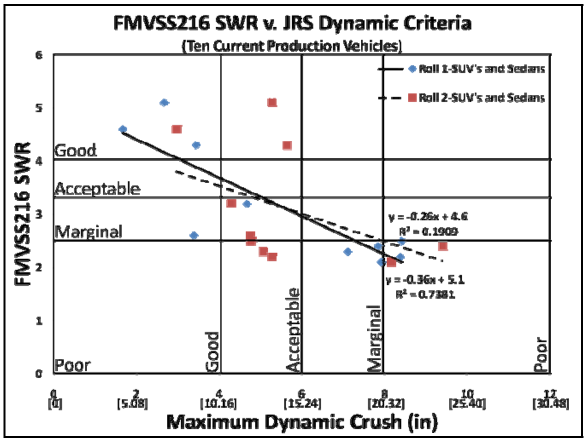

Figure 19. JRS Test Results, Current 10 Vehicles by Maximum Dynamic Crush.

Rating individual vehicles to correspond to real world injuries as a predictive rating function requires multi-dimensional correlation.

The dynamic characteristics of a vehicle are related to injury potential. The nonlinearity of roof deformation and the ability to predict the occupants' head position with the current restraint systems and the non-biofidelic Hybrid III dummy can be misleading. In all recent tests we have measured near and far side roof deformation in front of and behind the dummy which is located at about the mid roof rail position as well as lower neck load, moment, and duration. While this paper will not discuss the biomechanics of dummy injury measures it should be noted that the bending of the neck was related to human injury and an integrated bending moment (IBM) was closely related to vehicle intrusion.

Head and neck injuries are not accumulated, they occur during one roll or another when struck at more than 11 km/h (7 mph) with crush of more than 10 cm (4"). Figures 20 to 23 highlight and identify the outliers of the 10 production vehicle where the SWR and JRS dynamic ratings do not match by two criteria levels. The factors which make those vehicles unique within the broad range of each rating are currently being investigated. When using SWR as the rating basis the Honda CRV with a SWR of 2.6 is "marginal" but by JRS dynamic rating is "good" in residual crush and cumulative crush as shown in Figures 20 and 21. The dynamic rating is two rating levels better than the SWR rating. It would not be fair to penalize a manufacturer who has created a structure which is better from an occupant's protection point of view.

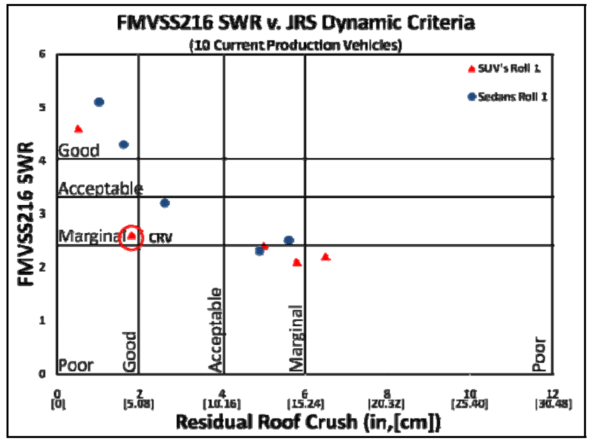

Figure 20. Highlighted Anomaly – CRV.

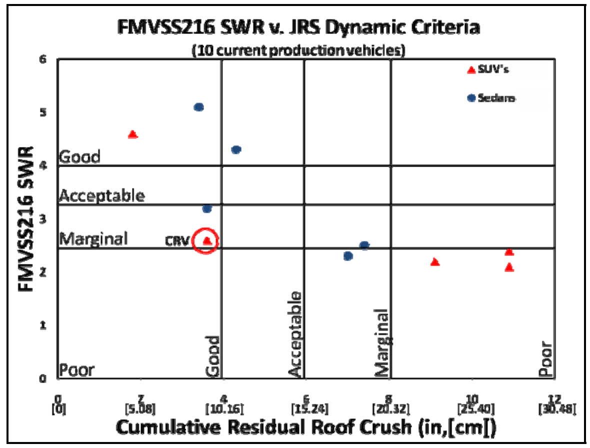

Figure 21. Highlighted Anomaly – CRV.

Maximum Intrusion Speed in roll 1 and 2 for the 10 vehicles tested is shown in Figures 22 and 23, with the vehicles that did significantly worse on the second roll of the dynamic testing highlighted. In Figure 22, the Camry and Sonata fell two levels to a "marginal" rating and the Chrysler fell two levels to a "poor" rating, despite "good" dynamic ratings for roll 1.

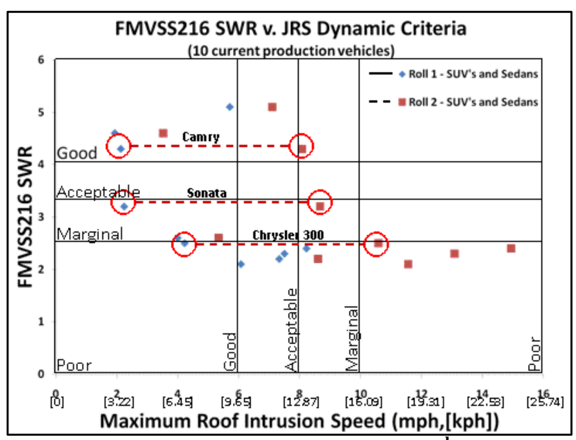

Figure 22. Highlighted Anomalies – 2nd roll rating.

Figure 23 highlights the CRV against the XC90 and Jetta, showing that the SWR rating of "marginal" is given, yet both rolls in the dynamic test remain at "good".

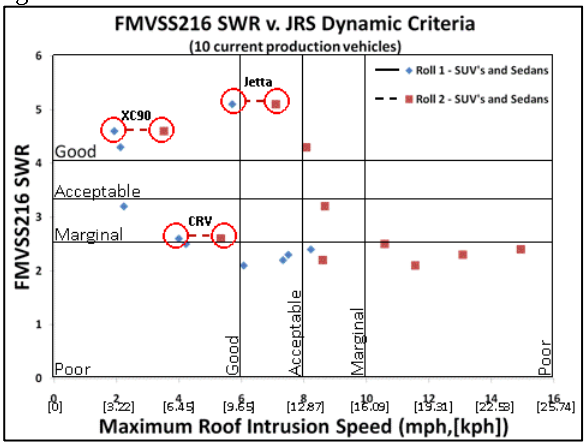

Figure 23. Highlighted Anomalies for Maximum Intrusion Speed – CRV.

The conclusion is that the disparities between FMVSS 216 SWR and JRS dynamic test results show that FMVSS 216 data alone is unacceptable for real world rollover ratings.

Considerations for the Proposed Rating System

Most vehicles when tested at 10º of pitch in the M216 test have half the strength of the FMVSS 216 test. This makes them vulnerable to excessive intrusion on a 10º of pitch roll. The XC-90 was subjected to an M216 test and resisted to a SWR of 2.2 about half its 216 SWR (two times most others, and apparently adequate).

Nash initially studied 273 cases and then expanded his study to 500 serious injury rollovers in NASS and found that roughly 60% of the vehicles had some top of fender and hood damage, consistent with more than 10º of pitch. [23]

This suggests that, at a minimum, any rollover rating system based on a FMVSS 216 one sided test be modified to also measure the second side at 10º of pitch and adjust the ratings on the basis of the results. JRS tests with anthropomorphic dummies and various types of padding and seatbelt systems have thus far been clouded by excessive roof crush and debate concerning the biofidelity of the ATD in measuring rollover related injury potential. Looking at the interior videos makes it clear that roof crush is a primary cause of injury to belted, unbelted, and ejected occupants. If roof strength can be increased to a 5º of pitch SWR of 4 or more and, a second side at 10º of pitch to more than an SWR of 2, then other safety systems will come into play and can be evaluated and factored into the ratings.

The Proposed Rollover Rating System

Figures 24 and 25 illustrate the way the proposed dynamic rollover rating system would be constructed. Figure 24 shows the relationship between two criteria; crush and crush speed for both rolls of the five LTVs (4 LTVs and one four door pick-up). Their performance is plotted on a formatted chart with the assigned rating categories of good, acceptable, marginal and poor. The two roll results are connected and identified for each vehicle.

It is easy to see that the XC-90 (denoted 1) performed entirely in the "good" category and the CRV (denoted 2) was also "good" with slightly higher crush and speed. The other three vehicles are problematic because they performed so poorly in the second roll at 10º of pitch. The rating assignment could be determined on the basis of the probability of these vehicles rolling with 10º of pitch as determined from geometric considerations. The performance of any vehicle in 10º of pitch circumstances may be assessed by the M216 second side test. However, similar to the FMVSS SWR rating, this form of testing would not be sensitive to the geometric features discussed earlier concerning the Honda CRV (Figure 11) that result in less roof crush at a lower SWR. Figure 25 is the same format plot for the 5 passenger cars.

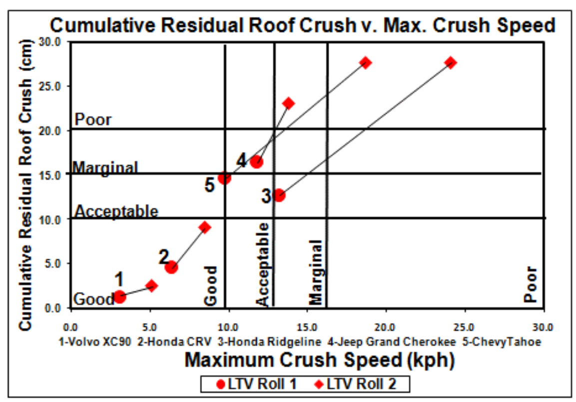

Figure 24. JRS Test Results, Current 5 LTV Vehicle Ratings for Two Rolls.

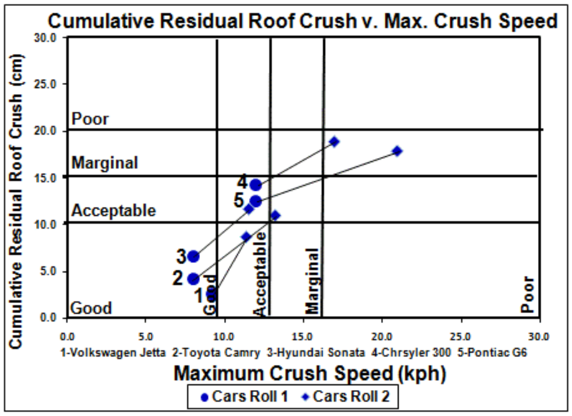

Figure 25. JRS Test Results, Current 5 Passenger Car Vehicle Ratings for Two Rolls.

The decision as to which rollover rating system to choose is based first, on the amount of crush, and second, on the impact speed. This is because if there were no more than 10 cm (4") of dynamic crush, the speed would be irrelevant for neck injury, although if the speed were high enough, a head injury could occur. If the dynamic crush were 15 cm (6") then a speed of 11 km/h (7 mph) would be the onset of serious neck injury.

Based on those criteria the XC-90, CRV, and Jetta would be rated "good". Considering the probability of 10 ° of pitch, the Camry and Sonata would be rated "acceptable". The Chrysler 300 and Cherokee would be rated "marginal". The G6, Tahoe, and Ridgeline would be rated "poor".

The purpose of this paper is to illustrate a dynamic rollover rating system, not to argue the biomechanical criteria. It is for that reason a speed consensus criterion and NHTSA derived (post crash negative headroom) cumulative crush data was used. It would be more appropriate but more controversial to use dynamic crush. In that regard the procedure is flexible and the ratings would perhaps only be more accurate but likely not shifted to a new level. It would also provide vehicle manufacturers the opportunity to design lighter, fuel efficient vehicles that are rollover crashworthy.

Based on the overall analysis of these ten vehicles for the JRS dynamic two roll testing, our proposed dynamic rollover ratings are shown in Table 1. The vehicles in bold type denote the disparity in rating using the dynamic versus SWR ratings.

Year/Make/Model	JRS Dynamic Rating	SWR Rating
2007 VW Jetta	Good	Good
2007 Toyota Camry	**Acceptable**	**Good**
2006 Hyundai Sonata	**Acceptable**	**Marginal**
2006 Chrysler 300	Marginal	Marginal
2006 Pontiac G6	Poor	Poor
2005 Volvo XC90	Good	Good
2007 Honda CRV	**Good**	**Marginal**
2006 Honda Ridgeline	Poor	Poor
2007 Jeep Grand Cherokee	**Marginal**	**Poor**
2007 Chevy Tahoe	Poor	Poor

Table 1.
Dynamic Rollover Ratings for JRS Tested Current Production Vehicles

Table 1 shows that the difference between JRS Dynamic and SWR ratings for the ten vehicles includes six matches and four miss-matches. The CRV is two rating levels better dynamically, whereas the Camry, Ridgeline and Tahoe are one level lower rated dynamically.

COMPREHENSIVE RATING SYSTEM

The comprehensive rating system would provide consumers with an idea of the overall safety of a particular vehicle. The proposed rating system would incorporate a rating for 4 different crash modes; front, side, rear, and rollover. Three of the four types of crash modes are currently being rated by the IIHS, NCAP and consumer rating groups such as Euro NCAP and ANCAP, on a "good", "acceptable", "marginal", and "poor" scale. The 4th rollover crash mode rating would be rated by the proposed JRS dynamic rollover rating system on the same scale. By combining the ratings for all 4 crash modes a composite rating can be established.

This would be done by computing a weighted average of these 4 ratings based on the frequency and fatality rate that occurs annually per crash mode. Calculating the average rating in this way gives more weight to the rollover crash mode that results in the highest fatality rate. Therefore a vehicle that performed very well in front, side and rear impact tests but not very well in rollover tests would be rated significantly less safe than a vehicle that performed very well in front, side and acceptably in rollovers. The individual crash mode ratings for the ten vehicles tested are shown in Table 2.

Year/Make/Model	Offset-Frontal *	Side *	Rear *	Dynamic Rollover
2007 VW Jetta	4	4	2	4
2007 Toyota Camry	4	4	2	3
2006 Hyundai Sonata	4	3	4	3
2006 Chrysler 300	4	1	2	2
2006 Pontiac G6	4	1	2	1
2005 Volvo XC90	4	4	4	4
2007 Honda CRV	4	4	4	4
2006 Honda Ridgeline	4	4	2	1
2007 Jeep Grand Cherokee	4	2	4	2
2007 Chevy Tahoe	N/A	N/A	N/A	1

4 - Good 3 - Acceptable 2 - Marginal 1 - Poor

* Ratings from NHTSA Vehicle Ratings website (N/A - Not Available)

Table 2.
Individual Crash Mode Ratings for Ten Vehicles.

CONCLUSIONS

- A consumer rollover rating system is long overdue. The best way to rate the crashworthiness injury potential of vehicles in rollovers is by utilizing a JRS dynamic test. Rating vehicles simply by FMVSS 216 gives grossly misleading (both over and understated) injury rate results.

- The ten vehicle JRS dynamic tests presented in this paper are a sample of the results that are achieved with dynamic testing and the basis for the consumer rollover rating system. Three of the vehicles would receive “good” ratings, two with “acceptable”, two with “marginal” and three “poor” ratings.

- When evaluating a rating system based solely on FMVSS 216, in comparison to dynamic testing, anomalies abound. The CRV is one such anomaly. The CRV emulates the rollover roof crush performance of vehicles like the XC-90 and the VW Jetta as shown in Figure 23.The CRV may be a styling-derived, partial and non-optimized implementation of a geometric roof improvement discussed in our companion geometry paper.

- JRS testing shows that a vehicle’s SWR does not provide a sufficient measure of rollover crashworthiness. Furthermore, it gives industry a faulty goal for improving vehicle rollover safety: Designing a vehicle to have an SWR above 4 does not ensure that it will give good rollover occupant protection.

- The proposed comprehensive ratings system includes a factored and weighted analysis by fatality rate and frequency of a vehicle’s performance in all four major accident modes. This system provides an overall rating that consumers could use when purchasing a new or used vehicle.

ACKNOWLEDGEMENTS

The authors would like to thank the following persons for their contributions to this paper:

- Carl E. Nash Ph.D.
- Terence Honikman Ph.D.
- Jacqueline Paver Ph.D.
- The management and staff of Xprts LLC.
- Garrett Mattos for all the Charts and Graphs
- Clarence Ditlow and Leonard Santos for their unwavering support and determination.

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