A Test Track Evaluation of Electronic Rollover Mitigation Technology

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Discussion Overview

- Definition of RSC
- Background
- Program Objectives
- Test Methodology
- Test Results
- Concluding Remarks

Definition of RSC

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- Roll stability control (RSC) systems are active safety systems specifically designed to mitigate on-road untripped dynamic rollover, typically via aggressive brake intervention
- Presently installed on may MPVs and light trucks
  - SUVs
  - Pickups
  - Minivans
  - 15-passenger vans

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Definition of RSC

- Vehicle manufactures and suppliers use different terminology to describe their respective on-road rollover mitigation systems
- Ford Motor Company owns the rights of the terms “Roll Stability Control” and “RSC”
  - In this presentation, “RSC” is used generally
  - References to “Roll Stability Control” and “RSC” do not necessarily refer to systems installed on vehicles produced by Ford Motor Company

Background

- NHTSA first began testing vehicles with RSC during the rollover NCAP revision work performed in 2003
- In 2004, one of the two 15-passenger vans tested by NHTSA in response to petition from the National Academy of Sciences was equipped with RSC
- During development of the FMVSS No. 126 ESC compliance test, all MPVs and light trucks evaluated by NHTSA were subjected to rollover tests
  - Some of these vehicles were equipped with RSC

Program Objectives

- Identify the combinations of test maneuvers and load configurations best suited for the evaluation of RSC effectiveness
- Perform test track evaluations of vehicle's equipped with RSC
- Evaluate the effect of RSC on path-following capability

Test Methodology
Test Vehicles and Loading

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- **Five Diverse Vehicles**
  - 2005 Ford Explorer
  - 2006 Jeep Grand Cherokee
  - 2005 Mitsubishi Montero
  - 2005 Nissan Armada
  - 2007 Cadillac Escalade
- **Five Load Configurations**
  - **Nominal Load** *(FMVSS 126)*
  - **Multi-passenger** *(rollover NCAP)*
  - **Rear Load** *(GVWR, rear GAWR)*
  - **Roof Load #1** *(max recommended)*
  - **Roof Load #2** *(SSF reduced by 0.1)*
- **Two Maneuvers**
  - NHTSA Fishhook
  - Sine with Dwell

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Test Results

Effect on Two-Wheel Lift (TWL)

- **Two Fishhook test series produced TWL with RSC enabled**
  - Mitsubishi Montero (Roof Loads #1 and #2)
  - Note: No Rear Load Fishhook tests performed with the Nissan Armada
- **Three Sine with Dwell test series produced TWL with RSC enabled**
  - The Mitsubishi Montero (Multi-Passenger load)
  - Nissan Armada (Rear Load)
  - Cadillac Escalade (Roof Load #1)

Two-Wheel Lift Summary
NHTSA Fishhook

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Make/Model	Nominal Load (mph)		Multi-Passenger (mph)		Rear Load (mph)		Roof Load #1 (mph)		Roof Load #2 (mph)	
	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled
Ford Explorer	--	--	--	--	--	--	--	47.7	--	44.6
Jeep Grand Cherokee	--	--	--	--	--	--	--	--	--	50.1[1]
Mitsubishi Montero	--	50.0	--	35.0	--	47.9	48.0	39.7	45.0	35.1
Nissan Armada	--	--	--	45.2	Tests not performed		--	40.7	--	42.9
Cadillac Escalade	--	--	--	--	--	--	--	--	--	49.5

[1]TWL produced during a Fishhook performed with a steering scalar of 5.5

Two-Wheel Lift Summary

Sine with Dwell

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Make/Model	Nominal Load (mph)		Multi-Passenger (mph)		Rear-Load (mph)		Roof Load #1 (mph)		Roof Load #2 (mph)	
	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled	RSC Enabled	RSC Disabled
Ford Explorer	--	--	--	--	--	--	--	--	--	--
Jeep Grand Cherokee	--	--	--	--	--	--	--	--	--	--
Mitsubishi Montero	--	--	267 deg @ 49.9 mph	144 deg @ 50.0 mph	--	--	Tests not performed		Tests not performed	
Nissan Armada	--	--	--	--	200 deg @ 50.5 mph	120 deg @ 50.5 mph				
Cadillac Escalade	--	--	--	--	--	--	--	--	204 deg @ 49.7 mph	--

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Effect on Vehicle Responses
Fishhook test results

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- RSC brake interventions induced major changes in how each vehicle responded to the Fishhook and Sine with Dwell steering inputs
  - Peak lateral acceleration reduced 9 to 45 percent
  - Roll angle reductions of 11 to 81 percent
  - Yaw rate reductions of 14 to 45 percent
  - Peak deceleration increased 84 to 294 percent
- Despite the increased decelerations, the vehicles consistently exited the Fishhook maneuver with higher speeds when RSC was enabled
  - 3.0 to 21.4 mph higher with RSC enabled

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Effect on Responsiveness

- Improved roll stability should not be achieved at the expense of crash avoidance capability
- Important factors:
  - Responsiveness
  - Path-following capability
- Regardless of load configuration, each vehicle evaluated in this study satisfied the minimum responsiveness criteria specified in FMVSS 126

Effect on Path-Following

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- **FMVSS 126 responsiveness criteria only specify that a minimum lateral displacement be achieved at one instant in time**
- **Further evaluation of how RSC interventions could affect crash avoidance capability was necessary**
  - **Combined path and yaw angle data**
  - **The distance traveled with outside front wheel lock**

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Effect on Path-Following (continued)

- **RSC interventions vastly improved the lateral stability and path-following capability of each vehicle, although the extent to which these improvements occurred was vehicle-dependent**
  - **RSC interventions allowed vehicles to maintain paths much closer to those commanded by the NHTSA Fishhook and Sine with Dwell steering inputs, despite the RSC-induced wheel lock present at the outside front of the vehicle**
- **The Ford Explorer, Mitsubishi Montero, Nissan Armada, and Cadillac Escalade each produced outside front wheel lock during NHTSA Fishhook and Sine with Dwell testing**
  - **During Fishhook tests, the maximum longitudinal distance traveled with outside front wheel lock ranged from 3.4 to 21.7 ft**
  - **For Sine with Dwell tests, the range was from 2.7 to 21.3 ft**

Objective RSC Identification

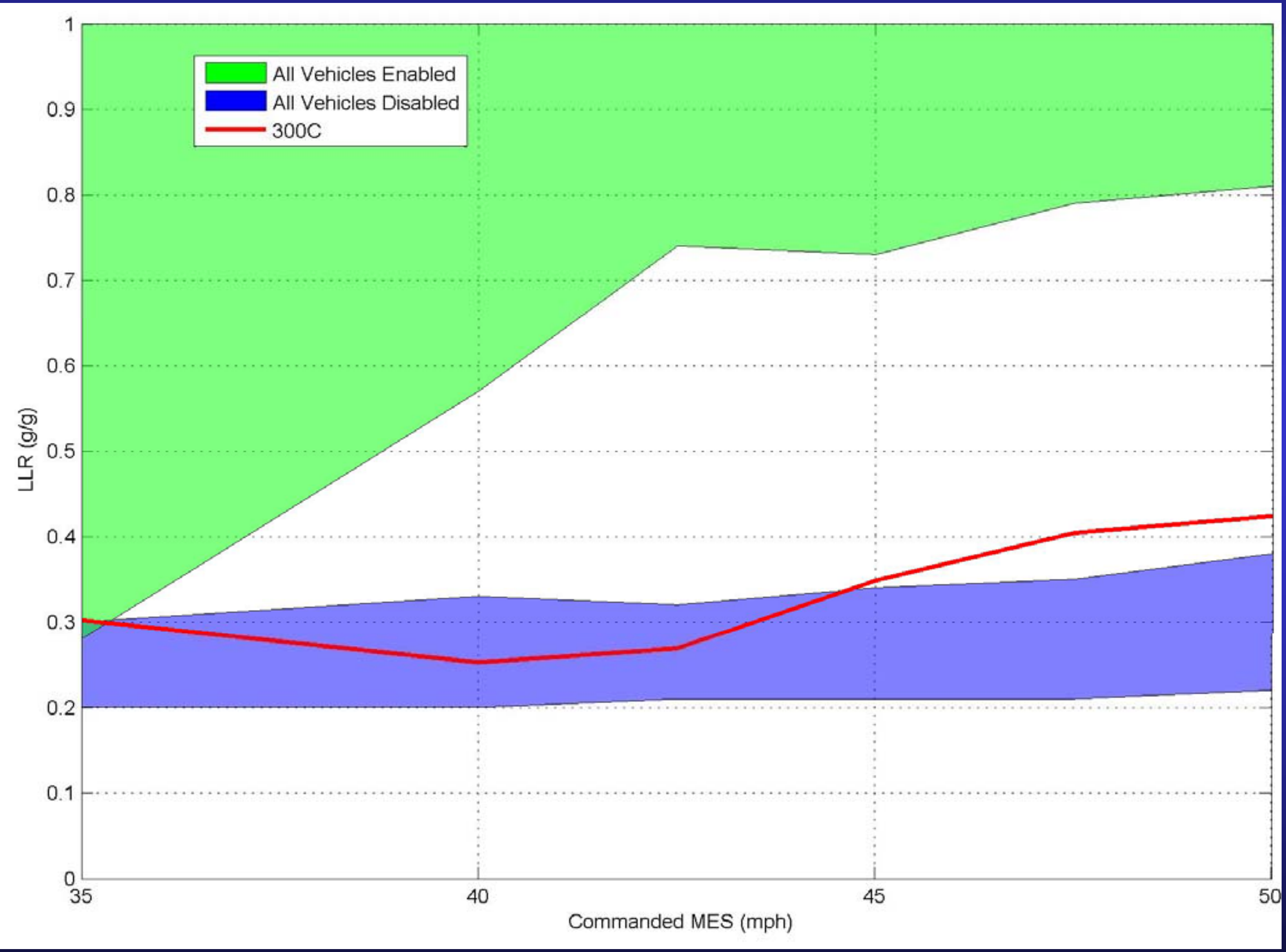
- Distinguishing vehicles with RSC from those only equipped with conventional yaw-based ESC systems may prove useful in the identification of vehicles for future crash data analyses
  - With appropriate vehicle selection, the most meaningful comparisons of ESC versus RSC field effectiveness can be made
  - The outcome of such analyses could help NHTSA reconcile the potential merits of RSC regulation
- Several ways in which data from the tests performed in this study could be used to identify the presence of RSC-specific interventions were explored

Objective RSC Identification (continued)

- Maximum Longitudinal-to-Lateral Acceleration Ratio (LLR)
  - Based on data produced during Fishhook tests
  - Calculated by dividing the maximum longitudinal acceleration by the lateral acceleration at the same instant in time
  - Able to distinguish vehicles with RSC enabled from those with RSC disabled
  - Capable of distinguishing RSC from conventional ESC (i.e., yaw-based) interventions, provided maneuver entrance speed is sufficiently high
- Sine with Dwell data are not recommended for LLR comparison
  - Cannot adequately distinguish RSC from conventional ESC

Objective RSC Identification

Example: LLR vs. Fishhook Entry Speed



Concluding Remarks

- TWL results clearly indicate RSC improved the roll stability of each of the vehicle evaluated in this study.
- Generally speaking, improvements in on-road untripped rollover resistance were seen in each of the five load configurations tested.
- The results of this study also indicate that simply equipping a vehicle with RSC does not guarantee TWL will be prevented in all driving scenarios
- RSC intervention strategies utilized by the vehicles evaluated, even those that use brief periods of wheel lock to stabilize the vehicle, did not appear to compromise crash avoidance capability

Concluding Remarks (continued)

- **Although the Fishhook-based LLR values appear to provide a good way to *identify the presence* of RSC control logic, the authors emphasize they are <u>not</u> intended to evaluate RSC *effectiveness***
- **The most effective and objective way to quantify RSC effectiveness on the test track remains the measurement of TWL**
- **The strength of the LLR metric is its identification capability, something the authors believe NHTSA may find very useful when trying to reconcile differences in RSC versus ESC crash data reductions**