Phase IV and NHTSA’s Light Vehicle Dynamic Rollover Propensity Research

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Garrick J. Forkenbrock
W. Riley Garrott
NHTSA / VRTC
Overview of NHTSA’s Recent Rollover Research Phases

- **Phase IV**
  - Spring 2001
  - Response to TREAD Act
  - Consideration of many maneuvers

- **Phase V**
  - Spring 2002
  - Research factors that may affect dynamic rollover propensity tests
  - Rollover and handling rating development

- **Phase VI**
  - Summer 2002
  - Evaluation of 26 vehicles using results from Phase IV testing
  - Rollover and handling tests performed

- **Phase VII**
  - Winter 2002
  - Refinement of rollover maneuvers using results from Phase VI

- **Phase VIII (NCAP Rollover Demo)**
  - Spring/Summer 2003
  - Evaluation of 18 vehicles
  - Rollover maneuvers only
Phase IV Background

TREAD Act Requirement:
Develop dynamic rollover propensity tests to facilitate a consumer information program

National Academy of Sciences:
“NHTSA should vigorously pursue the development of dynamic testing to supplement the information provided by SSF.”
Phase IV Objectives

- Test many maneuvers with a limited number of vehicles
- Select maneuvers appropriate for use in a Government rollover resistance rating system
Maneuver Recommendations

- Recommendations received from Government and industry
- NHTSA
  - VRTC
  - Safety Performance Standards
- Alliance of Automobile Manufacturers
- Consumers Union
- Ford Motor Company
- Heitz Automotive, Inc.
- ISO 3888 Part 2 Consortium
  - VW
  - BMW
  - DiamlerChrysler
  - Porsche
  - Mitsubishi
- MTS Systems Corporation
- Nissan Motors
- Toyota Motor Company
- UMTRI
Test Conditions

- **Test vehicles**
  - 2001 Chevrolet Blazer
  - 2001 Ford Escape
  - 2001 Toyota 4Runner
  - 1999 Mercedes ML320

- **Front and rear mounted aluminum outriggers**

- **All tests performed on a dry, high-mu asphalt surface**

- **Multiple configurations**
  - Nominal Load
  - Reduced Rollover Resistance
Tires

- **OEM specification**
  - As installed on vehicle when delivered
  - Make
  - Model
  - DOT Code
  - Inflation pressure

- **Frequent tire changes**

- **Inner tubes used during some maneuvers to prevent debeading**

*Test surface damage due to debeading*
**Test Maneuvers**

**Characterization**
- Constant Speed, Slowly Increasing Steer (SAE J266)*

**Fishhooks**
- Road Edge Recovery (Roll Rate Feedback Fishhook)*
- Fishhook (Fixed Timing)*
- Nissan Fishhook

**J-Turns**
- NHTSA J-Turn*

**Double Lane Changes**
- ISO 3888 Part 2*
- Consumers Union Short Course*
- Ford Path-Corrected Limit Lane Change
- Open-Loop Pseudo Double Lane Change

*Discussed in this presentation*
J-Turn

Note: Steering rate was based on successful Phase II testing
Fixed Timing Fishhook
(Symmetric)

**Note:** Steering rate was based on successful Phase II testing.
**Roll Rate Feedback Fishhook (Symmetric)**

Note: Steering rate was based on successful Phase II testing

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Handwheel Input (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blazer</td>
<td>326</td>
</tr>
<tr>
<td>4Runner</td>
<td>287</td>
</tr>
<tr>
<td>ML320</td>
<td>252</td>
</tr>
<tr>
<td>Escape</td>
<td>233</td>
</tr>
</tbody>
</table>
Question:

Why use the handwheel angle at 0.3 g?
Use of 0.3 g Handwheel Data

- NHTSA needed an objective way of calculating J-Turn and Fishhook steering angles
  - Vehicles respond differently to the same steering inputs
  - Maneuvers must adapt to the vehicle being evaluated
- Handwheel data at 0.3 g is repeatable and easy to measure
  - Not necessarily true for data based on maximum lateral acceleration
Closed-loop, Path-Following Double Lane Changes

Consumers Union Short Course

ISO 3888 Part 2

A = 3.1 x Vehicle Width + 0.25 m
B = Vehicle Width + 1.0 m
Evaluation Technique

- Each maneuver evaluated in 4 categories
  - Objectivity and Repeatability
  - Performability
  - Discriminatory Capability
  - Appearance of Reality

- Ratings assigned as follows
  - Excellent
  - Good
  - Satisfactory
  - Bad
  - Very Bad
Objectivity and Repeatability

- One of the largest disadvantages of the ISO and CU Double Lane Changes
  - Driver input variability unavoidable
- Use of a steering machine insures accurate, repeatable, reproducible inputs
Objectivity and Repeatability
(Example: Steering Inputs)

**Steering Machine-Based**
Fixed Timing Fishhook

![Graph](image1)

*Six tests are presented*

**Driver-Based ISO 3888 Part 2**
Double Lane Change

![Graph](image2)

*Nine tests are presented*
Each procedure was well developed

ISO and CU Double Lane Changes
- Simplest to perform
- Require little instrumentation

CU Short Course does not adapt course layout to vehicle

RRF Fishhook offers better adaptability than does the FT Fishhook
Lack of discriminatory capability is another large disadvantage of ISO or CU Double Lane Changes

- Entire range of max entrance speeds no more than 5.7 mph
- Driver variability accounts for up to 70% of this range
- ISO and CU Double Lane Changes were not capable of producing two-wheel lift during “clean” runs

J-Turn and Fishhooks sensitive to changes that reduce rollover resistance
### Discriminatory Capability
*(Example: Metric Comparison)*

#### Roll Rate Feedback Fishhook

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Configuration</th>
<th>Nominal Load</th>
<th>Reduced Rollover Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Left-Right (mph)</td>
<td>Right-Left (mph)</td>
</tr>
<tr>
<td>Toyota 4Runner (VSC on)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Toyota 4Runner (VSC disabled)</td>
<td>--</td>
<td>--</td>
<td>39.5</td>
</tr>
<tr>
<td>Chevrolet Blazer</td>
<td>40.3</td>
<td>40.1</td>
<td>36.8</td>
</tr>
<tr>
<td>Ford Escape</td>
<td>--</td>
<td>--</td>
<td>46.0</td>
</tr>
<tr>
<td>Mercedes ML320 (ESP on)</td>
<td>49.9</td>
<td>--</td>
<td>Tests not performed</td>
</tr>
<tr>
<td>Mercedes ML320 (ESP disabled)</td>
<td>46.4</td>
<td>50.5</td>
<td></td>
</tr>
</tbody>
</table>

**Minimum** two-wheel lift entrance speeds

#### ISO 3888 Part 2 Double Lane Change

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Configuration</th>
<th>Nominal Load</th>
<th>Reduced Rollover Resistance</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota 4Runner (VSC on)</td>
<td></td>
<td>37.6</td>
<td>39.3</td>
<td>-1.7</td>
</tr>
<tr>
<td>Toyota 4Runner (VSC disabled)</td>
<td></td>
<td>37.0</td>
<td>38.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Chevrolet Blazer</td>
<td></td>
<td>41.0</td>
<td>39.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Ford Escape</td>
<td></td>
<td>38.0</td>
<td>37.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Mercedes ML320 (ESP on)</td>
<td></td>
<td>36.0</td>
<td>37.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Mercedes ML320 (ESP disabled)</td>
<td></td>
<td>36.9</td>
<td>37.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**Maximum** “clean” run entrance speeds
Discriminatory Capability
(Two-Wheel Lift Summary, Nominal Load)
Discriminatory Capability
(Video Comparison)
Appearance of Reality

- Each rollover resistance maneuver related to a real driving scenario
- ISO and CU Double Lane Changes emulate emergency crash avoidance maneuvers
- Fishhooks emulate road edge recovery maneuvers
  - Also very similar to first two steering inputs of the double lane changes
- J-Turn steering least likely to actually be used, but possible
Question:

Are actual drivers able to input the steering angles and steering rates used for the NHTSA J-Turn and Fishhook maneuvers?
Answer: Yes!

- The ranges of NHTSA J-Turn and Fishhook handwheel angles and rates were within those observed during CU Short Course testing

- Maximum steering inputs
  - J-Turn: 1000 deg/sec for up to 0.40 seconds
  - Fishhook: 720 deg/sec for up to 0.45 seconds
  - CU Short Course
    - 1187 deg/sec for up to 0.50 seconds
    - 1026 deg/sec for up to 0.75 seconds
    - 831 deg/sec for up to 1.00 seconds
Can the NHTSA J-Turn and Fishhook maneuvers be performed on a two-lane public roadway?
Answers: 1. Yes (Fishhook)
2. Not Likely (J-Turn)

Path of the vehicle C.G. is indicated
Overall Assessment

- Roll Rate Feedback Fishhook deemed the best overall maneuver (see below)
- J-Turn the most basic maneuver, can be a useful compliment to the Roll Rate Feedback Fishhook
- Both maneuvers selected for use in Phases V, VI, and VII of NHTSA’s rollover research

<table>
<thead>
<tr>
<th>Criteria</th>
<th>J-Turn</th>
<th>FT Fishhook</th>
<th>RRF Fishhook</th>
<th>ISO 3888-2</th>
<th>CU Short Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectivity and Repeatability</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Bad</td>
<td>Bad</td>
</tr>
<tr>
<td>Performability</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>Discriminatory Capability</td>
<td>Excellent*</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Very Bad</td>
<td>Very Bad</td>
</tr>
<tr>
<td>Face Validity</td>
<td>Good</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

*When limited to vehicles with low rollover resistance and/or disadvantageous load configurations
Can the Slowly Increasing Steer maneuver be abbreviated since only linear range lateral acceleration data is used?
Answer: Yes!
(Provided enough data is considered)

Position when $Ay = 0.45 \, g$
Concluding Remarks

- **Phase VI and VII Technical Reports**
  - Complete, awaiting approval
  - Scheduled to be released with the next rollover notice
- **NCAP Rollover Demo testing is presently underway**
  - Ratings to be released as 2004 model year ratings
Additional Information

- Phase IV Technical Report (DOT HS 809 513)
- SAE Papers
  - 2003-01-1008
  - 2003-01-1009
- Rollover Docket
  - http://dms.dot.gov/
  - “Simple Search” for number 9663