Effect of Oversized Wheels and Tires on SUV Roll Stability

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Rollover Basics

- Rollover is a Function of:
  - Lateral Forces
  - Vehicle Geometry
  - Tripped vs Untripped
A vehicle’s sensitivity to rollover is a function of basic dimensions.

First-Order Metrics:
- Track Width (T)
- CG Height (H)

Static Stability Factor:
- $SSF = \frac{T}{2H}$
• SSF is used by NHTSA and others to assign vehicle rollover performance ratings
NHTSA Ratings - SSF

- NHTSA Rollover Ratings

![Rollover Ratings Statistical Model]

1. Enter chart with SSF = 1.20
2. Go vertical until intersect with appropriate tip/no-tip curve
3. Go horizontal to left to obtain % chance of rollover and corresponding star rating
**SSF Trends**

- **2005 NHTSA Paper**
  - *Trends in the Static Stability Factor of Passenger Cars, Light Trucks, and Vans*

### Exhibit 9: LTVs Redesigned with Increased SSF

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>Model Years</th>
<th>SSF</th>
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<tbody>
<tr>
<td>Ford Bronco 4x4</td>
<td>1980-1984</td>
<td>1.04</td>
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<tr>
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<td>1985-1996</td>
<td>1.13</td>
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<tr>
<td>Ford Bronco II 4x4</td>
<td>1987-1990</td>
<td>0.99</td>
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<tr>
<td>Ford Explorer 2-DR 4x4</td>
<td>1991-1995</td>
<td>1.09</td>
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<tr>
<td>Chevrolet S10 4x4 Blazer 4-DR</td>
<td>1991-2003</td>
<td>1.09</td>
</tr>
<tr>
<td>Chevrolet Trailblazer 4x4 4-DR</td>
<td>2002-2003</td>
<td>1.18</td>
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<tr>
<td>Nissan Pathfinder 4x4 4-DR</td>
<td>1990-1995</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>1996-2003</td>
<td>1.16</td>
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</tbody>
</table>
Track Width and CG Height - Alterations

- Once a vehicle is in service:
  - CG Height - Not easily altered
  - Track Width - Relatively easier to alter
    (Spacers, wheel size)
Track Width and CG Height - Alterations

SSF = 0.96  SSF = 1.0  SSF = 1.04
Wheel Backspacing, Offset

-47mm Negative Offset
Center Line

Zero Offset
Center Line

+10mm Positive Offset
Center Line

Outer side

1.65”
5.35”
7” wide wheel comparable to 2+5
-47mm conversion = 1.65+5.35

3.5”
3.5”
7” wide wheel = 3.5+3.5
Known as “Zero Offset”

3.89”
3.11”
7” wide wheel comparable to 4+3
+10mm conversion = 3.89+3.11
Case Study

• Pre-owned vehicle, sold with modified wheels/tires
• Rolled over on-road, untripped
• GE Scope:
  • Test stock vs. modified
  • Compare rollover thresholds for stock vs. modified
Testing

• **Test Objectives:**
  • To test/document the rollover threshold of the stock 1992 Ford Explorer XLT 4x2 with accepted industry handling maneuvers.
  • To test/document the rollover threshold of the 1992 Ford Explorer XLT 4x2 modified with aftermarket 22-inch wheels with 18mm offset and 265/35R22 102V tires with accepted industry handling maneuvers.
Testing

• 1992 Ford Explorer XLT 4x2
  • 4.0L V-6, Auto Trans
  • GVWR = 5020 lbs
Testing

Stock Configuration

Tires: Goodyear Wrangler SR.A
Size: P225/70R15 100S
Traction: 500 TW, Trac A, Temp B
Tread: 2 poly + 2 steel
Sidewall: 2 poly
Load: 1753 lbs. @ 44 psi
Wheels: OEM Aluminum 15x7 J

Modified Configuration

Tires: Cooper Zeon XST
Size: 265/35R22 102V extra load
Traction: 420 TW, Trac A, Temp A
Tread: 1 nylon + 2 poly + 2 steel
Sidewall: 2 poly
Load: 1874 lbs. @ 50 psi
Wheels: Black ice Nokote 22x8.5 JJ
Testing: Setup

- Instrumentation:
  - Accelerometer Pack
  - Doppler Speed
  - Steering Angle Stringpot
  - Data Collection
- Steering Limiters
- Outriggers
Testing

- **Stock:**
  - $TW_F = 58.0''$
  - $TW_R = 58.25''$
  - $H_{CG} = 27.25''$
  - $SSF = 1.07$

- **Modified:**
  - $TW_F = 57.5''$
  - $TW_R = 57.75''$
  - $H_{CG} = 28.75''$
  - $SSF = 1.0$
Testing: Fishhook Maneuver

- **Stock:** Rolled over at 42.5 mph
- **Modified:** Rolled over at 36.8 mph
Fishhook: Lateral Tire Forces During First Yaw

First Left Steer
Fishhook: Lateral Tire Forces During Yaw Transition

Right Steer
Testing: J-Turn Maneuver

- **Stock:** Did not roll over at speeds up to 49.1 mph
- **Modified:** Rolled over at 40.1 mph
Testing: J-Turn Maneuver

- Modified: Rolled over at 40.1 mph

- J-turn tests have been discounted by NHTSA as not truly limit tests because they do not incorporate significant roll momentum

- Rollover in a J-turn test underscores the dangerous condition of this vehicle in its modified condition.
<table>
<thead>
<tr>
<th>Configuration</th>
<th>Tire</th>
<th>Tire Size</th>
<th>Run #</th>
<th>Speed</th>
<th>1st Steer</th>
<th>Hump</th>
<th>2nd Steer</th>
<th>Steer Rate</th>
<th>1st LA</th>
<th>2nd LA</th>
<th>1st YR</th>
<th>2nd YR</th>
<th>2WL?</th>
<th>RA1</th>
<th>RA2</th>
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<td>FH001</td>
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<td>-</td>
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</tr>
</tbody>
</table>
Testing: J-Turn Maneuver

- J-Turn at 41 MPH
- Modified vehicle had significant rim contact
- How does the rim contact contribute to the observed decreased in roll stability?
Testing: J-Turn Maneuver

- J-Turn at 41 MPH
- Modified vehicle had major front rim contact
- Wheel rim does not make contact until much after two-wheel lift
- Wheel rim contact does not contribute to roll instability
Testing: J-Turn Maneuver

JTR01 (Modified)
S = 41.0 MPH
Peak LA = 0.81g

JTR03 (Stock)
S = 41.6 MPH
Peak LA = 0.86g
Conclusions

• Stock Explorer is unstable with respect to untripped rollover at five-passenger load conditions.

• Modified Explorer rolled over to outriggers at lower speeds than the stock Explorer and, additionally, rolled over in single-steer maneuvers where the stock vehicle did not.

• The oversized wheels and tires narrow track width by 0.5 inches, and also add a measured 1.5 inches to the vehicle’s CG height. The resulting calculated SSF is 1.00.
Conclusions

• Based on this testing, these modifications to an already unstable vehicle that result in raising the center of gravity height or narrowing the track width result in a more unstable handling package in terms of resistance to rollover.

• The modified vehicle in this test series had decreased rollover resistance compared to the stock vehicle and would significantly increase the likelihood of this vehicle rolling over untripped in the real world.
Questions?