Case Studies and Reconstruction Essentials for Tread Separation Accidents Involving Axle Tramp

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The Basic Scenario

VIDEO

Animation_Tramp_Delam
Introductions

- Engineering Institute
  - Accident Reconstruction
  - Accident Causation
  - Testing
  - Litigation Consulting

- Paul T. Semones, M.S.M.E.
  - Vehicle Dynamics Crash Analysis
  - Investigated ~200 Tread Separation Crashes
  - “Customer” of Accident Reconstruction
Background

- Tread separation-induced axle tramp research has been developed in defect analysis of the causes of car crashes
  - Much done at request of plaintiff attorneys
  - Much involving Ford Motor Company products (NOT the only mfr. to exhibit this issue)
- Defendants’ experts’ testing has supported the underlying theories
- Issue remains controversial
Engineering Institute Research

- ARC-CSI presentation is a recon companion to forthcoming ASME publication

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MAGNITUDE OF AXLE TRAMP RESPONSE TO PARTIALLY DETREADED TIRE IMBALANCE IN HIGHWAY-SPEED DRIVING

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IMECE2006-13600
– “Designing for Vehicle Stability During Rear Tire Tread Separation Events”

2007 ESV Conference, Paper #07-0142
– “Effects of the Process of Rear Tire Delamination on Vehicle Stability

SAE 2008-01-0583
– “Solid Axle Tramp Response Near the Natural Frequency and its Effect on Vehicle Longitudinal Stability”

2009 ESV Conference, Paper #09-0209
– “An Analysis of the Mechanism Causing Loss of Control During a Tire Delamination”
MOTIVATION
Motivation

- “…Failure to maintain lane…”
- “…Vehicular manslaughter…”
- “Unsafe turning movement”??

Example A

ENFORCEMENT ACTION

From the information gathered in this investigation, it is my conclusion that [redacted] was driving a Ford Explorer, southbound on CR215 north of CR215/Flamingo southbound on-ramp, when the tread separated from the left rear tire and she overcorrected by oversteering right. As a result of [redacted]’s actions, a crash occurred. From this crash, [redacted] suffered fatal injuries. Based on these facts and circumstances, a summons for [redacted] was submitted to the Clark County District Attorney’s office on [redacted] 2010 for one count of violating Nevada Revised Statute 484.3775 – Vehicular manslaughter, a misdemeanor and one count of violating Nevada Revised Statute 484.305 – Failure to maintain lane, a misdemeanor.
Motivation

- Tread separation axle tramp presents a unique control challenge to an unsuspecting driver.
- Evidences for axle tramp may not be widely known or understood in the accident investigation community.
- This presentation provides a potential explanation for loss of control during some tread separation accidents, and how to recognize this phenomenon.
FIRST LOOK AT TYPICAL AXLE TRAMP EVENT
Partial Detread Imbalance at LR

VIDEO
Excursion Run 4 Assembled
Partial Detread Imbalance at LR

Left Rear Tire with 50% of Tread and Top Steel Belt Removed

Rear Axle Tramp Marks in Terminal CW Yaw (upstream)

LR 50% Detread Tire

RR Normal Tire
Partial Detread Imbalance at LR

Rear Axle Tramp Marks in Terminal CCW Yaw (downstream)

Rear Axle Tramp Marks in Terminal CCW Yaw (upstream)

RR Normal Tire
LR Imbalanced Detreading Tire

Case Study #1
SCOPE OF PROBLEM
What are the limiting conditions under which this phenomenon may occur?
– Tire
– Speed
– Suspension
Scope of Problem – Tire

- Tread separation resulting in **imbalance**
  - Partial tread loss
  - Complete tread loss, multiple pieces
  - Complete tread loss, lengthy duration

- Remain inflated, allows bouncing action
  - Top belt loss only (typical 2-steel belt tire)

Case Study #8 Case Study #2 Example B
Scope of Problem – Tire, No Blowout
Scope of Problem – Tire Elements

- Two steel belts
  - Upper belt (#2) diagonal:
  - Lower belt (#1) diagonal:
- Belt-supporting *skim stock* rubber
- Polyester *body plies* below #1 belt
- Bottom belt (#1) separation from body plies results in likely blowout
- “Flat tires don’t bounce” – axle tramp not likely after blowout
Scope of Problem – Tire Elements

- Nylon Reinforcement
- Steel Belt#2
- Steel Belt#1
- Carcass
- Carcass
- Inner Liner
- Tread
- Belt Edge Strip
- Sidewall
- Rim Cushion
- Chafer
- Bead Filler
- Chafer
- Bead Wire Bundle
Scope of Problem – Tire, Blowout

- Is there evidence of “blowout” during the accident sequence?
  - Exposure of body plies (i.e., separation of bottom #1 belt from tire)
  - Location of first rim contact on roadway

Case Study #3
Scope of Problem – Tire, Blowout

LR Partial Detread

CW Terminal Yaw

LR Rim Mark Begins

Relative Road Motion in Yaw

Case Study #3
Scope of Problem – Tire, 1 Strip

Case Study #4
What if it’s a complete tread separation with 1 piece accounting for 360 degrees?

Rapid total tread loss \( (i.e., \text{a fraction of a second, a handful of tire revolutions}) \) would not be expected to produce major axle tramp event

Secondary evidence may indicate lengthy process, and thus major axle tramp event…
Scope of Problem – Tire, 1 Strip

- Lengthy tread separation process, or near-instantaneous?
  - Tire mark evidence of axle tramp
  - Vehicle debris along vehicle path, knocked loose from tread slapping
  - Tire marks on body / in wheel well
  - POR of tread
  - Eyewitness observations
Scope of Problem – Speed

- Highway speed
  - Solid Axle Tramp Resonance (~10-15 Hz)
  - Rotational inertia producing vertical force

<table>
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<th>Dia. in</th>
<th>Circ. ft</th>
<th>10Hz mph</th>
<th>12Hz mph</th>
<th>15Hz mph</th>
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<td>8.3</td>
<td>56</td>
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Scope of Problem – Suspension

- Hotchkiss
  - Solid Axle
  - Leaf Springs
- Shock Absorbers
  - Spacing
  - Angles (2 views)
  - “Stiffness” (damping force)
- Solid Axle, Coil Spring, 5-Link with Panhard Rod?
Scope of Problem – Suspension

- Solid Axle Motion
  - Hop ("Ride")
    - Single Wheel
    - Axle
  - Tramp ("Roll")
Scope of Problem – Suspension

- Shock Absorber Spacing
  - Roll/ride ratio = Shock Dist. / Track Width
  - Greater than 50% (Max possible ~80%)

1990’s Era Pickup
Shocks Inboard
R/R Ratio = 0.45

2000’s Era Pickup
Shocks Outboard
R/R Ratio = 0.79
Scope of Problem – Suspension

- Shock Absorber Angle
  - Rear-view angle inboard … the shocks’ effective motion is reduced in axle tramp

<table>
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<th>1990’s Era SUV</th>
<th>Shocks Angled Inboard</th>
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<tbody>
<tr>
<td>R/R Ratio = 0.52</td>
<td>(Bottom Mounts Only)</td>
</tr>
<tr>
<td>R/R Ratio = 0.30</td>
<td>(Top Mounts Only)</td>
</tr>
</tbody>
</table>

Effective R/R Ratio ~ 0.41?
Scope of Problem – Suspension

- Shock type
  - Part number
  - “Lot” number
- High Stiffness
  - Gabriel Ultra
  - Rancho
- Shock condition
  - Leaky?
  - *Testing has found little effect on damping*
Scope of Problem – Suspension

Part Number “37024ST”

Lot/Batch Number “P039E”
Scope of Problem – Suspension

Multiple Part Numbers for Multiple Applications

Part Number “747939”

Lot/Batch Number “Q09354”
VIDEO PROOF:
TREAD
IMBALANCE
CAUSES TRAMP
Partial Detread at Right Rear

VIDEO
Explorer Tread Flap II Assembled
Partial Detread at Right Rear

- Imbalance at one side causes tramp (alternating wheel hop) at both sides
- Can result in clear skipping marks
- Oscillating normal force = loss of traction
- May not result in complete lift-off of tire(s)
- Braking may worsen the condition
- Body lean toward imbalanced tire in terminal yaw … axle is still tramping
Partial Detread at Left Rear

VIDEO
Carr Bronco II
Partial Detread at Left Rear

- Imbalance at one side causes tramp (alternating wheel hop) at both sides
- Can occur without leaving any clear marks if no yaw angle develops
- Can result in complete lift-off of balanced tire, even when imbalanced tire seems to stay in contact

*Credit to Carr Engineering, 2008*
Partial Detread at Right Rear

VIDEO
Tandy Run 10
Partial Detread at Right Rear

- Imbalance at one side causes tramp (alternating wheel hop) at both sides
- Can begin essentially instantly
- Loss of final tread piece restores tire balance, tramp subsides, control may be regained by a skilled driver
- *Credit to Carr Engineering, 2000*
CONTROL EFFECTS OF AXLE TRAMP
Control Effects – What it’s NOT

- Conventionally relied upon research over the years...
  - Quantified oversteer after a full tread separation
  - Observed handling disturbance from rapid full tread loss
  - Considered drag effects as dominant

- Simple oversteer due to loss of traction at one tire after full tread loss ... but this is not relevant to axle tramp phase
Control Effects – What it IS

- Axle tramp during periods of tread imbalance, leading to loss of traction
- At worst: a loss of rear tire contact
- At least: an oscillating reduction in normal force
- Resulting oversteer tendencies
- Vehicle tends to overrespond ... “fishtailing”
Control Effects – Other Issues

- Drag during tread detachment
  - Produces a sudden disturbance
  - Initiates a heading change
  - Driver has to respond with a vehicle that is experiencing violent rear-axle effects

- Braking or deceleration may make it worse
  - Deceleration into resonant zone
  - *Weight transfer off rear axle allows greater axle tramp???

RECON & SCENE INVESTIGATION ESSENTIALS
Scene Investigation

- Upstream
- Yaw Marks
- Vehicle POR
- Eyewitnesses

Example C
Scene Investigation – Upstream

- Where are the tread pieces?
  - Size and location of each
  - Rule of thumb: search at least 300 feet up (~3 seconds of travel at highway speeds)
  - Downstream migration possible
  - Recover all pieces as evidence!

- What percentage of tread accounted for?

- Any body debris? Tail light plastic, fender well pieces
Case Study #5

Complete right rear tread found in two pieces

Tail Light Fragment

More Tail Light Fragments Found Upstream, Located on Police Scale Diagram
~210 degrees of tread from RIGHT rear tire (just over ½ of circumference)

Case Study #6

Tread Fragments (Not clearly photographed, not recovered)

Fender trim
Tire Evidence

- How large are the pieces of tread?
  - Degrees/percentage
  - Length

### Case Study #6

P235/75 R15

- Total Circumference: ~7.6 ft
- Tread Piece Overall length: ~6 ft
- Tread Piece Edge length: ~4 ½ ft
- Tread Piece Coverage: ~60%
  
  *(Based on Edge length)*

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Case Study #6
Scene Investigation – Yaw Marks

- Are there intermittent marks?
  - Wheel(s) hopping? Which tire(s)?
  - Alternating pattern due to tread variation?

- Evidence of late blowout?
  - Rim mark
  - Chattering
  - Deflation bunching

- Evidence of countersteer?
  - Narrower front tire mark
Scene Investigation – Yaw Marks

Case Study #7

Right Rear balanced tire skipping mark due to left rear rim chatter (<40 mph)

Left Rear 50% detreaded tire skipping mark

Left Rear imbalanced tire now deflated/-ing
Scene Investigation – Yaw Marks

Right Rear balanced tire oscillating mark

60+ mph

Left Rear imbalanced tire skipping mark

Left Rear partially detreaded tire

Case Study #8
Scene Investigation – Yaw Marks

~62 mph

Left Rear balanced tire skipping mark

Right Rear detreading tire varying mark

Left Front tire faint mark

Tread fragments

Case Study #9
Scene Investigation – Yaw Marks

Case Study #2

~50 mph

Right Rear partially detreaded tire oscillating mark

Left Rear balanced tire skipping mark

Alternative ABS theory has been advanced ...credible?
Scene Investigation – Yaw Marks

Case Study #10

- Left Rear balanced tire skipping mark
- Right Rear imbalanced tire skipping mark
- ~66 mph
- Left Front tire narrow mark
Scene Investigation – Vehicle POR

- What is condition of tire?
  - Debeading / tire evidence disruption can occur during vehicle removal
- Any tread in debris path?

Case Study #10
Scene Investigation – Witnesses

- Eyewitnesses to accident sequence
  - How far over did the vehicle move?
  - How many fishtailing movements?
  - Did they encounter any tread pieces?

- First responders to accident scene
  - Did they see or move any tread pieces?
Scene Investigation – Witnesses

Multiple eyewitnesses said vehicle crossed left yellow line

Left Rear complete tread
Recon – Implied Motions

- Initial drag
- First evidenced yaw angle – *Steeper than expected?*
- Implied fishtailing?

Right Rear detread

Recon Diagram by Dr. Brian Pfeifer

Case Study #10
Recon – Vehicle Contact Marks

- Tire marks on vehicle elements
  - In wheel well
  - Deformation of parts
  - Sweeping marks on exterior

Case Study #10
Case Study #10

- Broken tail light, any pieces found upstream?
- Missing trim panel, located upstream?
- Sweeping tread contact
Key Points (1 of 2)

- Is suspension susceptible to axle tramp?
- Map out the tread pieces/vehicle debris
  - Where did tread separation start?
  - How far did it continue?
  - Bound the potential tramp interval
- Identify tire marks for tramp indicators
  - Wheel hop or tread variation?
- Look for tread separation duration/severity indicators on vehicle
Look for implied vehicle motions from secondary evidence

- Speeds and rotational frequencies
  - Where is axle tramp resonance possible in accident sequence for given tire size?

Did deflation occur? When?
- "Blowout" … an often misused word
- Caused loss of control … or vice versa?
QUESTIONS?