An Approach to Assessment of the Handling Performance of Straight Trucks

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Scope
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• Assess the dynamic performance of 14 straight truck configurations
  – Six with no self-steering axle
  – One with a self-steering pusher axle that equalized load with the drive axles
  – Four with a self-steering auxiliary pusher axle with a maximum load of 6,000 kg
  – Three with a self-steering auxiliary tag axle with a maximum load of 6,000 kg

• Handling was potentially an issue for some of these
Handling
Handling

- Handling describes the response of a vehicle to steering
- If a vehicle is driven in a circle and its speed is increased and the driver steers to maintain the circle, then if the steer:
  - Is into the circle, the vehicle is understeer
  - Does not change, the vehicle is neutral steer
  - Is out of the circle, the vehicle is oversteer
Understeer

• Understeer is the handling characteristic experienced in normal driving
• An understeer vehicle is stable
Understeer

\[ a = \frac{V^2}{R} \text{ g} \]
Ultimate Understeer

• A vehicle understeer at its performance limit cannot be steered
• The vehicle will plough out along a tangent to the turn
• It may roll over if it departs from the roadway
Neutral Steer

• This is a transition between understeer (stable) and oversteer (unstable)
• Many heavy vehicles are relatively neutral steer
Neutral Steer

\[ a = \frac{V^2}{R g} \]
Oversteer

- The rear of the vehicle tends to slide out
- An oversteer vehicle is potentially unstable
- An alert driver can feel the onset of oversteer and can stabilize it, as long as the approach is gradual
Oversteer

Speed \( V \) (m/s)

Lateral acceleration \( a \) (g)

Tire forces

Radius \( R \) (m)

\[ a = \frac{V^2}{R \ g} \]
Ultimate Oversteer

• A vehicle oversteer at its performance limit spins out
• It will almost certainly roll over even if it does not trip on a curb or depart from the roadway
• The driver of a truck that is oversteer at its performance limit is invariably unable to respond fast enough to regain control
Stabilized Oversteer
ARFF Vehicle
ARFF Vehicle

- Experienced a disproportionate number of rollovers
- NRC-CSTT tested a vehicle
- Static roll threshold was 0.42 g
- Oversteer at about 0.32 g
- Vehicles could not be modified or replaced
- NRC-CSTT developed a driver training course
Performance Measures

• UMTRI 1986
  – Evaluated understeer at 0.25 g
  – No link between handling and crashes
  – Premature to regulate based on handling

• Woodrooffe & El-Gindy 1990
  – Three point performance measure

• PBS 2007
  – This is very sensitive to vehicle parameters
  – Need to determine what is satisfactory performance and what is not
Performance Standard

• Three point used 0.3 g
• If oversteer leads to rollover, perhaps loss of yaw stability should not be less than the static roll threshold
• This would almost certainly eliminate many vehicles otherwise considered satisfactory
• An electronic stability system should deal with the issue for “normal” vehicles
Requirements

• No oversteer for specified test conditions
  – US Federal Transit Administration bus qualification test
  – National Fire Protection Association standard for ARFF vehicles

• These tests are well below the static roll threshold

• May be OK for a bus

• Not necessarily suitable for an ARFF vehicle
PBS

- PBS identified that a handling performance measure would be desirable to ensure adequate steering control over a wide range of turn conditions
- PBS is now in operation, but has not yet established a handling performance measure
- The need is still recognised, and is still on the research agenda
Evaluating Handling
Understeer Coefficient

- \( U = \frac{\delta_{sw}}{N} - L a_y g / V^2 \)
- Performance standard \( dU/da_y > - L g / V^2 \)
- Too onerous to evaluate a handling diagram point-by-point
- Developed continuous evaluation of \( U \) and \( dU/da_y \) as performance measures
- No pattern to separate trucks with quite different handling characteristics
- Results were inconclusive
Eureka!

• The vehicles being considered divided naturally into two groups:
  – Reasonably well-behaved
  – Quickly became highly oversteer
• We didn’t need to worry about those that were well-behaved
• We simply needed to show those that were bad were actually really bad
Trucks - Fixed Axles

Configuration A

Configuration BL

Configuration BH

Configuration C
Trucks - Fixed Axles

Configuration D

Configuration E

Configuration F
Trucks - Pusher Axle

- Configuration A1
- Configuration B1
- Configuration C1
- Configuration E1
Trucks - Tag Axle

Configuration B2

Configuration C2

Configuration D2
High-speed offtracking

Path of centre line of rear axle

Outward high-speed offtracking

Path of centre line of front axle
Approach

- Computed high-speed offtracking in a steady turn at 100 km/h and 0.2 g
- Each truck loaded fully with a payload of gravel
- Auxiliary axle raised, and with various loads from 1,000 to 8,000 kg
Results - Tag Axle

![Graph showing high-speed offtracking (m) versus auxiliary axle load (kg)]

- Line B2
- Line C2
- Line D2

Auxiliary Axle Load (kg)

High-speed Offtracking (m)
Results

• High-speed offtracking clearly showed the tendency to oversteer of trucks B2, C2 and D2 with an auxiliary tag axle

• Truck A1, with an auxiliary pusher axle
  – Also tended to oversteer
  – Mostly driven by occasional drivers for local pickup and delivery
  – Difficult to ensure reliable operation of the auxiliary axle
• Locking steer of an auxiliary axle at high speed effectively prevented oversteer
  – A lock would be critical to safety of a vehicle
  – Must be totally reliable for the life of a vehicle

• An electronic stability system
  – Should prevent spin-out
  – May not prevent significant high-speed offtracking
Conclusions
Conclusions

• No simple handling performance measure
• No known relationship between handling and crashes
• Handling of most “normal” vehicles is not known to be an issue
• High-speed offtracking, or another simple measure, demonstrates oversteer
• Nothing more needed to demonstrate poor handling performance
Thank you for your attention!

Questions?