ROPS, vehicle safety rating and mitigation of risk

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Almost 90% of crashes involve some form of human error

• Rollover accident statistics
  • Vehicle must revolve $\geq \frac{1}{4}$ turn regardless whether vehicle ends up laying on its side, roof, returning upright

• Mine ROPS requirements

• Vehicle safety grading
  • NCAP and other

• Vehicle safety grading & Mine ROPS requirement comparison

• Mitigation of rollover risks in mines
  • SRT dependent turning radius, speed, etc.
Vehicle categorization

Mining equipment
• All trackless vehicles not defined as light commercial vehicles, busses, tractors for agriculture and forestry or quad bikes:
  • Dozers, Dump trucks, Front-end loaders, Fork-lifts
  • Back actors, Tow/service trucks, Bobcats, Excavators, etc

Light commercial vehicles
• Pick-up trucks (< 1 ton), light busses (< 18 passengers), light trucks (< 5 ton), SUV/s, multi-purpose vehicles
• Passenger cars
  • Mini, small, midsize & large automobiles & automobile derivatives
• Light truck vehicles
  • Pick-ups, vans, etc.

Busses
• ≥18 passengers
Injury severity score (ISS)

To evaluate injury severity of the occupant – shown to correlate well with mortality

\[
ISS = \sum_{i=1}^{3} (\text{Maximum AIS by body regions})^2
\]

\[
AIS = \text{Abbreviated Injury Scale}
\]

ISS > 12  \rightarrow \text{seriously injured driver}
NASS-CDS Classification of rollover initiation types

- **Trip-over**
  - Lateral motion of vehicle is suddenly slowed/stopped
  - Curb, pot-hole, pavement, etc.

- **Fall-over**
  - Surface slopes downward such that CoG becomes outboard of the wheels

- **Flip-over**
  - Vehicle is rotated along its longitudinal axis by ramp-like object
  - Turned down guardrail, back slope of a ditch

- **Turn-over**
  - Centrifugal forces from sharp turn

- **End-over-end**
  - Vehicle rolls in pitch motion

- **Climb-over**
  - Vehicle climbs up and over a fixed object (guardrail, barrier, etc.) of sufficient height
  - Vehicle must roll on the opposite side from which it approached the object

- **Bounce-over**
  - Vehicle rebounds off a fixed object

- **Collision with other vehicle**
  - Collision must be the immediate cause of rollover
Distribution [%] of single- and multiple event accidents by roll type

Distribution [%] of passenger car & LTV rollovers by roll types

- **End-Over-End**: PC-Single: 0, PC-multiple: 0, LTV-Single: 1, LTV-Multiple: 0
- **Other**: PC-Single: 0, PC-multiple: 0, LTV-Single: 1, LTV-Multiple: 0
- **Collision**: PC-Single: 0, PC-multiple: 1, LTV-Single: 12, LTV-Multiple: 13
- **Bounce-over**: PC-Single: 0, PC-multiple: 13, LTV-Single: 14, LTV-Multiple: 25
- **Fall-over**: PC-Single: 9, PC-multiple: 13, LTV-Single: 7, LTV-Multiple: 15
- **Climb-over**: PC-Single: 4, PC-multiple: 8, LTV-Single: 6, LTV-Multiple: 8
- **Turn-over**: PC-Single: 1, PC-multiple: 15, LTV-Single: 4, LTV-Multiple: 48
- **Flip-over**: PC-Single: 73, PC-multiple: 56, LTV-Single: 49, LTV-Multiple: 48

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Seriously injured drivers ($ISS > 12$) in a rollover by roll type

Distribution [%] of seriously injured drivers ($ISS > 12$)

- **High probability for unbelted LTV flip-overs**
- **Note increase for belted drivers for bounce-over**

All – belted, unbelted, improperly belted & unknown belt usage
Risk (number of) of serious injury per 1,000 accidents

Risk per 1,000 accidents (ISS > 12)

- **End-Over-End**: 335
- **Other**: 267
- **Collision**: 194
- **Bounce-over**: 83
- **Fall-over**: 0
- **Climb-over**: 0
- **Turn-over**: 0
- **Flip-over**: 0
- **Trip-over**: 0

**PC-All**
**PC-belted**
**LTV-All**
**LTV-Belted**

All – belted, unbelted, improperly belted & unknown belt usage

The use of safety belts reduces the risk of injury in all rollover roll types.

Risk indicated as 0 means that data was not available.

Risk for driver to be seriously injured highest in end-over-end rollovers.
Distribution of objects initiating trip-overs in cars & LTV’s

- Passenger Cars: 91
- LTV's: 93
Accidents – what causes most serious injuries?

- Intrusion: Roof rail or B-pillar at occupant’s position
- Vehicle interior side & roof
- Improper safety belt use

Occupants with greater magnitude of intrusion at their seat position 10x more likely to receive serious injury.
Rollovers: Accident data

- Trip-over: Most commonly induced when lateral motion of vehicle suddenly slowed or stopped
  - 57% of passenger car rollovers
  - 51% of light truck rollovers
  - 90% trip-overs initiated by ground contact
- Fall-over
  - Soil trip, curb-tip & ditch fall-over
  - 2nd most common rollover type
  - 13% passenger cars
  - 15% light trucks
- Bounce-overs
  - 8% passenger cars
  - 8% light trucks
Rollover test: FMVSS 208

1. Vehicle positioned at pre-event roll angle of 23° with driver lower-most in vehicle
2. Towed sideways at 48.3 km/h on dolly fixture, which is decelerated at 20g for 40ms
3. Vehicle released and rolls primarily about its longitudinal axis
   a) Vehicles roll from 2 to 5 times
Corkscrew rollover test

1. Vehicle is travelling forward @ 70 – 80 km/h
2. Climbs on a ramp with driver’s side
3. Front & rear wheels launched from the ramp
4. Vehicle becomes airborne, rolls 180° and lands upside down
1. Vehicle towed sideways on moving fixture
2. Moving fixture decelerated at known rate, releasing the vehicle
3. Vehicle moves sideways until tyres comes in contact with soil/ground
4. Soil accumulates at tyres & may induce rollover
1. Vehicle towed sideways on moving fixture towards stationary curb

2. Moving fixture decelerated @ known rate to release vehicle

3. Tyres contact the curb, inducing rollover
   a) Depends on speed & curb type
1. Vehicle towed forward towards negative side of slope with known inclination, at an angle to it
2. Vehicle make transition from flat ground to negative slope of ditch
3. Induces fall-over
ROPS and vehicle safety rating/grading

1. 10 Mine ROPS requirements.pptx
2. 20 Vehicle safety rating.pptx
3. Mitigation of risk
4. Fit ROPS to limit intrusion
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