Automated Truck Longitudinal Control and Test Results at Crows Landing

Xiao-Yun Lu
PATH
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Outline

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2. Hardware
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   • Half loaded
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Test Scenarios

• Vehicle combined weight tested
  • Empty flat trailer \((M=14061[kg])\)
  • Half loaded \((M=22226[kg])\)
  • Fully loaded \((M=31795[kg])\)

• Speed range tested: \(10 \sim 55[\text{mph}]\)

• Flat test track with total length \(~ 2100[m]\)

• Combined braking system tested
  • Air brake (EBS) + Jake brake + Transmission retarder
  • Air brake (EBS) + Jake brake
  • Air brake (EBS) + Transmission retarder
  • Air (EBS) brake only
Hardware

Cummins **N14+ 435[hp]** Turbo diesel engine
With Jake (compression) brake capability
  - 400[N.m] ~ 2 cylinder
  - 800[N.m] ~ 4 cylinder
  - 1200[N.m] ~ 6 cylinder

Transmission retarder
Euro-EBS/ABS
Most data reading and commanding are through J1939 Bus
Maneuvers

Vehicle speed to follow a predefined profile (following a virtual vehicle)

Maximum acceleration tested for different loads

\[
\begin{align*}
    a &= 0.55 \, [m/(s^2)] \quad \text{when} \quad v = 2.0 \, [m/s] \\
    a &= 0.24 \, [m/(s^2)] \quad \text{when} \quad v = 14.0 \, [m/s] \\
    a &= 0.06 \, [m/(s^2)] \quad \text{when} \quad v = 25.0 \, [m/s]
\end{align*}
\]

Maximum deceleration range tested

\[
0.4 \sim 1.0 \, [m/(s^2)]
\]
Test Results

Each run has 3 figures.

Units & terminologies used in the following figures:

- **spd**: Speed [mph]
- **dist**: distance
- **dist_err**: distance error [m]
- **spd_err**: speed error [m/s]
- **max_acc**: Maximum acceleration [m/s^2]
- **max_dec**: Maximum deceleration [m/s^2]
- **acceleration**: [m/s^2]
- **deceleration**: [m/s^2]
- **EBS**: Euro-EBS/ABS
- **Jake**: Jake (compression) brake
- **trtd**: Transmission retarder
Empty Flat Trailer, Run 1: max_spd=55[mph], max_dec=1.2[m/s^2], EBS + Jake + trtd
Empty Flat Trailer, Run 1: \( \text{max_spd}=55 \text{[mph]}, \text{max_dec}=1.2 \text{[m/s}^2\text{]}, \text{ EBS + Jake + trtd} \)
Empty Flat Trailer, Run 1:  max_spd=55[mph],  max_dec=1.2[m/s^2],  EBS + Jake + trtd
Empty Flat Trailer, Run 2: $\text{max} \text{ spd}=55, \text{ max dec}=1.0, \text{ EBS + trtd}$
Empty Flat Trailer, Run 2:  max_spd=55,  max_dec=1.0,  EBS + trtd
Empty Flat Trailer, Run 2:  max_spd=55,  max_dec=1.0,  EBS + trtd
Empty Flat Trailer, Run 3: \( \text{max_spd}=30, \text{ max_dec}=0.7, \text{ EBS + trtd} \)
Empty Flat Trailer, Run 3:  \( \text{max_spd}=30, \quad \text{max_dec}=0.7, \quad \text{EBS} + \text{trtd} \)
Empty Flat Trailer, Run 3: max_spd=30, max_dec=0.7, EBS + trtd
Empty Flat Trailer, Run 4: max_spd=10, max_dec=0.7, EBS + trtd
Empty Flat Trailer, Run 4:  max_spd=10,  max_dec=0.7,  EBS + trtd
Empty Flat Trailer, Run 4: max_spd=10, max_dec=0.7, EBS + trtd
Half Loaded, Run 1: \( \text{max_spd}=55, \text{ max_dec}=0.5, \text{ EBS} + \text{Jake} + \text{trtd} \)
Half Loaded, Run 1:  \( \text{max\_spd}=55, \text{ max\_dec}=0.5, \text{ EBS + Jake + trtd} \)
Half Loaded, Run 1: max_spd=55, max_dec=0.5, EBS + Jake + trtd
Half Loaded, Run 2: \( \text{max spd} = 55, \quad \text{max dec} = 0.9, \quad \text{EBS + Jake + trtd} \)
Half Loaded, Run 2: \( \text{max}_{\text{spd}}=55, \text{ max}_{\text{dec}}=0.9, \text{ EBS + Jake + trtd} \)
Half Loaded, Run 2: max_spd=55, max_dec=0.9, EBS + Jake + trtd
Half Loaded, Run 3: max_spd=55, max_dec=0.5, EBS + trtd
Half Loaded, Run 3: max_spd=55, max_dec=0.5, EBS + trtd
Half Loaded, Run 3:  max_spd=55,  max_dec=0.5,  EBS + trtd
Half Loaded, Run 4:  max_spd=30,  max_dec=0.7,  EBS + Jake + trtd
Half Loaded, Run 4: max_spd=30, max_dec=0.7, EBS + Jake + trtd
Half Loaded, Run 4: max_spd=30, max_dec=0.7, EBS + Jake + trtd
Fully Loaded, Run 1:  \( \text{max_spd}=55 \),  \( \text{max_dec}=1.0 \),  EBS + Jake
Fully Loaded, Run 1:  max_spd=55,  max_dec=1.0,  EBS + Jake
Fully Loaded, Run 1: max_spd=55, max_dec=1.0, EBS + Jake
Fully Loaded, Run 2: max_spd=55, max_dec=0.8, EBS + Jake
Fully Loaded, Run 2:  \( \text{max spd}=55 \),  \( \text{max dec}=0.8 \),  EBS + Jake
Fully Loaded, Run 2: max_spd=55, max_dec=0.8, EBS + Jake
Fully Loaded, Run 3: max_spd=25, max_dec=0.7, EBS + Jake
Fully Loaded, Run 3:  max_spd=25,  max_dec=0.7,  EBS + Jake
Fully Loaded, Run 3: \( \text{max_spd}=25, \quad \text{max_dec}=0.7, \quad \text{EBS + Jake} \)
Fully Loaded, Run 4: max_spd=10, max_dec=0.7, EBS + Jake
Fully Loaded, Run 4: $\text{max\_spd}=10, \quad \text{max\_dec}=0.7, \quad \text{EBS + Jake}$
Fully Loaded, Run 4: \( \text{max\_spd}=10, \quad \text{max\_dec}=0.7, \quad \text{EBS + Jake} \)
Fully Loaded, Run 5: \( \text{max_spd}=55, \quad \text{max_dec}=1.0, \quad \text{EBS only} \)

Empty trailer Mass is used in feedback control
Fully Loaded, Run 5: \[ \text{max\_spd}=55, \quad \text{max\_dec}=1.0, \quad \text{EBS only} \]

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Fully Loaded, Run 5: \[ \text{max}_\text{spd}=55, \quad \text{max}_\text{dec}=1.0, \quad \text{EBS only} \]
Empty trailer Mass is used in feedback control
Fully loaded, Run 6:  \( \text{max\_spd}=55, \quad \text{max\_dec}=0.5, \quad \text{EBS only} \)

Empty trailer Mass is used in feedback control
Fully Loaded, Run 6: max_spd=55, max_dec=0.5, EBS only
Empty trailer Mass is used in feedback control
Fully Loaded, Run 6:  max_spd=55, max_dec=0.5, EBS + Jake + trtd
Empty trailer Mass is used in feedback control
Fully Loaded, Run 7: max_spd=40, max_dec=0.7, EBS only
Empty trailer Mass is used in feedback control
Fully Loaded, Run 7:  max_spd=40,  max_dec=0.7,  EBS only
Empty trailer Mass is used in feedback control
Fully Loaded, Run 7: max_spd=40, max_dec=0.7, EBS only
Empty trailer Mass is used in feedback control
Future Work

- Fine tuning controller
- To smooth braking system actuation
- Vehicle following
- Grading up/down hills
- Other maneuver test