Voertuigdynamica van vrachtwagens en getrokken materieel

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HTAS Themabijeenkomst
Vehicle Dynamics Control
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University education

Bachelor/Master system

1 - master Mechanical Engineering (AES)
   specialisation Automotive Engineering Science
   within faculty of mechanical engineering
   -combustion engines Philip de Goey
   -automotive materials Marc Geers
   -powertrains Maarten Steinbuch
   -vehicle dynamics Henk Nijmeijer

2 - master Automotive Technology (AT)
   interfaculty programme (mechanical engineering, electrical engineering,
   chemical technology, mathematics & computer science, technology
   management, industrial design)

   supported financially by HTAS
Vehicle Dynamics & related courses

**Vehicle Dynamics** (40 – 65 students)
- vertical dynamics, ride comfort
- lateral dynamics, steering behaviour
- steady-state tyre behaviour
- focus mainly on passenger cars

**Advanced Vehicle Dynamics** (20 – 40 students)
- suspension kinematics, multi-body modelling
- tyre dynamics and applications
- truck vertical dynamics, (fatigue) loading
- a number of lecturers from DAF trucks

**Integrated Automotive Safety** (new)
- passive safety, injury biomechanics
- active safety systems, ADAS, cooperative driving
- a number of lecturers from TNO Automotive
Vehicle Dynamics research

Emphasis on:
- tyres
- commercial vehicles
- vehicle control

... but it may also include related topics
  e.g. multi-link suspension design/optimisation

FEM tyre modelling

Development of a contact model to improve correlation outdoor measurements and FE computations
Semi-empirical tyre modelling

Continued development of Pacejka tyre models
(in cooperation with TNO Automotive and prof. Pacejka)

- Magic Formula extensions to include tyre inflation pressure
- Motorcycle tyre modelling (large camber angles)
- Model validation, parameter identification, application to full vehicle simulations

Control of an over actuated autonomous vehicle

TNO VEHIL high performance moving base robot

Some characteristics
- Vehicle mass 480 kg
- Wheel base 1.4 m
- Track width 1.4 m
- Max. speed 50 km/hr
- Max. accel. 10 m/s²
- 0 to 50 km/hr 2.1 s
- Installed power 30 kW
- Battery pack 288 NiMH, D-cells, 350 V, 75 kg

3 motion degrees of freedom
8 actuators (4 steering angles, 4 drive/brake torques)
Overactuated system with a need for control allocation
Variabele geometry active suspension

Improve ride comfort and vehicle attitude for different driving conditions, using a variable geometry actuator

- low energy consumption compared to hydraulics (especially for attitude control)
- actuator hardware is build and tested
- controller development
  - low level: actuator control
  - high level: comfort, handling, events,…
- full vehicle simulations to evaluate performance

Truck modelling and validation

Create a validated multi-body model for handing and ride

limited complexity, suitable for control system evaluation
- vertical dynamics: discrete obstacles, Belgian blocks
- lateral dynamics: steady state cornering, step steer
- longitudinal dynamics: acceleration, braking

in cooperation with TNO Automotive and DAF Trucks
Dakar rally trucks

Improve the vertical dynamics on big road obstacles

De Rooy: spring/damper optimisation (fast rebound system)
GINAF: independent suspension, semi-active (hydraulic) system modelling, analysis, optimisation,…

The lateral dynamics of LZV combinations

LZV: Langere en Zwaardere Vrachtautocombinatie
Vehicle length/weight limits

Europe:
- tractor semitrailer: 16.5 m
- truck trailer: 18.75 m
- mass: 40 ton (dependent on country)

Australian road trains (53.5 m, 132 ton)
US (up to 35 m, 75 ton)
Sweden/Finland (25.25 m, 60 ton)

Advantages of a 25 m, 60 ton vehicle

Economical/environmental:
- reduced fuel consumption compared to separate vehicles (up to 30 %)
- single driver can transport more goods (+50 %)
- less vehicles on the road (small effect on traffic jams)

Cost structure road transport (2005):

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road tax</td>
<td>1.2%</td>
</tr>
<tr>
<td>Tires</td>
<td>1.3%</td>
</tr>
<tr>
<td>Insurance</td>
<td>3.0%</td>
</tr>
<tr>
<td>Interest</td>
<td>2.8%</td>
</tr>
<tr>
<td>Rep &amp; Maint.</td>
<td>3.9%</td>
</tr>
<tr>
<td>Depreciation</td>
<td>8.3%</td>
</tr>
<tr>
<td>Other cost</td>
<td>11.9%</td>
</tr>
<tr>
<td>Fuel</td>
<td>16.8%</td>
</tr>
<tr>
<td>Driver</td>
<td>50.8%</td>
</tr>
</tbody>
</table>

Road transport is growing…

Figure 4: Transport activity growth for EU-25 (index, 2000 = 100)
Disadvantages

safety:
• “interaction” with other traffic (cyclists, pedestrians, cars)
• stability, in particular roll-over

infrastructure:
• damage to bridges/roads?
• adaptations required (e.g. parking spots near highway)

See e.g. Bast report:
Auswirkungen von neuen Fahrzeugkonzepten auf die Infrastruktur des Bundesfernstraßennetzes, 2006

25 meter vehicles in the Netherlands

Since 2002: 25 meter busses in the city of Utrecht
Increased capacity required (25 m bus: 148 persons)

Another example:
APTS phileas
25 meter commercial vehicles

• Since 2004 limited experiments in the Netherlands (±150 vehicles)

• max. vehicle mass 60 ton (instead of 50 ton) in case of a single driven axle: 57.5 ton

• vehicle should be equipped with latest safety devices (e.g. vehicle stability control system, underrun protection, etc.)

• only allowed to drive on designated roads, outside of cities (always permit required, no railway crossings, ...)

• driver should have at least 5 years of experience

• ...

Possible configurations

max. two turning points:
  • backward driving
  • lateral stability

max. overall length: 25.25 m

load length limited to: 13.6 + 7.82 = 21.42 m
Evaluate behaviour using a simulation model

general idea:
• to do “virtual” testing
• compare different vehicle combinations – global behaviour
• initial focus: lateral dynamics/stability

vehicle modelling:
• many variants
• generic, not limited to a specific brand/type
• relatively low degree of complexity

simulation tool: MATLAB/Simulink/SimMechanics
Model parameters

- whenever possible the individual parts are legal with the existing regulations (e.g. 3 axle truck: 26 ton)
- fully loaded condition, density 350 kg/m$^3$ (food, vegetables)
- cargo floor height: 1.3 m, C.G. of cargo 1.0 to 1.25 m above floor

Static axle loads LZV D

Front axle 73567 N ( 7499 kg)
Rear axle1 90761 N ( 9252 kg)
Rear axle2 90769 N ( 9253 kg)
Dolly axle1 66075 N ( 6735 kg)
Dolly axle2 66228 N ( 6751 kg)
Trailer axle1 67080 N ( 6838 kg)
Trailer axle2 67070 N ( 6837 kg)
Trailer axle3 67060 N ( 6836 kg)

total mass 60001 kg
Swept path analysis

Requirement:
• swept path should be less than 8 m for a circle with an outside diameter of 14.5 m.

Results swept path analysis
Dynamics: single lane change

Based on SAE J2179
test for evaluating the rearward amplification of multi-articulated vehicles

Course and test specifications:
2.5 second period
24.5 m/s² (55mph)
61 m (200 ft) maneuvering section
1.46 m (4.8 ft) lateral displacement
0.15 g peak lateral acceleration

Traffic cone pairs
4.58 m (15 ft) stripes placed 0.6 m (2 ft) apart

Preliminary straight section, traffic cone pairs,
30.5 m (100 ft) spacing
Initial Straight section,
6.1 m (20 ft) spacing
"Maneuvering" section,
3 m (10 ft) spacing
Exit section,
6.1 m (20 ft) spacing

* not drawn to scale

simulation results for 80 km/h (SAE: 88 km/h)

Performance measures

Rearward Amplification (RA)
different vehicle units → different lateral accelerations (+ time shifts)

\[
RA = \frac{\max \left( a_{y,\text{trailing unit}}(t) \right)}{\max \left( a_{y,\text{towing unit}}(t) \right)}
\]

Dynamic Load Transfer Ratio (DLTR)

DLTR = 0 same vertical force left/right
DLTR = ±1 tyres on one side are lifted from the ground

\[
DLTR = \frac{\sum_{i=1}^{n} F_{z,Li} - F_{z,Ri}}{\sum_{i=1}^{n} F_{z,Li} + F_{z,Ri}}
\]
Example (configuration C)

rearward amplification

Lateral accelerations of the axles

\[ RA = \frac{2.88}{2.88} \]

dynamic load transfer ratio

Dynamic load transfer ratio

\[ DLTR = 0.75 \]

Animations
Results single lane change

The trade-off is obvious...

roll over risk
limited maneuverability
Ongoing research

- discussion with RDW, trailer manufacturers
- include other conventional vehicles
- validation with real LZV combinations
- include braking system and roll-over prevention using ESC (student Martijn Pinxteren)
- improve swept path calculation and include steered trailer axles (student: Jan Loof)
- analyse different loading conditions
- sensitivity analysis
- develop design guidelines
- ...

Outlook, future

The TU/e would like to set-up a working group to initiate research in the field of commercial vehicles as a HTAS programme

possible subjects:
- LZVs
- roll-over prevention
- design loads (incl. fatigue)
- independent suspension
- ...

...other questions regarding vehicle dynamics are welcome too!
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