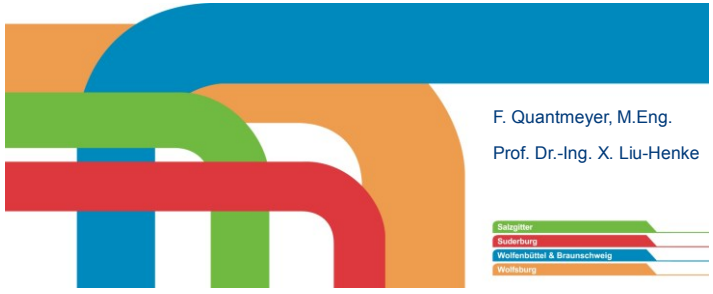
Ostfalia
Hochschule für angewandte Wissenschaften

Model Based Design of a Vehicle-Trailer Combination Stabilization

12th International Workshop on Research and Education in Mechatronics
September 15th – 16th 2011, Kocaeli, Turkey



F. Quantmeyer, M.Eng.
Prof. Dr.-Ing. X. Liu-Henke

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

Overview

1. Introduction
2. Virtual Testbed for Model Based Design and Testing
3. Vehicle-Trailer Combinations
4. Modeling of the Vehicle-Trailer Combination
5. Analysis of the dynamical behavior
6. Model Based Design of Vehicle-Trailer Combination Stabilization
7. Conclusion

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

1. Introduction

Joint Project:

Model of Vehicle-Trailer Combination for Model Based Design for a so called „Virtual Testbed“ for ECUs

Aim of the project:

- Development of new models for vehicle dynamics for testing the function of control algorithms of Vehicle-Trailer Combination Stabilization for the virtual testbed
- Investigation on different strategies for control by using Model-in-the-Loop- and Software-in-the-Loop-Simulation

Ostfalia University

R&D of Volkswagen AG

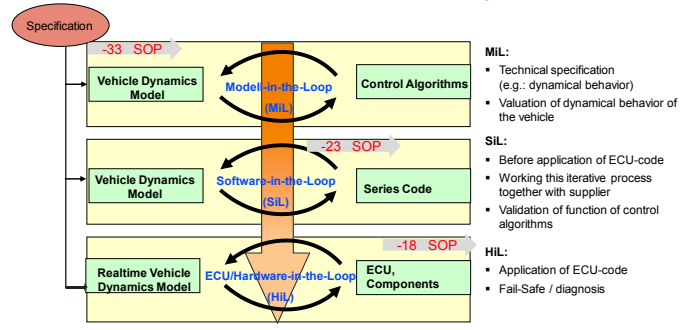
Niedersächsischen Forschungszentrum für Fahrzeugtechnik

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

1. Introduction

Model Based process of development and testing



MiL:
- Technical specification (e.g.: dynamical behavior)
- Valuation of dynamical behavior of the vehicle

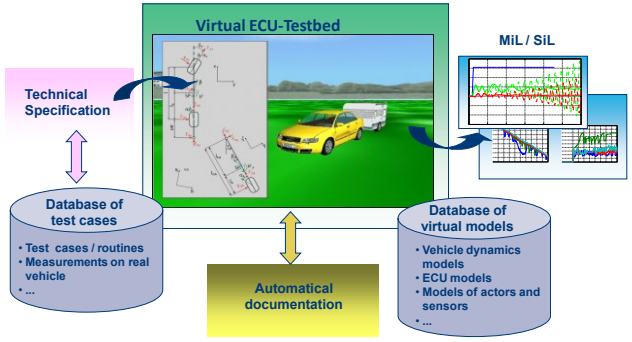
SiL:
- Before application of ECU-code
- Working this iterative process together with supplier
- Validation of function of control algorithms

HiL:
- Application of ECU-code
- Fail-Safe / diagnosis

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

2. Virtual Testbed



Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

3. Vehicle-Trailer Combinations

- In comparison with vehicle different dynamical
- Instability above the critical velocity
- Oscillations of the trailer – indicated by the kink angle or yaw angle of the vehicle

⬇

- Risk of accident

➡ Support for the driver in such critical situations:
Vehicle-Trailer Combination Stabilization

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

4. Modeling of Vehicle-Trailer Combination

The Vehicle-Trailer Combination

Ref: Volkswagen AG, Böckmann Fahrzeugwerke GmbH

➡

- Expansion of the database of virtual models with different types of trailers
- Different detailing of the models for system analysis, function development and testing

Different types of trailers:

- One or more axles
- With or without brakes
- With or without suspension

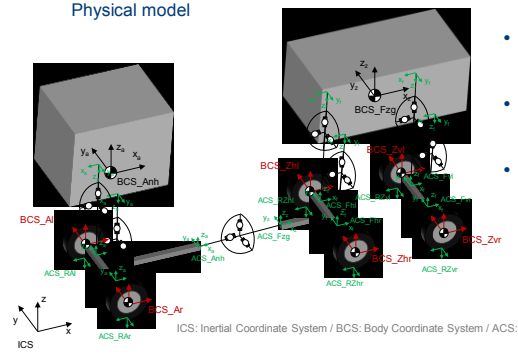
Transmission of force by trailer coupling

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

4. Modeling of Vehicle-Trailer Combination

Physical model



- Vehicle:
  Mass of vehicle body
  4 wheel masses
- Trailer:
  Mass of trailer body
  2 (4) wheel masses
- Trailer coupling:
  force transmission by using spring damper element with 6 DOF

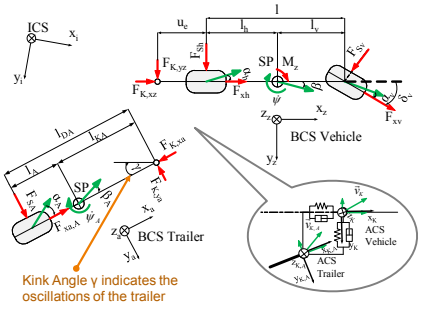
ICS: Inertial Coordinate System / BCS: Body Coordinate System / ACS: Attachement Coordinate System

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

4. Modeling of Vehicle-Trailer Combination

Model for model based control design



Dynamic functions:

State equations:

$$\begin{bmatrix}\dot{\beta}\\ \ddot{\psi}\\ \dot{\gamma}\\ \ddot{\gamma}\end{bmatrix} = \begin{bmatrix}a_{11} & a_{12} & a_{13} & a_{14}\\ a_{21} & a_{22} & a_{23} & a_{24}\\ a_{31} & a_{32} & a_{33} & a_{34}\\ a_{41} & a_{42} & a_{43} & a_{44}\end{bmatrix} \cdot \begin{bmatrix}\beta\\ \dot{\psi}\\ \gamma\\ \dot{\gamma}\end{bmatrix} + \begin{bmatrix}b_1\\ b_2\\ b_3\\ b_4\end{bmatrix} \cdot \delta_v$$

Ausgangsgleichungen:

$$\underline{y} = \underline{\underline{C}} \cdot \underline{x} + \underline{\underline{D}} \cdot \underline{u}$$

Kinematic functions:

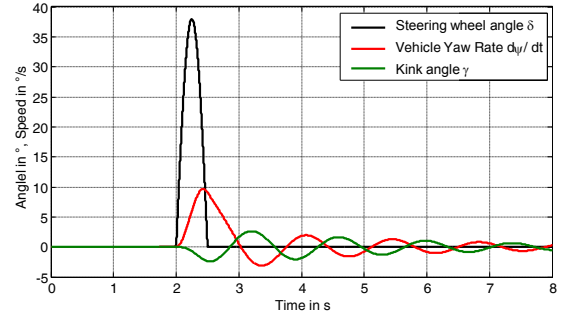
$$\underline{\underline{T}} = \begin{bmatrix}1 & 0 & 0\\ 0 & \cos\gamma & -\sin\gamma\\ 0 & \sin\gamma & \cos\gamma\end{bmatrix}$$

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

5. Analysis of the dynamical behavior

Response for sine impuls of steering wheel angle at 100 km/h

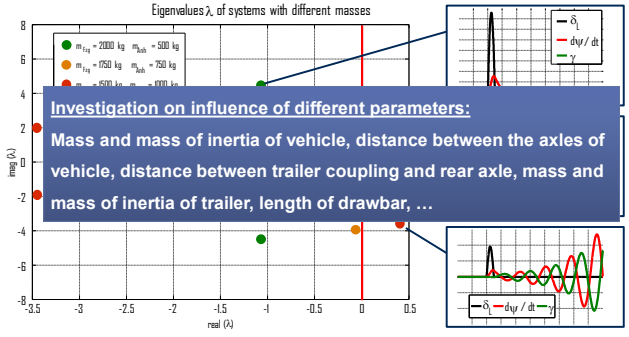


Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

5. Analysis of the dynamical behavior

Investigation on the influence of different parameters on system stability



Investigation on influence of different parameters:

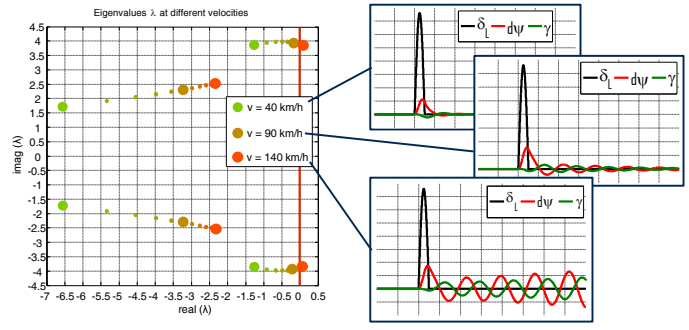
Mass and mass of inertia of vehicle, distance between the axles of vehicle, distance between trailer coupling and rear axle, mass and mass of inertia of trailer, length of drawbar, …

Ostfalia
Hochschule für angewandte Wissenschaften

Wolfenbüttel & Braunschweig

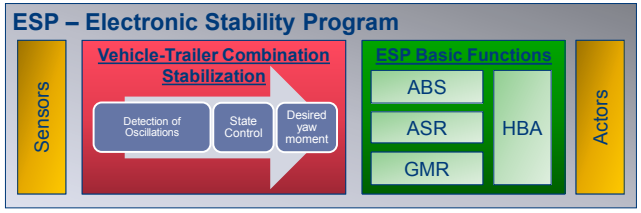
5. Analysis of the dynamical behavior

Influence of velocity on system stability



Ostfalia
Hochschule für angewandte Wissenschaften
Wolfenbüttel & Braunschweig

6. Model Based Design of Vehicle-Trailer Combination Stabilization

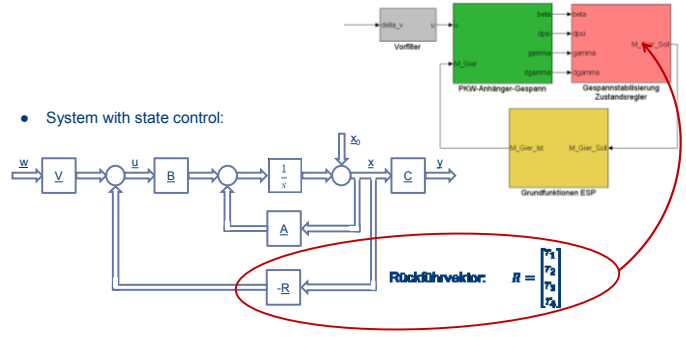


- Additional Function of ESP
- Detecting of the oscillations on the basis of ESP-sensors
- State controller generates a desired yaw moment to stabilize the system
- Realization of this yaw momentum by wheel individually braking

Ostfalia
Hochschule für angewandte Wissenschaften
Wolfenbüttel & Braunschweig

6. Model Based Design of Vehicle-Trailer Combination Stabilization

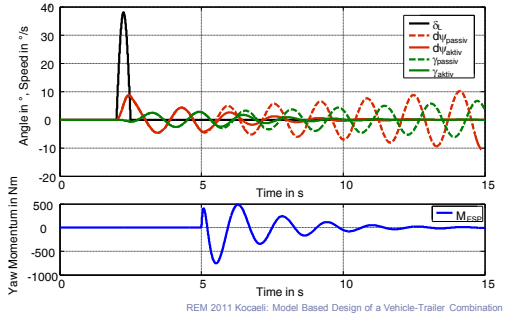
- System with state control:



Ostfalia
Hochschule für angewandte Wissenschaften
Wolfenbüttel & Braunschweig

6. Model Based Design of Vehicle-Trailer Combination Stabilization

Impulse of steering wheel angle at $v_{overcritical}$ = 140 km/h



Ostfalia
Hochschule für angewandte Wissenschaften
Wolfenbüttel & Braunschweig

7. Conclusion

- A virtual testbed has been described and expanded by trailer models with different detailing
- The virtual testbed is now ready for use in future projects for function development and testing for Vehicle-trailer combinations
- The dynamical behavior of the vehicle-trailer combination and the influence of its parameters has been analyzed
- On this basis a vehicle-trailer combination stabilization has been developed and tested

Thank you for your attention!