Requirements Determination from Vehicle to System Level of Mechatronics – A Tier-1 Approach to Model Based Development

Authors: Rabie Ait Ahmed Ouali, Markus Stobitzer, Dr. Hellmar Rockel, Schaeffler Technologies AG & Co. KG
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3. Setting the Scope: Requirements Elicitation from the Vehicle Level

4. Simulation Methods
   - 4.1 System Requirements from Vehicle Simulation
   - 4.2 Component Requirements from Vehicle Simulation

5. Outlook and the Big Picture
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Schaeffler in facts – strong starting point

- Strong customer base with approx. **11,800** customers
- **1.1 m** tons of processed steel p.a.
- Approximately **EUR 14.4 bn** Sales in 2019
- Almost **2,400** patents filed in 2019
- **8.1%** EBIT margin in 2019\(^1\)
- Around **84,200** employees worldwide\(^2\)
- More than **170** locations in **50** countries
- Far more than **10,000** different products

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\(^1\) Before one-off effects  |  \(^2\) As at June 30, 2020
Three divisions – automotive OEM, Automotive Aftermarket and Industrial
2 Introduction Schaeffler Technologies AG & Co. KG

Mechatronic Chassis Systems from Schaeffler – Active Roll Control System (iARC)

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Active roll control actuator

Improve vehicle dynamics:
- Increase agility
- Enable selectable driving modes

Enhance comfort:
- Reduce effect from road bumps
- Increase roll damping

WITH ACTIVE ROLL CONTROL

NO ACTIVE ROLL CONTROL

ROAD DISTURBANCE

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Benefits of Out-of-Phase-Steering:
- Maneuverability
- Driving Comfort
- Smaller turning circle
- Driving Agility

Benefits for driving with trailer:
- Reduce Hitch Angle
- Trailer Sway Mitigation
- Increased Towing Capacity
- Limp aside

Benefits of In-Phase-Steering:
- Vehicle Control
- Driver Comfort
- Passenger Comfort
- Driving Stability
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3 Setting the Scope: Requirements Elicitation from the Vehicle Level

A Simulation Based (Reversed) March through the V-Model

**Requirements:**
- Special interest from a Tier-1 perspective
- Virtual methods to drive requirements engineering from the vehicle level are very helpful!
  - Improved requirements quality
  - Increased understanding of customer's needs
- We will show two examples from the variety of our methodical approaches on the following slides.

**Virtual and Real Test Driving:**
- Well established
- State-of-the-art

**XiL-Scenarios:**
- Well established already
- Getting more and more sophisticated
- Several mixed scenarios (d.u.t. and its environment) possible and subject to development and permanent improvement

**Component Level Design:**
- State-of-the-art
- Huge amount of virtual methods in every domain available

Vehicle Simulation for Requirements Engineering is the topic here!

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Virtual Vehicle to Support Mechatronic Development (Overview)

- Support FuSaf-analysis of critical driving maneuvers
- Determine loads out of the vehicle chassis to the mechatronic system (interdependence with function)
- Analyze functional performance of the Schaeffler products on vehicle level
- Support acquisition process for iRWS and iARC systems on vehicle level
- Check requirements received from the OEM for plausibility and better understanding
- Enhance model quality by matching simulation and measurement data
- Optimize vehicle controller performance

Maximum Impact: Vehicle Requirements Interact with (almost) every Development Step.
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Vehicle Model Build-up with Schaeffler iRWS- and iARC-System Models

Matlab /Simulink

Vehicle level

Schaeffler Chassis Controller

Product level

Rear wheel steering

Active roll control system

- Information from CarMaker to Matlab
  - Front steering wheel angle
  - Vehicle velocity
  - Chassis tie rod forces (left right)
  - Roll angle

IPG - CarMaker

- Following vehicle information integrated:
  - K&C Data
  - Tire model
  - Vehicle, road, driver model
  - Damper curves
  - Validation of different driving maneuver

Integration Platform for our Products in Vehicle Context

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Requirements Analysis Procedure Using Vehicle Simulation

- Requirements from the OEM
- Vehicle Regulation (StvZO)
- Vehicle Norms (DIN)
- VDA Driving Maneuvers

Are the requirements realistic?
What does the requirements mean on vehicle level?
What does this mean w.r.t. functional safety?
Virtual Calibration of Vehicle Requirements Based on Vehicle Roll Characteristic

**iARC-requirement rolling behaviour from OEM for different driving modes:**

<table>
<thead>
<tr>
<th>Driving mode</th>
<th>Roll angle vs. lateral acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort mode</td>
<td>2.80 °/g</td>
</tr>
<tr>
<td>Dynamic mode</td>
<td>1.00 °/g</td>
</tr>
</tbody>
</table>

**Driving maneuver for calibration:**
Driving a circle with slowly increasing steering angle (1deg/s)
Constant velocity: 100 km/h

**Result of virtual calibration**

**Benefits of virtual calibration:**
- Saving of time with simultaneous engineering
- Simple and fast parameter optimization and studies are possible
- Safe commissioning of function in the vehicle
- Digital Twin of real democar

**Virtual Calibration Improves Development Maturity at an Early Stage**

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4 Simulation Methods

**Functional Error Simulation for Democar Vehicle Clearance**

**Simulation:**
FuSaf-Simulation to analyse the vehicle behaviour in different driving maneuvers
- Driving maneuvers (open and closed loop)
  - Fishhook-Maneuver
  - Steady-State Circle
  - Step Steer Test
  - Etc.

**Results:**
- Democar clearance (e.g. tip over hazard)
- Understanding of critical driving maneuvers

Example for iARC error @ Democar during Steady-State Circular Test:
- Vehicle loses ground contact
- Front axle error injection @ t=130s
  - iARC torque = 0 Nm

**Functional Safety Analysis for Safe Mechatronic Systems according to ASIL Specifications**
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4 Simulation Methods

Finding Model Architecture when Combining Model Classes

- Simulation of mechanical loads at axle level using virtual K&C test rig

**Schaeffler Chassis Component**

- Steering actuator as MBS in Simpack
- Need for load spectra for strength/fatigue calculation for mechanical design
  - Tie-rod forces and torques

**Integration in Vehicle Model in Simpack**

- Integration of chassis component
- Simulation of the test run
- Provide load spectra for strength/fatigue calculation
- Requires the whole vehicle data (Stiffness, 3D geometries)

**Integration in Axle test rig in Simpack**

- The whole vehicle model is reduced to an axle model in Simpack
- Integration of chassis component (steering)
- Provide load spectra for strength/Fatigue calculation on axle level
- Requires a virtual test rig to initiate wheel body contact forces
- The input forces will be generated from CarMaker simulation

Model Boundaries and Simulation Interfaces Chosen Carefully Considering Effort and Costs
Mechanical Loads from Virtual Test Drive

### CarMaker
- **Driving Scenarios**
  - VDA, Lane change,....
  - Special maneuvers
- **Vehicle Modell in CarMaker**
  - Generate forces for the test rig

### Simpack
- **Axle test rig in Simpack**
- **Tie rod Acting forces**

#### 5 DoF of the Wheel
- $V_x$, $\delta$
- $F_x$, $F_y$, $F_z$, $M_z$

Getting the Maximum Benefit from Each Modeling Class – Synergy of Multi-Body- and System-Simulation
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Summary:

- Two Examples from our Methodical Portfolio have been shown.

- Top Down Approach:
  - Vehicle Level (Stakeholder Requirements)
  - System Level (System Requirements)
  - Component Level (Component Requirements)

Outlook:

- Continue model and simulation based development
  - System Architecture Development
  - System Design
  - Verification, Integration, Validation

- Interaction of virtual and real instances of vehicle, system and components (mechanics, SW, ECU)
Models and real Instances of Function, Plant and Environment

Comprehensive View on Analytical and Simulation Models for Mechatronic Development
Overall Mission

- Continuously find optimal paths through the V:
  - Provide suitable models for the right purpose
  - Ensure consistency among all models

- Permanently
  - Increase Customer Orientation
  - Deepen System Understanding
  - Improve Efficiency

- In this sense vehicle simulation is our top layer in mechatronic development
Thank you for your attention.
Please feel free to ask questions.