e.GO – agile simulation to verify vehicle concepts in early development stages
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e.GO

das Stadtauto

Fun

Practical

Affordable
e.GO will boost e-mobility, exciting customers with cars that are fun, practical and affordable.
e.GO has clearly positioned itself since the company’s foundation and is shaping a new form of electromobility

- Fun
  - Acceleration 0 - 50 km/h: 3.2 sec
  - Agile & maneuverable
  - Inspiring design
  - Safety first

- Practical
  - Made for most daily needs and ranges
  - Compact exterior and interior
  - First choice for second car

- Affordable
  - Price from 15.900 €; before subsidies
  - Total Cost of Ownership (TCO) 40% lower than conventional cars
  - Worthwhile without subsidies

Q1 2015 Foundation of e.GO Mobile
Highly iterative development is supported by the rapid implementation and testing of prototypes

Rapid implementation of prototypes ...

Product maturity

... the example of e.GO Life

- concept design
- body parts
- building of a functional prototype
- fast expert tests

The rapid market expedition with functional prototypes is a success factor in the development of radical innovations in the e-mobility market.
e.GO enables the production of affordable vehicles with the latest technologies

How to develop a highly iterative Prototype?

**Digital Prototype**
- **CAx – Design: DMU (Full-Vehicle Package)**
- **Digital Twin**
- **Simulation of Mechanical Strength (FEA)**
- **Full Vehicle Simulation – Ensuring Requirement Fit**

**Physical Prototype**
- **Process Validation**
- **Empowerment of Prototyping and Production Team**
- **Fast validation of Technical Concepts**
- **Durability Tests in early stages**
Does the vehicle concept fulfill the requirements set by the product management?

→ To answer this question in an early development stage, e.GO used Matlab / Simulink to simulate the vehicle quite without a physical prototype.
Driving Cycle / Testing

*Developing a city cycle to fulfill customer requirements*

- a new car concept needs a new Driving cycle!
- Tracking of an inner-city driving cycle (s ~ 19 km, t ~ 45 min, \( v_{(average)} = 25 \text{ km/h} \))
- also using standard cycles to ensure comparability to other vehicle concepts
Simulation of an electric vehicle

Elements of the Simulation Model

- The complex interaction of components is simulated in the Simulink model
- Validation of the model with rapid prototypes

Input Data

Physical Components
- Battery
- Motor & Inverter
- Gearbox
- Cooling System
- Vehicle

Driver Model

Controller Models

Output Data
Validation

Elements of the Validation Process

- Several Model-elements
- Validation of model with rapid prototypes
- Finalization of e.GO Life Vehicle Concept

Simulink Model
- inclusion of all components
- Defining Environmental Inputs
- Defining Input & Output-Parameter

Funktional Prototype
- Testing of selective functions
- Improving the simulation model
- Increasing the prototype maturity

Final vehicle
- Validation of the final system design
- Matching on the physical vehicle and the simulation model
**Vehicel Model**

**Longitudinal Dynamics Simulation**

**Vehicle Models – Driving resistance**
- Drag (Air resistance)
- Rolling resistance
- Acceleration resistance
- Slope resistance

**Battery Simulation**
- Internal resistance
- Thermal behavior
- SoC, DoD, SoH
- Current
- Voltage
Modellbeschreibung und Simulationsmethodik

BATTERIEMODELL/ ÜBERBLICK

- Modell mit äquivalenter elektrischer Schaltung
- Energieverlust von Komponenten basiert auf dem Innenwiderstand
Modellbeschreibung und Simulationsmethodik

**BATTERIEMODELL / DETAIL**

### Physisches Modell
- Battery current is given by:

\[ I_{Batt} = \left( \frac{V_{OC} - (V_{OC}^2 - 4P_{Batt,Req} \cdot R_{int})^{\frac{1}{2}}}{2R_{int}} \right) \]
- Battery voltage is calculated:

\[ V_{Batt} = V_{OC} - R_{int} \cdot I_{Batt} \]

**Beschreibung**
- \( I_{Batt} \): Batteriestrom / A
- \( V_{OC} \): Batterie Leerlaufspannung / V
- \( V_{Batt} \): Batteriespannung / V
- \( P_{Batt,Req} \): Leistungsanforderung von der Batterie / W
- \( R_{int} \): Batterie Innenwiderstand / Ω

### Eingang
- Eingangsgröße:
  - Leistung der EM
  - Leistung der Hochspannungsbatterie

### Ausgang
- Ausgangsgröße:
  - Batterie SoC
  - Batteriestrom
  - Batteriespannung

- Modell mit äquivalenter elektrischer Schaltung
- Energieverlust von Komponenten basierend auf dem Innenwiderstand

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