Modular Drivetrain Concept for Electrical Commercial Vehicles

- MAN Truck & Bus AG
- ZG GmbH

Braykoff | Moser | Zornek | Wirth | Koppold
Bonn | 27.06.2018
Introduction

Cooperation of MAN and CNL → sustainability at transport and logistics
Introduction

Development of e-trucks (BEV) @ MAN Truck & Bus AG

- IAA 2016: MAN presents e-truck (BEV) based on TGS (heavy-duty long haul application)
- 2017: start of cooperation between MAN and CNL (“Council für nachhaltige Logistik”); initiative comprises Austrian companies which aim at further development of sustainable transport and logistics
- 2017: MAN develops e-truck (BEV) based on TGM 6x2 with gross vehicle weight in 26-tons-class; application aims at distribution transport with range up to 200 km
- 2017 – 2018: testing of new powertrain and corresponding vehicles at MAN
- 2018: delivery of e-trucks for CNL companies will start
Introduction

Challenges for the development of the electric drivetrain

- Higher transmission ratio of $\approx 7.5$ needed in order to use speed range of the electric motor
  - no suitable serial axle in portfolio, new powertrain concept has to be found
- Very short period of time for development & production (4 months)
  - simultaneous engineering team at MAN, support by ZG GmbH
- Type and interface of electric motor not finalized at the start of the project
  - development of the gearbox has to be independent of motor design, thus “backpack” gearbox solution on axle favoured
- Limited number of vehicles (10 in a first step)
  - focus on cost efficiency
Modular Drivetrain Concept for Electrical Commercial Vehicles

**Concept finding**

**Boundary conditions**

- Electric motor & transmission:
  
<table>
<thead>
<tr>
<th>Max. engine speed</th>
<th>Max. engine torque</th>
<th>Total transmission ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000 min⁻¹</td>
<td>3500 Nm</td>
<td>≈ 7.5</td>
</tr>
</tbody>
</table>

- Investigations on different transmission concepts (e.g. approaches with spur gears) → planetary gearbox chosen because of package reasons

- Consideration of different planetary gearbox topologies:
  
  - \(i_{2S} = 1.5 \ldots 1.6\)
  - \(n_1 = 0\)
  - \(i_{1S} = 2.5 \ldots 3.0\)
  - \(n_2 = 0\)

  → Chosen concept
  → Hypoid gear set \(i ≈ 4.6\)
  → Load on housing too high
  → No suitable hypoid gear set in portfolio

**Load on housing too high**

**No suitable hypoid gear set in portfolio**
Modular Drivetrain Concept for Electrical Commercial Vehicles

Gearbox design

Modular concept

- Replacement of pinion housing with new planetary gearbox
- Carry-over of proven pinion shaft design and bearings
- Advantages:
  - Usage of an existing, already tested and homologated axle as basis
  - No changes at chassis frame and suspension necessary because of lightweight and compact planetary gearbox
  - Assembly at serial line possible
  - Combination of the planetary gearbox with different axle ratios possible
  - Adaptation of this concept to all types of driven axles for truck & bus possible

- Reduction of development time and costs
Modular Drivetrain Concept for Electrical Commercial Vehicles

Gearbox design

**FE calculation for complex elements**

- Calculation of deformation and stress for complex shafts and housing by means of FE
- Flexible mounting of the annulus in order to ensure good load sharing between the 5 planets
Gearbox design

Dimensioning of gears and bearings

- Design of gears and bearings based on a measured load cycle of heavy urban application
- Deformation under load considered → usage of FE components for complex elements
- Additional forces induced by adjustments of the propeller shaft also considered
- Modifications of the gears focused on best compromise regarding strength, efficiency and NVH behaviour
Modular Drivetrain Concept for Electrical Commercial Vehicles

**NVH Behaviour**

- Simulation of run-up for different load conditions
- Comparison of the acceleration of the axle housing with and without the additional planetary gear stage
- No significant worsening of the acoustic behavior due to planetary gear stage expected

![Graph comparing acoustic behavior without and with planetary gear stage](image_url)
Modular Drivetrain Concept for Electrical Commercial Vehicles

**NVH Behaviour**

- Extensive measurements of the airborne noise have been performed at the MAN axle test rig.
- Results of simulation confirmed: additional planetary gear stage does not lead to an increased noise level.
- Internal limiting values for the noise emission of axles were met.
Lubrication and efficiency

Tests with transparent gearbox housing

- Extensive tests have been conducted in order to determine the optimum of the oil level for the planetary gear stage
- Lubrication of gears and bearings under all operating conditions ensured
- Optimization of measures to reduce gearbox losses due to windage and churning at high rotational speeds
Modular Drivetrain Concept for Electrical Commercial Vehicles

Lubrication and efficiency

- Calculation of gearbox efficiency and power loss maps
- Estimation of the maximum oil temperature based on the gearbox losses
- Oil temperature is not expected to reach critical values
- Confirmation by test results

Efficiency:

Power loss:

Oil temperature:

area not relevant for this drivetrain
Quality and production

High quality standards, assembly at serial production line

- High quality standards for manufacturing and assembly
- Quality assurance by detailed documentation of component measurements and assembly process → good traceability
- Final assembly of axles at serial assembly line in Munich MAN plant
Modular Drivetrain Concept for Electrical Commercial Vehicles

Summary and outlook

Next steps

- Delivery of the e-trucks to the customers
- Close surveillance and support of the vehicles by MAN
- Gain field experience by measurement of BEV load cycles under realistic operating conditions in demanding transport application of trade, production and logistics companies
- Basis for future development of commercial vehicles with electric drivetrains