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Concept ELV² - Development of an Electric Drive Axle for Heavy Commercial Vehicles

International Congress - ELIV
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Motivation

Problem

- Growing demand for electric cars and trucks
- Faster development of powertrains required
- Due to the characteristics of electric machines, new powertrain topologies emerge

Solution

→Holistic design approach

→Evaluation on different stages of simulation

→Optimization of existing transmissions

ika's Approach

1: Transmission Synthesis → 2: Transmission Concept →

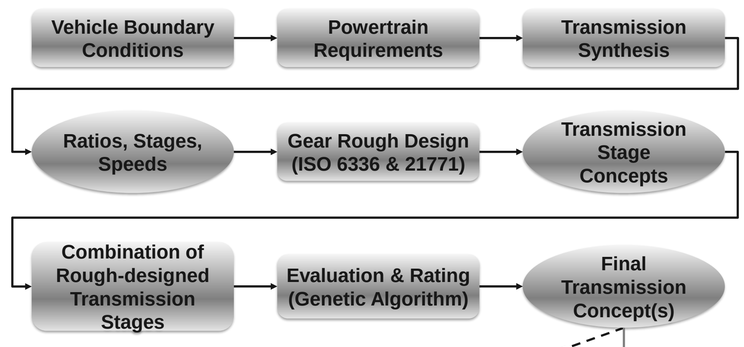
3: Efficiency Evaluation and Optimization→ 4: Thermal Evaluation →

5: Optimized and Evaluated Transmission Model

Transmission Synthesis, Design and Evaluation

Brief description of model

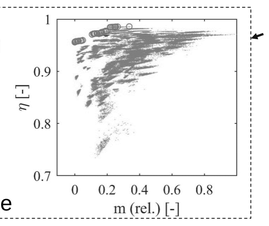
- Automated transmission topology synthesis
- Rough gear design based on standards
- Two-staged evaluation (1st after synthesis, 2nd within genetic algorithm)
- Evaluation weights may be chosen for different vehicle types (e.g. trucks and cars)



cf.: https://doi.org/10.1007/s41321-021-0420-8

Exemplary solutions for a truck transmission

- Circles: Pareto-Optimum:
  - η: Gear efficiency
  - m (rel.): Relative mass to compare
- Dots: Single solution
- >300 different topologies à ~10^5 different gear variants per stage



*: part of following models (see https://doi.org/10.1007/s38313-019-0126-9)

E-Axle Schematic Diagram

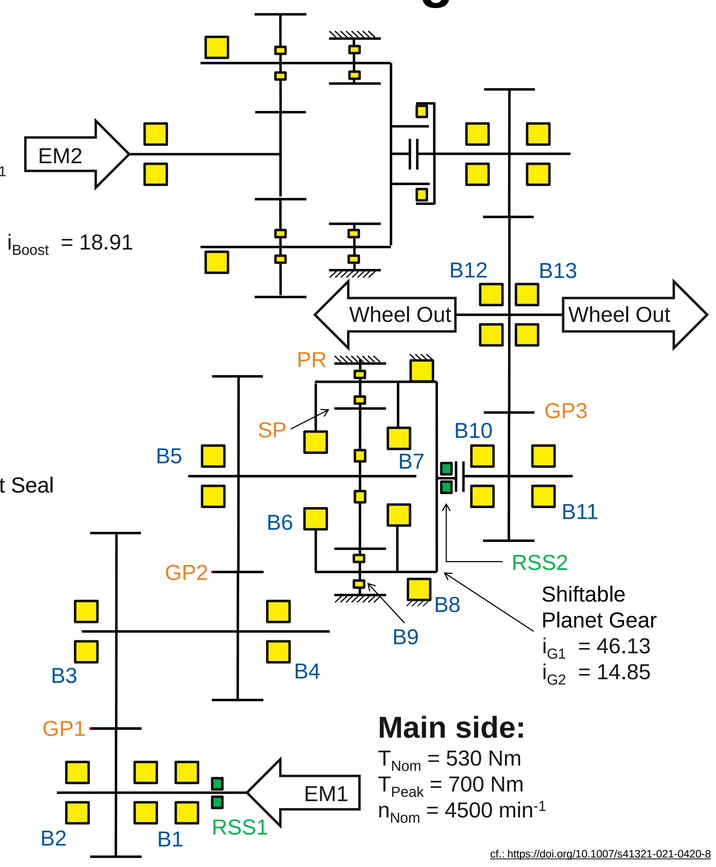
Boost side:
T_{Nom} = 260 Nm
T_{Peak} = 305 Nm
n_{Nom} = 4500 min^{-1}

i_{Boost} = 18.91

B: Bearing

GP: Gear Pair
PR: Planet-Ring
SP: Sun-Planet

RSS: Radial Shaft Seal



Main side:
T_{Nom} = 530 Nm
T_{Peak} = 700 Nm
n_{Nom} = 4500 min^{-1}

cf.: https://doi.org/10.1007/s41321-021-0420-8

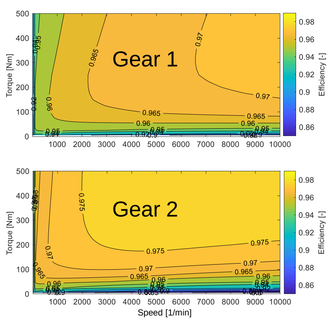
Efficiency Evaluation

Iterative efficiency calculation

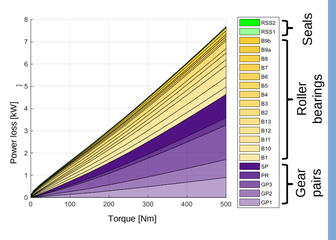
- Force, torque and speed model of the full transmission
- Iterative analysis of torque and power losses as a function of the direction of power flow
- Loss calculation according to state of the art and research for gear pairs, roller bearings and seals

Evaluation of total efficiency and individual losses

- Static loss and efficiency analysis
- Dynamic energy demand assessment for specific operating points or reference driving cycles
- Evaluation of individual sub-component losses for efficiency optimization



- Efficiency @ 60°C
- Sub-component power losses @ 4500 rpm



Thermal Evaluation

Definition of boundary conditions

- Initial housing draft is automatically generated
- Systemic boundary conditions are supplemented by the properties of the lubricant
- Ambient temperatures and the load spectra are included

Thermal network model

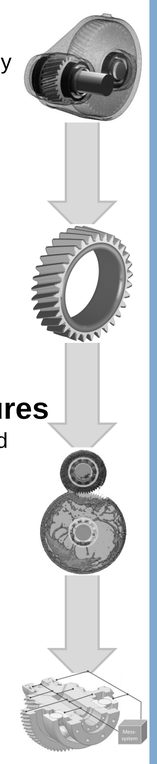
- Gearbox components are modelled in 3D to derive their thermal properties
- Thermal nodes can be determined (heat capacity, heat transfer coefficient,...)
- Properties are integrated into a time-independent transfer matrix

Calculation of component temperatures

- Load-dependent transfer coefficients are calculated
- Oil distribution is considered using SPH-based distribution simulations
- Coefficients are transferred into a conductance matrix
- Time-step based solution is performed

Verification via measured data

- After simulation, a comparison with the measured values is conducted
- Measurement of rotating gearbox elements is complex; Since a telemetry unit is required



E-Axle Concept

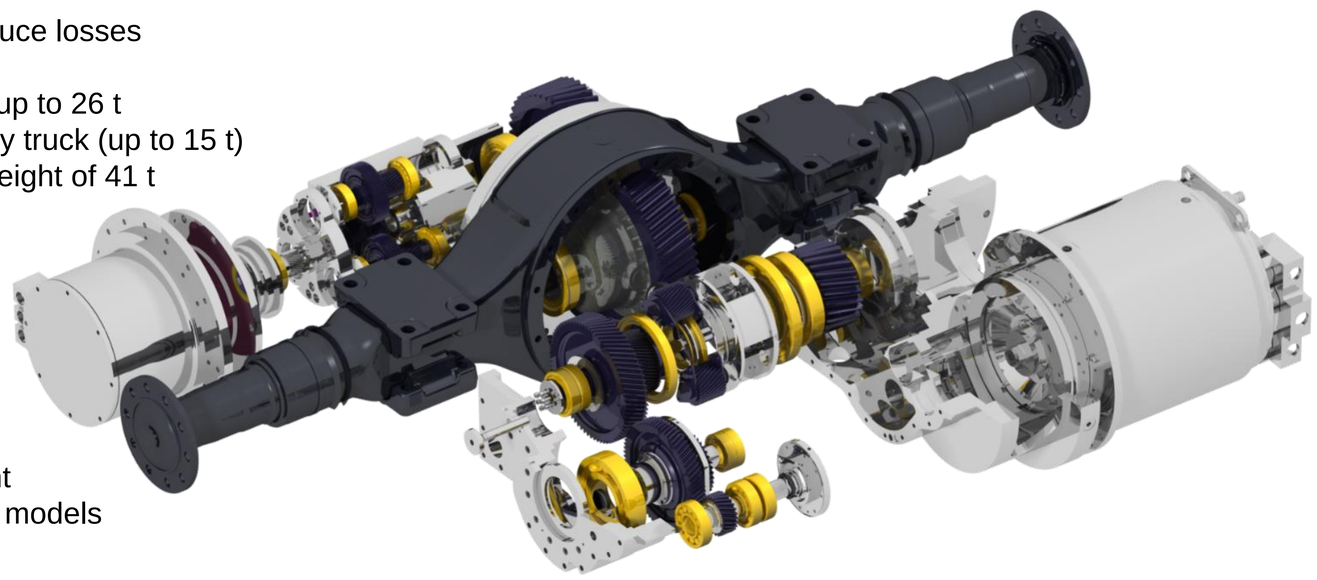
Properties

- Two speeds
- Detachable sides to reduce losses

- Main side: Drives truck up to 26 t
- Boost side: Drives empty truck (up to 15 t)
- Combined: Maximum weight of 41 t

Next Steps

- Finalize buildup
- Efficiency measurement
- Validation of presented models



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