Comparison of Electric Powertrain-Topologies for AWD-Vehicles

An Approach for Design and Optimization
AWD-share in new registrations (Europe)

Source: European Automobile Manufacturers Association ACEA, 2018
Improved efficiency

Electric All-Wheel Drive

Greater Range. Quicker Acceleration. All Weather Confidence.

ORDER YOURS  NEW INVENTORY  TEST DRIVE  EVENTS
Dissolving the AWD trade-off

ICEV

BEV

How?

Images: woxikon.de, kostengünstiger.de, diegoldenenase.de, ltespresso.de
Basic idea
Powertrain

Electric Drive

Transmission

Battery
Powertrain: Electric Drive

Electric Drive

Variables:

- Type (PSM or IM)
- max. Speed
- nom. Torque

Analytic Component Design Calculations

Dimensions

Assigning Material to Subcomponents

Weight

Material Costs
Add-on Part Costs
Manufacturing Costs

Production Costs
Powertrain: Transmission

Transmission

Variables:
- gears (1 or 2)
- 1\textsuperscript{st} gear ratio
- 1\textsuperscript{st} to 2\textsuperscript{nd} gear ratio

- two stages
- parallel configuration only
- different final drives

Differential  Torque-Vectoring  Wheel-Individual
Powertrain: Battery

- 18650-Cells
- 400 km fixed Range (WLTP)
- Iterative weight calculation
- variable length and position
Powertrain: Battery

- 18650-Cells
- 400 km fixed Range (WLTP)
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Design-Variables per axle

Topology
- Wheel-individual Drive
- Central drive open differential
- Central drive Torque-Vectoring

Choice of Components
- 1- or 2-speed Transmission
- PSM or IM electric motor

Design / Scaling of Components
- 1st gear
- 1st to 2nd gear
- torque
- speed
Glider

Powertrain
Glider: Parameter-Adaption

- Roll Center
  - Anti-Roll Bar Stiffness
    - Suspension Kinematics
  - Spring Rate
    - Damping Rates
    - Inertia
- Drivetrain & Glider Masses
  - Center of Gravity
    - Battery Position
- Powertrain Parameters
  - Segment Specific Glider Parameters
Glider

Powertrain
Optimization

Objective Function

- Preprocessing
- Powertrain Design Calculation
- Adaptive Control Design
- Parameter Adaption
- Torque Allocation
- Vehicle Dynamics Model

Simulation Model

- Powertrain Model

Evaluation of Objectives (Handling and Dynamics, Consumption, Costs)

Design Variables

Optimization Algorithm
Overall Results

Consumption in kWh/100km

Handling & Performance
(the lower the better)

Powertrain Costs in 1000€
Variation of installed nominal Power
Optimal Distribution

**Consumption in kWh/100km**

- **80 / 40**

**Powertrain-Costs in €**

- Battery Costs
- Remaining Powertr. Costs

**Vehicle Weight in kg**
Results

Topology

• FWD or RWD remain lightest option

• 2-motored AWD with large drive-unit in the rear and small one in the front is the cheapest AWD

• Torque-Vectoring is way more cost effective and lighter than wheel individual drive-units
Results

Motors

- Large ASM or PSM in the rear for acceleration
  - ASM cheaper but less efficient
  - PSM is more efficient than ASM
  - PSM cost savings do not pay off in the chosen case

- Small PSM in the front for efficient handling of continuous load
Results

Transmission

• 2 speed transmission equally qualified

• Additional weight is compensated by acceleration and efficiency

• Additional efforts for development and rise in complexity is neglected $\rightarrow$ SIMPLIFICATION!
Discussion and Summary

Small differences between Motor-Types and Transmission-Types
→ No “easy” answer
→ “it depends”

Electric AWD enable improved Handling, Performance AND Efficiency
→ Dissolve the trade-off
→ Large motor rear and small in the front is ideal for both: Dynamics and Efficiency
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THANKS FOR YOUR ATTENTION!
Why?

Load Points

Efficiency Map

Maximum Torque small EM

Rear Axle Percentage of total Torque in %

Torque in Nm

Speed in 1/min

Torque in Nm

Speed in 1/min

Efficiency in %