Collaboration for a Sustainable Future

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Outline

- Global Megatrends Relevant to Transmissions
- Transmission Trends for the US Market
- Engine-Driven Demands on Transmission Development
- Transmission Types and Development Trends
- Vehicle-Level Energy Flow Example
- Summary
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- Global Megatrends Relevant to Transmissions
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Our automotive world is going through a paradigm shift; changes expected in the next 10 years will be bigger than experienced in the past 50 years.

TRENDS & DRIVERS OF THE TECHNOLOGICAL TRANSITION IN AUTOMOTIVE INDUSTRY

GLOBAL MEGA TRENDS

Environmental & Air Pollution

Urbanization & Increasing Mobility

Sustainability

Connectivity & Digitization

DRIVERS

Emission & CO₂/FE Regulations

Subsidies & Incentives

Financing

Consumer behavior

NEW TECHNOLOGIES & TRENDS

Alternative Powertrains / E-Mobility

Connected Cars, Autonomous Driving

Shared Mobility

New vehicle concepts

Source: FEV
Several OEMs will offer new electric passenger vehicles the next years; therefore technology costs for electrification will decrease

OEM ANNOUNCEMENT REGARDING ELECTRIFICATION

- Tesla to begin Model 3 volume production
- Tesla targets annual sales of 500,000
- PSA to launch first electrified models on Efficient Modular Platform (EMP)
- JLR will electrify all models
- Aston Martin plans 25% of sales to be electrified
- Tesla targets annual sales of 1mn units
- Renault-Nissan plans joint platform for EVs
- Subaru to launch first full EV
- Volvo targets 1mn total sales of electrified sales
- Daimler plans 15-25% of production to be electric
- Aston Martin plans all models to be electrified by 'mid of 2020s'

- Daimler targets annual sales of 100,000 units
- PSA to have 40% of global models electrified (hybrid, PHEV, BEV)
- Ford to have 13 new electrified models
- Porsche plans 50% of cars to be electric
- BMW plans 15-25% of sale to be electrified
- VW plans to have 30 new EVs accounting for up to 25% of sales (2-3mn units)
- Ford to have 40% of global models electrified
- PSA to have 7 PEHV and 4 BEV models built on EMP
- Honda plans two thirds of sales to be electrified
- GM plans to produce 500,000 electrified vehicles by year-end
- Volvo will no longer sell car solely powered by ICES
- PSA to have 40% of global models electrified
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Source: BMI Research, FEV
Vehicle market is expected to grow and become highly electrified until 2035

SALES FORECAST: ICE BASED VEHICLE VS. PURE ELECTRIC VEHICLE

- Sales peak projected around 2030
- Four markets expected to reach 70.6 m sales by 2030
- Largely dominated by China (37 m)
- Net growth despite increased shared mobility adoption

- Peak ICE sales projected around 2025

- Exponential increase of pure electric vehicle sales expected driven by
  - Cost reduction and range increase
  - Improved charging infrastructure
  - Adoption from shared mobility

- Cross-over point between ICE based and pure electric vehicles predicted in 2040 timeframe

1): Vehicle sales include passenger cars and light duty trucks up to 3.5 tons; light commercial vehicles are excluded; 2): Including Stop/Start, Mild Hybrid, Full Hybrid, Plug-in hybrid
Source: FEV
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A variety of hybrid architectures are expected to co-exist in the US electrified powertrain space

US MARKET DEVELOPMENT LIGHT VEHICLES <3.5 T

Segment shares

~ 18 million vehicles

OEM shares

*From January to May
Source: Copyright © IHS, www.ihs.com, AutoInsight 01/2017, all rights reserved; FEV

Note: Pure electric vehicles including battery, fuel cell electric and range extender vehicles
Source: FEV
Many transmission types are expected to co-exist in the US automotive landscape.

SALES SHARE FORECAST PER TRANSMISSION TYPE

1): Includes AMT; 2): Including AT 4&5; 3): Dedicated Hybrid transmission: Mainly Powershift transmission – other hybrid sales are allocated to DCT, AT & CVT categories; 4): Fixed gear & power shift transmission 5): Sales include passenger cars and light duty trucks up to 3.5 tons; light commercial vehicles are excluded; AD = Automated driving  
Source: FEV
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ICE and electrification trends will impose requirements on transmission and driveline development

KEY CHALLENGES FOR CURRENT AND FUTURE TRANSMISSION DEVELOPMENT

**Downsizing/Boosting**

**Electrification**

**Fuel economy vs. Driveability vs. NVH**

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**Resulting impacts and challenges for transmission development**

**Fuel Economy**
- Reduced parasitic losses
- Long last gear ratio
- Aggressive torque converter lock-up schedules (zero-slip)
- Electrification
- Start/Stop
- ...

**Driveability**
- Short first gear to combat:
  - Reduced transient torque (e.g., turbo lag) during launch
  - Use of transmissions without torque converters, e.g., DCT
- Small ratio steps
- ...

**NVH and Refinement**
- Advanced isolators for increased “engine out” torsionals
- NVH countermeasures for transmission-specific issues:
  - CVT
  - DCT
  - Hybrids

Source: FEV
Advanced systems are being developed for improved torsional isolation

**EXAMPLES OF SOLUTIONS FOR IMPROVED TORSIONAL ISOLATION**

**Torque Converter Damper Simulation Models**

- **Base - Turbine Torsion Damper (TTD)**
  Turbine and pump are rigid coupled. Turbine is elastic decoupled from transmission input shaft.

- **Version 1:**
  Two Stage Damper (TSD)
  Turbine and pump are elastic decoupled. Turbine and output shaft are elastic decoupled.

- **Version 2:**
  Same as TSD plus Centrifugal Pendulum Vibration Absorber (CPVA) tuned to main engine order applied to the turbine.

**Simulation**

- Multi body simulation (MBS) can be utilized as an effective tool for torsional vibration analysis and damper layouts.
Advanced systems are being developed for improved torsional isolation

EXEMPLARY OF SOLUTIONS FOR IMPROVED TORSIONAL ISOLATION

Remarks

- Advanced torsional damping systems such as a two-stage damper and pendulum absorber can offer sufficient isolation in most cases.

- Low-cylinder count engines with cylinder deactivation can pose additional challenges.
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Different degrees of hybridization span the space between conventional vehicles and BEV.

**Conventional Vehicles**

- Gear Box
- Fuel Tank

**Hybrid Electric Vehicles**

- Micro Hybrid
- Mild Hybrid
- Full Hybrid
- Plug-In Hybrid
  - + Electric Drive
  - + Kinetic Energy Recovery & Boosting
  - + Plug-In/REX

**Battery Electric Vehicles**

- Battery

- Start-Stop & Intelligent Energy Management
- Increasing electrical power
- CO$_2$-Emissions
- Battery size/price
- Complexity ICE
- Complexity Transmission
- Downsizing Diesel and Gasoline
- Gasoline NA
- Gasoline Atkinson
A variety of parallel hybrid architectures are feasible based on the location and number of electric machines in the driveline.

OVERVIEW OF PARALLEL HYBRID ARCHITECTURES

<table>
<thead>
<tr>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
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</thead>
</table>

E-Drive possible
### Gear Ratios and Ratio Spread
- Ratios: 5-7
- 7-speed only in niche applications
- Ratio Spread: 5-6

### Key Design Trends
- Advanced isolation systems in conjunction with DMF
- Friction reduction: e.g., seal and bearing optimization, super-finished gears
- Integration of e-clutch systems

### Electrification
- Adaptation for micro/mild/full hybrid operation
- Modular architecture: P2 (RWD) and P3 (RWD) possible with integration of e-clutch
- DHT with e-Torque fill in AMT to improve shift quality and add hybrid functionality

### Hydraulics
- Active oil-level management enabled by on-demand electric pump
- Electro-mechanical and electro-hydraulic actuation systems for AMT
### PLANETARY AUTOMATIC TRANSMISSIONS

#### Gear Ratios and Ratio Spread
- **Ratios**: 7-10
- **Ratio Spread**: 8-10

#### Key Design Trends
- Multi-stage dampers and isolation systems
- Friction reduction: e.g., active clutch plate separation, super-finished gears
- Wider use of selectable one-way clutches
- Pressure/torque sensors for feedback control

#### Electrification
- Adaptation for micro/mild/full hybrid operation
- Modular architecture: P2 (RWD) with reduced number of ratios for PHEV
- Use of e-CVT with simplified “range box”
- P4 architecture with FWD transmissions for AWD

#### Hydraulics
- Downsized/two-stage mechanical oil pump in combination with electric pump
- On-demand actuation systems
- Low viscosity fluids balancing friction, leakage, and durability
Dual Clutch Transmissions (DCT)

DUAL CLUTCH TRANSMISSIONS

**Gear Ratios and Ratio Spread**
- Ratios: 6-10
  - 9-10 speeds only in niche applications
- Ratio Spread: 5-6

**Key Design Trends**
- Advanced isolation systems in conjunction with DMF
- Multiplexed actuation systems
- Integration of torque converters or electric machines (application dependent)
- “Winding gears” for niche applications

**Electrification**
- Adaptation for micro/mild/full hybrid operation
- Modular architecture: P2, P2.5, and P3 possible
- P4 architecture with FWD transmissions for AWD

**Hydraulics**
- Downsized/two-stage mechanical oil pump in combination with electric pump
- On-demand actuation systems
- Low-loss wet clutch modules
- Low viscosity fluids balancing friction, leakage, and durability
Continuously Variable Transmissions (CVT)

CONTINUOUSLY VARIABLE TRANSMISSIONS

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<th>Gear Ratios and Ratio Spread</th>
<th>Key Design Trends</th>
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<tr>
<td>Ratios</td>
<td>Innovative variator designs</td>
</tr>
<tr>
<td>- Simulated shifts needed to satisfy market-specific customer driveability preferences</td>
<td>Reduced variator ratio spread in conjunction with external ratios for enhanced efficiency</td>
</tr>
<tr>
<td>Ratio Spread: 6-7</td>
<td>Pressure/torque sensors for feedback control</td>
</tr>
<tr>
<td>- Ratio spread increase up to 8 feasible</td>
<td>DNR functionality using dog clutches</td>
</tr>
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<table>
<thead>
<tr>
<th>Electrification</th>
<th>Hydraulics</th>
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<td>Adaptation for micro/mild/full hybrid operation</td>
<td>Downsized/two-stage mechanical oil pump in combination with electric pump</td>
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<tr>
<td>Modular architecture: P2 with reduced variator ratio spread</td>
<td>On-demand actuation systems</td>
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<tr>
<td>DHT architectures in conjunction with variators</td>
<td>Low viscosity fluids and dedicated traction drive fluids</td>
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<td>P4 architecture with FWD transmissions for AWD</td>
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FEV has developed a variety of electrified transmissions to meet the challenges of the automotive industry.

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<th>Conventional Vehicles</th>
<th>Hybrid Electric Vehicles</th>
<th>Battery Electric Vehicles (w/ REX)</th>
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<tr>
<td>Gear Box</td>
<td>Micro Hybrid</td>
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<tr>
<td>Fuel Tank</td>
<td>Mild Hybrid</td>
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<td></td>
<td>Full Hybrid</td>
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<td>Plug-In Hybrid</td>
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- **Next Generation DCT incl. P2 Hybrid**
  - FEV DCT Family
    - Full on-demand actuation
    - Wet DCT with dry DCT-like efficiency

- **Hybrid Module for AT and CVT**
  - FEV E-PGS
    - Planetary-based
    - eCVT launch (PGS + EM) for Hybrid
    - Full on-demand actuation (PREX)

- **Multi-Mode DHT Single E-Motor**
  - FEV PREX3
    - Low complexity, layshaft based
    - High-performance electric driving

- **Multi-Mode DHT Twin E-Motors**
  - FEV Hybex3
    - AMT technology
    - Electric torque support

- **Low-cost, single EM Hybrid AMT**
  - FEV HDU Family
    - Extremely compact
    - 1/N/P functions
    - 2-speed powershift

- **EDU with integrated EM and inverter**
  - FEV EDU

PGS: Planetary Gear Set
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A systems level view is needed to ensure that all driveline components are optimally utilized in satisfying vehicle energy demands.
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- The industry is facing multidimensional challenges from a legislative, economic, and societal perspective. Technical solutions must satisfy all of these requirements to succeed in the marketplace.
- Driveline technologies to meet future requirements are either already available or under development. However, different markets have different requirements and hence multiple technical solutions will co-exist.
- Driveline lubrication needs will evolve as the quest for optimizing powertrain efficiency continues.
- It is important to use a “vehicle-level” perspective to optimize the operation of driveline components, such that both direct and indirect efficiency can be maximized.