FEV GmbH
Neuenhofstraße 181
52078 Aachen · Germany

Phone +49 241 5689-0
Fax +49 241 5689-119
marketing@fev.com
www.fev.com

# Transmission optimization by Electric Actuation - FEV's Electric Powershift Transmission

The direct contribution of the driveline in fuel consumption (Figure 1) shows that the driveline has the second highest fraction (15%) of losses. Therefore transmission optimization has a significant potential to reduce $CO_2$ emissions. The optimization can be performed with different approaches - conventional and advanced.

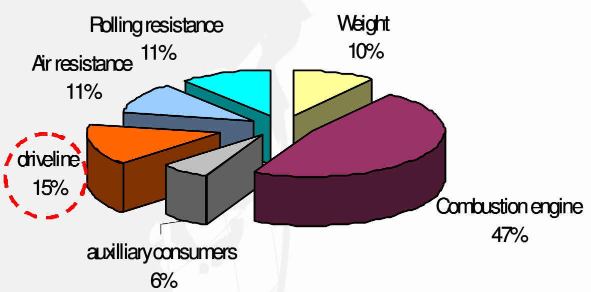


**Figure 1: Direct Contribution of Driveline**

Conventional steps of optimization are drag torque, converter/damper and hydraulic losses minimization. This conventional development can reduce the fuel consumption by 4% (simulation of NEDC for C-class vehicle, 2.8l gasoline engine with a 6AT). This approach optimizes the driveline losses by 25 %. For further optimization advanced technologies are required. The highest potential has a hydraulic less clutch actuation. This approach reduces the fuel consumption with additional 5% so that the conventional and advanced optimization steps reduce the fuel consumption by 9% (Figure 2). In total the driveline losses are reduced by 60%.

Based on these simulation results FEV developed a new Automatic Transmission (AT) (Figure 3). This concept is an innovative 7-speed hybrid transmission for transverse installation. The AT is based on three planetary gear sets (PGS). The first PGS is coupled with the internal combustion engine (ICE) and the E-motor (EM). To achieve the required 7 speed AT two additional planetary gear sets (AT1 and AT2) are coupled with the differential. This alignment of the planetary gear sets, the E-Motor and ICE has to be controlled with 3 clutches (C1, C2, C3) and two breaks (B1, B2). Thereby, the existing gear ratios of the PGSs can be multiplied with the clutches/brakes to generate ratios.

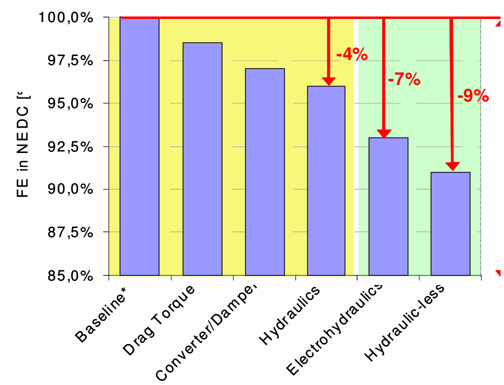


**Figure 2: Transmission Optimization Potentials**

The vehicle launch can be performed pure electrical or with the clutch C3. To achieve the described fuel economy a hydraulic-less clutch actuation is required.

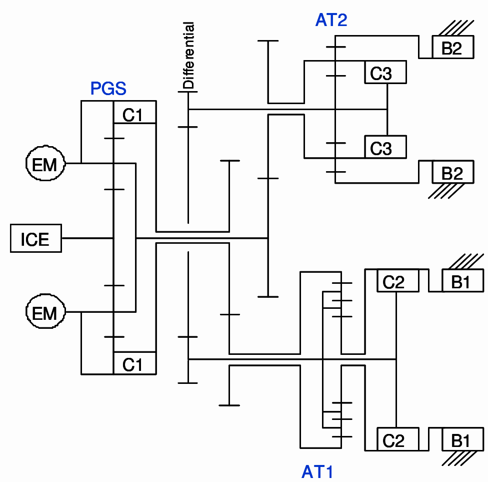


**Figure 3: Transmission Concept**

Fur this application FEV developed an electro mechanical clutch actuator, which works hydraulic-less. The improvement of the electro mechanical actuator can only be achieved with a power less opened and closed position. FEV realized this requirement with a cam disc. The additional coupling of a non linear stiffness compensates wear and thermal strain. To validate the simulation results a component test rig for the electro mechanical actuator which was built-up (Figure 4). The clutch actuator test bench was equipped with a force, speed, current and position position measurement device for detailed dynamic in-

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vestigations. Additionally the used components are equal to the final components so that also durability investigations can be performed. The control strategy is also developed by FEV and is based a Rapid Control Prototyping Unit.

Exemplary one measurement with the highest requested load is shown in Figure 5.

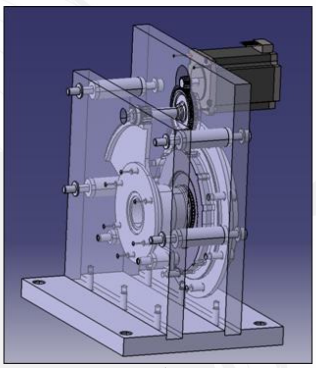

**Figure 4: Electric Clutch Actuation Test Rig**

The engagement time of the worst case scenario is below 140 ms, which meets the dynamic requirements for a complete gear shift with two intersection clutches


Figure 5: Clutch Actuation Measurement

The main data of the electric clutch actuator is listed in the Table 1. The E-motor is an electric stepper motor with a high torque and speed performance. This provides short actuation time. The mechanical design provides the powerless end position which corresponds only 1% of the hydraulic clutch actuation power.

The clutch actuator components were also design into the AT for the package investigations in a A-class vehicle with the highest package constrains.

| | |
|---|---|
| Max. Force | 11.000 N |
| Engagement Time | 140 ms |
| Total Shift Time | 400 ms |
| Power Consumption - closed | 0 W |
| Power Consumption - opened | 0 W |
| Peak Power Consumption | 120 W |
| Total Gear Ratio | 1/72 |

**Table 1: Main Data of Electric Clutch Actuator**

FEV's Electric Powershift Transmission (Figure 6) - 7 speed hybrid automatic transmission - has a torque capacity of 200 Nm. This Parallel Hybrid Transmission has all required functionalities as:

- Start-stop
- Pure electric driving
- Boost- & recuperate
- ICE restart out of e-drive
- No torque drop while shifting

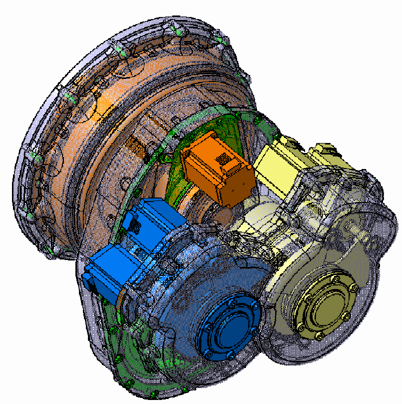

**Figure 6: FEV's Electric Powershift Transmission**

Contacts: Dipl.-Ing. Thomas Huth
Institute for Combustion Engines
RWTH Aachen University
E-Mail: huth@vka.rwth-aachen.de

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