SCALABLE HYBRID DUAL-CLUTCH TRANSMISSION

With the tough CO₂ targets under the European legislation for 2020, hybridisation is one of the key elements to improve fuel-efficiency. Getrag compares a 48 V belt-driven e-machine solution with a solution based on a dual-clutch transmission with integrated e-machine. The 7HDT300 torque split hybrid transmission features a large scalability of the electric machine from mild to plug-in hybrid drives and a map-optimised interaction of the combustion engine and e-machine.
HIGHER DEMANDS

Reducing CO₂ emissions and fuel consumption, while meeting higher demands for dynamics and comfort, are major development objectives for car manufacturers. This strong focus is being driven by end consumers as well as CO₂ regulations up to zero-emission zones in big cities. Within the overall vehicle set-up, the powertrain system is one of the key enablers to meet these requirements. Besides the need for lowest possible fuel consumption, the related costs are significantly important to enable a technology for the mass market. To achieve a remarkable effect on fleet consumption, fuel saving technologies need to be accepted by end customers, in that the real cost of ownership shows a benefit versus standard cars.

Today’s available parallel hybrid drive solutions are only ready for niche market volumes and therefore purchased mainly due to their “green” halo effect, instead of their benefit for real cost of ownership. A reasonable alternative is a hybrid kit suited for meeting various customer requests to enable higher overall volumes and development synergies. To start with, the 48 V hybrid is an ideal base for entry level hybridisation, due to its lower cost for battery and electric components without the need for specific safety measures like in high-voltage applications. The base component of this 7HDT300 hybrid kit is the 7DCT300 dual clutch transmission from Getrag. Thanks to the so-called torque split design, this transmission can be flexibly scaled from mild to plug-in hybrid.

BASE TRANSMISSION

Starting in 2015, the Getrag dual-clutch transmission 7DCT300, will be introduced in several vehicle programmes by various OEMs. It is the first model of a new transmission generation. The new DCT with electrohydraulic clutch and electromechanical shift actuation was developed to ensure high fuel-efficiency, low weight, low inertia and excellent drivability. The seven-speed gearset is ready for a maximum engine torque of up to 300 Nm and offers a gear ratio span up to 8.6. By using a newly developed low inertia wet dual clutch with on-demand oil cooling, the transmission is ready for downsized engines that are increasingly used by OEMs.

HYBRIDISATION KIT

DCTs are suitable for multiple hybridisation topologies, as the e-machine can be connected to the transmission by different methods. Compared to an automatic transmission based on planetary gearsets or to continuous variable transmissions (CVT), further optimisation potentials can be achieved thanks to the flexible hybridisation concept. Getrag is focussing on the so-called torque split hybrid to achieve maximum fuel efficiency improvement with lowest possible on-cost.

As shown in the so-called torque split design, the torques are summed up at the ring gear that is connected to the differential.

As shown in the e-machine is connected to the input shaft with even gears. It is oriented axially parallel to the input shaft and connected via a single ratio...
step. The chosen gear ratio allows the use of high speed e-machines, which are operated in much higher speed ranges (>18,000 rpm) than the internal combustion engine. Compared to a conventional parallel hybrid with the engine and motor running at the same speed, this arrangement is superior as to weight, inertia, package and cost.

Moreover, the torque split hybrid allows operating the internal combustion engine and the e-machine with different gears. When the internal combustion engine is connected to the output via an odd gear, the e-machine can be added to the torque path by closing clutch 2, assuming no even gears are engaged. Alternatively, the e-machine can be connected to the torque path with an open clutch 2 and a selected even gear. Due to this flexibility, the e-machine can be operated in the best efficiency area over a large range of driving conditions. Typically, the e-machine and the internal combustion engine have their best efficiency area at different speed levels. Therefore, the torque split hybrid principle, together with independent shiftable gears, provide fuel efficiency advantages.

Getrag hybrid transmissions offer full hybrid functionality, including:

:: Stop/start
:: Extended sailing
:: Pure electric driving
:: Re-starting the internal combustion engine during electric driving
:: Boost and recuperation via the e-machine.

Besides functional aspects, one of the key elements for hybridisation is the integration of the e-machine within the available installation space. shows a comparison of the 7DCT300 base transmission with the 7HDT300 hybrid transmission. Thanks to the package-optimised design with a small high-speed e-machine, the 7HDT300 can be used in many vehicle platforms in the given installation space. Scaling the e-machine power can be done by modifying two parameters – the number of windings and the length of the assembly. The latter can be varied by changing the active length of the e-machine via reducing the number of stator and rotor steel plates.

### COMPARISON OF 48 V HYBRID TRANSMISSIONS

In order to provide for additional electric consumers, the 48 V power supply is gaining significance, as it needs no additional high-voltage safety measures. Thus, the next logical step for introducing a 48 V hybrid is adding a belt-driven e-machine to the engine. Especially the continued usability of existing 12 V manufacturing technologies of conventional claw-pole alternators enables a cost-attractive solution. Moreover, this electrical system can be implemented with today’s battery and semiconductor technology.

shows the layout of a 7HDT300 hybrid drive with integrated e-machine and power connector for inverter. Compared to the belt solution, the 48 V torque split hybrid design offers a number of advantages. As described before, the 48 V torque split hybrid features an e-machine that is integrated in the transmission case. For the belt solution, an air-cooled claw-pole e-machine is used, whereas the integrated solution can be designed with an oil-cooled asynchronous machine or a permanent magnet synchronous machine. This flexibility offers more electric performance and thus more fun to drive. In , important key data of these two different solutions are shown.

As a consequence of the higher efficiency and power of the integrated e-machine, advantages like better efficiency, more available power and a lower fuel consumption are available. A conventional C-segment car without stop/start system was used as a reference for the comparable simulation. Major reasons for higher efficiency of the torque split hybrid can be found in the ability for pure electric driving and the extended sailing, thanks to the elimination of the combustion engine drag torque.

Depending on the battery capacity, pure electric driving up to 20 km/h is possible. As a result the 48 V torque split hybrid offers driving functionalities close to full hybrid versions but at much lower costs. The “bottleneck” of the belt solution can be seen in the lower continuous power of its e-machine. Another advantage of the mild torque split hybrid is the good compatibility with downsized engines that are gaining importance. These engines profit from the low inertia of the wet dual clutch. Furthermore, even the e-machine of the 48 V hybrid can add up to 80 Nm torque for engine support.

### TORQUE SPLIT PLUG-IN HYBRID

In current full and plug-in hybrids, the e-machine is mounted between the engine and transmission. Here, a separating...
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clutch avoids drag losses. In this respect, the hybrid functionality corresponds with that of the torque split hybrid. But the e-machine necessarily runs with the same speed as the engine. As a consequence, a small high-speed e-machine is not applicable. Moreover, scalability within the installation space is limited, and the efficiency maps of engine and e-machine cannot be optimally considered by accordingly using different gears.

In contrast to this parallel design, the motor support within the 7HDT300 is scalable to a large extent – from 48 V with 20 kW peak power up to battery voltages of more than 360 V with more than 80 kW peak power. In accordance to the installed engine, the hybrid system can be easily adapted by scaling the e-machine. The powerful e-machine allows pure electric driving up to more than 130 km/h. The technical data of such an e-machine are shown in ➌.

Despite the high power density of this e-machine, an asynchronous machine can be used to eliminate the commercial risk of rare-earth magnets. Depending on the capacity of the battery (for example, pure electric mileage of up to 50 km), it is possible to achieve fuel efficiency improvements up to 80 % compared to a conventional powertrain.

**SUMMARY**

Thanks to its wet dual clutch with electro-hydraulic clutch actuation and its electromechanical shift actuation, the new 7DCT300 dual clutch transmission made by Getrag is a capable basis for its 7HDT300 hybrid variant. Compared to conventional parallel hybrid transmissions, especially the torque split design and the scalability from 48 to 360 V, offer efficiency benefits. Scaling the electric machine needs no additional installation space in the transmission case, allowing high flexibility for vehicle integration and applications.

Especially in the 48 V hybrid solution, the integration work of the e-machine enables efficiency and performance advantages compared to the belt solution [7]. The scalable, flexible and modular approach opens the possibility to meet various customer needs, thus accelerating the market penetration of affordable hybrid drives.

**REFERENCES**


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