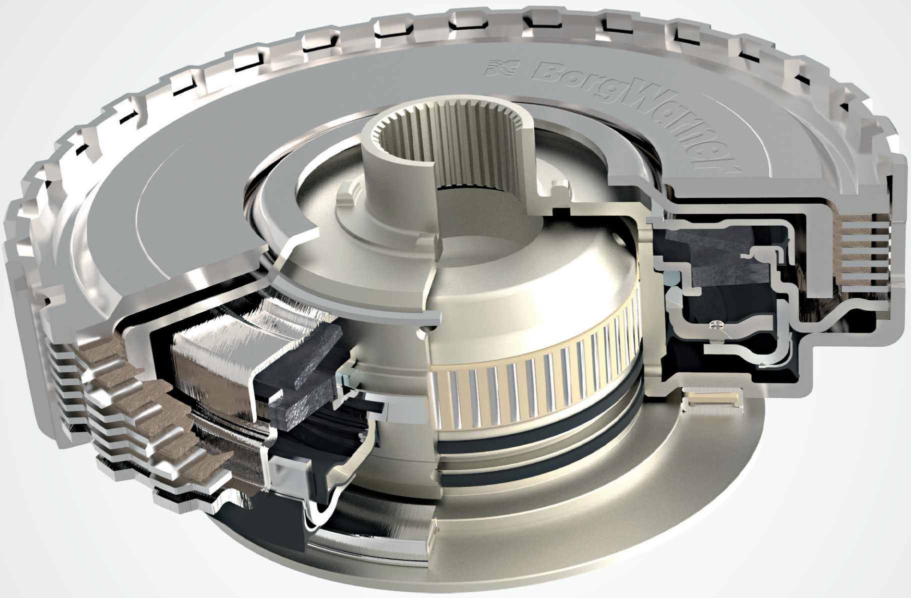

Hybrid

BorgWarner's Latching Clutch

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Latching clutch

P2-hybrids and vehicles using other types of transmission will gain from a novel latching clutch that saves energy by containing forces within the mechanism. The design has been successfully prototyped.

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Ambitious European regulations on vehicle CO_2 emissions – the toughest in the world – include financial penalties for car manufacturers which fail to meet them. The fleet target for 2020 is 95 g CO_2/km, making every gram saved crucial to vehicle design and development programs.

BorgWarner fully understands how vehicle transmissions can contribute to overall vehicle efficiency and is continually searching for gains in existing technologies while developing new, innovative designs that use less energy and allow the use of novel approaches like ‘sailing’ where the drive is disconnected. Underpinning this work is the requirement to maintain or improve comfort and driving performance.

One of the company’s most recent developments in this sector is a mechanical latching mechanism. It has the potential to contribute to energy savings in many drivelines, including dual clutch transmissions (DCTs), conventional automatics, the disconnect clutch in P2-hybrids and the forward clutch in CVTs.

Alternative solutions to a single clutch in an automatic, CVT, or hybrid transmission, require controllable engagement and a failsafe mechanism along with the usual requirements of a clutch. The solution shown in Figure 1 cannot be controlled during disengagement, although a characteristic ‘opening behaviour’ can be achieved using a one-way-orifice in the hydraulic system. For automatic gearboxes, therefore, the solution is appropriate for some clutches.

The force-displacement characteristics of Belleville springs are at the heart of the latching mechanism. Use of an asymmetric snap ring and ramp within the clutch housing allows a detent mechanism to be designed. Once the engaged condition of the multidisc clutch is reached, a slight further increase in pressure

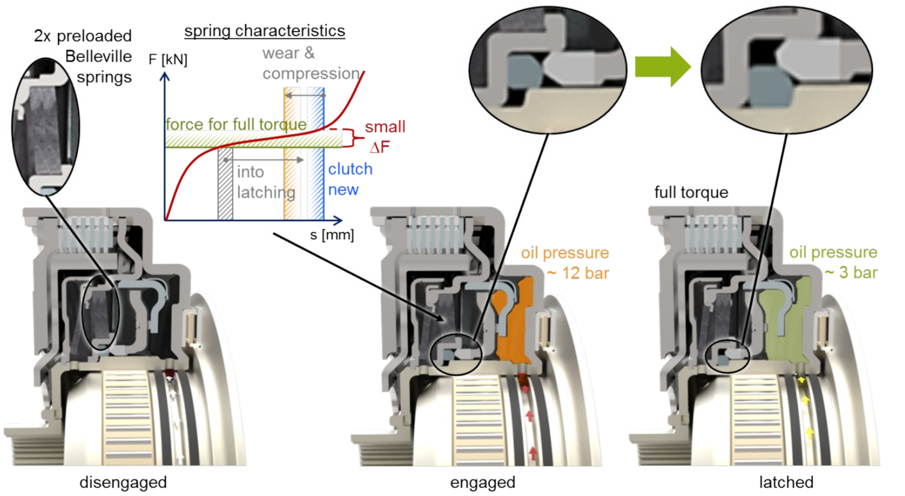

Figure 1. Functional principle – a mechanical clutch for a hybrid disconnect system.

activates the latching mechanism allowing the slotted ring to fall into a detent groove. Now the pressure needed to hold the clutch at full torque transmitting capacity can be reduced because the detent contributes to the clamping load – pressure is only required to keep the snap ring in the groove. Force magnification depends on the angles formed by the components involved. High oil pressures are avoided by using just the near-constant-force portion of the spring's characteristic curve. This is shown in the 'engaged' cross-section of the diagram.

Different pressure amplification profiles can be achieved by changing the ratio between the disc clamping force and the hydraulic piston force. Adjustments can be made by manipulating the angles which influence the travel of the snap ring before it reaches the latching detent groove.

BorgWarner's current prototype is shown in Figure 2. It is a small radial design for FWD clutches in CVTs and incorporates clutch discs. A rendered CAD cross-section is shown on the left with a description of parts and, on the right, is a picture of the clutch integrated into a two-motor testbed.

Simulations of different vehicle types and transmissions have demonstrated the energy saving potential of BorgWarner's design. They show how latching technology can increase pump efficiency along with the hydraulic system as a whole and its 'consumer systems'. The development also allows new functions to be designed that can massively simplify the realisation of new operating modes for a cars and vans. These include stop-start and 'sailing' systems for electrified, hybrid and conventional vehicles.

P2-hybrids perhaps represent the most exciting of potential applications for latching clutches. These use disconnect clutches to disengage the gasoline or diesel engine from the drivetrain in different driving modes – pure electric drive or 'sailing,' for example. Normally, to minimize drag torque when disengaged, lubricated multi-disc clutches are used on small acting radii. However, to transmit full torque, higher pressures are needed and this can result in losses in the hydraulic system as well as direct mechanical losses. To reduce such losses, clutch pressure is adapted to the torque transmission requirement. However, use of the latching mechanism renders this unnecessary allowing pressures can be significantly and permanently lowered. Figure 3 shows an example of a P2-hybrid architecture with a disconnect clutch. Vehicles using this architecture would normally use a hydraulically actuated automatic transmission but to achieve the maximum benefit of using a latching mechanism, a common hydraulic system would be designed.

BorgWarner believes CVTs are leading candidates for the new technology and predicts

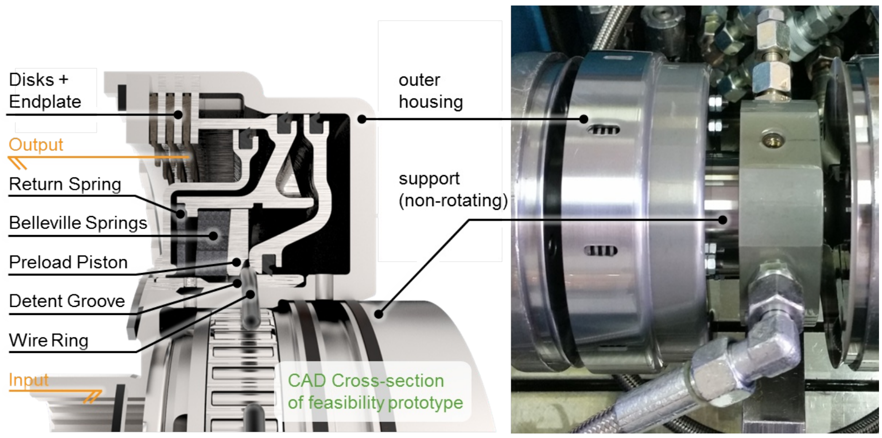

Figure 2. Integration of the prototype clutch in the testbed, rendered cross-section on the left.

that savings of 53.9 W hydraulic power and 26.9 W mechanical power can be achieved if the FWD clutch and the torque converter lock-up clutch (T/C L/C) are latched. Pressure can be reduced to 3 bar, the level needed in any case for lubrication purposes. The saving equates to around 1.75 g CO_2/km in a representative customer cycle. A failsafe solution comes free of cost since the latching clutch disengages completely when pressure falls below operational levels. Initial test bench results have verified simulation and dimensioning predictions.

A DCT prototype with the hydraulic latching valve incorporated has demonstrated a power saving potential of 2.39 g CO_2/km when maximum system pressure is reduced to 1.5 bar in WLTC class 3 cycles. The valve latches at a specified pressure level and can only be opened with the help of a second pressure channel which ideally serves the DCT's second clutch. The ability to design a system which has a controlled opening means reduced torque transmission is possible, if required.

The operation of conventional automatic gearboxes will also benefit from BorgWarner's development. A typical eight-speed unit with five shift elements has three clutches and two brakes – all designed as lubricated multi-disc clutches – and the WLTC simulation showed that all of them were actuated around 60 % of the time. Further studies showed that should each clutch incorporate the type of hydraulic latching valve in the prototype, a saving of 3.5 to 4.5 g CO_2/km (depending on latch pressure level of 3 to 1 bar) in WLTC class 3 was achievable.

Adding more features to transmission systems without increasing drag and demanding more hydraulic power are key development targets for mechanical clutches. The latching clutch meets both objectives and emerged as a result of BorgWarner's extensive expertise and experience in transmission design and production. It now joins the family of products and systems in advanced development ready to be offered to vehicle manufacturers.

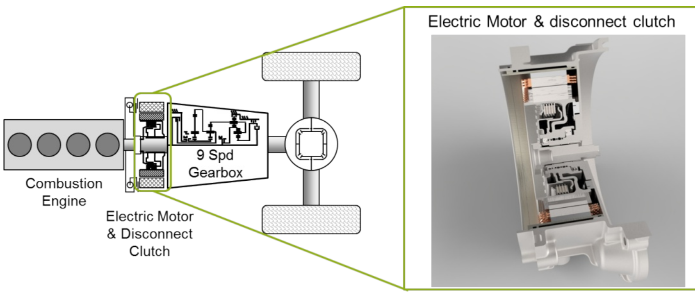

Figure 3. Example of a P2-hybrid drivetrain with an integrated disconnect clutch.

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