Compact Disconnect System for Electrified Drivetrains

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Recently, powertrain electrification has gained more importance for OEMs around the world due to more stringent emissions regulations with ambitious future CO_2 emissions targets, which are difficult to achieve with conventional powertrains using internal combustion engines only. In an attempt to further reduce fuel consumption and CO_2 emissions, an increasing number of vehicles using a wide range of systems such as stop/start systems, mild hybrid systems, plug-in hybrid systems and battery electric systems have been introduced.

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Introduction

One option that can help OEMs to comply with emissions regulations is brake energy recuperation. To make the most of it, the kinetic energy must not be lost in the form of heat at the brakes. Simulations conducted by BorgWarner have shown that a mild hybrid system with an electric power range of 10 to 25 kW is most suitable for adaptation since it offers a relatively low system complexity combined with high functionality. On the basis of the New European Drive Cycle (NEDC) and the CO_2 emission target of 95 g/km, which will be obligatory for new passenger car registrations as of 2020, using a mild hybrid system is the best choice in terms of the recuperation potential of the braking energy. It allows the lion's share of the braking energy of a normal passenger car to be recuperated with an electric motor featuring a power rating of about 15 to 25 kW.

For this reason, BorgWarner developed a mild hybrid drivetrain concept that can maximize this recuperation potential, permitting disconnection of the engine without the use of an additional disconnect clutch. This innovative cost-efficient concept uses a one-way clutch (OWC) in combination with a dual-clutch transmission (DCT), see Figure 1, and a small electric motor. The advanced setup allows pure electric driving or

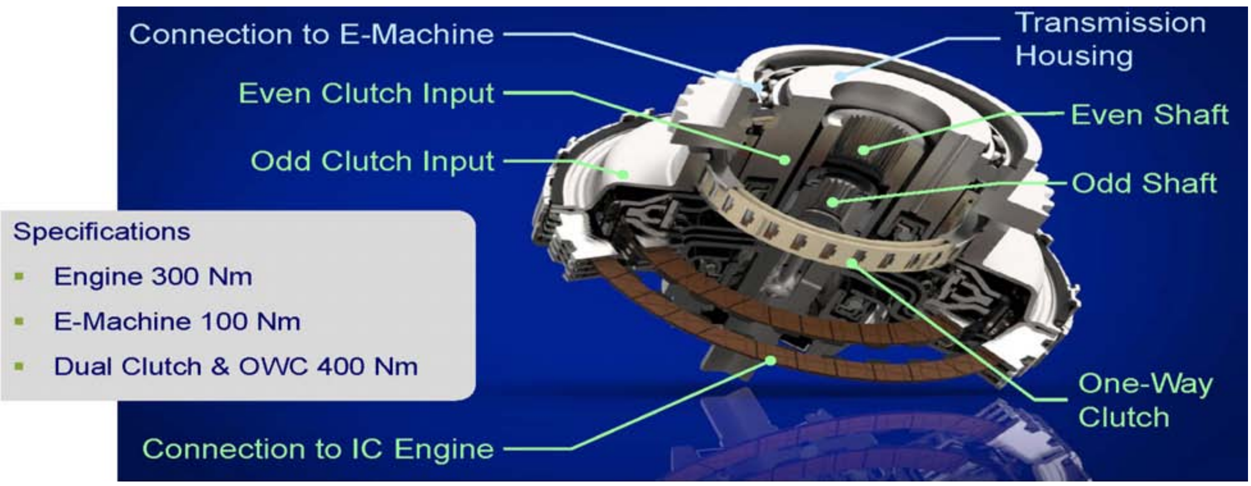

Figure 1. Highly efficient one-way clutch (OWC) in combination with a dual-clutch transmission (DCT).

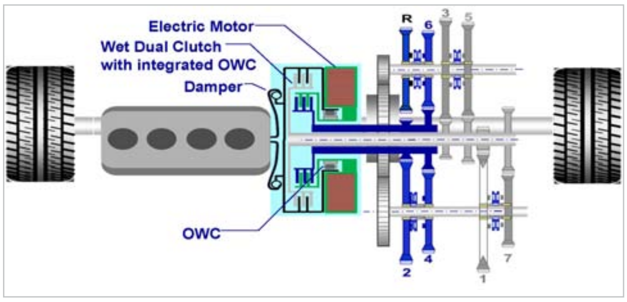

Figure 2. Hybrid powertrain with OWC placed between the engine and the clutch for even gears of the dual-clutch module.

sailing while maximizing the recuperation potential, thus making it interesting for mild hybrid and 48 V systems.

One-way clutch powertrain concept

Disconnection of the combustion engine is the key enabler for pure electric driving and the maximization of the recuperation potential. A disconnect clutch allows engine shut-off in pure electric driving mode and offers maximum flexibility in terms of electric driving in all gears as well as the option of shifting between gears without any torque interruption whatsoever. The drawback to using a disconnect clutch which transmits the maximum powertrain torque is that it requires additional components, actuation and usually also extra space between the engine and the transmission.

For this reason, BorgWarner's solution makes use of an OWC instead of a disconnect clutch. The OWC overruns when the engine is shut off so that it is disconnected from the powertrain while the vehicle moves along using the electric motor. In addition to extremely low drag losses, OWCs provide high torque density which facilitates compact packaging, especially in comparison with disconnect clutches, and they do not need any additional controls or actuation.

Extensive testing of numerous layout combinations has led to a concept for mild hybrids that features an OWC which is placed between the engine and the clutch for even gears of the dual clutch module, as seen in Figure 2. The electric motor is placed between OWC and even clutch, which permits the electric motor to be used for pure electric driving in all even gears and in reverse gear and allows extremely compact packaging. Besides being able to boost or recuperate in most gears, the combustion engine can operate in all of them.

The electric motor provides the braking torque during deceleration, hereby regenerating the braking energy and charging the battery. In this powertrain concept, engine braking is realized by connecting the appropriate odd gear via the respective clutch if the battery is fully charged. As this setup is intended for a mild hybrid with an electric power of about 25 kW, the only limitation compared with the setup including a disconnect clutch is the fact that it is not able to offer pure electric driving in odd gears. Since pure electric driving in even gears would be sufficient for the vehicle speeds possible with this power configuration, this disadvantage is negligible.

Modes of operation

BorgWarner extensively investigated the functionality and safety of this concept specifically with regard to the main driving modes to be expected from a hybrid vehicle, which are driving with a combustion engine and pure electric driving as well as boosting and recuperation using the electric motor. By selecting the correct gears and the appropriate clutch engagement, the OWC configuration facilitates all of these driving modes. In addition, electric boosting or regeneration in one of the even gears with a higher gear ratio than the odd gear selected while using the combustion engine for driving in odd gears is possible when both clutches are engaged.

Moreover, BorgWarner simulated various driving

Figure 3. The one-way clutch (OWC) offers significant packaging benefits as well as high torque density and excellent comfort.

situations, including transitions between different driving modes, to test the functionality and performance of this hybrid powertrain. The initial acceleration of the vehicle with the help of the combustion engine is followed by cruising at a constant speed. While cruising, the combustion engine is switched off, as the electric motor alone can provide the power required for sustaining the constant driving speed. In this scenario, the OWC is in freewheeling mode and the engine is disconnected. When the engine is switched on, the OWC engages smoothly as the vehicle moves along. Due to the excellent controllability and thermal robustness of a wet dual clutch, the engine can be started conventionally by using the engine starter, or it can be activated by means of controlled engagement of the odd clutch while the electric motor is still driving the vehicle via the even clutch. Engagement and disengagement of the OWC are usually not noticeable, thus increasing comfort for the driver.

Conclusion

BorgWarner's innovative and cost-efficient concept for a hybrid module including an OWC as the engine disconnecting device helps OEMs meet the increasingly stringent emissions regulations and improve fuel economy. Replacing the engine disconnect clutch and its actuation, the OWC, as seen in Figure 3, reduces the complexity for clutch control and offers significant packaging benefits while still supporting all driving features such as electric driving, boosting, load point shift, coasting, engine braking and recuperation.

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