

Combustion



Hybrid



Electric

A New Level of Vehicle Stability

BorgWarner Electrifies Torque Vectoring

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A New Level of Vehicle Stability – BorgWarner Electrifies Torque Vectoring

BorgWarner's new electric rear drive module (eRDM) takes full advantage of 48-volt power supplies, enabling torque vectoring and hybrid driving modes for excellent vehicle dynamics and improved safety as well as reduced CO₂ emissions.

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Usually combined with an all-wheel drive (AWD) system, mechanical torque vectoring axle systems are available on a number of premium vehicles. Although their high mass and low efficiency negatively impact fuel economy and CO₂ emissions, they have been shown to be very capable in generating high levels of yaw authority, the result being outstanding control of vehicle dynamics. Striving to further optimize torque vectoring, BorgWarner has developed an innovative 48-volt electric rear drive module (eRDM), see Figure 1, capable of providing outstanding electric torque vectoring performance along with full-function mechanical AWD. Due to its mechanical connection to the driveline, it combines



Figure 1. Mounted in a series production vehicle available with torque vectoring, a prototype of BorgWarner's eRDM copes with extreme driving conditions.

significant CO₂ savings allowed by 48-volt hybridization in a P3 configuration with excellent

driving dynamics provided by torque vectoring via direct 48-volt electric motor control with no compromises on AWD performance.

High performance specifications

Vehicle-level modelling for optimizing system performance and value was used to determine the eRDM's system specifications. In order to determine the best balance between system cost and hybrid functionality, BorgWarner has run multiple simulations based on the New European Driving Cycle (NEDC) and the Worldwide Harmonized Light-Duty Vehicle Test Procedure (WLTC). Additional simulations were conducted to compare the performance of a two-speed and a single-speed gearbox.

The simulations showed that a maximum operating speed in hybrid mode of around 80 km/h would be optimal for recovering most of the regenerative energy available while a maximum operating speed of around 130 km/h would maximize the regeneration potential. Accordingly, the latter was chosen for the demonstration vehicle.

Additionally, simulation results showed that a wheel torque capacity of 700 Nm provided electrically would recover most of the available regenerative energy. An increase in torque capacity in hybrid mode would mean little or no improvement of the regeneration function.

Moreover, higher electric power increases the amount of regenerative energy that can be recovered, but incremental improvements decrease at higher power. These test results, along with the fact that the power of a 48-volt system is nowadays usually limited to 15 to 25 kW by the vehicle power supply and the battery, prompted BorgWarner to choose 20 kW as the peak power for their current demonstrator vehicle.

Comparing a two-speed and a single-speed gearbox with regard to the regenerative energy recovered during drive cycles shows a slight advantage for the two-speed solution. However, single-speed gearboxes provide a higher general value, so BorgWarner preferred a solution of this kind to the two-speed gearbox.

Sophisticated design

Equipped with a 48-volt motor which drives two planetary gear sets, BorgWarner's eRDM also includes the components of a traditional RDM and has an input from the rear prop shaft, see Figure 2. A gerotor pump is used to supply the 48-volt motor with cooling lubricant and allow hydraulic control of the shift mechanism. Moreover, system costs are significantly reduced by employing fins for passive heat rejection, making an external heat exchanger redundant.

Its innovative design allows the eRDM to operate in torque vectoring or hybrid mode or disengage the 48-volt motor from the system. In hybrid mode, the motor is connected to the differential case by a double-reduction helical gear set, allowing it to be used to add torque to the differential case for torque assist or recover kinetic energy in regenerative mode. As a result, the system facilitates functions like regenerative braking, electrical sailing, and boosting for CO₂ reductions and improved fuel efficiency. On the other hand, by connecting the motor to the sun gear of the double planetary gear, the module

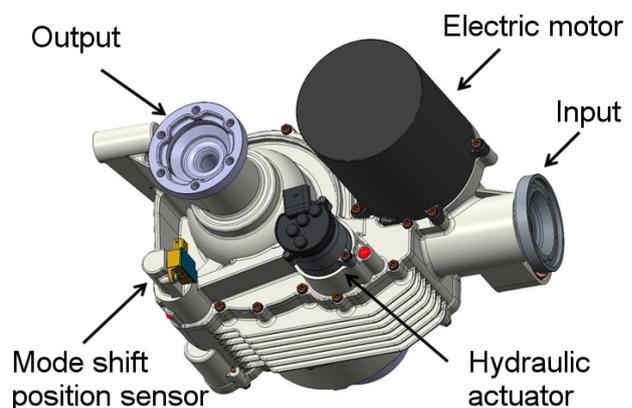


Figure 2. BorgWarner's eRDM combines torque vectoring and hybrid functionality in an innovative design featuring a 48-volt electric motor and a traditional RDM.

enters torque vectoring mode. Depending on vehicle signals such as yaw rate, wheel speed, steering wheel angle and throttle position, the eRDM allows the active distribution of torque between the two wheels for outstanding driving dynamics and stability.

Superior performance and efficiency

Using an electric motor capable of delivering up to 1,200 Nm of torque to facilitate the torque vectoring function provides numerous benefits. Compared to most clutch-based systems, for instance, better actuation torque accuracy and a torque step response of significantly less than 100 ms can be achieved – in some scenarios, clutch-based systems struggle to go below 100 ms. Another significant improvement in the controllability of the eRDM compared with a clutch-based system is the fact that it can operate in all four quadrants and is able to move between them smoothly.

Also, the majority of clutch-based torque vectoring systems use two clutches in combination with a step-up/down transmission with the clutches spinning at a differential speed of 10 percent of the absolute wheel speed. Even with an inactive system and clutches and lubrication management optimized with regard to drag losses, the inherent losses due to the always present

differential speed over the clutches have a significant impact on fuel economy, which means a significant advantage for BorgWarner's eRDM solution utilizing direct electrical actuation.

Another advantage of the eRDM is its performance regarding peak and average losses during sporty driving. Since 10 percent overspeeding on the clutches is typical for clutch-based systems, power losses can reach several tens of

following the initial avoidance manoeuvre as the other systems do. As a result, BorgWarner's advanced technology considerably improves driver comfort and safety by supporting average drivers in resolving dangerous situations more easily. In addition, the eRDM offers better cornering behavior than most other systems do – independently of the clutch friction characteristics. In terms of understeering, the behavior of a vehicle equipped with BorgWarner's eRDM is much

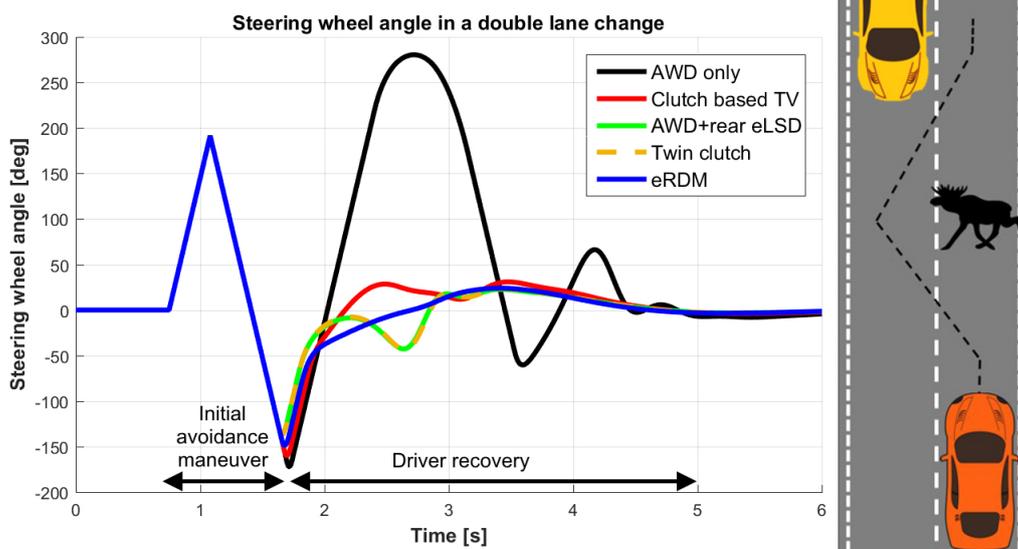


Figure 3. The eRDM offers significant benefits in terms of stability and requires less steering effort during dangerous evasive manoeuvres.

kW at moderate or high speeds. This can force the system to limit or degrade the performance due to thermal limits. By contrast, the eRDM allows energy to be transferred easily to or from the battery, thereby significantly improving the system availability in both sporty driving and hot climates.

In order to compare the eRDM's performance to that of AWD clutch-based torque vectoring and twin-clutch systems and to an AWD system with rear-axle electronic limited slip differential, BorgWarner simulated an evasive manoeuvre including a double lane change at 100 km/h, shown in Figure 3. The results of the simulation show that the eRDM does not require as much steering input by the driver to stabilize the car

more predictable since it is independent of throttle position and acceleration.

Initially designed for a mechanical AWD vehicle, the eRDM featuring electrical torque vectoring is also applicable to electrically driven axles on hybrid electric and electric vehicles. Moreover, BorgWarner is also currently developing an eRDM variant featuring just the hybrid driving functionality without torque vectoring as a cost-effective option for the mass market.

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