BorgWarner’s iDM eAxle
Transforming EV and Hybrid Propulsion
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BorgWarner’s fully Integrated Drive Module (iDM) products massively simplify the design of pure electric and hybrid passenger cars and light commercial vehicles by giving OEMs access to primary or secondary propulsion modules based on a common architecture and integrated power electronics. The iDM product is an eAxle unit that combines transmission, electric motor and inverter in a compact integrated design offering high efficiency and low weight.

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**Future Demands**

With the trend towards pure electric (EV) and hybrid electric vehicles (HEV) gaining momentum globally, manufacturers of cars and light commercial vehicles are looking for easy-to-fit fully tested and validated electric traction and transmission systems to meet the rapid evolution of vehicle models.

It is predicted that by 2023 the HEV market will account for 30% of passenger cars (25.2 million vehicles) while the penetration of pure electric vehicles will reach 5% (5.7 million). As a current leading supplier of technologies for HEVs and EVs – including electric motors, transmissions, battery packs, power electronics and thermal management systems – BorgWarner is both well prepared and well placed to meet all OEM demands. Indeed, the company anticipates that in that same year, 33% of all EVs and 46% of HEVs manufactured globally will feature its content.

**Versatile and Flexible iDM Modules**

BorgWarner’s iDM modules (Figure 1) are seen as key enablers for electrification and demonstrate the company’s holistic approach to the development of future solutions, its close working relationships with global vehicle manufacturers and a deep understanding of their needs.

iDM modules integrate highly efficient power electronics with an advanced transmission technology, inverter and industry-leading water-cooled drive motor technology featuring the company’s efficient bar wound stator solution. They are easy to integrate either at the front or the rear axle of passenger cars and light commercial vehicles, depending on the architecture and the application. As well as pure electric vehicles, the iDMs are also suitable for P4 hybrid vehicles, in which the technology is a secondary drive unit.

![Figure 1. The all-in-one propulsion solution for electric mobility combines transmission, electric motor and inverter technologies.](image-url)
The iDM family comprises three distinct products known as iDM 90, iDM120 (Figure 2) and iDM160. These offer a scalable and modular architecture along with a wide range of gear ratios, making them flexible and adaptable to customer demands. Operating at 250 to 450 volts of direct current (V DC), they have peak power densities of 90 kW, 120 kW and 160 kW respectively, at a nominal level of 330 V DC, and peak torque outputs between 2,200 Nm and 3,800 Nm.

The latest iDM development includes specially developed integrated power electronics (Figure 3). This allows for a small package with low complexity and minimum losses. In addition, it offers full software functionality with an option for the high-level control of vehicle dynamics and energy management, built upon the industry standard AUTOSAR platform. The software architecture allows safety aspects such as ASIL D to be realized. To handle the increasing volume of data exchange within modern vehicle systems, BorgWarner’s state-of-the-art power electronics can be used with a FlexRay or CAN FD bus.

A description of BorgWarner’s iDM modules would not be complete without a more detailed look at the core components and contributing technologies. These include some of the most important and innovative solutions ever to have emerged from the company’s Research & Development facilities worldwide.

**Transmission and Electric Motor Technology**

At the heart of the iDM is an integrated electric motor and transmission, and BorgWarner has industry leading solutions for both. The transmission technology is based on the company’s eGearDrive®, which contributes to extended battery powered driving range thus reducing the required vehicle battery capacity with its highly efficient layshaft gear train and low-weight design. It handles input speeds as high as 16,000 rpm and has a high torque capacity while offering smooth, quiet operation with superior noise, vibration and harshness (NVH) behaviour. Based on the vehicle manufacturer’s desired propulsion characteristics, performance is optimized with various available gear ratios to provide a tailored solution. An optional electronically actuated park lock system is also available.

The second core component can, for one thing, feature the company’s patented HVH, or high voltage hairpin, electric motor. With its innovative

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**iDM 120 Performance**

Figure 2. BorgWarner’s iDM is available in three scalable designs: iDM90, iDM120 and iDM160.
stator winding technology and power electronics, it achieves a peak efficiency of more than 95% and delivers superior power output and torque performance for its size and weight. A fully integrated rugged and compact electronic control unit includes BorgWarner’s latest generation of inverters. The controller has a flexible architecture well matched to electrification requirements of EV and HEVs, facilitating operation from 250 to 450 V DC with peak power levels matched to the three iDM products.

Besides that, BorgWarner engineers developed another alternative: rectangular-wire electric motors with the highest efficiency and power density on the market. Instead of conventional round-wire windings, these use rectangular windings in a hairpin or continuous S-winding configuration (Figure 4). Several layers of these interlocking flat wires provide a better slot fill than conventional windings. The formed rectangular wire armature has a higher exposed surface in the end-turn area compared with tight bundles of stranded round wires. This design results in machines with short end turns and enhanced heat removal capability. These are enabling factors for the development of compact electric machines with higher power and torque densities. The rectangular-wire design shows 30% less resistance at low speeds than conventional round-wire machines. The winding scheme also simplifies critical connections between conductors, improving reliability and robustness.

Both, HVH and S-winding strategies offer a significant improvement in terms of space requirements—a reduction of more than 20% compared with round wires—and more than 10% less mass than conventional motors having similar performance characteristics.

Managing Heat Output
Thermal management is a major factor in the iDM design as it is closely related to performance and cost. A key parameter when selecting a cooling system is understanding the cost/performance balance for each application. Cost/performance studies show that first supplying the coolant to the power electronics and then sending it on to the electric machine in a water jacket, results in the lowest system cost while still meeting specific performance and package requirements. The higher the performance, the more interesting the thermal management solutions, such as direct oil cooling, become.

NVH Optimization
BorgWarner has a long history of outstanding NVH performance and continues to lead the evolution of quiet, smooth propulsion products for the electrification market. The mature component level development of the transmission

Figure 3. The iDM’s highly integrated power electronics allow for a small package with low complexity.

Figure 4. S-wind configuration with rectangular wires.
based on the company’s eGearDrive, bar wound stator technology and control electronics, evolved into the iDM product family.

BorgWarner’s expertise in design, analysis and testing is evident in the exceptional NVH performance of the iDM products. Tools were developed and embedded in engineering processes to optimize design features affecting NVH performance while still meeting other performance targets. For example, the electric motor’s electromagnetic torque ripple and radial forces are optimized in the design process along with performance features such as total output torque and efficiency. The eGearDrive transmission design minimizes gear mesh transmission error for NVH while still meeting gear strength and durability targets. At the system level, housing deflection and dynamic performance are optimized while also meeting reduced mass targets.

BorgWarner’s strong engineering processes and nimble organization are world leading in terms of design, optimization and construction and with regard to correlation cycles belonging to the development cycle of the iDM products.

**Summary**

Reducing emissions and providing cleaner mobility solutions are significant challenges for both OEMs and suppliers. With BorgWarner’s compact, lightweight and highly efficient iDM products (Figure 5), electric vehicles consume less energy and drive farther on a single battery charge.

Providing smooth and quiet operation with superior NVH behavior, the advanced all-in-one propulsion solution for electric driving fulfills the requirements of leading-edge electric and hybrid drives, enabling OEMs to design powerful, clean and efficient cars.

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