Combustion Hybrid

Looking ahead into the future of turbocharging

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Turbocharging system manufacturers are steadily increasing the scope of their technical solutions to adapt to an expanding range of engine concepts. BorgWarner delivers innovative technologies, including the eBooster® electrically driven compressor, ball bearing systems and variable turbine geometry (VTG) turbochargers for gasoline engines, that pave the way towards the car of the future.

Dr. Hermann Breitbach, Vice President Global Engineering and Innovation, BorgWarner Turbo Systems.

Improving efficiency and transient behavior

BorgWarner's eBooster® electrically driven compressor shown in figure 1 takes full advantage of the company's long-standing product leadership in turbocharger development and combines optimal performance and efficiency with outstanding NVH (noise, vibration, harshness) behavior. Equipped with a permanent magnet motor for compact dimensions, high efficiency and minimal torque fluctuation and thus greatly reduced noise generation during operation, this leading-edge solution provides an electrical efficiency of over 95 percent, making it especially efficient when compared to other electric motor designs such as switched reluctance motors. A critical component of engine design and manufacturing is space. BorgWarner's eBooster technology is compact when compared to other electrically driven compressors, achieving a homogenous package by balancing the footprint of motor, compressor and electronics. The power and control

Figure 1. Optimally matched to the turbocharger, BorgWarner's eBooster® electrically driven compressor improves the fuel efficiency of vehicles using 12- or 48-volt power supplies.

electronics required were also integrated into the package. Furthermore, leveraging its expertise as a leading turbocharger manufacturer, BorgWarner optimally matched the eBooster electrically driven compressor and the turbocharger.

High versatility

Parallel to the first series application of the eBooster electrically driven compressor in a relatively large gasoline engine featuring a 48-volt power supply, BorgWarner is actively developing eBooster variants which are suited for smaller engines with 12-volt systems. A 12-volt eBooster electrically driven compressor generates around 2.5 kW of electric power. This demonstrates the potential of using 48-volt power supplies to enable more power, since BorgWarner's 48-volt eBooster solution can generate up to 6 kW. Currently, however, boosting is limited to short bursts of up to around 20 seconds. This will change to continuous operation for both variants in the future, making 3 kW permanently available from the 48-volt eBooster technology and around 1.5 kW from its 12-volt variant.

Extended boost times of between 30 seconds and 2 minutes have been revealed to be beneficial in a variety of driving situations, such as traveling uphill with a heavy vehicle. Through even longer boost times, new potential applications, including even more engine downsizing or more economical gear shift strategies, are opened up for BorgWarner's leading technology. Performance boosting at higher engine speeds is another possible application of the eBooster system besides enhancing low-end torque and helping naturally aspirated, non-turbocharged engines in achieving a well-rounded torque curve.

Achieving 90 percent of its maximum speed after just 230 ms, BorgWarner's eBooster solution provides the superior responsiveness of a mechanical supercharger. In addition, the system helps

Figure 2. BorgWarner's advanced ball bearing system significantly enhances turbocharger response and efficiency by reducing friction.

keep engine responsiveness despite the elimination of a scavenging gas exchange with its quick response time and boosting capabilities even into the medium engine speed range.

Turbocharger optimization

BorgWarner is actively developing technologies to improve the efficiency of modern hybrid and combustion engines as well as innovative technologies for electrified powertrains. Several of the company's advanced solutions, including an advanced ball bearing system and variable turbine geometry (VTG) turbochargers for gasoline engines, are ready for mass production.

Utilizing a sophisticated design and high-performance materials, BorgWarner's innovative ball bearing system shown in figure 2 offers reduced bearing friction and better rotor dynamics compared to conventional journal bearings. The new solution allows the gap between compressor housing and wheel to be minimized, thus providing another major advantage compared to journal bearings, where certain tolerances have to be allowed to avoid rubbing. Minimizing the gap improves the system's thermodynamic efficiency, which in turn contributes to enhanced turbocharger performance. As a result, engine performance is also increased and, as tests conducted by BorgWarner have revealed, fuel efficiency is increased by up to 2 or 3 percent.

Since 2006, BorgWarner has been delivering its highly exhaust heat resistant VTG turbochargers featuring sophisticated materials to a German premium sports car manufacturer's gasoline engines. However, VTG turbochargers can also be ideally applied to modern engines with Miller combustion cycles: capable of supplying the required boost pressures, they can be manufactured utilizing less sophisticated materials, as temperatures generated by these types of engines are lower, reaching 900 to 950°C instead of 1,050°C. Drawing on the company's long-standing know-how and experience, BorgWarner has designed cost-efficient, modular and robust VTG turbochargers, see figure 3, for various gasoline engines. Depending on the customer requirements, these highly modular components can be produced using different materials, providing tailor-made solutions for a variety of applications. This modularity also allows BorgWarner to leave the production process and the underlying concept largely untouched.

Figure 3. Based on a modular system allowing tailored solutions for a variety of specifications, BorgWarner's mass-market-ready gasoline VTG turbochargers improve transient behavior, emissions and fuel efficiency.

A peek into the future

By already developing the next innovative technology, BorgWarner reaffirms its role as a global product leader for advanced turbocharging solutions and continues to support its customers with innovative products for future propulsion systems. The company's eTurbo™, see figure 4, is the next stage in turbocharger development and follows a drive concept similar to the eBooster electrically driven compressor. A single-shaft solution which consists of an ultra-high-speed electric motor attached to a turbocharger, this advanced technology allows electrical energy to flow bi-directionally, either generating it from the

Figure 4. BorgWarner's innovative 48-volt eTurbo™ combines an ultra-high-speed electric motor and turbocharger to provide boost assist or convert exhaust gas flow into electrical energy.

exhaust gas flow or using it to add torque to the turbocharger shaft. While both the eBooster system and the eTurbo enhance time to torque and allow engine downsizing and downspeeding, the former is better suited for lower engine speeds, with the eTurbo providing superior performance at medium to high engine speeds. Since packaging considerations might also play an important role in selection of technologies, the eTurbo offers both functions in one, albeit slightly larger component, while the eBooster electrically driven compressor is an additional component that is still flexible with regards to packaging. The dual functionality of the eTurbo's electric motor, able to either add power to the shaft and thus assist turbocharging or act as a generator, makes it especially attractive for long haul, heavy-duty applications.

Turbocharging is set to go on playing a crucial role in modern gasoline engines, significantly enhancing the driving experience by improving transient response while saving fuel and reducing emissions, as automakers follow the trend towards powertrain electrification and mild hybridization with 48-volt systems.

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