Combustion Hybrid

BorgWarner eBooster® Electrically Driven Compressor – Electric Boosting for Improved Fuel Economy

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As an addition to conventional turbocharging concepts, BorgWarner's eBooster® electrically driven compressor improves boost pressure and transient engine behaviour at low engine speeds to allow downsizing for improved efficiency or increased engine output with excellent transient torque.

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Introduction

Development of more efficient and clean engines is driven by costumer demand for fuel efficiency and better drivability as well as challenging regulations. As a result, boosting fuel economy through downsizing and downspeeding as well as improvement of low-end torque and transient engine performance has become a major focus of the automotive industry. To meet the high demands in terms of fuel efficiency and performance, OEMs employ different solutions in the field of powertrain electrification, such as the introduction of 48-volt electrical systems. This high-voltage power supply offers significant improvements in efficiency and facilitates new

Figure 1. BorgWarner's eBooster® electrically driven compressor supplements a conventional turbocharger.

functions such as high-power electric boosting for enhanced low-end torque and transient response without any noticeable turbo lag. As a product leader in clean, energy-efficient propulsion system solutions for combustion, hybrid and electric vehicles, BorgWarner is dedicated to offer the best possible support to its customers. For this reason, the company further expands its strong portfolio of high-performance boosting technologies for combustion and hybrid engines.

Benefits for both – diesel and gasoline engines

BorgWarner's eBooster® electrically driven compressor as shown in Figure 1 was designed to improve boost pressure and transient engine behaviour at low engine speeds without increasing exhaust back pressure and negatively impacting on the engine gas exchange since no additional turbine is needed. This is a great advantage, especially for gasoline engines susceptible to engine knock. A comparison drawn between the new concept and a multistage turbocharger solution shows that the eBooster electrically driven compressor configuration allows flexible packaging, leaves more exhaust heat for the aftertreatment system and causes less heat flux into the engine compartment.

The eBooster electrically driven compressor is preferably installed downstream of the turbo compressor as seen in Figure 2. Here, with smallest volume between compressor and engine, the engine response to the eBooster electrically driven compressor is quickest. With conventional turbo matching, the eBooster technology can enhance transient behaviour while maintaining engine output. In another concept, transient response can be kept constant by utilising a larger turbine with lower back pressure, which leads to increased engine power and reduced fuel consumption due

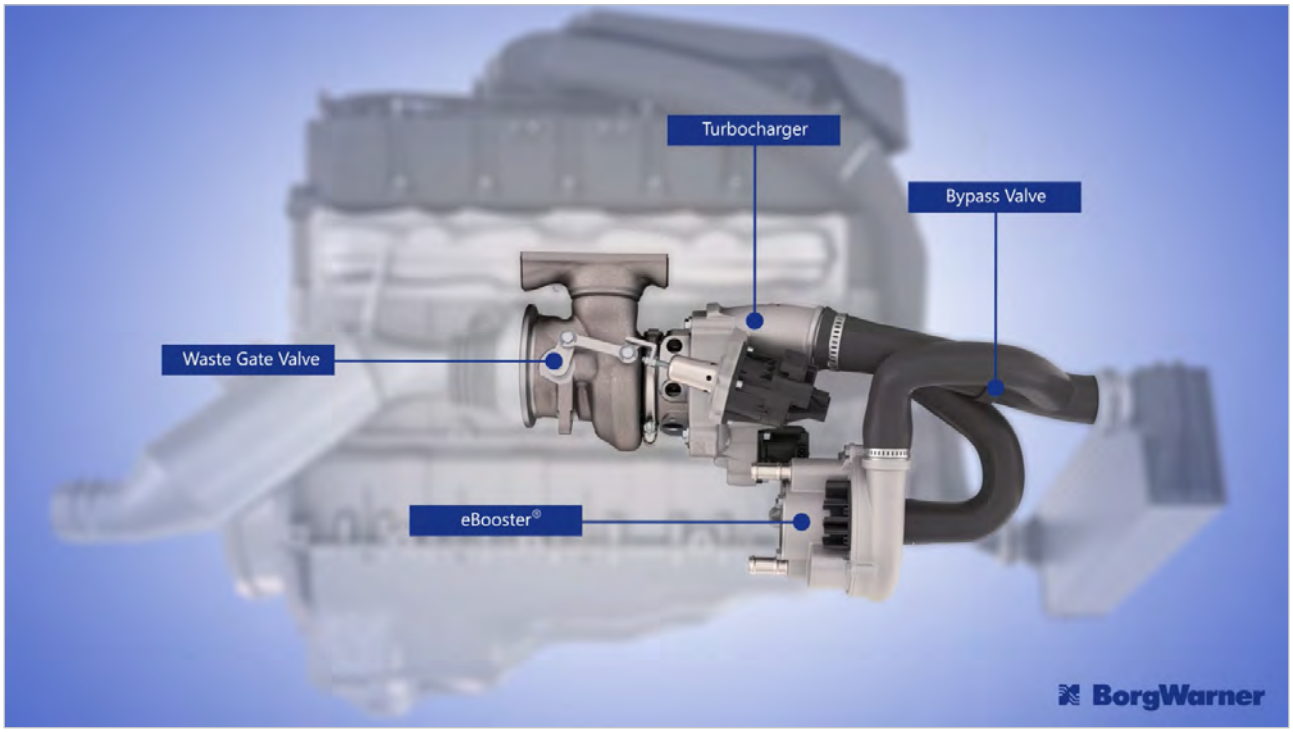

Figure 2. The eBooster electrically driven compressor is preferably installed downstream of the turbo compressor.

to the lower back pressure at high loads and less need for fuel enrichment at full load. Focussing on the emission cycle operating range, the following analysis demonstrates the potential of a 12-volt eBooster electrically driven compressor with a power of 2 kW. A 2.0-litre diesel engine with a single-stage variable turbine geometry (VTG) turbocharger was the basic configuration which was compared to two equally powerful 1.6-litre engines, one featuring a VTG turbocharger with an additional eBooster electrically driven compressor and one with a regulated two-stage system (R2S®). Among other results, the 1.6-litre engine featuring a VTG turbocharger showed a significant gap in torque without eBooster electrically driven compressor operation. Due to downsizing to 1.6 litres, low-end torque is limited. This can be compensated for using the eBooster electrically driven compressor. In comparison, the R2S configuration also meets the torque targets, but it takes more energy from the exhaust gas flow than the eBooster electrically driven compressor consumes when in the high-pressure stage. When the electrical energy is gained from recuperation, the eBooster technology provides an advantageous overall energy balance compared with the R2S in addition to the main fuel economy benefits achieved through downsizing.

Before boost pressure builds up, the 2.0-litre engine offers an initial torque advantage over the 1.6-litre engine. However, the torque gradient of the 1.6-litre VTG engine becomes steeper and achieves full-load torque earlier than the two other configurations do as soon as the eBooster electrically driven compressor starts operating. Nonetheless, the eBooster configuration can only provide transient boost in steady-state operation, whereas the R2S system can maintain a high boost pressure. According to the FTP-75 drive cycle analysis, the eBooster electrically driven compressor is operated at 2 kW and a minimum maintained speed of 6,000 rpm with an average power consumption of 210 W. Since the eBooster technology provides additional boost pressure, a higher amount of EGR can be used to achieve advantages in NO_X emissions. As a result, fuel efficiency is increased by up to about 4 percent in comparison with the R2S concept. Compared with the reference engine, advantages with regard to particulate emissions are also expected as the time of the air-fuel ratio at the smoke limit has decreased by 5 percent.

Advanced design for maximum efficiency

The eBooster electrically driven compressor has to meet certain specific design requirements to offer the best possible functionality. First of all, the inertia of the electrical motor as well as the electrical and mechanical losses have to be minimised. Moreover, the motor should feature a very compact design with integrated and extremely efficient power electronics. It should also be able to withstand high temperatures. Finally, the NVH (noise, vibration, harshness) behaviour has to be considered, and the eBooster technology has to be modular and available as a 12-volt and a 48-volt version. Since a brushless permanent magnet DC motor featuring highly heat-resistant samarium-cobalt magnets is much more efficient than asynchronous or switched reluctance motors, this configuration was selected. The eBooster electrically driven compressor allows a maximum speed of 70,000 rpm to be reached from a standstill in 270 ms – virtually in the wink of an eye. This speed was chosen to realise an on the whole homogenous package with a roughly similar diameter between motor, power electronics and the compressor side of the eBooster electrically driven compressor.

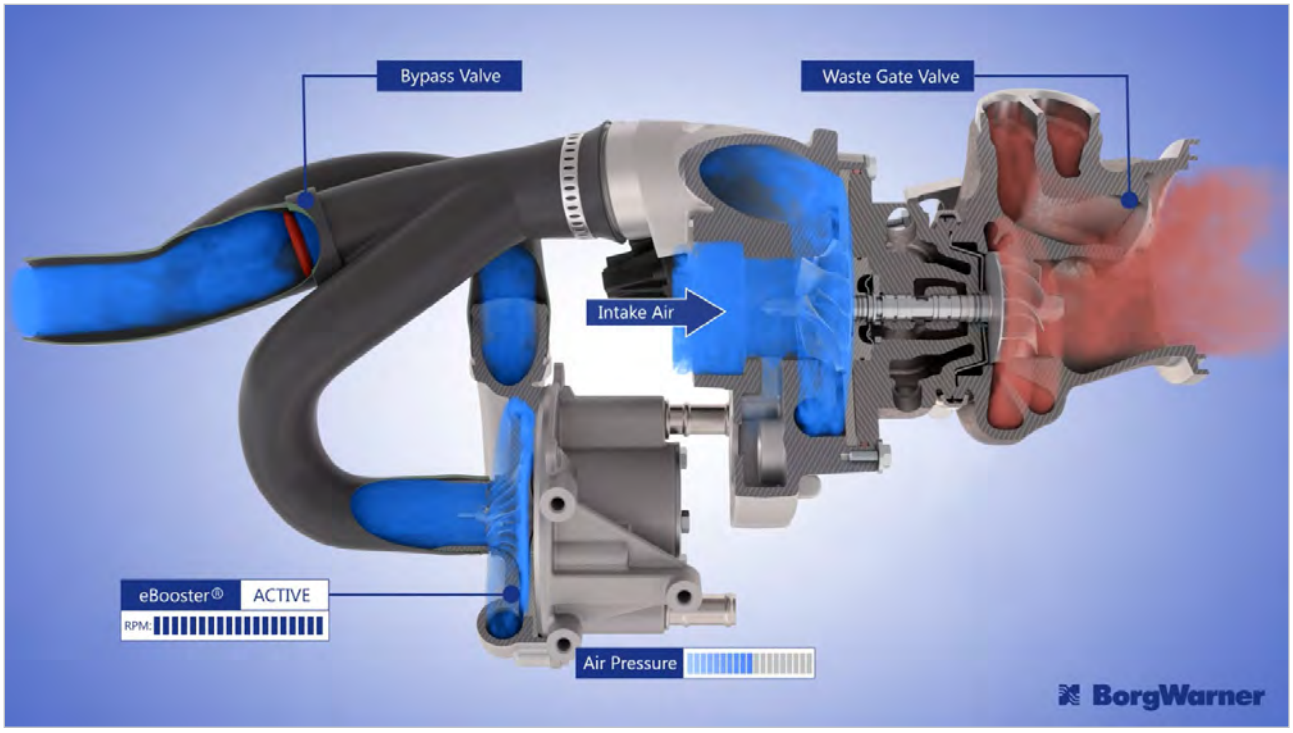

Figure 3. The eBooster electrically driven compressor improves transient performance and fuel economy.

Other substantial design elements of the eBooster electrically driven compressor include power electronics using parts with minimal resistance specifications and highly efficient capacitors, a good connection from electronic board to housing to provide efficient heat transfer, and a stator optimised for long 'on' times and high duty cycles by utilising a high-density copper filling. Additionally, since water cooling with good heat transfer to the stator and the power electronic board was feasible for the 48-volt configuration, this option is preferred over air cooling, which only worked for the 12-volt eBooster electrically driven compressor. Overall, the 48-volt eBooster configuration is preferred because it achieves a permanent power of around 3 kW under favourable operating conditions while offering numerous advantages such as additional benefits with regard to transient performance and fuel economy as well as lower currents and higher power for larger-displacement engines, see Figure 3.

Summary

BorgWarner's eBooster electrically driven compressor supplies boost pressure very quickly, even at low engine speeds, making it an excellent and highly efficient addition to the conventional turbocharger to improve engine fuel economy, transient response and consequently allow the engine power density to be increased. In addition, improvements in fuel efficiency and the optimisation of emissions, particularly in the case of diesel engines, are facilitated by matching the eBooster electrically driven compressor and turbocharger as an overall system.

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