© Sonceboz

Emission Reduction for Combustion Engines through Precise Actuator Technology

Torque motors enable precise control of regulation flap functions, offer high positioning speeds and are capable of diagnosis. In the following, Sonceboz gives an overview of the state of the art in torque motors and the further development potential, especially in respect of further emission reductions in diesel and gasoline engines.

AUTHORS

Mathieu Rust
is Business Unit Manager – Emissions Control Passcar at Sonceboz SA in Sonceboz (Switzerland).

Arthur Raffard
is Business Unit Manager – Engine and Thermal Management Trucks/Off-Highway at Sonceboz SA in Sonceboz (Switzerland).

ADVANTAGES OF TORQUE MOTORS

Exhaust gas recirculation, air intake throttle, and variable turbine geometry are key technologies required for compliance with engine emission and fuel consumption limits. To reduce exhaust emissions through dynamic and reliable positioning of the engine control actuators, Sonceboz has developed compact brushless electric motors with particularly short response times. Standard H-bridges integrated in the engine control unit control these devices, which provide a rapid and reliable angular movement. Compactness, durability, and reliability ensure optimal integration in a large variety of engine applications, from passenger cars to heavy commercial vehicles, and especially for extreme condition environments. The torque motor technology now electrifies many parts of the vehicle by, for example, replacing pneumatic actuators and brushed motors for positioning valves and flaps, **FIGURE 1**.

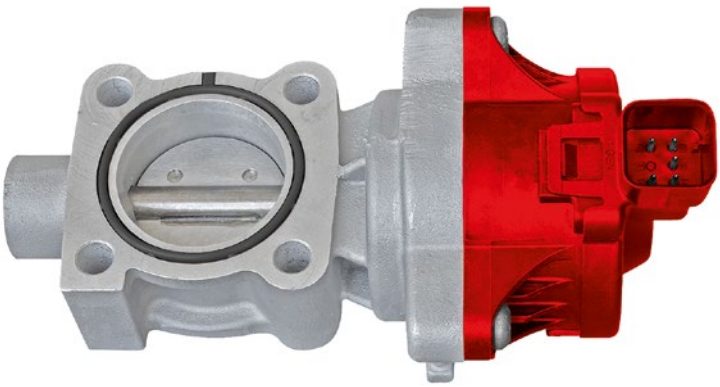


FIGURE 1 Electrically operated exhaust gas recirculation valve (© Sonceboz)

Torque motors are particularly suitable for harsh and demanding environments where reliability is of real value. Brushed actuators, for instance, cannot compete with torque motors when it comes to durability and reliability due to the number of components, the wear of brushes, or to thermal dissipation. Where torque motors' brushless technology easily withstands more than 500,000 km, brushed motors can show wear damage already after much shorter distances due to the constant physical and electrical contact between rotor and stator.

Brushless DC (BLDC) torque motors by Sonceboz, in particular, provide exceptional durability (tested over 70 million movements), robustness, and good vibration resistance, due to their technology and design. This forms the basis for a quality with failure rates of close to 0 ppm. The direct drive magnetic technology and the simplicity of the mechanical design ensure this reliability.

More and more OEMs are therefore switching to brushless torque motors, especially for applications with a short response time. Nowadays torque motors are providing greater advantages in terms of Total Cost of Ownership (TCO) than brushed actuators, as the latter often have to be replaced after a certain number of operating hours. This is particularly critical with commercial vehicles where TCO is of utmost importance. Torque motors also score points when compared with pneumatic systems. Their use can save the whole pneumatic system while reducing component costs, space as well as energy consumption within the vehicle. Compared with pneumatic applications, torque motors have the clear advantage that power is only used when necessary, in other words there does not have to be any constant pilot pressure.

Positioning precision is another great advantage of torque motors compared with pneumatic systems, where hysteresis and losses make precision positioning almost impossible. Indeed, electric motors are able to achieve and maintain accurate positions with great dynamics. Position changes within 30 to 50 ms can be achieved thanks to the Sonceboz torque motors, which is much faster than most pneumatic systems. This response time enables the use of the torque motor for a variable valve lift application, **FIGURE 2**.

FIGURE 2 Torque motor for variable valve lift with integrated failsafe function and customer specific interface (© Sonceboz)

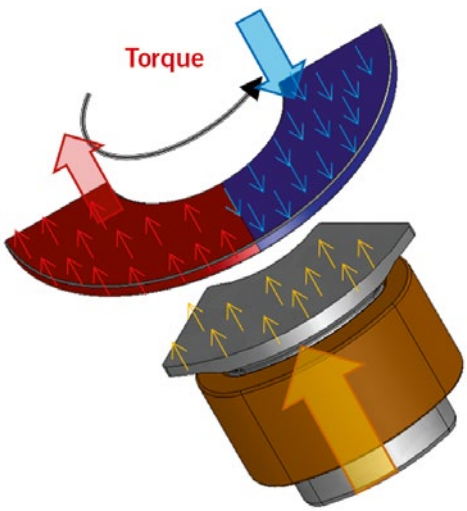
ADDITIONAL FUNCTIONS

The technology is based on a magnetic circuit technology developed by MMT (Moving Magnet Technologies), an R&D center located in Besançon (France) and a sister company of Sonceboz, **FIGURE 3**. MMT has been continuously expanding and improving their technological portfolio with brushless motors including the torque motor range, which today represent a mature solution. A complete product family is available, offering different sizes of motors with rotor diameters ranging from 36 to 51 mm, and different magnet grades adapted for the applications. A position sensor is also integrated in this single-phase motor, which allows regulating the position very precisely using the vehicle control unit. This position sensor is able to deliver the rotor position through different communication protocols such as PWM, SENT, or Analog signals.

The complete stator over-molding process, used for all torque motor variants, is a real technical advantage for mechanical durability against harsh vibration environments, but also very efficient for thermal dissipation, which allows the motors to withstand up to 160 °C ambient temperature and still be able to deliver a continuous torque. High waterproofing is also a feature of the Sonceboz torque motor range. Thanks to a laser weld between stator housing and cover, the internal motor components (sensor Printed Circuit Board (PCB), magnets, and electrical connections) can be protected from dust and corrosive fluids.

The motor heart of the Sonceboz torque motor is based on four adjacent iron cores, which are working synchronously against a four-pole disc magnet with a very thin airgap to optimize the

FIGURE 3 Functional layout of the magnetic circuit concept (© Sonceboz)



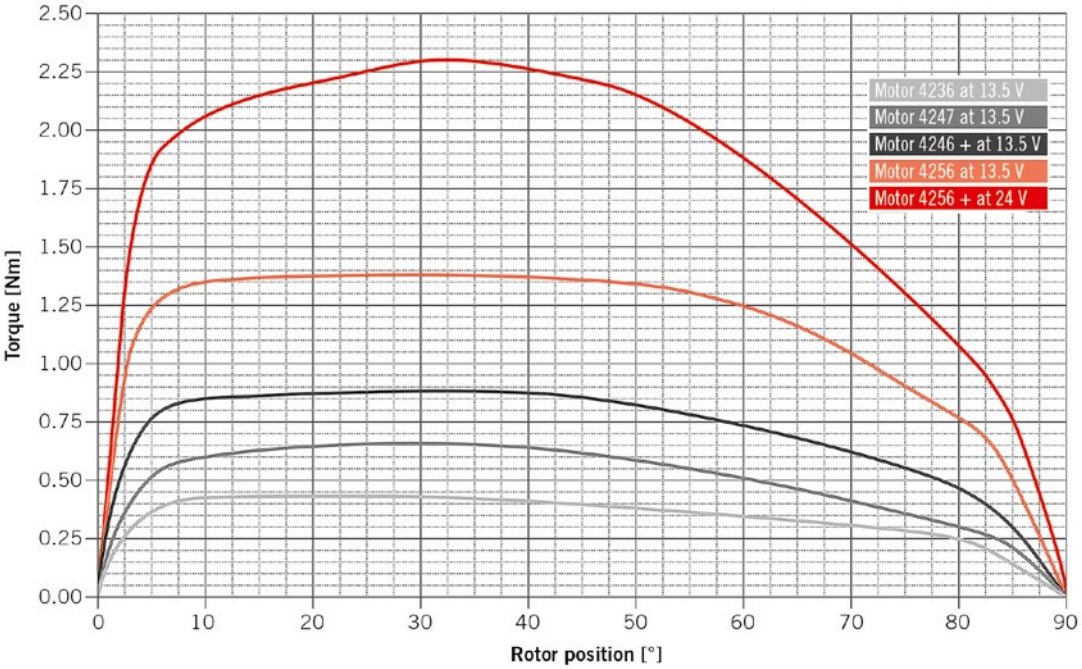


FIGURE 4 Peak torque curves of various torque motors (© Sonceboz)

flux density in a reduced space. This configuration defines the compact motor design, which makes this product the most efficient in terms of torque density compared to any other direct drive actuator on the market.

As the position sensor design, based on Hall Application-specific Integrated Circuit (ASIC) components, is very well integrated with the motor magnetic circuit, the product has a very limited component count. This is the best way to offer compactness and reliability to the customer.

The motor is driven via an H-Bridge in the vehicle control unit with a simple Proportional Integral Derivative (PID) controller and can be tuned to control the motor dynamics and stability according to the application's characteristics.

The safety functions implemented over the years by Sonceboz include an optional return spring being used when an uncontrolled position carries high application risks. This ensures a known failsafe position, even in the event of a power cut or signal interruption. As the torque motor is a direct drive, in other words does not contain any transmission gearing, cogging and friction torques are extremely low. This makes it possible to dimension the return spring much more efficiently and therefore create a more compact design for the entire valve system, including end stop. This return spring is implemented inside the motor housing, being a very safe solution because the spring, which is greased, is protected from external radiation and dust, and is able to provide the maximum returning torque over the product lifespan without any risk of deterioration due to friction, particles, corrosion or other influencing factors.

Special elastic mechanical end stops are also available to be combined with the spring function. The aim is not only to define a useful stroke, but also to damp the shock when the motor reaches the end stop, thus avoiding the impact which can damage the internal parts. Again, this contributes to the product reliability.

Sonceboz's Swiss production facility is based on fully automated assembly lines to ensure high quality levels and productivity. Even so, lean manufacturing offers customers the possibility to customize their products. One can choose variants based on a clipped or laser-welded cover, sensors with or without PCBs, lip seal or not, and many other details to perfectly match application-specific needs. Dealing with mechanical interfaces, one can choose again between a bolt fastening with rear nuts, or screw fastening using molded-in ears. Depending on the application, customers directly weld a lever or coupling element onto the shaft, or use a pre-assembled customer-specific interface.

By increasing the torque density, Sonceboz is now able to produce a wide range of torque motors. Different torque levels are available for each size, depending on the grade of components used. Today, the torque motor portfolio covers peak torques between 0.45 and 2.30 Nm, **FIGURE 4**.

REDUCED EMISSIONS

Torque motors which are also suitable for high temperatures allow, for example, the use in the guide vane actuator system of turbochargers with variable turbine geometry. The motors are mounted directly on the turbocharger housing to control the adjustment of the guide vanes and thus the exhaust gas flow, **FIGURE 5**. In addition to the known advantages, they make it possible to quickly adjust the flaps thanks to the integrated position feedback with positioning times of below 100 ms. For the manufacturers, this means a significant reduction in turbo-lag due to improved charge pressure control. At the same time, the turbochargers can be designed for an additional torque range, ultimately meaning fewer hazardous substances in the exhaust air and reduced fuel consumption.

In exhaust gas recirculation systems, torque motors control the exhaust gas recirculation valves or flaps, enabling fast and accurate control of the exhaust gas recirculation flow for optimal low-emissions combustion. The system thus supports compliance with the latest emission standards Euro 7, China 6a and 6b, Indian BS6, Canadian Tier V, US EPA and post EPA 10. Mechatronic systems that actuate the inlet flaps on the intake side are another way of reducing emissions. They achieve higher exhaust gas recirculation rates than the abovementioned recirculation systems, are compatible with on-board voltages between 12 and 24 V, have actuation times of less than 100 ms, are extremely durable and are resistant to high temperatures thus helping avoid soot accumulation. The single-phase power supply can be provided by any standard control unit. The Sonceboz torque motors, **FIGURE 6**, have been used successfully for more than fifteen years. Today, most engine manufacturers in Europe, the USA, and Asia regard them as among the most reliable actuators.

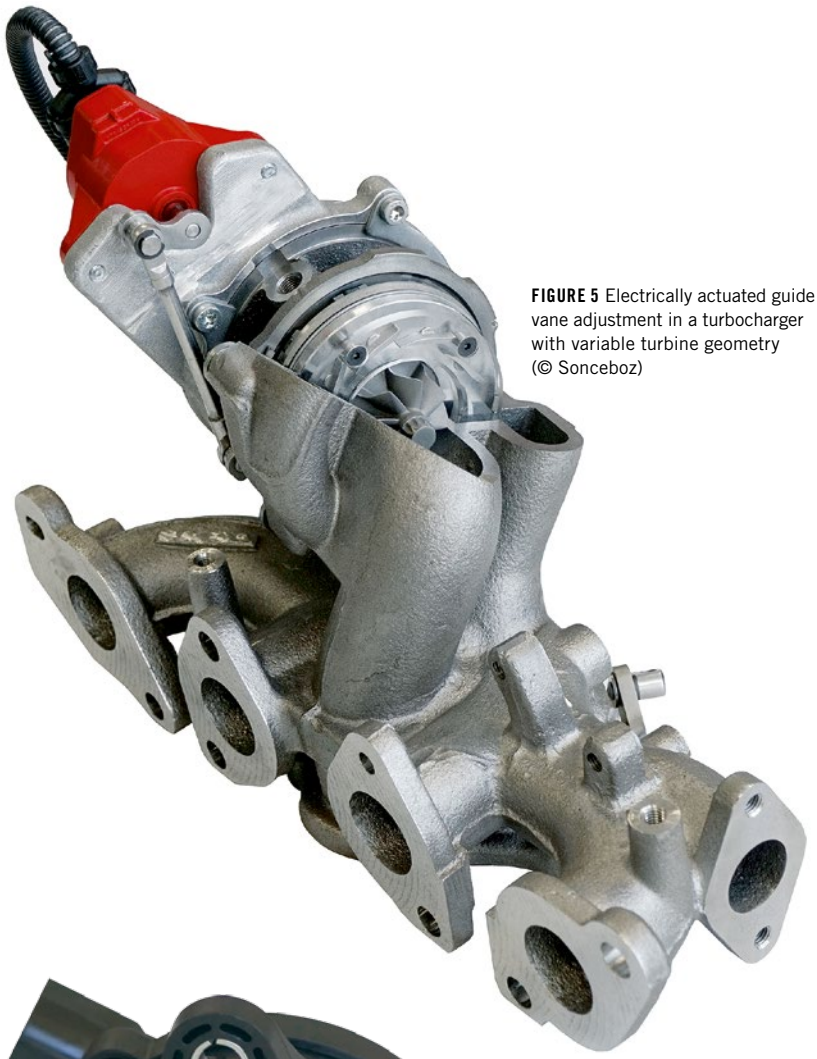


FIGURE 5 Electrically actuated guide vane adjustment in a turbocharger with variable turbine geometry (© Sonceboz)

FIGURE 6 Example of a torque motor for emissions control applications (© Sonceboz)

OUTLOOK

The further development of brushless torque motor technology certainly is not over yet, especially in the Asian market which has recognized the trend and demands ever new versions, with innovative new magnet circuits or original customer specific mechanical interfaces. Sonceboz is also able to rely on MMT's research and basic research potential in this respect. The company develops new solutions for meeting these special requirements. This is what makes this technology so unique and almost unrivaled in the market. Sonceboz sees further possibilities in commercial vehicles, such as air intake modules for Liquefied Natural Gas (LNG) engines, exhaust gas back pressure valves or compressed air charging.

Sonceboz torque motors are the best choice for complex applications requiring endurance, repeated movements to the same positions, durability, compact design, or fast reaction times. New hybrid and electric vehicles are also still going to provide countless new application opportunities. The new torque motors will stand out through an increase in torque density with ever increasing accuracy and diagnostic capabilities as well as more compact customer-specific housings.