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Garrett VNT turbo with rotary  
electric actuator

# The power of turbocharging

In 1905, Alfred J Büchi, a Swiss engineer, filed the first patent for turbochargers to be applied to internal-combustion (IC) engines. Today, exactly 100 years later, more than 50% of all newly registered passenger cars in Europe are turbodiesels. Due to its superior performance and reliability, the turbodiesel dominates the European luxury vehicle market. According to the U.S. Environmental Protection Agency (EPA), four of the top 10 most fuel-efficient vehicles for sale in the U.S. for the 2005 model year are turbodiesels. Indications are that the turbodiesel will see a growth rate in the U.S. similar to that in Europe in the coming years.

Internal-combustion engines use a lot of air—about 9000 L per liter of gasoline and about 20,000 L per liter of diesel fuel. As a result, ensuring proper supply of air is critical for fuel-economy improvement and emissions control. Since the filing of the first patent, turbochargers have kept pace with IC engines with innovations such as pulse turbocharging, divided scrolls, wastegates, higher speeds, lighter materials, variable-geometry turbines, and compressors.

Based on certification test data published by the vehicle manufacturers, turbodiesels on average are seen to be 30-35% better than their best-in-class nonturbocharged gasoline engine counterparts. The evolution of modern diesel engines directly benefited from variable geometry turbine (VGT) technology, an industry breakthrough first pioneered by

Honeywell as represented through its Garrett variable nozzle turbine (VNT) technology. First adopted in passenger cars in 1991, VGT today is featured in millions of passenger vehicles, light- and medium-duty diesel trucks, and heavy-duty commercial vehicles. The latest developments in VNT and its control facilitate exhaust gas recirculation, which, together with catalytic exhaust treatment, enables diesel engines to meet critical U.S. EPA Tier II Bin 5 emissions regulations. This next wave of turbodiesel technology is expected to save the U.S. more than 350,000 barrels of petroleum a day.

While turbocharging is widely acknowledged as indispensable to diesel engines, its role in improving the performance and fuel economy of gasoline engines has yet to be fully appreciated. This is largely due to the fact that gasoline turbocharging has long been associated with racing and sports cars. However, downsized turbocharged gasoline engines/vehicles can deliver a 16-18% improvement when designed for fuel economy rather than "sportiness." This is because a smaller engine runs at more optimum conditions while the turbocharger "steps in" when needed to provide additional air/torque/power normally achieved by a larger engine. Electrically actuating the movement of vanes and electronically controlling their position consistent with vehicle/engine needs are at the forefront of what turbo engineers are working on to gain even



Garrett AVNT turbo

better fuel efficiency.

In recent years, there has been wider recognition that improving air supply is both critical and achievable—hence the proposition of two-stage turbocharging. With its added pressure ratio and air flow, two-stage turbocharging is increasingly being used to meet stringent emissions and fuel economy requirements. As can be expected, packaging can be a challenge here, though not insurmountable. Always intent on building a better mousetrap, engineers at Honeywell are working on a unique “two-in-one” design, packaging compressor wheels back-to-back for two-stage compression as well as for unique wide flow range high exhaust gas recirculation applications.

Hybrid technologies lately have attracted much attention, especially in the U.S. Are hybrid and turbocharging two complementary technologies? Hybrid powertrains also run a smaller engine at more optimized conditions, relying on the electrical motor to provide extra torque when needed. Brake energy is recovered to recharge batteries. Unfortunately, there is concern that much of the recovered brake energy is used up in carrying the extra weight of batteries and electricals. Emerging turbo technology such as Honeywell’s e-Turbo has the potential of carrying hybrid technology to the next level.

Honeywell’s e-Turbo has an electric motor generator mounted on the same shaft as the turbocharger. When the vehicle/engine calls for more torque and

the turbo needs some help, the electrical motor “steps in” to provide extra air/torque. When there is too much exhaust energy, it generates electricity to store in batteries. This synergy with hybrid philosophy offers the opportunity to further downsize the engine while at the same time reducing the capacity or weight of batteries needed.

As for fuel cells, they are just as dependent on the efficient supply of air as conventional IC engines. A fuel cell needs supplementary power to run its air supply because exhaust energy is not high enough for a turbo to be self-sustaining. An e-Turbo can be suitably tailored to meet this critical need.

Having proven itself to be an indispensable enabler to modern diesel engines, turbocharging today faces a new set of challenges: driving and controlling exhaust gas recirculation, boosting downsized gasoline engines, shaping torque curves with variable geometry and e-Turbo technologies, and packaging two-stage turbochargers while providing high flexibility of operation. Looking further ahead, integrating turbocharging fully with hybrid and fuel-cell powertrains is the new research frontier.

It may be 100 years old, but turbocharging truly is a technology fit for the 21st century. With many innovations in the pipelines, it will stay relevant to the needs of IC engines as well as advanced powerplants. **aei**



Garrett e-Turbo prototype