NEW GENERATION OF SCROLL-TYPE SUPERCHARGER

MORE POWER AND REDUCED CONSUMPTION

Handtmann Systemtechnik in Biberach has re-examined and completely redesigned the scroll-type supercharger system for supercharging and increasing the power output of gasoline engines. Sophisticated engine process simulation carried out by the project partner Bertrandt has proven the benefits of the scroll-type supercharger compared to other supercharging concepts. As a result, Handtmann is now presenting the scroll-type supercharger as a solution for downsizing applications. Areas of application include single- and two-stage supercharging concepts for gasoline and diesel engines designed to achieve low exhaust emissions.

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HISTORICAL DEVELOPMENT

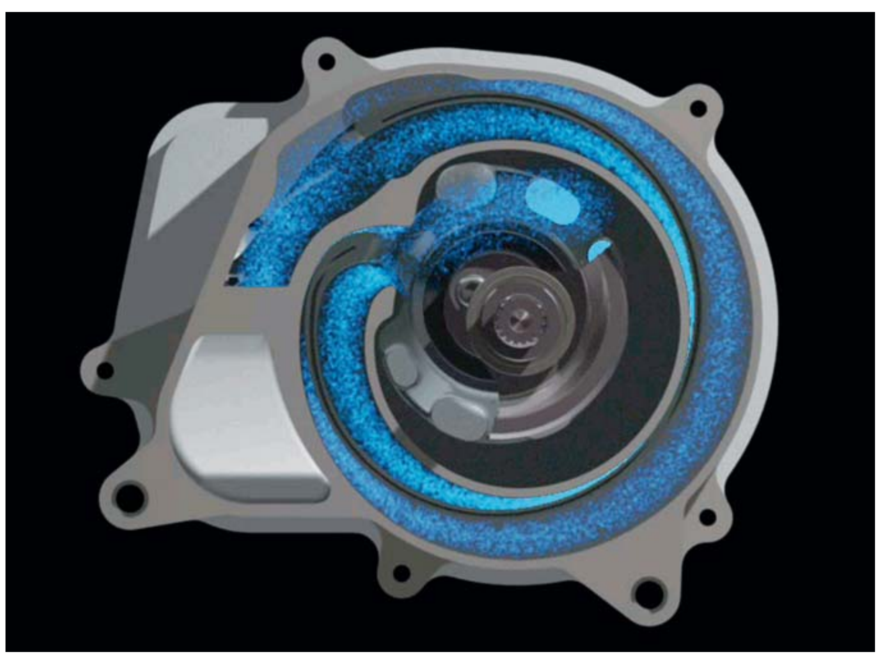
The scroll-type supercharger belongs to the group of mechanical superchargers and works according to the displacement principle. It was invented and patented as long ago as 1905. At that time however, the complex manufacturing and material requirements prevented it from being produced on a large scale. It was not until the 1980s that Volkswagen took up this technology and marketed vehicles with a system that became known as a so-called G-Lader (G supercharger) [1].

DESIGN AND PRODUCTION

Handtmann Systemtechnik has a high level of expertise in aluminium and magnesium die casting due to its integration into the Handtmann Group. What is more, its systematic approach is consistently complemented by a high level of development competence and broad technical knowledge of assembly and testing processes. In addition, Handtmann's Automotive division supplies intake manifold modules, exhaust gas recirculation components and other add-on parts for car engines, thus ensuring an optimum and highly cost-effective manufacturing process due to the integrated network of casting, mechanical machining, assembly and testing activities [2]. The depth of in-house production at Handtmann therefore guarantees a high level of process reliability.

This special level of experience and development expertise is a pre-requisite for the company's ability to fully exploit the potential of the scroll-type supercharger. Using state-of-the-art methods, the Handtmann scroll-type supercharger (Handtmann Spirallader, HSL), ❶, was further developed, turning it into a highly efficient supercharging system to meet the future requirements of the automotive industry [3]. The aim was to produce a cost-optimised supercharger system capable of being mass-produced and especially suitable for downsizing concepts. The development phase of the HSL focused on the optimisation of fuel consumption and CO_2 emissions as well as the supercharger's response in the low engine speed range, to name just a few of the key points.

The most fundamental modification to the HSL compared to the previous G supercharger concept is the displacer. The single-scroll design – the previous version had a twin-scroll design – significantly reduces the machining requirements. The use of a special sealing contour (hook-type seal) in the HSL eliminates the need for an outer running surface, thus noticeably reducing the size of the unit while still maintaining the same displacement volume. A further-developed high temperature resistant magnesium die cast alloy for the displacer considerably improves its mechanical properties. What is more, all sliding



❶ Cut-open view of the scroll-type supercharger Handtmann Spirallader (HSL) components, such as sealing strips and sealing surfaces, are now made of the very latest friction- and wear-optimised materials and tribological coatings.

PRACTICAL BENEFITS

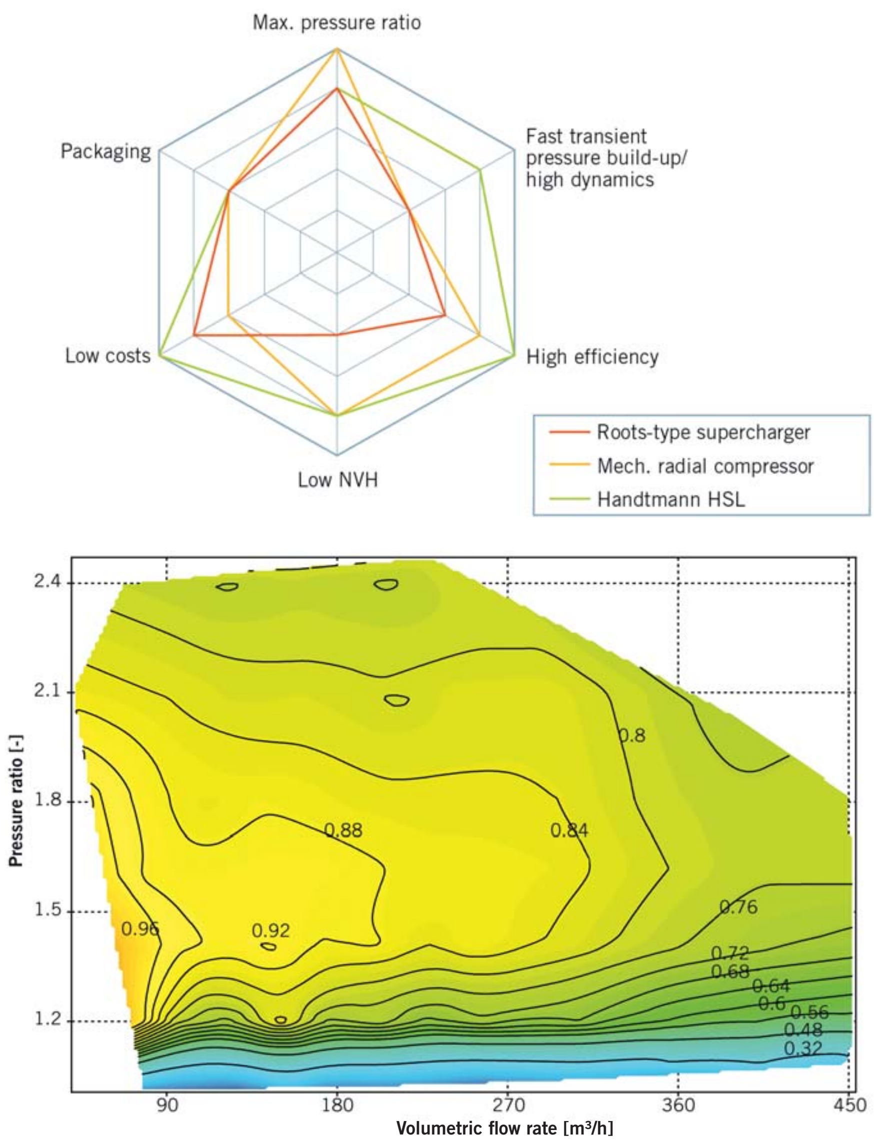
Compared to a mechanical screw-type supercharger or an exhaust gas turbocharger, the HSL enables the internal combustion engine to develop maximum torque even from idling speed (low-end torque) while at the same time having a higher overall efficiency. The resulting high level of dynamics significantly enhances the driving experience. This is essentially due to the overall higher isentropic efficiency and a very high overall efficiency [4], ❷. At the current state of development, efficiency is more than 70 % over a broad map area and is thus approximately 10 % points higher than the overall efficiency of previous scroll-type supercharger concepts.

In customer-relevant driving situations, the HSL operates for the most part in its optimum efficiency range. For the customer, this means measurable fuel consumption benefits. Additional potential is provided by downspeeding of the engine in combination with longer gear ratios while still offering excellent driving performance.

To minimise the mechanical friction losses of the internal combustion engine, the HSL can be optionally equipped with an electromagnetic coupling. This offers on-demand control of the power supplied by the HSL at an almost constant driving speed or low engine load. The low mass moment of inertia of the HSL ensures largely unnoticed activation processes and a spontaneous response to different power requirements. Further advantages of the HSL include:

: controllability of the boost pressure independent of the exhaust gas flow
: almost vibration-free operation in the charge air flow eliminates the need for cost-intensive noise reduction or insulation measures
: improvement in the thermodynamic efficiency of the internal combustion engine due to positive gas exchange work
: the high EGR compatibility supports optimisation measures inside the engine
: the optimised close-coupled catalytic converter arrangement ensures better light-off behaviour due to the elimination of the exhaust gas turbocharger (enthalpy sink)
: the lower exhaust backpressure reduces the boost pressure required and lowers the knocking potential, thus offering the possibility of increasing the compression ratio
: no need for measures to protect the turbocharger, such as full-load enrichment
: compact design and no maintenance requirements.

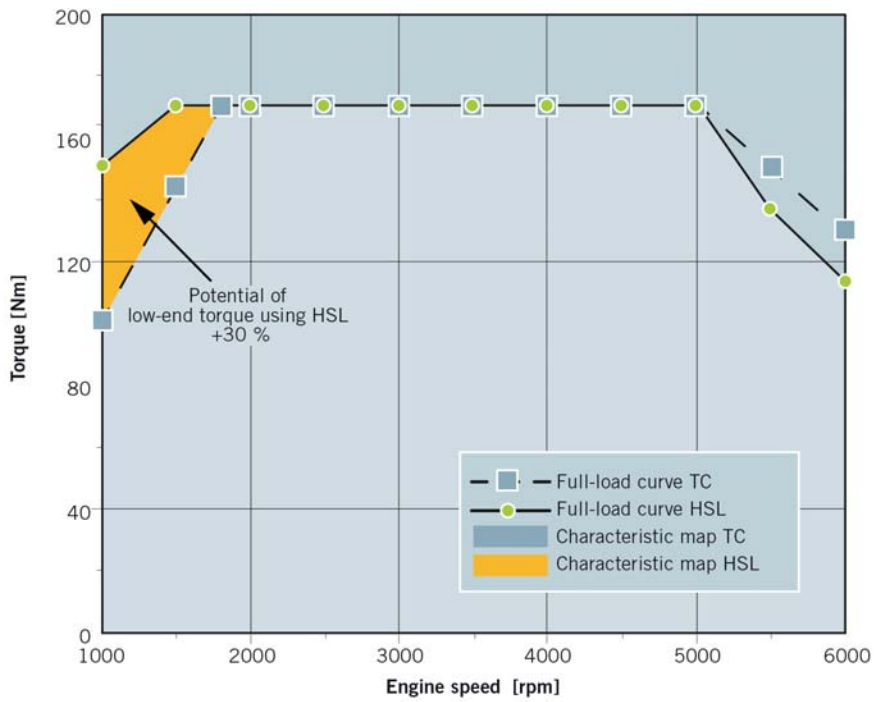
These and other advantages can be flexibly combined to make the HSL suitable for all gasoline and diesel engine applications. Furthermore, the scroll-type supercharger housing can be provided with numerous fittings for other auxiliary units of the engine periphery. This specific design of the HSL should be fundamentally taken into consideration in an engine package.



❷ Comparison of selected supercharging systems (top) and HSL efficiency map (bottom)

SIMULATION-AIDED POTENTIAL ASSESSMENT

The engine efficiency advantages of an HSL compared to an exhaust gas turbocharger were evaluated by means of gas exchange simulation carried out at the development service provider Bertrandt at its Neckarsulm site. The engine model was derived from a 1.0 l gasoline engine that is normally supercharged by an exhaust gas turbocharger and which is adapted and optimised to the specific requirements of exhaust gas turbocharging. The exhaust gas turbocharger used



❸ Full-load curves and engine maps of a gasoline engine with 1.0 l displacement and HSL supercharging or exhaust gas turbocharging at a required specific power output of 90 kW/l

as a reference in this case was selected to achieve a high specific power output of more than 90 kW/l for the engine. At the same time, very high low-end torque was required from 1700 rpm upwards, ❸, thus corresponding to the current state of technology.

The aim of the gas exchange simulation was to create an efficiency map for the engine, ❹. In order to compare the different types of compressor drive systems (mechanical energy in the HSL compared to exhaust enthalpy in the exhaust gas turbocharger), the boost pressure of the two supercharger versions was controlled by a wastegate or bypass. The other boundary conditions remained unchanged.

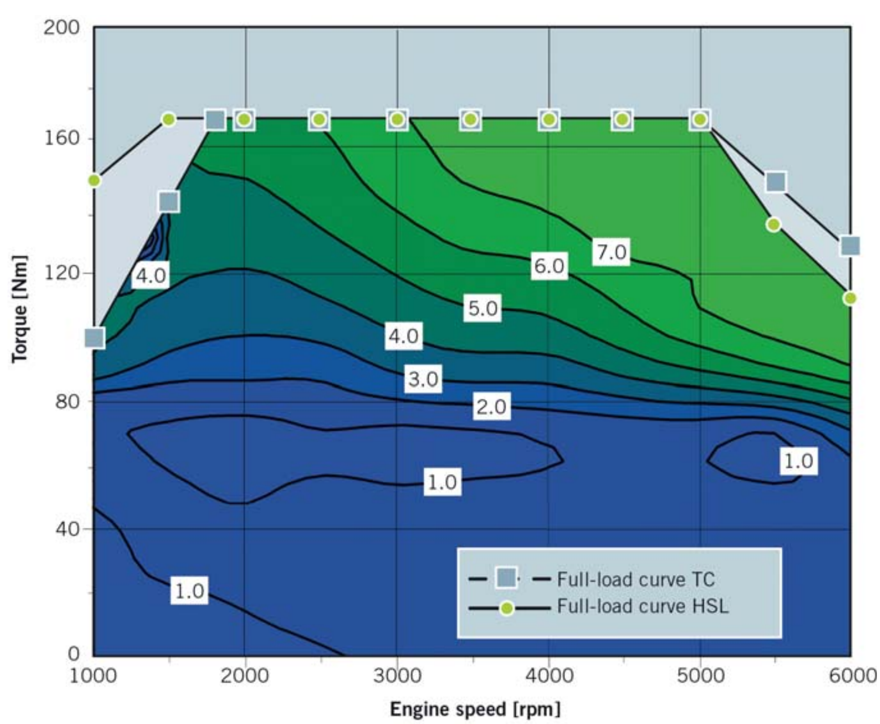
The calculated differential map of the effective specific fuel consumption (BSFC) shows efficiency advantages of up to 7 % for the gasoline engine supercharged using the HSL. An explanation for the fuel consumption advantage can be found in the lack of a turbine. Due to the lower exhaust backpressure, the HSL has to build up less boost pressure for the same engine output [7]. Although the exhaust gas turbocharger has some advantages in this respect by using exhaust enthalpy to compress the charge air, the HSL has clear advantages not least due to the fact that maximum overall efficiency is between 10 and 12 % higher. Optimisation measures to improve the efficiency, in respect of the particular charging system, of the internal combustion engine were not considered in the gas exchange simulation in the first evaluation. Additional potential is available by applying such measures as [5, 8]:

: optimised valve timing (later exhaust valve opening)
: an adapted intake runner length and intake volume of the induction system
: an optimised charge air duct.

The application of Bertrandt's own simulation tool called Virtual Powertrain for cycle simulation [6] clearly showed that, with an unchanged powertrain configuration, fuel consumption advantages of up to 3 % can be achieved by using the HSL. Advanced optimisation measures were not considered, which means that the real fuel consumption reduction potential in a cycle, for example by applying downspeeding measures, is likely to be even greater. Due to its working principle, the HSL is largely stable towards pressure fluctuations in the intake manifold and is therefore predestined for use in internal combustion engines with only two or three cylinders in particular.

TEST BENCH RESULTS

After the extensive simulations carried out by Bertrandt, several prototypes were developed and built. These were



❹ Percental specific fuel consumption benefit of the HSL compared to an exhaust gas turbocharger then subjected to intensive test bench testing, during which the HSL fulfilled the endurance strength requirements with excellent results. In addition, a turbocharged gasoline engine was equipped with two-stage supercharging with the HSL, which generated the boost pressure in combination with an exhaust gas turbocharger. The original power output of the gasoline engine was raised by over 40 % to more than 170 kW. Maximum torque increased by more than 100 Nm to 365 Nm and is available virtually above idling speed. These figures are approximately at the same level as those of a current 2.0 l turbocharged gasoline engine, but are achieved with 30 % less cubic capacity. Development partners confirmed the excellent drivability of the prototype during road tests.

AREAS OF APPLICATION

When used as a stand-alone supercharging system, the HSL is suitable for small-displacement downsized gasoline engines in which the less favourable efficiency of the exhaust gas turbocharger at low engine speeds comes together with a low exhaust gas enthalpy. In this case, the HSL offers significantly better low-end torque characteristics as well as the possibility to use a speed-reducing and therefore more fuel-efficient transmission design. Due to its good efficiency characteristics, the HSL is optimally suited for use as a booster for two-stage supercharging systems in combination with an exhaust gas turbocharger. In this configuration it is suitable for engines with displacements of up to 2.0 l. Compared to a mechanical screw-type supercharger, the HSL provides better power and torque characteristics at low engine speeds, while at the same time significantly reducing fuel consumption. On the other hand, an exhaust gas turbocharger can be used to achieve a higher end power output due to the relatively wider compressor map.

OUTLOOK

A further application area of the HSL is emission-optimised small-displacement diesel engines. For this application, Handtmann has developed a complete low-pressure EGR circuit and has equipped it with components developed in-house. This proved that the HSL can provide high boost pressures in combination with a high exhaust gas recirculation rate even at low engine speeds. Due to the elimination of the exhaust gas turbocharger, the exhaust system can be consistently further dethrottled. Compared to a diesel engine with an exhaust gas turbocharger, a significant reduction in NO_x and particulate emissions is possible at low engine speeds, particularly during acceleration phases. Handtmann is currently testing this application on an engine test bench with a small-displacement series-production engine. As in gasoline engines, the HSL also achieves higher low-end torque in diesel engines, thus enabling the use of longer and consumption-optimised gear ratios.

SUMMARY AND CONCLUSION

Supercharging with a Handtmann scroll-type supercharger offers a high potential for improving fuel consumption and exhaust emissions in gasoline and diesel engines. What is more, this technology can be combined with start/stop systems or integrated into hybrid powertrains. By applying state-of-the-art development and production methods and using innovative materials, Handtmann has succeeded in adapting the scroll-type supercharger to today's requirements. Its high efficiency even at low engine speeds makes the HSL predestined for use as part of a two-stage supercharging system. At the same time, it is also beneficial when used as a stand-alone application in small-displacement combustion engines.

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