Dynamic Injection Measurement Technology

APPROACH

With the introduction of the diesel CR and DGI technologies, the requirements on flow measurement for engine development have changed over the course of the last two decades. In both research and development and in production, continuous fuel consumption measurement has been complemented by cycle-related injection quantity measurements and the analysis of the corresponding rate curve. Driven by the goals of reducing fuel consumption and emissions, we are currently experiencing a new spurt of innovation in the field of combustion development with a major impact on injection technology and injection measurement technology. As a pioneer in applications for common rail and GDI technologies, AVL remains the market leader in dynamic injection measurement systems thanks to the Shot-to-Shot™ measurement technology.

BENEFITS AT A GLANCE

- Shorter development times: cycle-synchronous correlation of injection quantities and time behavior with the relevant system and engine parameters
- Reduction of measurement times: high measurement accuracy reduces the measurement period on the testbed and on the production line
- Protection of development steps: precise analysis, for example, of minimal quantities and multiple-injections as components of the indicating data collection
- Robust development tool: efficiency due to universal applicability and high long-term stability of calibration

TASK

Decreasing exhaust gas emission limits and the requirements for continuously lower fuel consumption are currently the primary driving forces behind the further development of engine technology. The strategy and precise control of the fuel combustion play a central role. These different focuses require the detailed analysis of the injection rate curve related to the engine cycle:

- The development and production of capable injectors and injection systems requires the accurate analysis of opening and closing behavior. Testing the injector during production requires high precision and long-term reproducibility of injection quantity measurement.
- Today, combustion strategies with layer loading and multiple-injection sequences play an important role in the development of GDI internal combustion engines. The highest measurement resolution of low separation times at low injection quantities pose extreme challenges for the measurement technology.
- The exact optimization of performance, consumption and exhaust gas emissions on diesel engines has become an extremely complex task due to the application of different components for exhaust gas aftertreatment. The precise quantity measurement of multiple-injections, down to the smallest partial injections, has to be implemented in the overall engine map in realistic conditions.

The Shot-to-Shot™ measurement technology is used in all examples mentioned above and, thanks to its superior characteristics, it plays a part in ensuring our customers' products have competitive advantage.

THE COMPETENCE AND EXPERIENCE OF AVL HELPS CUSTOMERS KEEP UP WITH THE RAPID PROGRESS IN INJECTOR TECHNOLOGY AND TO MASTER THE HIGH-TECH PRODUCTS OF TODAY AS EVERYDAY TECHNOLOGIES OF TOMORROW.

REFERENCES

Combustion development on single-cylinder engines

STS is an important contribution to the correlation of characteristic combustion and injector parameters in realistic conditions. The research departments of the most renowned German automobile manufacturers and suppliers are among our customers.

Production testing of injectors

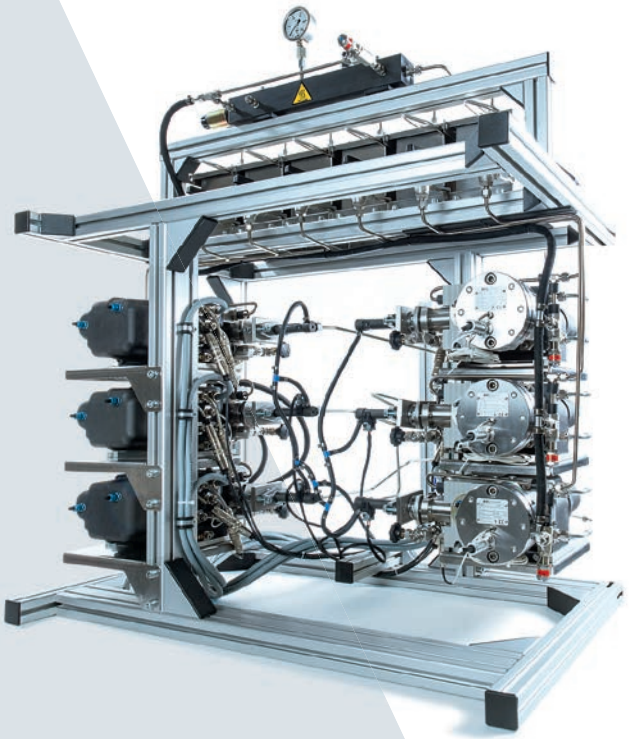
The current challenges with 100% testing of injection quantities are measurement time reduction, minimal injection quantities and achieving the required measurement accuracy. STS serves as the only practical means of production measurement for the market leader in SCR systems.

Engine calibration

The parameterization of the engine controller with map data on the system testbed equipped with STS significantly reduces calibration expenditure on multicylinder engines. As a standard tool, STS has been ensuring the timely and economical implementation of development projects at AVL for years.

Installed base

More than three decades of competence in the field of flow sensory systems. More than two decades of experience in the field of injector testing and more than three years of successful applications of STS measurement systems in a variety of customer-specific applications with widely varying requirements.



GASOLINE INJECTION QUANTITY MEASUREMENT

AVL STS PLU 131 Gasoline

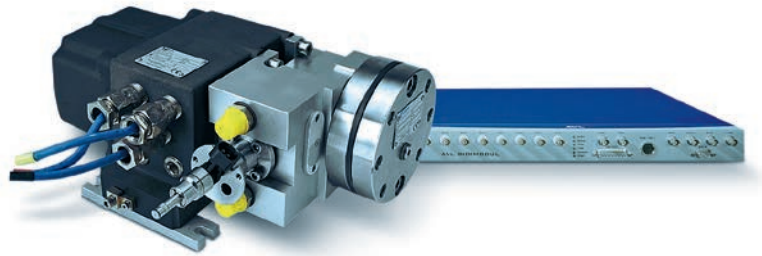
Research and development are two application focuses in the field of internal combustion engines for the AVL Shot-to-Shot™ PLU 131 flow measurement system. In the course of such work, the shot quantity measurement and the details of the chronological rate curve for fuel injection provide valuable findings for the optimization of combustion behavior. Furthermore, shot quantity measurement has become increasingly widespread as part of production testing for fuel injectors.

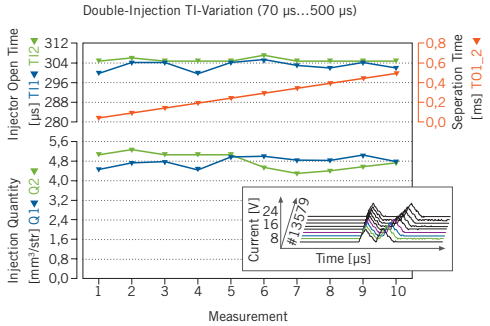
MEASUREMENT PRINCIPLE

The dual PLU measurement principle provides STS with a very flexible hydraulic configuration of the measurement design due to the combination of a rotatory and a translatory positive displacement meter. As a result, the STS measurement system can be used on the high-pressure side of the injector (upstream) and in the low-pressure area (downstream).

APPLICATION

The versatility of STS provides an additional option of a dynamic injection quantity measurement at the operating single-cylinder engine and at the spray chamber, turning the AVL Shot-to-Shot™ PLU 131 flow measurement system into an indispensable measurement tool when characterizing injectors and developing spray image and combustion behavior.
When looking at the example of stratified charge combustion with its cascades of subsequent injections, the importance of these measurement values becomes particularly clear.
However, STS is now also used for 100 % series testing purposes in the manufacturing of injectors for homogenous operation.





Gasoline Upstream – Multiple-Injection Analysis: injection quantity and injector open time measurement of a double injection profile with variable separation time (TI = 70 … 500 µs)

BENEFITS AT A GLANCE

- Flexibility: Applications are possible on both the high-pressure side of the injector (upstream) and low-pressure side (downstream)
- Versatility: Large measurement ranges between flow and injection quantities combined with high measurement accuracy for even minimal quantities
- Shorter development times: quick characterization of prototypes due to shot measurement at the operating engine or spray chamber
- Relevant results: No influence on the injection system due to the instrumentation device principle (Δp = 0)

DIESEL INJECTION QUANTITY MEASUREMENT

AVL STS PLU 131 Diesel

For diesel applications, the AVL Shot-to-Shot™ PLU 131 flow measurement system is used for the research, development and production of injectors, injection systems and corresponding combustion engines.

The connection with the AVL indicating technology family IndiAdvanced offers convenient options for rate curve analysis as part of the indicating data collection. The timing analysis and the minimal quantity measurement in particular are very important measurement variables for multiple-injections during diesel combustion.

MEASUREMENT PRINCIPLE

In diesel applications, the system is used in downstream configuration on the low-pressure side of the injectors at up to 200 bar of counter pressure. The dual PLU measurement principle entails the combination of a rotatory and a translatory positive displacement meter. Using STS, you can determine the injection quantities precisely and also record the rate curves in high resolution.

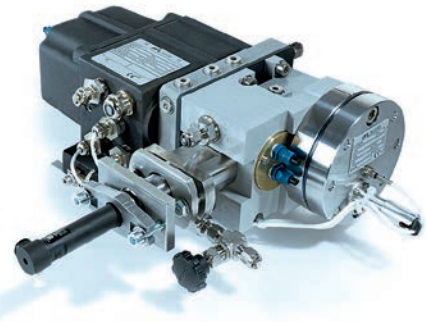
APPLICATION

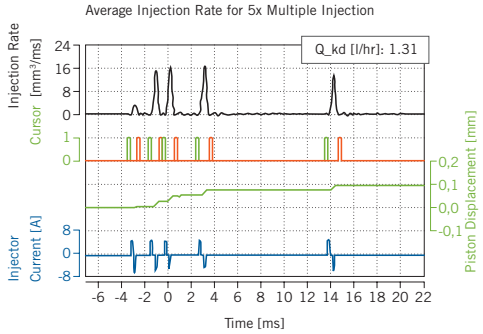
Diesel CR injectors are characterized on component benches regarding injection rate, injection quantity as well as open and closing delay times. Complete injection systems are pre-calibrated during the engine development procedure on the fully instrumented multiple-cylinder system testbed to save valuable development time and costs on the engine testbed at a later point in time.

Renowned heavy duty vehicle manufacturers use STS to optimize their unit-injector fuel injection systems on full HD engine testbeds, for example. Within the framework of 100 % testing of the injector series production, STS satisfies the extreme requirements of a robust, fast shot quantity measurement with high accuracy.

BENEFITS AT A GLANCE

- Compliance with the emission limits through reliable characterization of the relevant parameters to control multiple-injection systems
- Reduction of engine testbed development time for the calibration of injection systems due to pre-mapping of injection parameters on the injection system testbed
- Cost efficiency of the production test due to short measurement times and robust measurement systems
- High relevance due to large operating ranges for pressure and temperature which allow different loads and speeds to be measured under realistic conditions





Diesel Downstream – Multiple-Injection Analysis: injection rate measurement of a typical CR diesel multiple-injection sequence with pilot, main and post injections. Piezo injector current, piston sensor displacement and cursors for quantity measurement are seen below.

UREA INJECTION QUANTITY MEASUREMENT

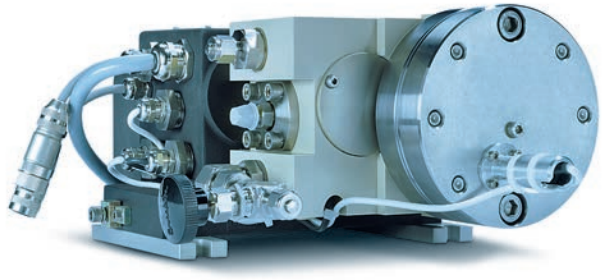
AVL STS PLU 131 Urea

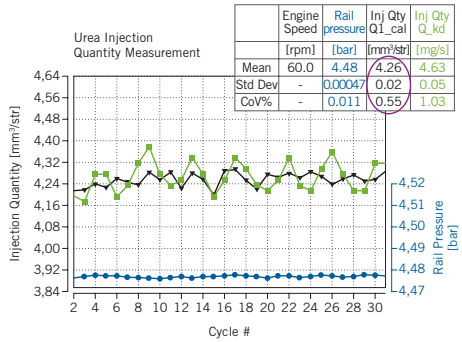
The development and production of SCR injection systems requires precise shot quantity measurement of the urea dosage in the exhaust gas system. In doing so, the characterization and testing of curves and functionality are implemented in an advantageous manner and under realistic conditions for both injectors and complete injection systems.

MEASUREMENT PRINCIPLE

Just like in low-pressure fuel injection, a precise consumption measurement on the undisturbed SCR system can only be implemented at the feed side (upstream) of the injector. The most important difference compared to fuel is the extremely low level of urea consumption, which amounts to only five percent of diesel consumption.

With these extreme requirements, the AVL Shot-to-Shot™ PLU 131 is the only flow measurement system that also satisfies the requirements for measurement accuracy. This is achieved through the dual PLU measurement principle with two complementing sensors for dynamics and injection quantities.





Urea Upstream Injection Quantity Measurement: Injection quantity statistics over 30 injections of an injector characteristic test down to extremely low flow rates of 10 g/h

APPLICATION

To measure the minimal quantities of urea injectors, component testbeds for SCR system development comply with stringent requirements on stability of pressure and temperature conditions as well as the precision of flow measurement. This is the only way to ensure actual injector properties are characterized without interference from error sources. The high level of measurement accuracy at extremely low flow rates as low as 0.01 l/h is also the reason AVL Shot-to-Shot™ PLU 131 Urea has been the only approved means of measurement in the production system of the world market leader for SCR systems since 2006.

BENEFITS AT A GLANCE

- Relevant results: application on high-pressure side of injector (upstream) for shot quantity measurement on low-pressure injectors
- Development safety: high level of measurement accuracy on a broad measurement range with minimal influence on the system
- Production quality: fast and precise measurements at the full range of operating parameters when testing injectors with the 100% test

FLOW MEASUREMENT FOR COMPONENT TESTING

AVL PLU 131F, PLU 131S, PLU 131U

The AVL product line PLU 131 offers a wide range of high precision flow meters for all kinds of applications in various fields of combustion engines. In addition to standard flow meter versions for all kinds of fuels and test fluids, specialized models for water or urea solution are available. Other device types have been designed for high media pressure up to 200 bar and high media temperature up to 150 °C.

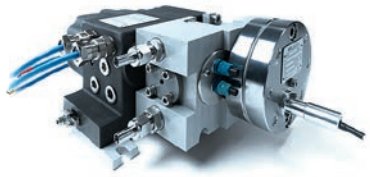
The different measuring ranges cover everything from small quantity measurement of 0.05 l/h to high flow rates of 300 l/h. The measurement accuracy is 0.1 % of the measured value over the complete measuring range of the individual device types of up to 1:500.

MEASUREMENT PRINCIPLE

The dual PLU measuring principle entails the combination of a rotatory and a translatory positive displacement meter. The servo-controlled gear counter determines the flow volume from the rotation. The dynamic piston sensor controls the engine speed and ensures zero pressure difference (Δp = 0) between inlet and outlet. This prevents internal leakage flow in the sensor. Over the complete measuring range, the measuring device generates no pressure difference in the hydraulic system being measured.

APPLICATION

The main fields of application of the PLU 131 are test benches and production lines for automotive fuel supply components. The PLU measurement principle is suitable for pulsating flows and can be applied in direct hydraulic adaptation for the testing of pumps, injectors and control valves on the inlet (upstream) side as well as on the outlet (downstream) side. AVL PLU 131 sensors increase measurement accuracy and reduce measuring time for continuous flow measurement.



BENEFITS AT A GLANCE

- Reduced measurement time due to high-precision flow rate measurement
- High flexibility due to broad range of media compatibility and extremely large measuring ranges
- Reliable results with upstream measurement (high-pressure side) and non-interference between meter and hydraulic system (Δp = 0)
- Low cost of ownership due to outstanding robustness and long-term stability of calibration