Smart software for reliable laser drilling

Laser drilling technology is increasingly proving its worth to the automotive industry. The clever interaction between a **SELF-CALIBRATING** laser processing system's hardware and its software control system serves to optimise the production process and obtain incredibly precise hole diameters.

Figure 1. The ›FocusONE‹ laser system in use

SIMON MOHR, MUHAMMER KÖR, ULRICH GRUSEMANN AND WILHELM APPELT

Lasers have shown themselves to be versatile tools for use in industry and in manufacturing. The flexibility that they offer is a real asset when it comes to implementing Industry 4.0. The fully automated laser processing machines engineered by stoba Customized Machinery are suitable systems for micrometre-scale laser drilling applications – individually formed holes are drilled using femtosecond lasers in a process that does not produce burring and does not adversely affect the material properties through the generation of heat. Intelligent software ensures that the laser systems deliver high production quality.

Process optimisation: Cost, precision and reliability

Process optimisation, and in particular process reliability, are of the utmost importance to the automotive industry. The following use case of one of the world's leading automotive accessory manufacturers perfectly showcases the laser process's capabilities. The customer's objective was to speed up the production of fuel injectors and significantly reduce the reject rate. They wanted to process two different workpieces with different drilling patterns. The manufacturer looked into various methods, such as EDM hole drilling, but they were put off by the relatively high process costs and long set-up/take-down times that these options entail.

The prospect of a customised ›FocusONE‹ laser processing system **(Figure 1)**, on the other hand, ticked all the right boxes. Its holistic machine concept, featuring an integrated five-axis scanning system for laser microprocessing – engineered by Puchheim-based company Scanlab – made it a clear winner.

A system that allows for micrometre-scale machining of two different workpieces, each with up to 15 different drilling pattern variants, was designed for the automotive customer. Additionally, the pre-defined drilling recipes are able to automatically undertake micrometre-scale corrections to the diameter.

> CONTACT

MANUFACTURER
SCANLAB GmbH
D-82178 Puchheim
Tel. +49 89 800746-0
info@scanlab.de
www.scanlab.de

stoba Customized Machinery
D-87700 Memmingen
Tel. +49 8331 98487-0
sales@stoba-memmingen.de
www.stoba.one

Figures: Scanlab

	Transmission timing	Data quantity	Usage
Ethernet interface	Asynchronous	Large	Process preparation/ process adjustment
EtherCAT interface	Field bus timing	200 bytes	Process control and process monitoring
PLC interface	10 µs	10 bits	Process start-up and laser control

Figure 2. Overview of the scanning system interfaces

Scan system is easy to integrate

One of the major benefits, as far as integrators are concerned, is the ›precSYS‹ five-axis microprocessing system's cleverly conceived interface concept, which allows for fast, easy integration into various different machine concepts **(Figures 2 and 3)**. The Ethernet interface is used for tasks at the preparatory stage of the process, e.g. for sending laser jobs in the form of XML files to the scanning system. Laser jobs define the movement of the focal point within the work envelope using metric units. Once the XML files have been sent to the laser optics, they are validated to make sure that the laser jobs that have been loaded are properly defined and that they can be executed. When they are uploaded, laser jobs are each assigned a unique ID, which is used, for example, for addressing and selecting laser jobs via the EtherCAT interface. While workpieces are being processed by the machinery, other laser jobs can be updated or loaded onto the precSYS via the Ethernet interface.

The scanner can be integrated directly into a machine control system via the EtherCAT interface. The machine control system continuously and cyclically controls and monitors the on-going process. Control commands are issued to the precSYS by setting certain bits in the process data stream. For command sequences, the handshake method must be used: After the first command has been sent, the EtherCAT master waits for the corresponding response from the scanning system. The machine control system monitors the process data stream before further commands are sent **(Figure 4)**.

A PLC interface with a super-fast response time enables low-level access to the RTC5 control board, which in turn allows synchronous control of the integrated scanning units, laser and other peripherals. The PLC interface is used for tasks such as starting laser jobs. It is so responsive that jobs from multiple precSYS systems can be started at the same time **(Figure 5)**.

Figure 3. Integration-friendly interface configuration on the ›precSYS‹ five-axis microprocessing system

Benefits of interaction between soft- and hardware

The system consists of both software and hardware components. The scanning system plays an important part in the machine solution. The integrated five-axis microprocessing system is designed for the high-precision drilling of micrometre-scale holes. The ultrashort pulse (USP) lasers produce holes that are not only incredibly clean but also burr-free. Depending on the customer's production procedure, the parts generally only need minimal cleaning afterwards. The scanning system focuses the laser beam on a spot approximately 20 µm in size where the material is to be drilled into. The precSYS's five axes allow the focal point to be adjusted and enable the beam direction to be precisely controlled, with the possible angle of incidence ranging from -7.5 to +7.5°.

▶

Figure 4. Handshake method for control commands

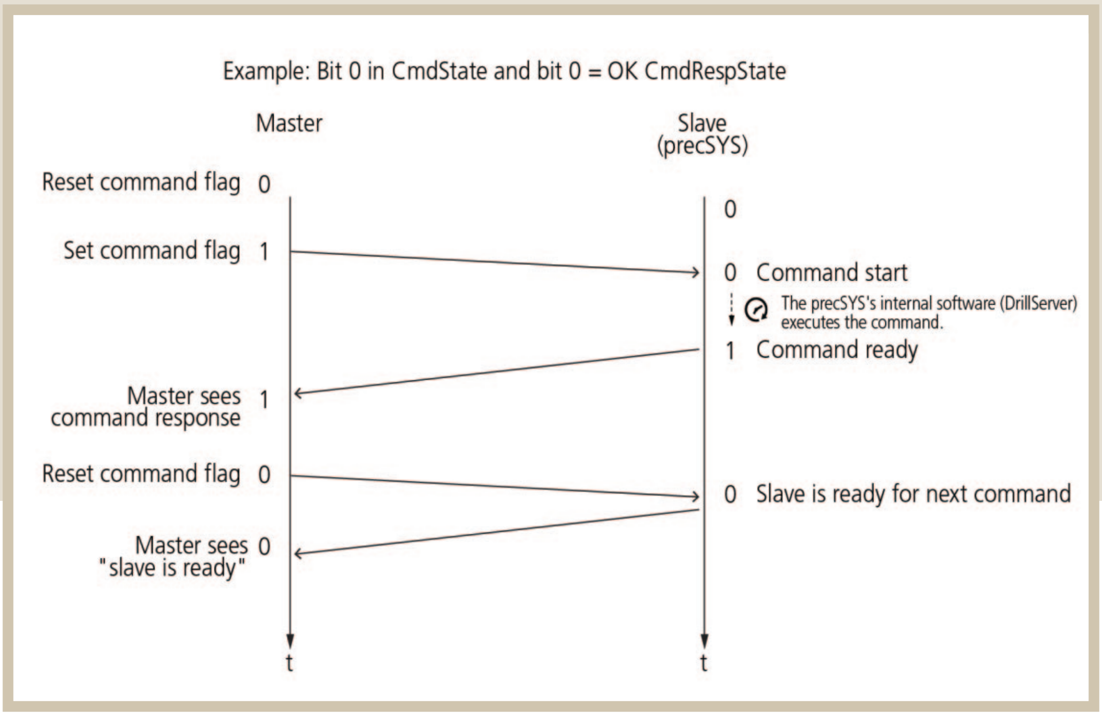


Figure 5. Typical workflow in job mode

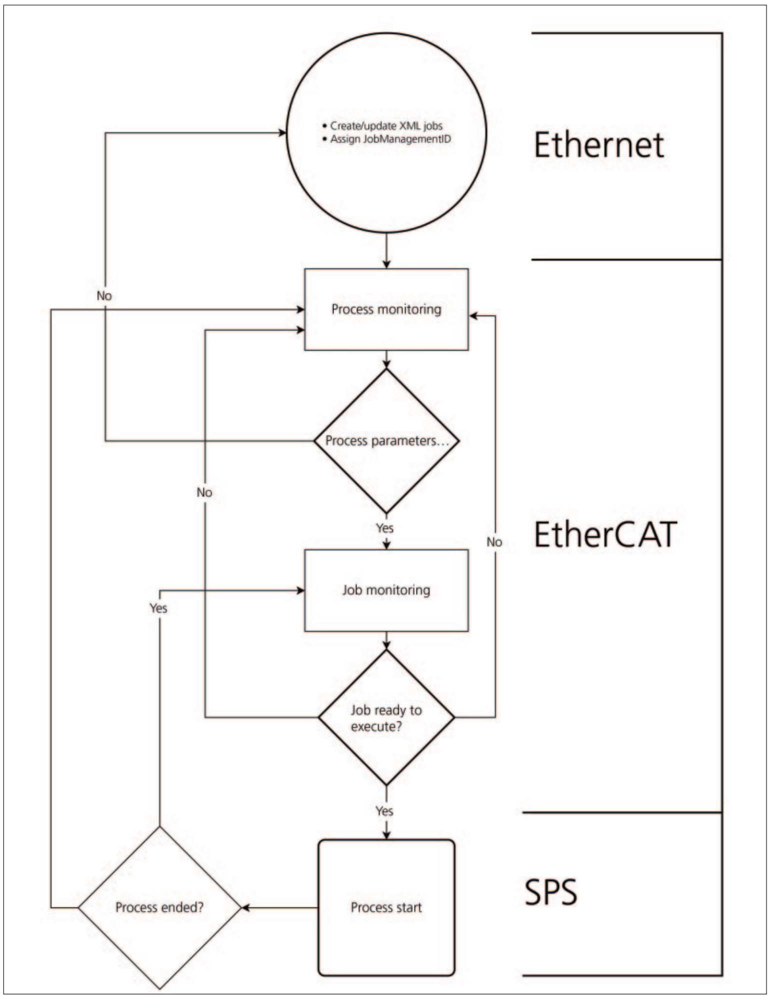


Image field calibration and fine adjustment

Before leaving the factory, every scanning system is calibrated to a high degree of precision. Using a visual model, the scanner control system calculates the system-specific calibration data and the target values for the five system axes based on the Cartesian target positions. By optimising the commissioning process when integrating the scanning system, the customer can reproduce the degree of precision with which the image field was calibrated at the factory. The user will be assisted in this process by experienced service personnel. The most important steps in the commissioning procedure are as follows **(Figure 6)**:

- Setting/checking the following laser beam parameters: Diameter, divergence and polarisation,
- Calibrating the laser beam at the scanning system's entrance, and
- Calibrating the laser beam at the scanning system's exit using the fine-adjustment unit.

The fine-adjustment unit is crucial here. When the system is calibrated at the factory, the position and angle of the calibration laser beam are measured in the home position by a 4D beam position sensor and saved as a reference in the scanning system. This reference point can then be used whenever needed to recalibrate the process laser beam in the customer's system to the system's optical axis – this must be done by correctly positioning the precSYS's galvanometer scanners. The fact that a scanning system can be so precisely calibrated and finely adjusted to a saved reference point has been instrumental in realising sophisticated machine concepts such as stoba's FocusONE. Against a backdrop of constantly evolving demands on processing machines, Scanlab is continually developing both the software-aided integration and the calibration processes of scanning systems.

Figures: Scanlab

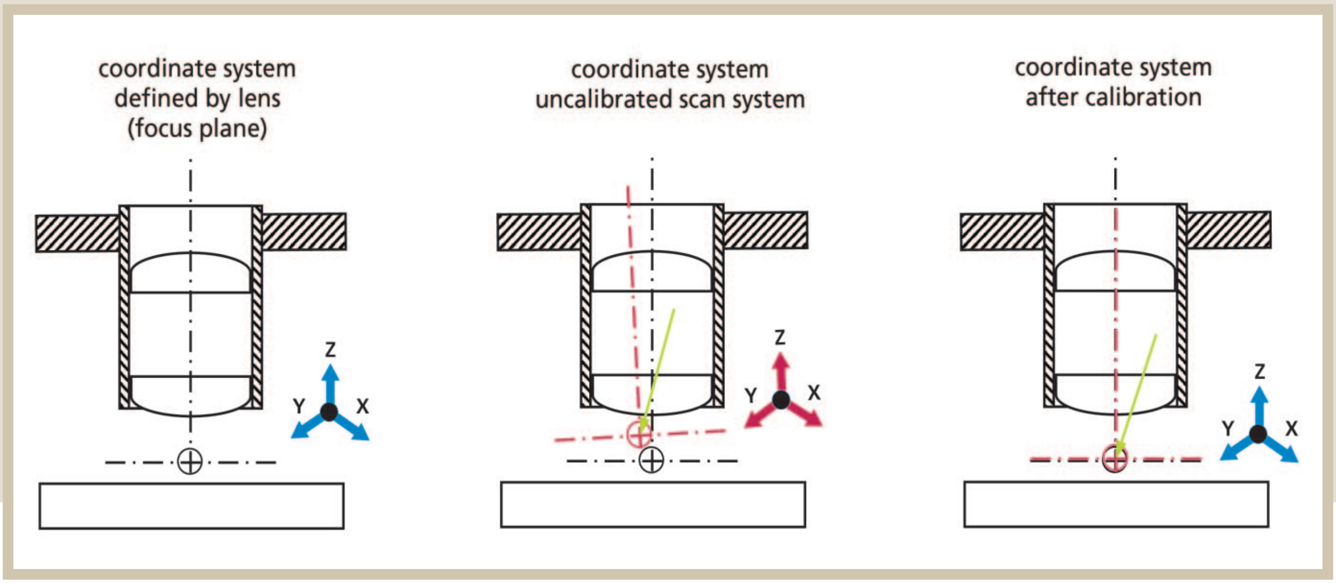


Figure 6. Commissioning the scan system with beam position sensor

Defined procedure and low reject rate

The component type and the required hole variant can be selected at the touch of a button. There is no need to re-equip the machinery at this stage – it is only the parts handling system used for both component types that must be re-equipped when changing component types. It will take experienced workers around 5 minutes to re-equip the parts handling system; workers do not require any prior knowledge to learn how to do this.

Optical measuring systems in the system check that the workpiece material is the correct thickness. Workpieces that fall outside of the tolerance are rejected before the laser processing stage. This prevents these defective components from under- ▶

COMPANY PROFILE

Supplier | Micromachining

3D MICROMAC

Products | Services:

- Laser micromachining systems for various high-tech applications
- Laser-based ablation, structuring, drilling, cutting, and surface modification
- Laser process development
- Laser contract manufacturing

Key Markets:

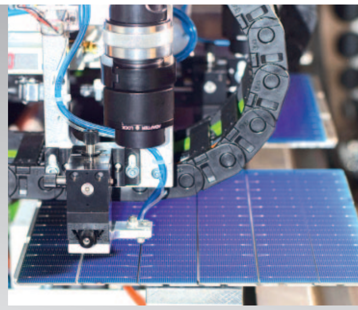
- Glass and Display
- Automotive & Sensors
- Photovoltaics
- Medical
- Semiconductor
- Advanced R & D

> Contact

MANUFACTURER
3D-Micromac AG
D-09126 Chemnitz
Tel.: +49 371 4004 30
sales@3d-micromac.com
www.3d-micromac.com

microFLEX™ roll-to-roll laser system for processing of flexible substrates

3D-Micromac's showroom and application center



microCELL™ MCS – high throughput laser cutting system for half- and shingled solar cells

3D-Micromac – Micromachining Excellence

3D-Micromac is the leading specialist in laser micromachining. Our team of experts develops processes, machinery and complete systems at the highest technical and technological level. 3D-Micromac systems have been successfully implemented in various high-tech industries worldwide. This includes photovoltaic, semiconductor, glass and display industry, micro diagnostics, and medical technology. Our target is to completely satisfy customer demands even on the most complex projects. In the field of laser contract manufacturing, we offer the customer-specific development of laser processes as well as the contract manufacturing of components and workpieces for small and large series.

3D-Micromac adheres to high-performance and future-oriented micromachining processes at high production efficiency. Our technologies have set international standards for true innovation. Since we place great importance on continually expanding our know-how, we are diligent about keeping up with the latest research. On a daily basis, we combine recent results with our customers' demands to realize them in practice.

The Company

The two workpieces used have separate feeds and undergo separate separation processes – this means that, at this stage, there is no need to re-equip the machinery. when changing workpieces.

At the next stage, both workpiece types can share the same parts handling system; it will take trained/experienced workers approx. 5 minutes to re-equip the parts handling system for the other workpiece type. All this involves is undoing 14 screws. Workers therefore do not require any prior knowledge to learn how to do this task.

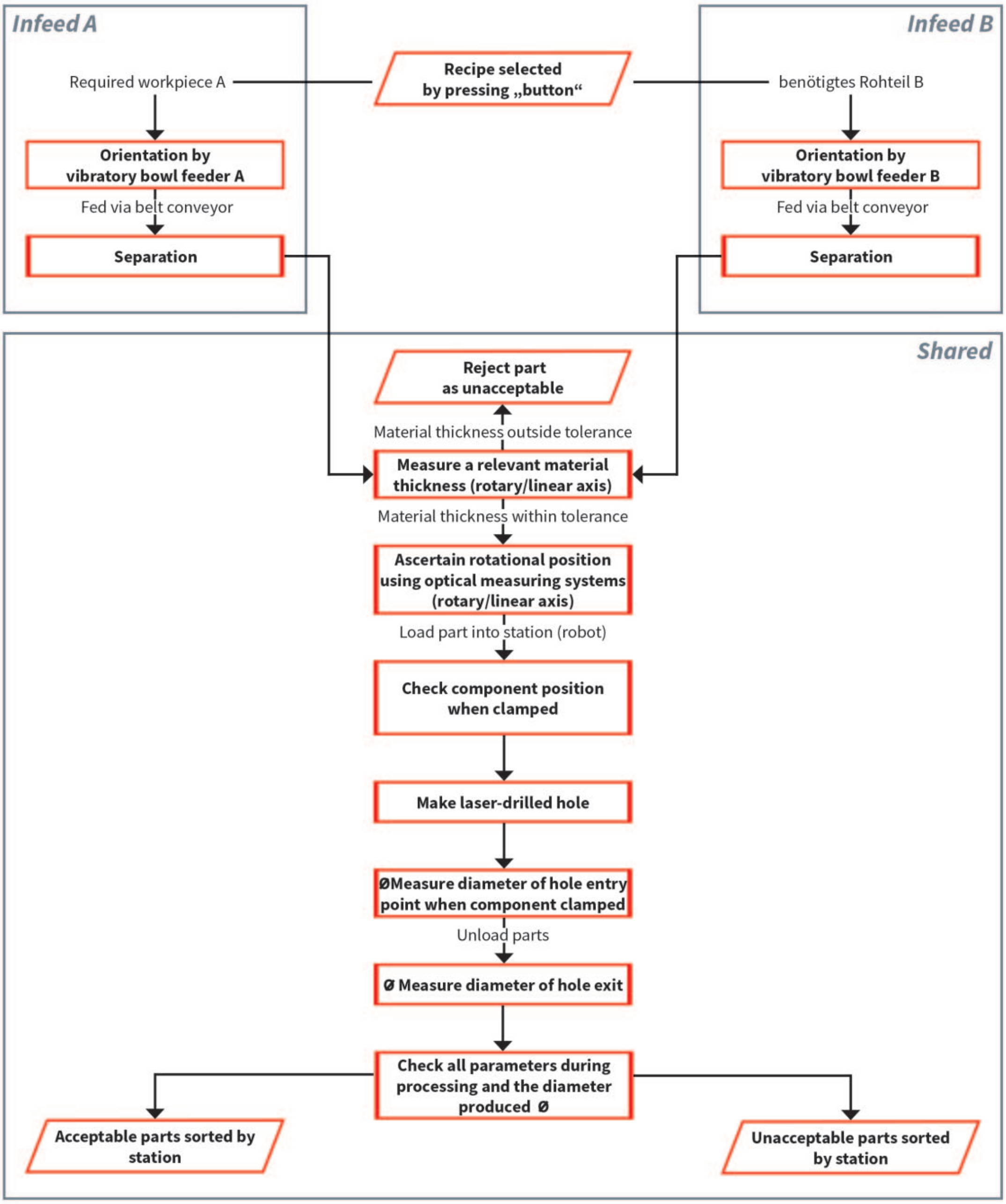


Figure 7. Workflow for the FocusONE

mining the value creation process further down the line. Additionally, the component's rotational position is measured to ensure that it is correctly positioned with respect to the drilling pattern. In the next step, a robot loads the workpieces into the station. The component's position is once again checked while it is clamped in place. Once this stage is complete, the laser processing stage can begin. The diameter of the drilled holes is automatically measured both at the hole entry point while the workpiece is clamped in place and at the hole exit **(Figure 7)**.

AI for further process optimisation

Other important machine parameters are measured, checked and documented at the same time, e.g. the laser power and the temperature. To optimise the system's profitability and productivity, it has been updated to feature automatic hole diameter correction. The software that is used to operate the overall system plays a central role here. A camera measures the diameter of the drilled holes and sends the measured values to the machine software. The machine software collates the actual data pertaining to the holes. This data is analysed using a strategy that has been specially devised for the component in question. Thus, for example, outliers that are attributed to measuring errors can be excluded. Any negative trends can also be identified. Based on the identified trend, the hole diameter can be adjusted in the laser recipe in order to halt the trend or even reverse it. The machine also learns from past trends.

Figures: stoba

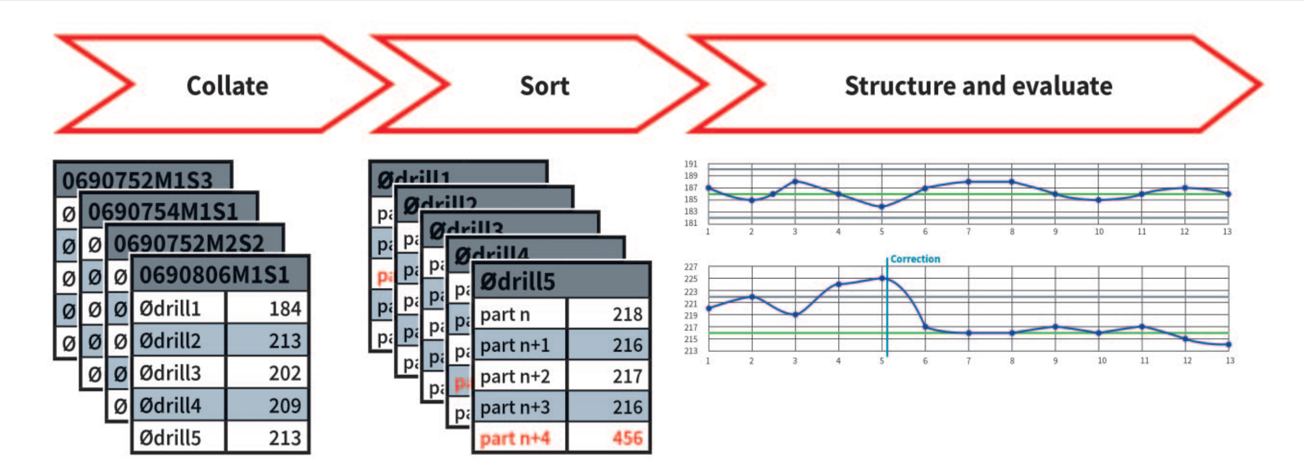


Figure 8. Diagram showing automated correction process

If there is already an exact match, the machine will be quicker to react. The machine software sends the raw data for the required parameters to the scanner control system via the Ethernet interface in real time in the form of an XML file. This means that corrections can be made between two components at any time, even with a cycle time of less than 8 seconds **(Figure 8)**.

Up to 99.7% availability

Stoba provided the company with on-site support, assisting them with the commissioning process and guiding them through the production process on their FocusONE. For 6 weeks, Simon Mohr, project manager at stoba, was on hand to offer the automotive supplier help and advice. A few weeks later, the user was fully conversant with their new system. The processes are stable. In parallel, the system is monitored with automated parameters in order to continually optimise service and support. This is particularly useful in the event that a malfunction is reported, as it enables the issue to be resolved as efficiently as possible. The focus is always on how the customer can eliminate the problem themselves, thereby avoiding production stoppage. In most cases, any malfunctions that are reported can be rectified directly via a body cam and remote support service. Additionally, preventative maintenance is scheduled with the customer to comply with the specified maintenance intervals. The schedule takes into account production cycles and allocates time and in-house human resources to the task.

An optimised set-up makes all the difference

The bespoke system has provided the automotive supplier with a solution that is perfectly tailored to their specific requirements. Indeed, it actually exceeded the original requirements. Besides a reduction in the component reject rate, the customer also benefited from more streamlined production processes and shorter set-up/take-down times. Additionally, the system was set up so that production stoppage could be prevented through timely intervention. Operators receive prompt warnings and error messages, enabling them to continue series production uninterrupted and without any issues.

How this can benefit other industries

Stoba's expertise can benefit industries beyond the automotive sector and is easily transferable to other markets. Components with nozzle-shaped holes can also be found in medical products such as inhalers and needles, for example. Filters and the delicate mechanisms of luxury watches also have micro-holes. Furthermore, the scanning system that is used allows holes to be drilled with other cross sections besides circular, including elliptical, funnel-shaped, rectangular, or any other geometric shape. In other words, it offers a suitable solution for a wide range of applications. ■

AUTHORS

SIMON MOHR is a laser technology expert at stoba Customized Machinery in Memmingen, Germany; simon.mohr@stoba-memmingen.de

MUHAMMER KÖR is Head of Sales at stoba Customized Machinery in Memmingen, Germany; muhammer.koer@stoba-memmingen.de

ULRICH GRUSEMANN is an application developer at SCANLAB in Puchheim, Germany; info@scanlab.de

WILHELM APPELT is a software developer at the same company; info@scanlab.de