Pushing the frontier of automation

Robots and digitalization for stable processes

Robotics is no rocket science anymore. Affordable and reliable modules reveal new views on automation. Experienced equipment-suppliers profit from the opportunities. Based on existing process know-how robotics merges with Industry 4.0 and empowers highly efficient and stable production equipment of the next generation. Labor cost reduction is by far not the only benefit. Automation basically stabilizes processes. Combining it with digital tools and smart metrology, real-time quality data can be generated and processed in an unprecedented way. Feedback of this output into the process will raise the level of process stability and quality significantly. Stable processes and high quality-levels are the bedrock of competitive production in high wage countries. In other words: robotics and digitalization are the tools to secure the future of high-quality production sites. *By Peter Weber*

The complex process chain in ophthalmic lens production is subjected to innumerable influencing parameters along each single process step. Single deviations of these parameters may sum up to severely reduce the quality of the final product, the spectacle lens. Thus, in theory, one gains control of the process by measuring and monitoring each parameter in a control chart and instantly reacting on significant deviations with adjustments.

Automation meets digitalization

Let us consider a very simple example. The control parameter "temperature" is measured by a sensor within a curing oven. This parameter is fed back into the temperature control electronics, which in turn change the magnitude of the parameter "heating current". By this the measured temperature is adjusted towards the target temperature. In this case, the process control is straight forward.

Now the next step is to monitor the more or less fluctuating temperature and connect the actual oven temperature to each lens (or batch) in a database. This is the key to connecting deviations in quality with fluctuations along the process chain.
The data monitoring is, for this example of a simple temperature-reading, just a technical question of connecting the sensor output to a digital database. Still, if your process depends on many such parameters, the systematic monitoring becomes a challenge.
On the other end of the complexity scale, consider the inspection step of the lenses after surfacing: in that case the measured data do not only consist of a "few" overall parameters. For each lens an enormous amount of data is created, each calling for elaborate algorithmic evaluation. On top of that each lens needs individual handling to be positioned precisely in the sophisticated metrology setup. In this environment, the combination of robotics and digitalization unfolds its full benefit.

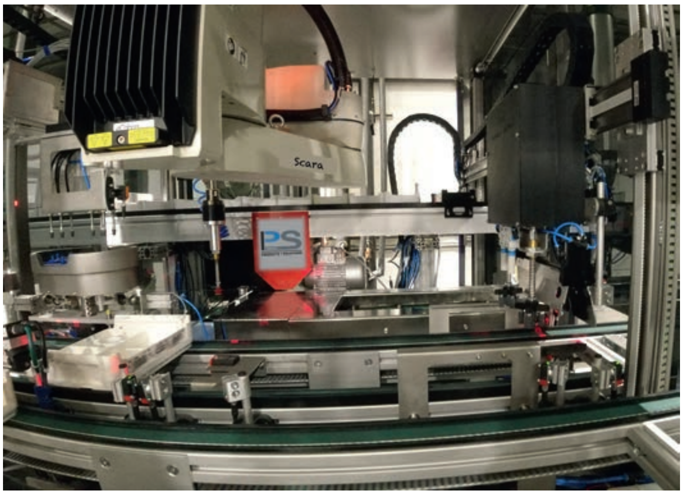
Strong process knowledge is a must

We all know that the exact measurement of all parameters along a process chain can never be obtained. And subsequently, the exact control of all influencing factors is not possible. The great challenge in mastering processes is the determination of those parameters which influence process stability the most. Thus, no matter what sophisticated metrology or data-analyzing tools you use, the groundwork is sound process engineering with a deep understanding of the interdependencies within and between process steps. This is one core message of Jürgen Krall (IMACO Products and Solutions), based on years of experience in automation: one can only harvest the benefits in the field of robotics and digitalization with a strong understanding of the processes.

Robots enable real-time process control

Proper understanding of existing processes yields well-defined interfaces for the new approaches of robotics and digitalization. We all know how tedious it can be to control a process based on three-times-a-day handwritten temperature and conductivity tables.
For real-time process control it is inevitable to have all the relevant data available in digital format. Basically, the lab becomes an internet of things (IoT). Every piece of equipment, every gauge, every sensor needs to be connected to a central database. And, as mentioned before, in many cases this data acquisition on a large scale cannot be integrated into the existing process just "en passant". Many key-measurements require extensive handling. This is the reason why new prospects of robotics and automation open completely new ways for the equipment suppliers.

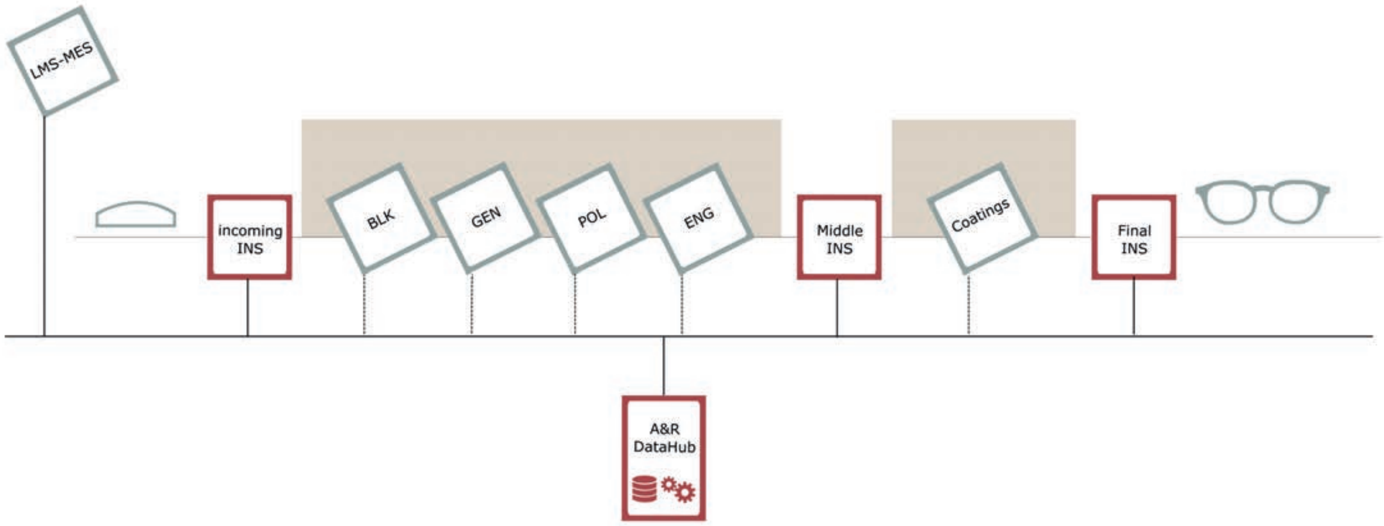
In the last years, many equipment manufacturers extended their R&D activities into the fields of software and data management. Dr. Christian Laurent, head of development at A&R, reports that just recently his company rolled out a newly developed DataHub in the field. The core of the system is a central database which directly communicates with the lab's metrology about product quality and constantly feeds these data into intelligent analytical algorithms. By means of automation and digitalization an enormous amount of data can be evaluated statistically in real time, yielding patterns and interdependencies, which in turn can be fed back to control the production process. Fluctuations in the process can be compensated before there is any violation of customer's specifications.



Glimpse into the handling unit before brush cleaning. Source: J. Krall, IMACO Products and Solutions

Robots master complex handling steps

In the context of merging automation with metrology, it is worthwhile to take a look at the interface between the surfacing process and coating. Krall describes an amazing ensemble of robotics and image recognition. In the past an operator manually moved lenses from job trays onto the conveyor belt of the brush-cleaner. In that movement, by a brief glance, the operator checked the lenses for damages or unacceptable residues after pre-cleaning. In parallel the operator moved the job ticket from one tray to another.
The challenge is the complexity of the seemingly simple human work step. In this case, according to Krall, the solution is a linear system for the ticket transfer, a SCARA (selective compliance assembly robot arm) robotic system for the lens handling, and a simple CCD camera system for the inspection. Krall points out that there are a lot of human motion sequences which, in terms of speed, no robot could reach.
The key point in fact is that a robot does a motion sequence always in the same way, independently of factors like personal fitness or the operator's training. When considering process stability,

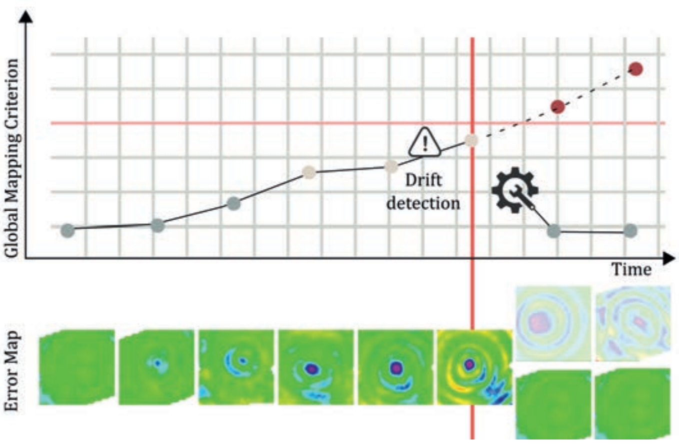


Central process-data management: the A&R DataHub collects and shares statistical product and process metrics. Source: C. Laurent, A&R

this is of cause the decisive advantage. And this is particularly eminent for a visual inspection step. Evaluation algorithms for the CCD-data define quantitative and measurable criteria for allowed and not allowed residues or damages. A visual inspection by operators always leaves space for subjectiveness.
Thus, the combination of robotics and software-based camera inspection boosts the quality of the available process data. It is less probable that unsuited lenses are processed onwards, and the quantitative data can be used for quality tracking and continuous improvement.

Robots help create mass data

Laurent provides another vivid example of how automation is the enabler for metrology. He describes the possibilities of a control chain for the free-form surfacing process. A survey of each lenses' power-map in automated inspection right after deblocking yields an error map for each single lens. This is a colored map of local deviations with respect to the target surface.



Real-time process control loop stabilizes lens quality and productivity: Violation of specifications (hor. red line) is anticipated, and corrective actions (after vert. red line) readjust the process proactively. Source: C. Laurent, A&R

Based on such error maps, design deviation datasets are computed. Primarily this allows to individually tolerate each lens.
But the essential feature in connection with the DataHub is the statistical evaluation of all error maps of all lenses. As the expected (i.e. tolerated) deviation for each position on the lens is not a constant over the whole surface and also differs from lens to lens, it is quite sophisticated to calculate. But by analyzing each individual free-form against the actually measured error-map, smart algorithms can, by application of certain criteria, draw conclusions on the stability of the front-up free-form surfacing process.
By these analytical means it becomes possible, in real time, to trace systematic deviations back to certain process steps, certain machines, and certain root causes, and to instantly adjust the related process parameters in the surfacing process.

To gain even more process control and to improve lens quality, Laurent suggests to measure the front surface of each semi-finished lens before it enters the free-form surfacing. According to his experience these surfaces tend to deviate significantly from the specifications. On the one hand the free-form parameters for each lens could be instantly and individually adjusted to yield better free-form results. On the other hand, knowledge of the exact initial state of the surface before free-form processing greatly increases the efficiency of the previously described process control mechanisms. An essential factor for the creation of this enormous amount of data is smart automation of the complex measurement workflow.

Robots support statistical process control (SPC)

Philippe Vaudeleau, CEO of FISA, manufacturer of cleaning and hard lacquer equipment, regards automation as part of his company's DNA. By now FISA equipment only comes

Fully automated in-line cleaner with a combination of two robots and a linear handling system. Source: P. Vaudeleau, FISA

with fully automated processes. Apart from the reduction of labor costs, for Vaudeleau stabilization of processes is the greatest benefit for his customers from automation. Automation is closely linked to digitalization and process data acquisition.

The fully automated FISA equipment is designed with a range of sensors to feed all the relevant process data into a central database in real-time. This opens up completely new opportunities for statistical process control (SPC). Process data are directly accessible for evaluation, yielding control charts for everybody in real time, allowing statistical evaluation, and establishing the direct link to the quality data of each respective lens.

Vaudeleau enthusiastically reports about the extra possibilities, which arose at customer's sites, where RFID-tagged job trays were already implemented. But also for the classic paper production card, the link between each individual lens and the respective process data can be easily done via the classic barcode scanning.

From robots to cobots

Vaudeleau sees the need to stay ahead of technology as one of the biggest challenges for a company like FISA in the context of robotics and automation. R&D has a strong position in the group, reporting directly to the CEO, with roughly 10% of the company's turnover going back to the central development site at Milan.

FISA developers rely on a combined strategy of linear handling systems and 6-axis robots (or, more specifically: cobots). The flexibility and adaptability of the robot is necessary to grab lenses from the tray, lying there in a more or less undefined position. The high-precision linear system on the other hand is the proper choice for a critical process like extracting the lenses out of the lacquer. Concerning robots, FISA recently made the step towards cobots.

Collaborative robots are equipped with advanced sensors and safety features that allow humans to work right next to it, while a classic robot represents a severe hazard to human personnel and needs to be kept separately. The rise of cobots, as Vaudeleau estimates, will have significant impact on the degree of automation in ophthalmic industries. For small loads like spectacle lenses, cobots are sufficiently affordable and fast enough by now to play a major role.

A&R, FISA and IMACO incorporate decades of experience in the specialized market of spectacle lens production. They represent the archetype of equipment suppliers in this segment. Based on their process knowledge, they all heavily rely on three paradigms: first, keep hardware simple to ensure feasibility on the shop-floor. Second, put the complexity into the software and the data acquisition. And third, embrace the new possibilities of robotics, automation, and digitalization to stay ahead in terms of quality and costs. Common expectation is that with cheap, easy-to-maintain, easy-to-program cobots, the remaining gaps of automation along the process chain of lens production will soon be closed. ◆

Interview Partners

1. *Dr. Christian Laurent, R&D Director Automation & Robotics: manufacturer of equipment for accurate measurements, process control and automation in ophthalmic industry. www.ar.be*

2. *Jürgen Krall, IMACO Products + Solutions GmbH: 20 years of experience as general manager in the field of industrial equipment and expert for automation. www.imaco-ps.de*

3. *Philippe Vaudeleau, CEO, FISA Group: supplier of cleaning and hard-lacquer coating equipment for the ophthalmic industry and other fields of manufacturing. www.fisa.com*

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