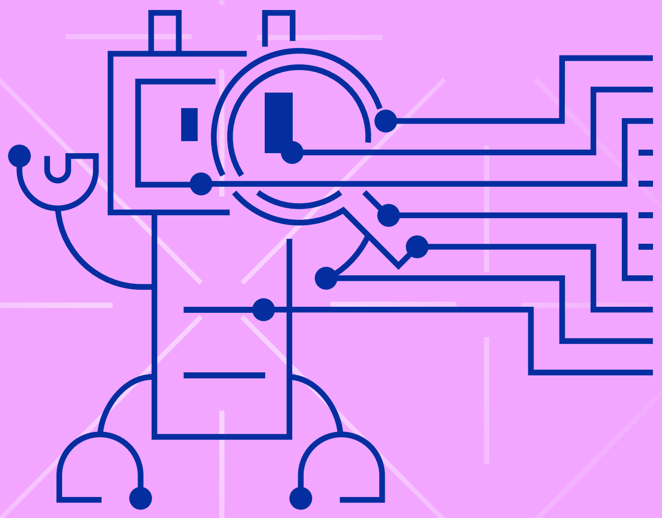
Developing Real-Time, In-Mold Process Monitoring

This is the story of how a German company with over a half-century of experience producing scientific instruments to quantify material behavior and verify quality assurance for parts made with those materials entered Industry 4.0 by developing a real-time, in-mold process monitoring system that is both material and process agnostic, yet provides molders with the very data they most need to better control their processes and unlock higher productivity to compete in global markets.

By Dr. Alexander Chaloupka, Managing Director & CTO sensXPERT



sensXPERT®

EXPAND your sense of the possible

The constantly changing world of manufacturing

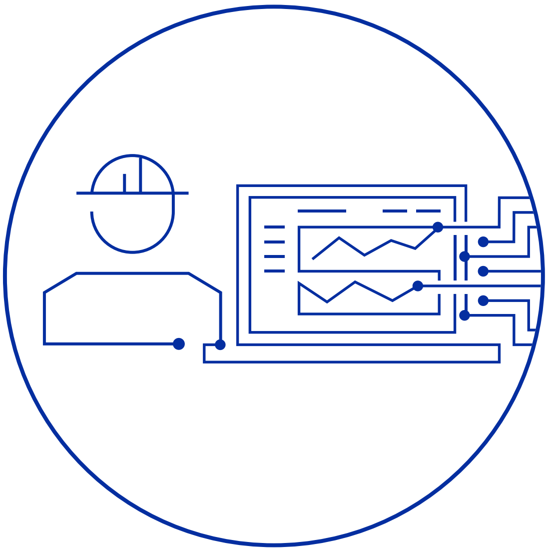
The manufacturing sector globally is in the midst of a profound change. It is not just increased regulatory pressures, globalization, competition, and pressures to produce products more sustainably, which manufacturers have had to contend with for several decades.

And it is far more than the pandemic-related shipping delays, raw material shortages, fragile supply chains, and issues filling open positions in plants that have characterized the past few years. It also is that manufacturing itself is in the midst of its fourth major reinvention: Industry 4.0.

This revolution is characterized by the ongoing digitization of design, engineering, and production – which drives greater productivity and sustainability with a smaller carbon footprint. However, it also enables and, in fact, necessitates unprecedented transparency, collaboration, and sharing among members of increasingly agile and interconnected supply chains.

To participate, leading manufacturers are turning to a new set of technologies, including data analytics, enterprise cloud computing, artificial intelligence/machine learning, automation and robotics, automated workflows, industrial internet of things (IIoT), edge computing, digital twins, and new levels of cybersecurity.

There are few areas of the manufacturing sector that have not been affected by this transformation, and any company attempting to develop new technology to increase manufacturing productivity must be Industry 4.0 compliant if it hopes to succeed long term.



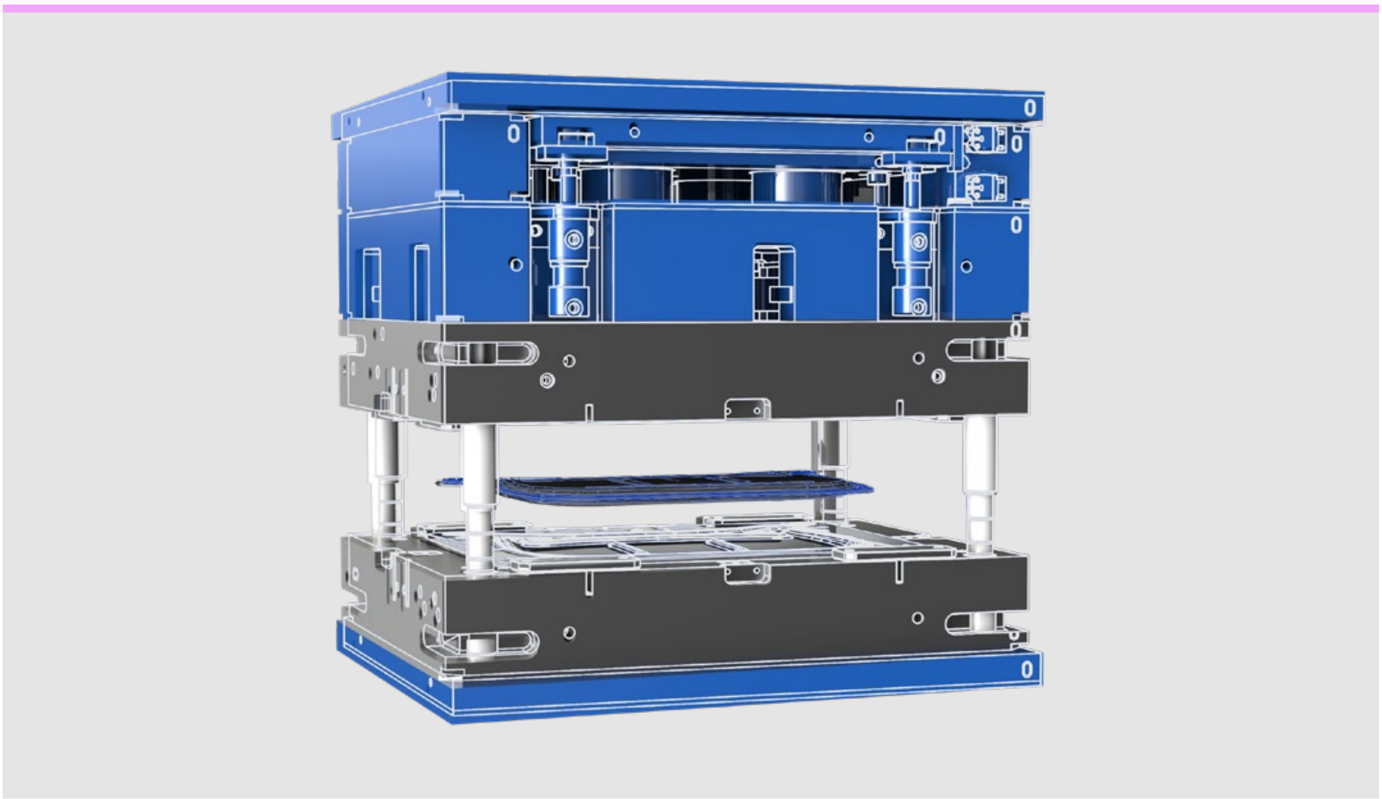

ANALYTICS DASHBOARD
REAL TIME

Why it is difficult to help molders become more productive

Given the ever-present cost pressures that plastic processors face, there are few broadly available tools to help them become more productive that are not limited in use to specific polymers or specific processes or both, and that provide real-time information not information after the cycle is complete and a good or bad part has already been produced.

This is especially true on the thermoset side or when reactively polymerizing thermoplastics, where a far more complex set of interactions occurs in the mold (i.e., polymerization and, with thermosets, crosslinking) that are also more affected by conditions outside the press (e.g., ambient temperature and humidity, age of the material, conditions under which the material was stored prior to processing, and temperature balance inside the mold).

To control such processes, molders need access to multiple streams of materials characterization data accessible at any point throughout the molding cycle. Unfortunately, most receive little more than in-mold temperature and pressure readings, and those are not always very accurate. The situation is further complicated by the large number of polymer grades and process variants in use in industry today. Additionally, it can be challenging in a conservative manufacturing environment that tends to use problem-solving approaches based on trial and error to implement new solutions that rely more on digital tools than physical ones. And there are other challenges too.



Machine and process issues

The same material running in identical molds mounted in identical model presses of the same age placed side-by-side in the same facility will each exhibit process drift from the other presses over time – and that is in a single facility with each mold and press experiencing the same ambient conditions. For multinational processors with facilities in multiple countries operating under different climatic conditions, the situation becomes even more complex – particularly when thermosets are being processed. How does a molder servicing a global automotive program ensure that parts being molded in Germany, Mexico, and China using materials, molds, and presses from different suppliers are all the same and will meet program specifications when produced in cool damp, hot dry, and hot humid conditions simultaneously?

Another issue is that most molding processes are neither self-monitoring nor self-adjusting. Rather, teams of specialists must monitor process parameters and, relying on their experience, manually adjust equipment as the process begins to shift. As has already been noted, many conditions inside the mold and outside the press can affect how material is processing from one cycle to the next, let alone from one shift to the next and in different countries on different continents. Due to process complexities and the number of variables that can affect process and, therefore, part consistency, the support of experts is needed to monitor molding conditions and modify press settings as the process starts to drift. Unfortunately, many regions are experiencing shortages of skilled labor as experienced staff retire and too few well-trained junior workers are available to replace them.

Equally challenging can be a general lack of transparency along each process step by various members of the supply chain and insufficient education among supply chain members about thermoset materials (and the factors affecting them). And still other issues also need to be addressed.

Datasheet data are insufficient

Today's plastic part designers and processors rely heavily on in-house materials characterization, modeling and process simulation, the knowledge and skills of experienced molders, and datasheets from materials suppliers. Information in such datasheets is necessarily limited, being monotonic (single-point) data measured at a particular time, temperature, rate, and load. Therefore, such data cannot be used to interpolate or extrapolate to conditions other than those under which tests were conducted – which are rarely the conditions parts experience in the real world.

Furthermore, quality assurance (QA) testing takes place after demolding and downstream from molding operations. There can be a considerable time delay between opening of a mold and characterizing the demolded part – sometimes in a physically different location. Rather than be alerted while a molding cycle is still underway that conditions are starting to drift and unacceptable parts are likely being produced – ideally early enough that a technician can modify process settings to ensure acceptable parts are produced that cycle and the ones that follows – with downstream testing, molders can produce many defective parts before being alerted to an issue. This leads to a significant waste of time, energy, and material – conditions hardly ideal given the cost and quality pressure molders face from OEM customers.

Reaction kinetics & its missing link

Another problem is that traditional reaction kinetics equations, which industry has relied on for decades to predict the behavior of polymeric materials during processing, are not accurate enough and do not account for all the influences – such as shear behavior between runner, nozzle, and tool, and permanent stressing of material due to pressures induced during processing – that can affect final part performance. This extends to other parameters like injection times, the impact of raising or lowering mold temperatures, and shear effects seen in hot or cold runners and at various gates or in different cavities in multicavity tools. It even includes lot-to-lot variation that can be seen in the same grade of material. In fact, few processors are aware of all the factors that influence material behavior during the production process. And often the link between manufacturing conditions and material performance that impact the bottom line are not clearly defined.

More useful data

Again, thermoset molders face additional challenges consistently controlling their very complex processes using temperature and pressure data alone. They would really benefit from access to real-time materials characterization data that helps them better understand what is occurring inside their tool at any point in the molding cycle in order to keep the process balanced and to produce consistently in-spec parts. For example, if a molder is producing undercured parts, they will not meet datasheet specifications, and if a molder is overcuring parts, they will be brittle and prone to premature failure. If a process becomes unstable, it may shift between undercuring and overcuring. Or it may be difficult to achieve the target glass-transition temperature, which in turn means that parts will fail dynamic mechanical analysis (DMA) or differential scanning calorimeter (DSC) tests during QA checks. Still another challenge for thermoset molders is understanding when aging material hits a critical point where properties are being lost and for thermoplastic molders understanding when their recycled feedstock contains contaminants that will negatively affect molded part quality.

The four types of critical real-time data

To help molders better control their processes in real time, it would be highly advantageous to have access to 4 types of real-time data:

Gel Point

This indicates how crosslinking is proceeding, whether the material is likely to fill the tool or cause a short shot. It can also indicate if microscopic damage is occurring in the material and whether the material is properly mixing at converging flow fronts.

Glass Transition Temperature (Tg)

This indicates the range of temperatures where material will provide adequate mechanical performance. Hence, it is important during initial part specification but it also is used as a QA test of thermoset molded part quality.

Degree of Cure

This indicates how far crosslinking has proceeded inside a part. Since proper cure is critical for achieving all subsequent performance criteria for the part, the degree of cure is used as a QA check to test thermoset molded part quality.

Flow-Front Detection

This indicates how a tool is filling and whether material is still moving at a given point in time. It also indicates viscosity of the material, which can be helpful for troubleshooting aging material or material that is being processed at too cool a temperature because the mold was open too long.

While it is certainly possible to obtain multiple streams of data in real time from inside a mold if it is properly instrumented, the problem then becomes that the sheer volume of data collected in each moment is simply too big and complex for humans to interpret fast enough to be able to react and make a difference. And most technicians cannot hold enough historical data in their memory simultaneously to compare current process conditions against previous ones to accurately predict whether this cycle is likely to produce good or bad parts. While humans are not capable of doing this, computers are. This is where the tools of Industry 4.0 come in and how the sensXPERT system of real-time, in-mold process monitoring was developed.

Why NETZSCH?

Formed almost 150 years ago and an early producer of both firefighting and agricultural equipment, NETZSCH Group has evolved over time to become a global company with a physical presence in 36 countries and over 4,000 employees.

NETZSCH Analyzing & Testing (A&T) is one of 3 main business units within the corporation. It has become a global leader with over 50 years of experience in materials science and more than 20 years of experience in sensor technology – mainly targeting scientific characterization and quantification of material behavior.

Given the rapidly changing manufacturing environment and company leadership's commitment to staying future relevant, new business models were implemented that led to the development of several corporate ventures charged with developing novel products combining digital devices with more traditional scientific measurement tools. sensXPERT is one of those ventures that got its start within the Analyzing & Testing business unit.

As luck would have it, about the time that the team that would become sensXPERT was working to develop a hybrid system of digital and physical tools to better monitor plastics processing, an interesting consortium formed in Germany that provided the perfect opportunity to refine sensor and computer algorithm technologies that the team had already been working on for several years.

The CosiMo project

In 2018, the Bavarian State Ministry of Economic Affairs, Regional Development and Energy underwrote a 3-year research collaboration that drew on the collective resources and expertise of 13 partners drawn from research, academia, and industry.

The program, which came to be called CosiMo (Composites for sustainable Mobility), had a goal of evaluating new materials and manufacturing processes to find more cost-competitive and sustainable options for producing composite parts for both the automotive and aerospace industries to support sustainable mobility.

Collective expertise

The organizations that participated in the CosiMo project included:

Faurecia Clean Mobility
Tier 1 producer of ultralow-emission powertrain components

Christian Karl Siebenwurst GmbH & Co. KG
Model and moldmaker

Premium Aerotec
Aerostructures provider

KraussMaffei Technologies GmbH
Plastic processing equipment producer

NETZSCH-Gerätebau GmbH
Materials characterization/process monitoring via dielectric sensing system producer

iba AG
Process data acquisition and analysis systems supplier

Kuka AG
Robotics and plant automation producer

ESI Group
Computer simulation software supplier

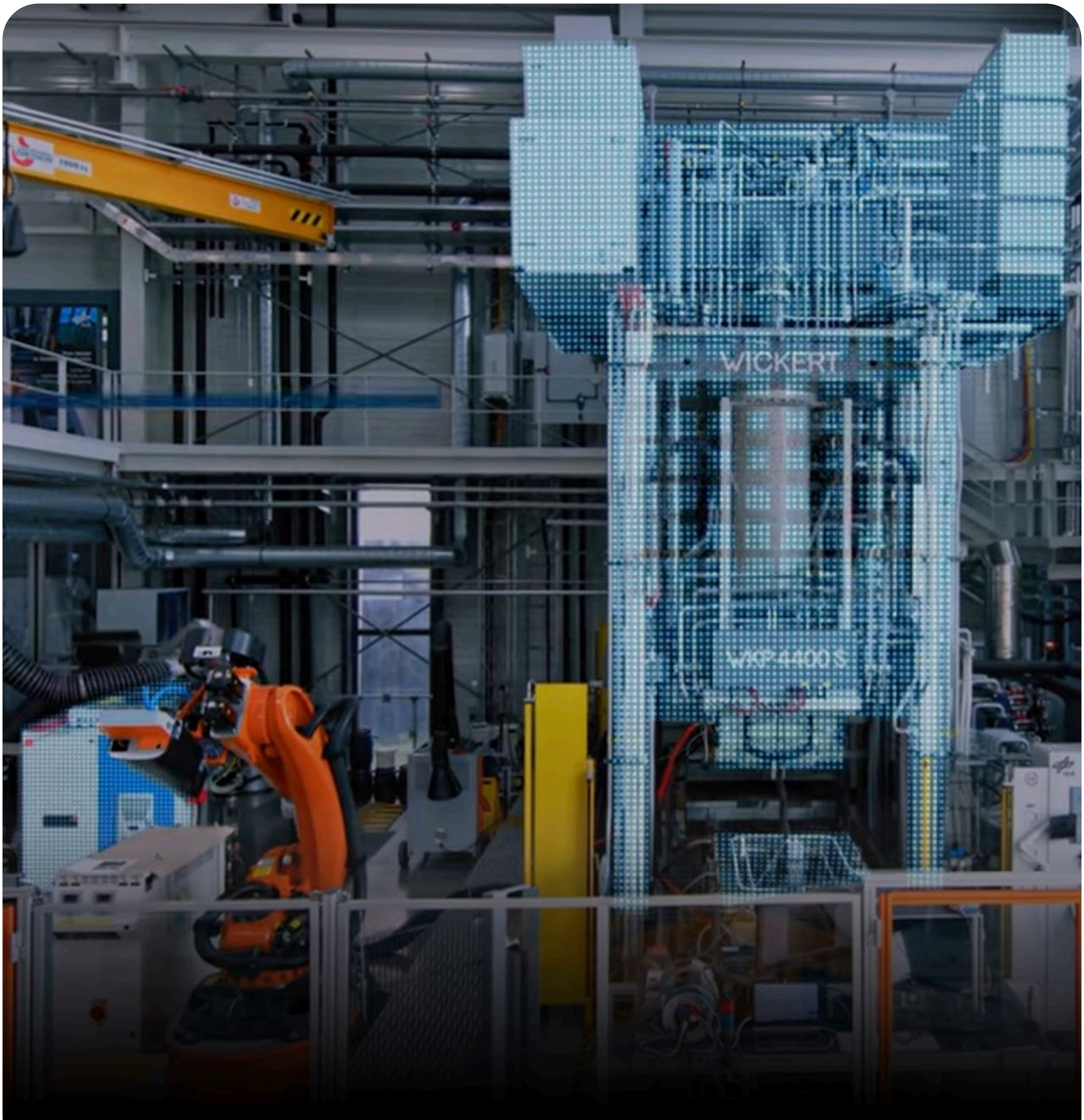
SGL Carbon
Carbon fiber, graphite, and intermediate composite products supplier

DLR Zentrum für Leichtbauproduktionstechnologie Augsburg (DLR-ZLP Augsburg)
German center for aerospace, energy and transportation research

The University of Augsburg's Institute of Materials Resource Management (MRM)
Research on materials/processes for efficient techno-economic development

The University of Augsburg's Institute for Software & Systems Engineering (ISSE)
Research on software and systems engineering

Institute for Textile Technology GmbH (ITA Augsburg)
Textiles research



CosiMo

Composites for Sustainable Mobility

Thermoplastic RTM
Digitized composite processing
Sensor-based quality control

Demonstrator project

Since Faurecia was the project lead, and other team members supported the automotive industry, the team chose as its demonstrator project to mold a thermoplastic composite cover to protect the battery modules of a series production battery electric vehicle (BEV). Since battery enclosures (consisting of covers and trays) are safety-critical parts, they have become the heaviest component on most BEVs before battery modules are loaded. Therefore, it is highly desirable to reduce their mass, which would help vehicles drive further on a given charge, increasing energy efficiency. Faurecia designed the initial cover, which was further modified by select team members to facilitate moldability.

Most battery covers are still produced in stamped steel or aluminum, although a few use carbon fiber-reinforced prepreg and a growing number are produced in sheet molding compound (SMC) – both compression molded. Composite battery covers are lighter, resist corrosion, and are more damage tolerant than metal covers. They also provide greater design freedom and opportunities to consolidate subcomponents, which, in turn, reduces or eliminates many secondary operations, facilitates assembly, and can be more cost competitive than metallics depending on production volumes owing to the reduced number of tools sets (stamping dies) and presses required to supply the program.

Increased sustainability

To increase part sustainability, the team selected a thermoplastic composite – polyamide 6 (PA6) reinforced with a recycled fiberglass nonwoven developed by ITA Augsburg – in place of the usual thermoset matrices used with SMC and carbon fiber-reinforced prepregs. (Thermoplastic tapes were considered but eliminated owing to challenges achieving good drapability and filling complex geometry.) PA6 offers lighter weight and greater toughness than SMC and lower cost than carbon fiber-reinforced prepreg. The polymer is widely used in the automotive industry, so is a material that OEMs and Tier suppliers are already familiar with, it is globally available, and is known to offer sufficient thermal and chemical resistance for use in most areas of an automobile – including use on the interior of battery modules. Being thermoplastic, PA6 also offers the benefit of being fully recyclable (melt reprocessable) at end of life while permitting reuse of scrap in non-safety-critical applications and enabling subcomponents to be quickly and economically joined via plastic welding.

The major disadvantage of using a fully polymerized thermoplastic matrix is that even in a molten state, its viscosity is relatively high, making it challenging to achieve good fiber wetout in sufficiently high fiber weight or volume fractions to reach the structural performance required of a battery cover. The team overcame this issue by opting to in situ polymerize ε-caprolactam monomer into PA6 polymer. At temperatures above 100°C, caprolactam's viscosity drops quite low, enabling it to achieve fiber-weight fractions as high as 60%, which are 10-20% higher than fully polymerized PA6 can usually achieve.

To reactively polymerize a thermoplastic in a mold like a thermoset, the team chose the thermoplastic RTM or T-RTM process, which is a variation on resin transfer molding (RTM) and was developed by KraussMaffei in 2016. Since the battery cover was large (110 cm x 53 cm) but its geometry was fairly simple and well within the capabilities of compression molding to produce, that type of press was selected for part forming.

Another benefit of choosing to reactively polymerize caprolactam into PA6 is that sustainability of the battery cover could be further increased by using recycled monomer. In North America, post-consumer and post-industrial recycled PA6 carpet scrap has been depolymerized into caprolactam, then repolymerized back into PA6 parts used in the automotive industry for 2 decades, so there already is an established supply chain.

Need for in-mold process monitoring

To an extent, most polyamide polymers are hygroscopic and prone to dimensional fluctuation with changing humidity. In fact, PA6 requires predrying before molding for just this reason. During in situ polymerization, caprolactam also is prone to rapid aging effects, plus its polymerization is affected by such things as thermal conductivity through the material, heat transfer through the mold, presence of sizing on and shape of reinforcements and fillers, and even thermal conductivity of reinforcements and fillers (e.g., carbon fiber, carbon black, graphene nanoplatelets, and carbon nanotubes). Further, it can be challenging to know when to stop the process and eject parts.

The process begins when a technician places a dry fiber preform cut to near-net shape into a preheated tool that typically is held between 150°C and 170°C. The two part resin system – consisting of caprolactam held at 100°C in one tank and an activator/catalyst held at room temperature in a second tank, with both chemicals constantly agitated to ensure good mixing – are piped into a special mixing head where they are combined and injected into the tool at relatively low pressures (<10 bar). The fiber preform is impregnated as the liquid monomer passes through it and begins polymerizing and building molecular weight to form the PA6 matrix. Typically after 2 minutes, a fully polymerized net-shape part is ejected.

However, given the large size of the battery cover and the fact that the recycled fiberglass nonwoven was challenging to impregnate without dry spots or air bubbles, which lead to voids and weak spots in the final parts, researchers found they needed to infuse more slowly to ensure good wetout and avoid trapping air in the preform. That led to an effective cycle times of 4.5 min to mold the cover. While in commercial use, the recycled mat likely would have been pre-sized, for the CosiMo program the supplied reinforcement was unsized and adding sizing was outside the scope of the study. Also, while higher molding pressures could have been used to infuse more swiftly, there still would have been risk of introducing bubbles/voids in the final part, not to mention flashing the mold with the low-viscosity monomer. Hence, a practical challenge researchers faced was determining at which point in the molding cycle polymerization was complete and the part could be ejected. This addressed the dual need to keep molding cycles as short as practical and to avoid exposing parts to excessive heat for longer than necessary so as not to cause thermal degradation. That, combined with the earlier mentioned issues with caprolactam itself, made it desirable to have an accurate process simulation and in-mold monitoring system to better control T-RTM and assure that acceptable parts were being produced. Based on earlier research, NETZSCH team members also were keen to go beyond standard thermal analysis and attempt to collect real-time materials characterization data.

Fortunately, KraussMaffei had designed the T-RTM process for automation – important to cost-effectively support automotive-scale production volumes without necessitating use of multiple presses and tools – so the equipment already used closed-loop process controls.

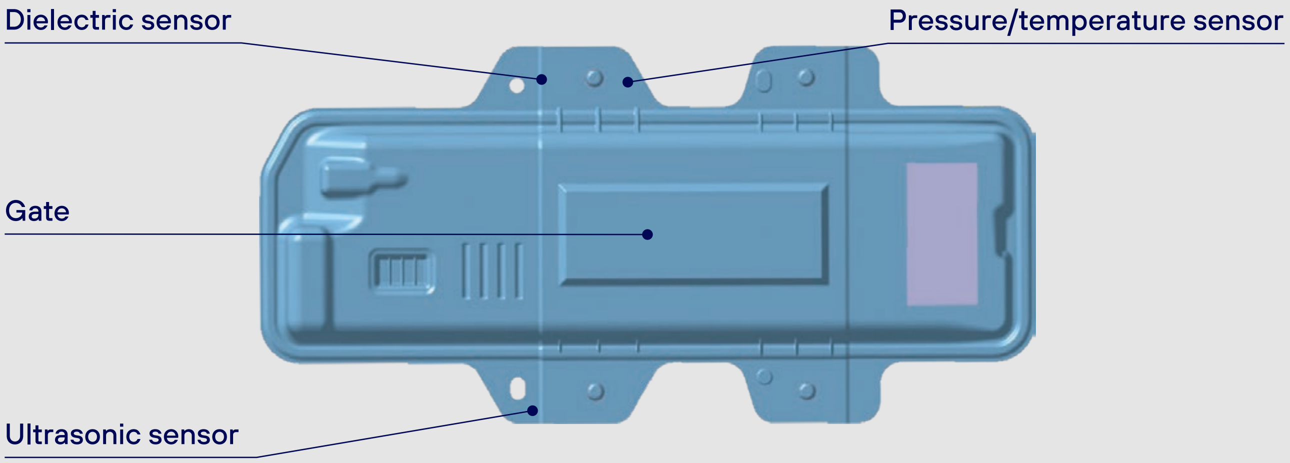
Mapping the dependencies

Initially, the team had planned to do a smaller plaque study to map the dependencies between material and process. However, pandemic-related delays led the team to skip the initial study and move straight into mapping the dependencies with the much larger and more complex battery cover instead. This was accomplished by instrumenting the center-gated T-RTM tool produced by Christian Karl Siebenwurst and installed at DLR-ZLP Augsburg, where molding would take place in a compression press outfitted with KraussMaffei's T-RTM system.

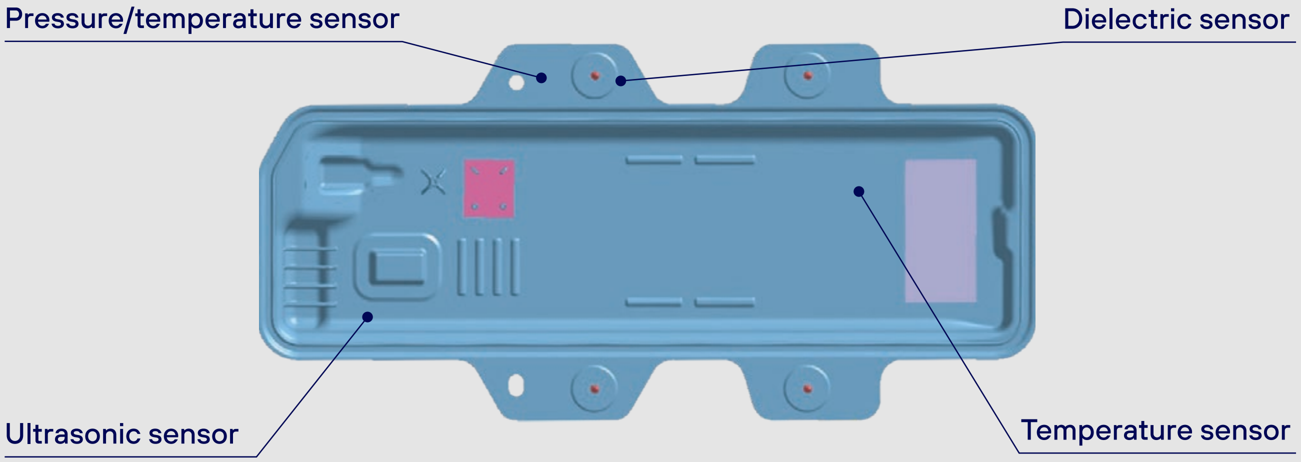
The tool was fitted with a total of 74 sensors representing four different sensor types mounted on both core and cavity sides of the mold. These included 3 temperature sensors (see image below); 4 sensors that measured both temperature and pressure (see image below); 8 dielectric sensors that measured multiple parameters (e.g., gel point, Tg, degree of cure, and flow front advancement; green dots above); and 57 ultrasonic sensors to measure material flow/movement (see image below).

Once the mold was instrumented, parts were produced using different process settings, then physically tested (i.e., via DSC and for residual monomer content) to evaluate mechanical performance and to check for defects in order to better understand the influence of process settings on final part quality and performance.

Cavity side of the mold



Core side of the mold



The unique data analytics capabilities allow for dynamic process adaption, **thus providing the long needed holistic transparency.**

Dr. Alexander Chaloupka

Managing big data streams

Compared with the simple temperature and pressure data usually available to processors, the highly instrumented mold produce a rich array of data streams that provided a much more detailed picture of liquid injection, infusion, and polymerization behavior with respect to different part thicknesses, shapes, and fiber layup. Some of these variables were a function of the mold design, which featured sections with different thicknesses and geometry, while some of the variables were introduced by modifying how the preforms were cut and laid up in the tool and how infusion was handled. Interestingly, although there was some redundancy in the types of data that the different types of sensors measured – 2 provided data on tool temperatures, 2 provided data on tool pressures, and 2 provided a picture of the advancing polymer flow front – researchers realized that the dielectric sensors not only were the most durable type of sensor installed in the mold, but they also provided the broadest range of data and would cover all the desired data sets themselves.

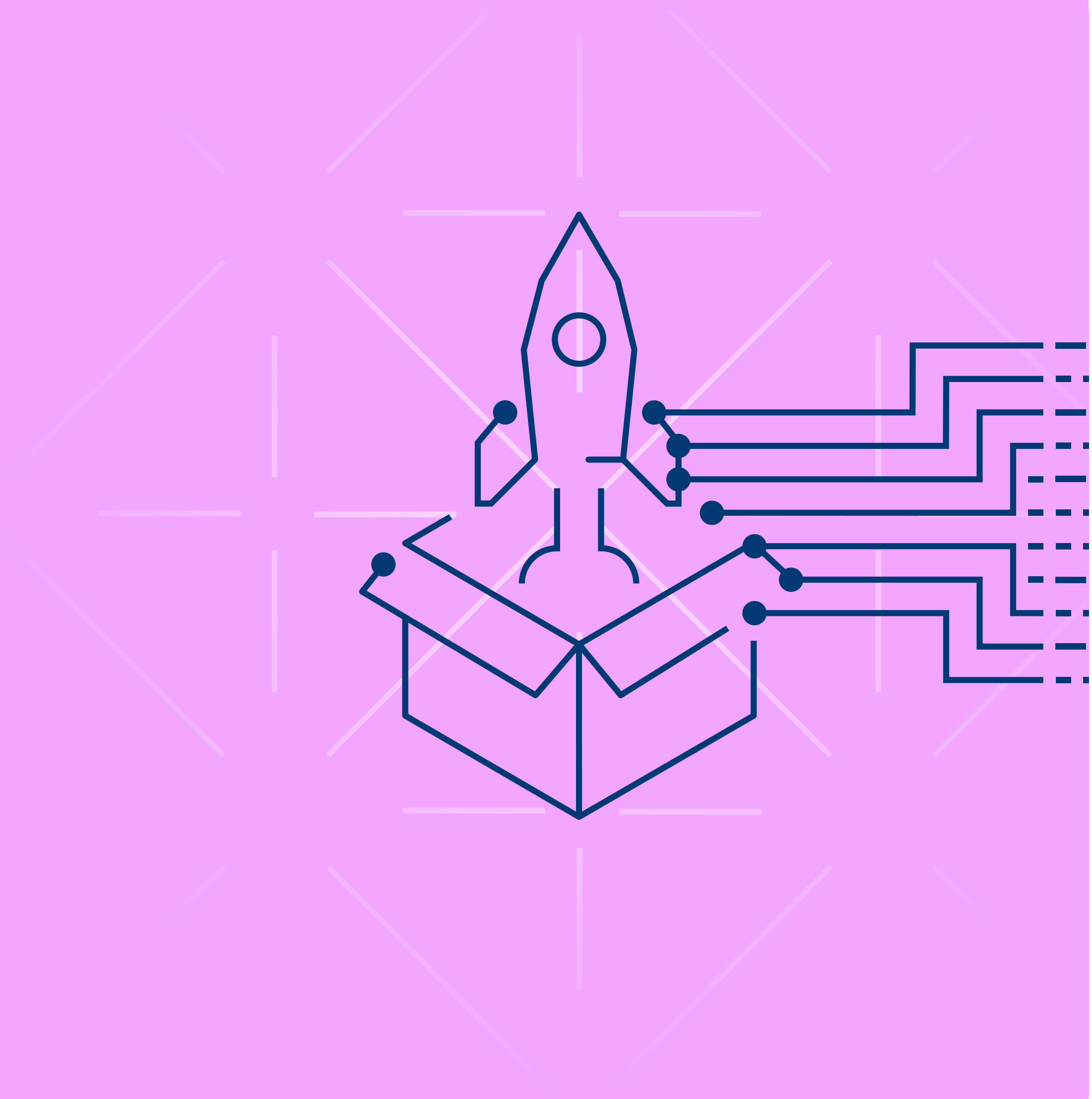
Both the University of Augsburg and DLR-ZLP Augsburg had a goal to simulate the T-RTM process with the hope that this initial attempt at digitizing the production approach could be refined to produce self-learning and dynamic closed-loop process controls for future T-RTM systems from KraussMaffei. The 56 ultrasonic sensors successfully provided the desirable data stream on flow behavior inside the mold. The dielectric sensors were able to measure polymer solidification and track its advance across the mold cavity. When such a data stream was fed into algorithms, the CosiMo team was able to access real-time data on degree of polymerization as the molding cycle proceeded. Ongoing work is focused on using model-generated virtual datasets to predict optimum processing conditions for different materials in other molding processes.

Owing to the previous research that NETZSCH data scientists had been working on before CosiMo started, kinetic modeling based on DSC measurement data generated by the University of Augsburg and dielectric sensor calculations were used to develop algorithms that mapped the degree of polymerization at different temperature settings – a tool that proved helpful in the study. Subsequently, the predictions were validated by running more molding trials to compare simulation predictions against actual measured results from lab-performed post-process studies with good agreement.

CosiMo project takeaways

The CosiMo project represents another step toward the full digitization of plastics processing. Although not all goals were realized, the project underscored the challenges of manipulating very large and complex datasets, mapping dependencies, and then developing much-needed predictive tools that can be used by processors to guide decisions impacting part quality and process productivity.

1. Domain knowledge is crucial for using machine learning in a manufacturing setting to predict when deviations will occur.
2. Only by combining physical-world measurements and data science is it possible to see how every aspect of the material and molding process interact.
3. Too many members of the plastics industry do not fully understand what occurs in the mold – especially when thermosets are being processed; and too many experienced technicians have a feeling for what needs to be done but struggle to verbalize that understanding so it can be shared with others.
4. The only way to solve the challenges plastics processors face is to clearly understand the many interactions between the manufacturing process and the material and to accurately map the dependencies.
5. Collaboration between all members of the supply chain is critical as no member has all the knowledge needed and the competencies required to transform the plastics industry.



Handling and evaluating the large amounts of manufacturing data and its endless interrelating crossroads **is simply impossible for humans.**

Dr. Alexander Chaloupka

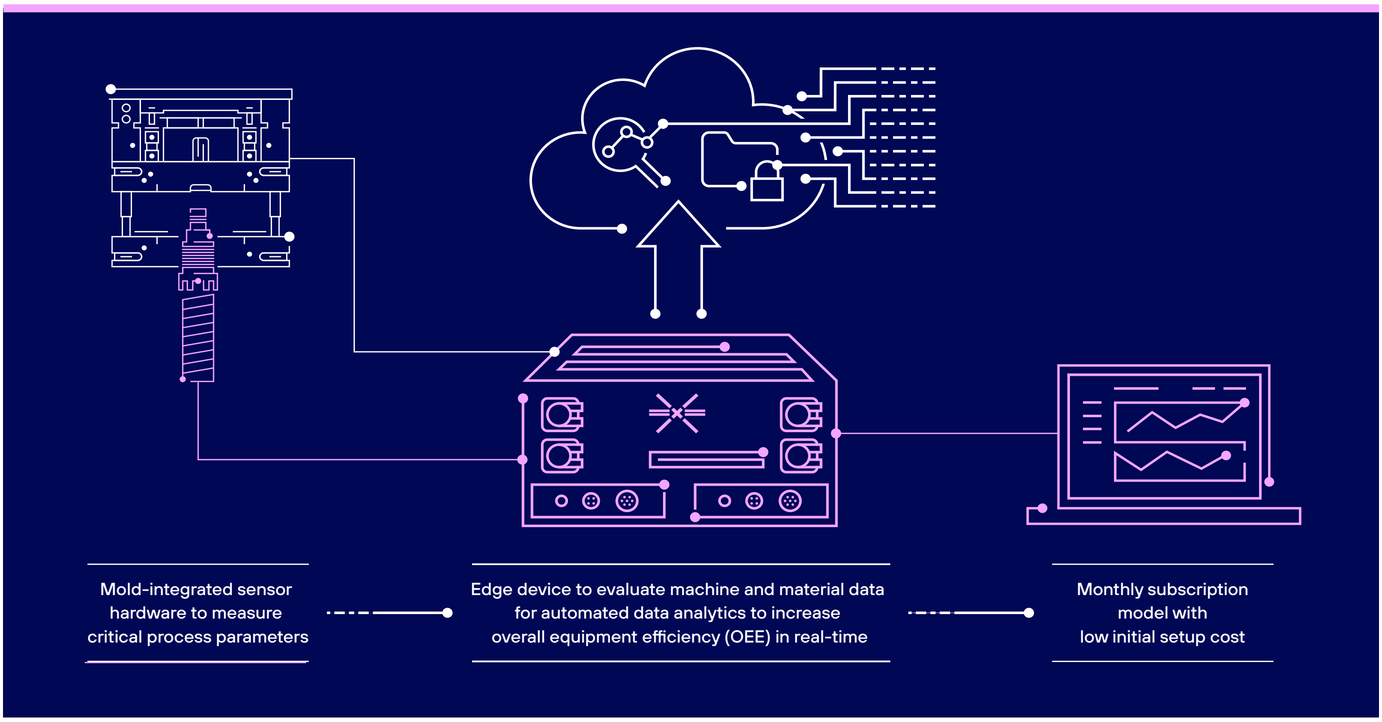
Helping molders better control their processes

During the CosiMo project, NETZSCH demonstrated that its dielectric sensor technology and the developed material models could be used to successfully monitor and control a manufacturing processes digitally in real-time. Since July 2021, the team that developed this novel in-mold process optimization technology has operated under the brand name sensXPERT acting as a standalone corporate entity called NETZSCH Process Intelligence GmbH.

The transition has enabled NETZSCH to further refine the technology by applying material knowledge and data science to develop advanced process analysis technologies that meet Industry 4.0 requirements and help molders better understand how their process is proceeding moment-by-moment.

As a direct result of the CosiMo project, sensXPERT technology was installed at an industrial molder producing PA6 semi-finished goods by reactively polymerizing ε-caprolactam.

From the outset, the plug & play sensXPERT system has been designed to be flexible, both process and material agnostic, and to minimize installation time and cost to provide a rapid return on investment (ROI). The sensXPERT system consists of both hardware and Cloud-based software that provide molders with real-time in-mold materials characterization data and predicts how this is likely to impact the ultimate performance of a part once demolded.



Hardware

The heart of the sensXPERT system are dielectric sensors that are installed in a new mold as it is being built or in an existing mold that is being repaired or modified for engineering changes. While 8 dielectric sensors were used in the CosiMo tool, subsequent research has shown that only 2 are actually needed – one positioned at or close to the main gate and one positioned at the end of flow – regardless of part size. The sensors can be installed on either the core or cavity side of the mold. This provides more opportunities to position sensors in a location that will not disrupt a visually sensitive (Class A) surface as well as reduces costs for instrumenting the tool.

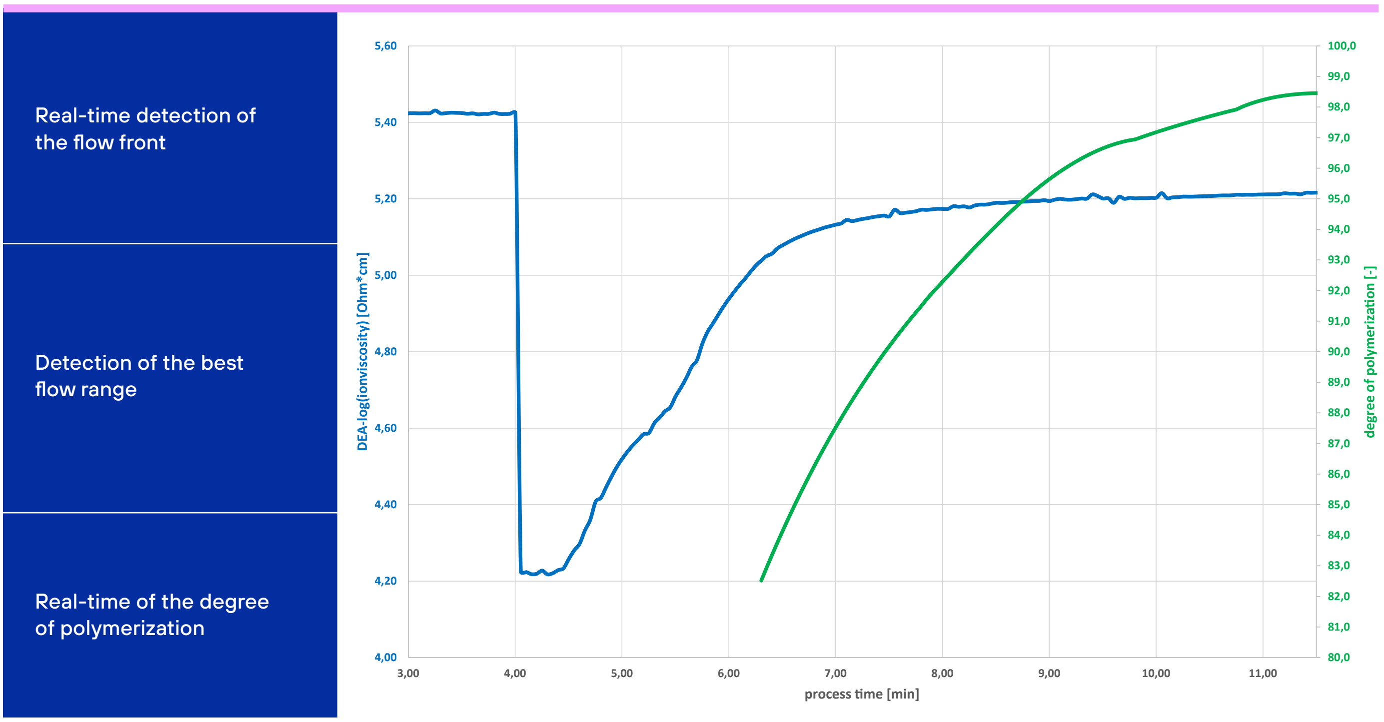
Data collected by the sensors are transferred to an edge device placed outside but close to the press. The edge device collects sensor data and transfers it to the Cloud via secure servers maintained by Amazon Web Services.

Software

The other key aspect of the sensXPERT system are the mathematical and physical/chemical models of polymer behavior – developed by University of Augsburg – and machine learning algorithms – developed by NETZSCH – that constantly scan incoming data for patterns and deviations on patterns. The algorithms translate the raw sensor data into predictive quality criteria that are fed back to technicians monitoring a given press and process via a web app, which enables the system to communicate with a technician without need for a laptop/keyboard.

An additional layer of machine learning algorithms helps the system parse the combination of process parameters and sensor data flowing in from molds in manufacturing facilities all over the world and map the dependencies for a wide variety of materials and processes as well as operating conditions using data science. This helps the system become smarter and more accurate over time. If algorithms note that a particular dataset is different or changing from the established pattern, the local edge device as well as the local technician monitoring that process are alerted. At present, once alerted via the web app, the operator can decide whether or not to intervene and change a process setting.

Eventually, the goal is to have the algorithms instruct the edge device to alert the press and adjust process settings automatically, if needed. Meanwhile, the machine learning software remembers the pattern and the response and instructs any press connected to the system running a similar process and material, effectively retraining the system on a regular basis to continuously enhance process performance.



Real-time detection of the flow front

Detection of the best flow range

Real-time of the degree of polymerization

Real-world performance optimization

sensXPERT has built extensive databases that enable the system to accurately predict part quality based on complex and interrelated factors occurring both inside the mold and outside the press each molding cycle. This effectively enables molders to shift from physical QA testing downstream from the molding process to real-time, in-mold QA monitoring, which helps a processor understand whether the current cycle is likely to produce in-spec parts upon demolding. As more data flow into the system every month, the system gets smarter and more accurate, which sets it apart from any other molding productivity tool currently on the market.

Results that speak for themselves

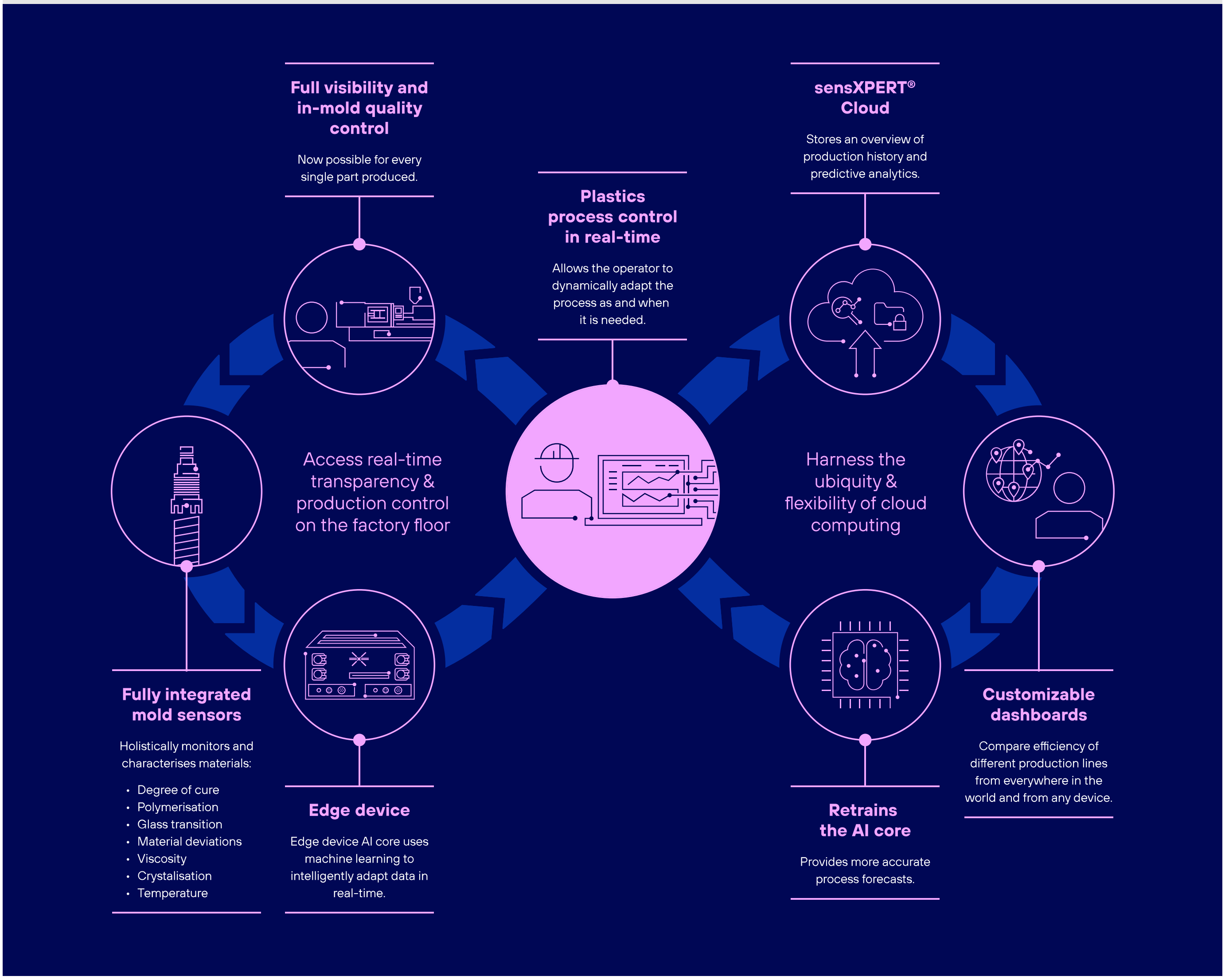
Several years of field testing has shown that the system is effective in helping processors:

Shorten cycle times as much as **30%**

Reduce scrap by up to **50%**

Save as much as **23%** energy usage

Reduce machine downtime due to maintenance, software installation, and troubleshooting errors by up to **15 days/year**



Full visibility and in-mold quality control

Now possible for every single part produced.

sensXPERT® Cloud

Stores an overview of production history and predictive analytics.

Plastics process control in real-time

Allows the operator to dynamically adapt the process as and when it is needed.

Access real-time transparency & production control on the factory floor

Harness the ubiquity & flexibility of cloud computing

Fully integrated mold sensors

Holistically monitors and characterises materials:

- Degree of cure
- Polymerisation
- Glass transition
- Material deviations
- Viscosity
- Crystalisation
- Temperature

Edge device

Edge device AI core uses machine learning to intelligently adapt data in real-time.

Retrains the AI core

Provides more accurate process forecasts.

Customizable dashboards

Compare efficiency of different production lines from everywhere in the world and from any device.

Unlocking potential through better process understanding

This work has shown that there is a lot of hidden potential that part manufacturers will continue to have difficulty accessing until they better understand the impact process parameters have on material performance and gain more consistent control of their molding processes.

sensXPERT helps processors produce better parts more consistently while meeting Industry 4.0 requirements.

How we are helping molders understand processes better

Plug and play solutions designed to **minimize** adding costs to **installation** and **process setup**

Real-time process optimization via evaluation of quality markers and **predictive notification of divergences** from optimum process/material patterns;

Process transparency, **digital component mapping**, **in-mold QA**, and full **tracking/traceability** for **every part** produced

Productivity increase and financially-based data valuation, including:

- scrap reduction
- cycle-time optimization
- reduced energy usage
- greater uptime and overall equipment effectiveness (OEE)
- optimized use of human-based resources
- reduced wear and tear on presses and tools
- resin supplier independence

Rapid return on investment (days to weeks).

Dr. Alexander Chaloupka
Managing Director & CTO sensXPERT

About Alex
Only a few people in the world share his level of composite knowledge. The physicist turned entrepreneur with +10 years of experience in Research & Development, Sales and General Management founded the sensXPERT in-mold solution and drives the technological innovations at NETZSCH' Corporate Venture sensXPERT.

Learn more at www.sensxpert.com or contact the team at www.sensxpert.com/contact

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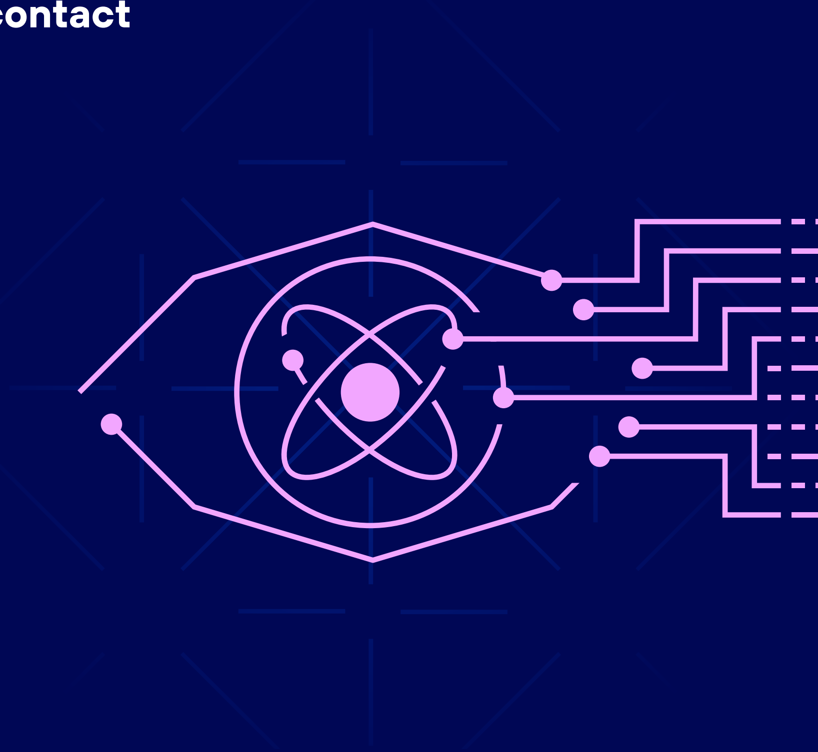

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