Machine Learning

*Industry 4.0 technologies are boosting the quality and productivity possible in a new generation of injection machines and auxiliaries*

By Pat Toensmeier

*Engel's e.connect Industry 4.0 software provides online support, remote maintenance, and predictive maintenance.*

Courtesy of Engel
The ongoing digitization and connectivity of injection molding technology was a prominent feature of machinery exhibits at NPE2018. Machine exhibitors at the big show, held May 7 to 11 in Orlando, Fla., highlighted the process capabilities and operational benefits that the evolving cyber-physical molding systems provide.

The benefits of the technology include exponential improvements in process efficiency, part quality, manufacturing economy, and data generation and analysis. Data analysis, in particular, provides clear indications of primary and auxiliary equipment performance in a work cell, which allows molders to improve operational parameters and meet needs ranging from rapid detection of molding problems to predictive maintenance and trend analysis.

Injection machine makers note that the data generated by digitized machines and auxiliaries in work cells, which in turn are linked to plant-wide networks, aid molders in developing proactive operations that streamline production.

“We have [molders] who have combined the stream of analytical data coming off their machines, coupled with consistent downtime management, and turned that detail into actual predictive analytics based on true data science,” says Michael Ellis, director of marketing and communications at Milacron.

“Our portal has the ability to provide digestible Pareto analysis or auto-generated reports that can be sent on an interval basis,” he adds. “Molders see what areas absorb most of their downtime and put actions in place for improvement. We have had users see five- to 10-point improvements in their OEE (overall equipment effectiveness) in a matter of months.”

The move toward greater digitization and connectivity of molding operations is part of Industry 4.0, which represents the evolution of conventional industrial automation to the revolutionary capabilities of modern digital technology and networking systems.

With Industry 4.0, advanced technologies like data generation, the Industrial Internet of Things, and cloud-based storage and retrieval systems are among the capabilities used to connect and network primary machines, robotics, and auxiliaries. An important goal is to create flexible production systems that minimize human error by reducing—or even eliminating—the amount of manual setup and operator attention required for molding runs. Such systems collectively form a “smart factory,” which employs these and other advanced digital technologies to streamline operations and related tasks such as maintenance and molding history reports.

Industry 4.0 is gaining acceptance among injection molders as they learn more about its benefits. Their acceptance is important to their competitiveness, in that major OEMs increasingly require that all of their suppliers, not just Tier 1 vendors, have the degree of process control, materials traceability and other benefits that Industry 4.0 automation and data provide.
Injection machinery suppliers are consequently broadening offerings in this area. Most of the 30 or so companies that build or distribute injection machines in North America supply digital control and automation packages geared toward Industry 4.0. Other parts of the world, notably Europe (Industry 4.0 began in Germany) and parts of Asia, are also heavily invested in the technology to improve quality, productivity and profitability.

While each machine supplier’s process is different, most 4.0 systems achieve common goals. Injection machines are equipped with advanced controllers and software, and connected to upstream and downstream peripherals—e.g., hoppers, chillers, mold and molding components, robots, and conveyors—in a work cell. The digital control is programmed with preset operational parameters. When a job is selected, the control, by itself or via a router or networked manufacturing execution system (MES), calls up the process data. After verifying that each piece of equipment in a particular work cell is correct and connected, the control downloads process data to the molding machine and peripherals, and molding begins.

During the molding process, sensors relay data on equipment and component performance. This information alerts operators about potential quality problems, owing to changes in areas like melt viscosity, injection pressure, chiller dewpoint, material content, and other setpoints.

The communication between machines in a work cell is being improved by ongoing developments in data exchange interfaces. Some of the most important are new and recent protocols from Euromap, the German standards organization:

- Euromap 77 covers interfaces for injection machines and MES. The new standard provides a unique interface for injection machines and MES from different manufacturers to assure compatibility. Euromap 77, a successor to Euromap 63, is based on OPC UA, internationally recognized process control software that converts the communications from a...
conventional machine programmable logic controller (PLC) to the OPC protocol. (OPC UA stands for Object Linking and Embedding for Process Control United Architecture, a technology for communication between machines that has been developed, updated and licensed by the OPC Foundation of Scottsdale, Ariz.)

- Euromap 79 covers interfaces between injection machines and handling devices such as robots.
- Euromap 82 covers interfaces between injection machines and peripheral devices.

One benefit of generating voluminous data with Industry 4.0, says Sonny Morneault, vice president of U.S. sales at Wittmann Battenfeld Inc., is that in the event off-spec parts are molded, a processor can rapidly trace and isolate the material or process conditions responsible for the problem and discard a portion of a molding run, rather than scrap the entire job and start over.

"Big data is big money," Morneault notes. "The potential for data generation and analysis is endless [with Industry 4.0]."

Many machine builders include augmented reality (AR) and virtual reality (VR) and associated digital twin modeling in 4.0 systems. AR and VR allow a user to develop an identical digital version of a design—the digital twin—and prove its validity before money is spent on physical development.

The use of AR/VR and digital twins has been applied to major projects. Luxury carmaker Maserati, for example, used the technology to confirm the design and layout of an auto production plant in Italy. Other manufacturers have used AR/VR and digital twins to fine-tune machine engineering or to finalize the interior design of new or expanded factory buildings right down to determining the best production line layouts for worker ergonomics.

In injection molding, AR/VR and digital twins can be used to design or inspect machines, as well as mold assemblies and molded parts. "Using virtual reality when developing new products makes it possible to understand complex relationships and to visualize details in an interactive environment that cannot be seen in the real world," says Heinz Gaub, managing director of technology and engineering at Arburg GmbH + Co. KG.

Arburg, for one, offers this capability with its 4.0 system. Gaub adds that the technology can improve maintenance and troubleshooting by the computer-aided enhancement of an injection machine and its components.

Five leading injection molding machine suppliers interviewed prior to NPE about their Industry 4.0 systems: Wittmann Battenfeld, Arburg, Milacron, Engel Austria, and KraussMaffei Group (whose holdings include injection machine maker Netstal). Following are highlights of their remarks, which indicate the capabilities that are available in the market and the benefits that 4.0 systems provide to injection technology.

**Fast Start, Fast Finish**

Wittmann Battenfeld’s “crown jewel” in smart machine technology is Wittmann 4.0, a system whose capabilities include connecting and verifying the components of an injection molding work cell for setup. The Wittmann 4.0 system achieves fast and error-free setup of molding runs and generates real-time data on numerous operating parameters, which can be downloaded and analyzed. This information can include custom data specified by the molder.

Like most injection machine suppliers, Wittmann Battenfeld (WiBa) developed Wittmann 4.0 in-house, so it provides full connectivity and broad data generation when linking the company’s three main product lines: injection machines, robots and auxiliaries. The system also connects WiBa injection machines to other brands of robots and auxiliaries, though the extent of connectivity and data generated is usually narrower than with its own versions of these machines.

With Wittmann 4.0, processors capture and export mold, machine and peripherals data and use them for analysis, quality control, part traceability, predictive maintenance, molding history, and other critical needs.

Additional benefits include rapid setup, improved part quality, efficient material use, the ability to isolate off-spec parts without compromising an entire molding run, specifying ever-tighter setpoints as needed, and major gains in productivity.

Two components form the core of the 4.0 system: WiBa’s latest-generation Unilog B8 controller, an upgrade from the Unilog B6, which connects the injection machine to robots and auxiliary equipment, and the Wittmann 4.0 router, which identifies, integrates and configures connections and links them to specific work cells that are connected to a company-wide network.

Here is how it works: Mold and equipment setpoints for each production run are programmed into the Unilog B8 controller on the molding machine. The Wittmann 4.0 system also allows production data to be retrieved through a networked MES. Setup begins with selection of the appro-
appropriate data set, which is relayed via the controller to the router. The router automatically checks the IP address of the designated work cell to make sure the correct auxiliaries for the molding run are connected to the machine and other equipment in the work cell. The router then transmits via an Ethernet network the operational settings for each device in the work cell to the Unilog B8, which controls their operations.

The Wittmann 4.0 system operates within the parameters of the OPC UA standard. Once the machine control confirms connections for the peripherals and molding machine in a designated work cell are in place, the production specifications for the molding run are transmitted from the controller to the relevant machines.

WiBa calls this “plug and produce.” Networked cable connections from each machine in a work cell to the router confirm data selection and setpoints for a production run. IT specialists are thus not needed to configure work cells, and machine operators focus entirely on the mechanical needs of machine and peripherals setup. Sonny Morneault says the system eliminates the potential for human error, since the parameters of the injection machine, peripherals, and robot are automatically called up by the production cell.

The data that can be generated for analysis includes bin and hopper locations, resin and additive throughput, dryer and chiller temperatures, mold fill rates and melt temperatures, injection pressure, and robot timing. WiBa worked with IQMS of Paso Robles, Calif., to develop the data software.

Molders can additionally customize the data they want with eDART software developed by RJG Inc. of Traverse City, Mich. RJG designs and adds user-defined pages to the Unilog B8 control that allow a molder to gather process information he or she deems vital. Examples Morneault cites include dryer dewpoint, melt viscosity, and injection hold time.

WiBa also offers HiQ software for the 4.0 system. HiQ lets molders set up increasingly tight process control adjustments to maintain exact settings for critical parts, or to compensate for ambient environmental factors like temperature and moisture, or for material composition such as regrind or masterbatch content.

Morneault says the benefits of Wittmann 4.0 pay off for molders. One undisclosed molder reduced process and mold changeover time on a 1,000-ton machine to less than 12 minutes, due to the speed at which the connection of auxiliaries and molding machine was achieved and the setpoint data for production called up.

**Smart Machine Controls**

Arburg has been demonstrating fully automated injection machines that require no manual setup since the 1986 K show. While this predates Industry 4.0 technology, the company states that its long experience with full automation gives it considerable momentum in applying the benefits of 4.0 systems to molders’ needs.

The building block for Arburg’s Industry 4.0 system is its proprietary ALS host computer connectivity module, an MES designed for injection molding plants. Computer functions include integrated traceability and archiving of orders and batches, maintenance planning and generating reports on OEE and other critical areas.

Multiple injection machines can be networked with the ALS computer, due to its OPC UA communication protocol, which Arburg has been using since 2010. Molds and peripheral equipment, including finishing lines, can also be networked via the computer. Arburg engineers are working on further compatibilizing data exchange between primary machines, robotic systems, and peripheral equipment, efforts that will include integration of the new and recent Euromap 77, 79, and 82 interfaces.

One target the company has in its sights for 4.0 technology is the “smart machine,” which Heinz Gaub says “self-adapts to an optimal state and sends and receives...
data to and from the host computer system via a network—a capability that would border on artificial intelligence.

Arburg demonstrated the versatility of Industry 4.0 at NPE, with the networked production of high-volume “smart parts,” luggage tags with embedded near-field communications (NFC) chips that contain personal information submitted by customers. After molding, the tags have a 3D graphic selected by individual customers applied to their surface by Arburg’s Freeformer additive manufacturing (AM) system.

The Freeformer system is notable in that it uses conventional molding resin—costing several dollars per kilogram (or 2.2 pounds)—as a material source, rather than the usual materials that have been specifically formulated for AM, which can cost $200/kg or more.

Arburg says the demonstration showed how high-volume parts can be individualized by a digitally networked and fully automated production line that included a six-axis robot to transfer parts from the molding machine to the Freeformer system.

Increasing Throughput

Reduced downtime is one of the benefits molders derive from Milacron 4.0, the company’s branded technology, says Michael Ellis. “We have had a number of customers with significant improvements in their downtime experience,” he notes. Much of this stems from more efficient changeover timing, owing to the ability of the technology to synchronize aspects of their operations.

Another advantage is the ability to develop effective preventive maintenance models and better manage part quality based on system alerts. “Alerts can catch in five minutes or less quality escapes that many times go unnoticed by operators for an entire shift,” Ellis explains. “The ability to do that is a game-changer when it comes to reducing scrap and improving quality.”

The technology is backed up by remote connections to Milacron technicians, who troubleshoot quality problems in real time to help reduce or eliminate their potential for machine downtime. “With real-time fault information being passed to the cloud, we can accurately provide feedback and point to issues quicker than ever before,” Ellis says.
Milacron’s work with real-time machine diagnostics is laying the foundation for expansion of its 4.0 technology to another critical area: machine intelligence. Ellis says the company is looking at ways of combining quantitative machine and mold data with augmented reality and digital twin representations of molded parts and machine components to enhance productivity. Such a capability would allow the fine-tuning of machine and mold components, along with potential tweaks to a part’s design, to optimize production and reduce or even eliminate the potential for quality problems.

**Fluctuation Detection**

Engel brought new and expanded capabilities in 4.0 operations to NPE. One notable development in its technology, which Engel calls Inject 4.0, was the acquisition in October 2016 of MES specialist T.I.G. of Rankweil, Austria.

T.I.G., which operates as an independent Engel subsidiary, is the developer of Authentig software, a multi-module system whose capabilities include integration of different equipment brands within a network. Authentig also provides smart monitoring of injection machine functions, process optimization, predictive maintenance, and energy use, among other functions.

Engel bundles Inject 4.0 products in three main areas:

- Smart machine performance, which includes the company’s iQ intelligent assistance systems for melt volume weight control, clamp control, and flow control;
- Smart production, which involves networking and integration of production systems with Authentig software; and
- Smart service for online support, remote maintenance (via Engel’s e-connect.24 software) and predictive maintenance (using e-connect.monitor software).

“Intelligent assistance” refers to the ability of the software to monitor critical process parameters and detect and immediately correct fluctuations before they cause quality problems, says Paul Kapeller, product manager for digital solutions at Engel Austria. In raw material, for example, detection of a fluctuation in melt volume by the iQ weight control software would result in an on-the-fly adjustment to the current shot to prevent an off-spec part. Similarly, the iQ clamp control software calculates “mold breathing” and continuously readjusts clamping force to stay within setpoint.

“With production cells becoming more complex due to increasing process integration and automation, controlling them must become that much more simple and intuitive,” says Kapeller. “This is an important goal in smart machines. Self-adapting assistance systems play a decisive role in this. They increase process consistency and quality without requiring the machine operator to acquire special expertise.”

**Molding After Humans**

Industry 4.0 will, experts say, eventually eliminate human intervention in molding operations. While there will probably be specialists overseeing machinery and network connections in smart factories, either on-site or remotely, their jobs will be mostly IT and data related. Increasingly, self-adapting and self-adjusting machines will be the “eyes and ears” of molding and will alone maintain product quality and productivity.

Among companies that have developed enabling software in this area is KraussMaffei Group, which has three such programs in its Plastics 4.0 system.

Adaptive Process Control (APC) Plus monitors and maintains molded part quality “and quickly compensates for
provides a great deal of transparency regarding machine
ly a manufacturing execution system, MaXecution
for small and medium-sized molding plants. Technical-
Germany last October, is also data-analysis software, but
traceability of and compliance with quality standards.”

“Problem solving, process and machine diagnostics, and better
provides a continuous comparison of process data from
several machines, he says, along with “simplified trou-
“DataXplorer provides a nearly microscopic look at
MaXecution, formally unveiled at the Fakuma expo in
several machines, he says, along with "simplified trou-
MaXecution provides a great deal of transparency regarding machine
and mold utilization, productivity indicators including
and OEE, and statistics on machines and part rejects. The
objective, says Schwarz, is to give smaller molders a "bet-
ter overview in production planning, increased machine
utilization and shorter throughput times, and compara-
bility of machines by means of KPIs (key production
indicators).”

There is little doubt that Industry 4.0 technologies will
dominate injection molding and redefine productivity
and quality standards for the industry. This capability
will soon be a critical competitive asset, as well as a main-
bottom-line growth and profitability. The
categorization of molding operations according to the
technical challenge of different products—commodities,
engineered parts, etc.—may well become obsolete. Indus-
try 4.0 could put most molders on equal footing when it
comes to quality, productivity and profit margins, pro-
viding they invest in the technology and maintain their
understanding of and expertise in it.

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