Digital Integration – Flexibly Automated Plastics Processing

Automated Production Makes It Possible to Increase Part Quality, Process Reliability and the Productivity and the Flexibility of the Production Processes

At present, two automation trends are in evidence among plastics processing companies: On the one hand, the complexity of systems is increasing, while on the other, customers are seeking flexible solutions owing to ever faster product changes, increasing version diversity and, consequently, ever smaller unit volumes per order, down to one-off parts. This means, for example, that high-volume products can be individualized as one-off parts in a flexibly automated, digitally integrated production system by combining injection molding, generative production and "Industry 4.0" technologies.

One of the advantages of the mobile cell is the larger operating zone available, as the small six-axis robotic system moves along a seventh linear axis (figures: Arburg)

Automation has been one of the most significant major topics in the industry for many years and the objectives are the same in all cases, i.e. high part quality, process reliability, availability and productivity. The demands placed on plastics processing are becoming increasingly complex due to the integration of functions in the mold and the incorporation of downstream processing steps in automated production cells. The demand is for systems tailored to individual cases and turnkey systems, the design of which involves consideration of the entire value-added chain.

A Reality Today: Equipped for the Future with Industry 4.0

Modern machine technology is not enough, however, to survive against worldwide competition in the long term. That is why innovative machine construction companies are increasingly transforming themselves into suppliers of flexibly automated production systems for integrated production in the digital factory.

"Industry 4.0" directly affects the entire plastics industry. This term principally relates to the IT integration of machines, molds, workpieces and logistical peripherals (**Fig. 1**). Some of the individual aspects that many injection molding companies already use include production with automated machines and complete turnkey systems, interactive maintenance planning, self-organizing logistics and batch-related data archiving.

A host computer system is of central importance here, providing for efficient control of several machines, automation and the entire production process simultaneously. The product itself is transformed into an information carrier by means of an applied DM code. Using the knowledge of its own history and current state, as well as its eventual purpose, it communicates with the machines and controls its progress through the process sequence. The product uses the DM code to identify itself to machines and to supply information for the next production step. In addition, all process steps can be documented seamlessly and without error and the relevant process parameters can be uniquely assigned at a later point.

The host computer system assigns an individual web page in a cloud to each product. Using the code, the relevant product, process and quality data for the entire production process can be retrieved at any time and anywhere in the world online using a mobile device – even after several years (**Fig. 2**). This plays an important role, for example in the traceability of safety-related parts, such as airbags for the automotive industry and implants for medical technology. This type of traceability is also the basis for just-in-time production.

Alternative: Standard Robots instead of Special Automation

It is always worthwhile considering automation – irrespective of the size of the company, the product or the batch size. The range extends from simple pickers and linear handling robots to six-axis robotic systems.

Pickers are specially designed for the reliable removal of sprues to a high degree of precision. Compared with pneumatic devices, models using powerful, energy-efficient servo-electric drive technology significantly reduce set-up and cycle times. This means, for example, that the mold-entry axis of an Integral-picker V (manufacturer: Arburg GmbH + Co KG, Lossburg, Germany) with an acceleration of 20 m/s^2, the mold-entry axis is extremely dynamic and reaches speeds of up to 2,000 mm/s (**Fig. 3**). Simultaneous stroke-dependent movements are another major advantage. The three servo-electric movement axes dispense with the need for set-up work during order changes.

One frequent obstacle is the fact that it is not possible at the procurement stage to foresee all the requirements that the systems will have to meet in future. Thus, for example, with high-speed applications, a linear robotic system with a fast-action mold-entry axis (up to 4,000 mm/s), enabling short mold-open times, may be the best option (**Fig. 4**). Thus, mold-entry time was reduced by 38 % compared with a standard mold-entry axis in a process involving the production of two tubs. Over a year, this results in a production increase of more than 1.2 million molded parts. The advantage of such solutions compared to specially designed automation systems is that a linear robotic system is not limited to a single application, but can also carry out other insertion, removal and set-down tasks in the event of product changes.

Interactive: Cooperation between Human and Robot

If a higher degree of flexibility is required for insertion tasks, interactive operation with human/robot cooperation can be the ideal solution for small and medium-sized batch sizes (**Fig. 5**). The production of office scissors is an example of how operatives can work hand-in-hand with a robotic system.

Fig. 2. Industry 4.0 in practice: the example of a toy buggy with individualized code shows how production units can be networked and data can be archived on a part-specific basis

Fig. 1. The term "Industry 4.0" principally relates to the IT integration of machines, molds, workpieces and logistical peripherals to create cyber-physical production systems

During the injection molding cycle, the operator manually positions the metal blanks in the gripper of a linear robotic system. This does away with the need for expensive provision and feed devices for the inserts and the system can be quickly and easily changed over for other products. In the next step, the robotic system automatically places the inserts into the mold of the injection molding machine. Interactive operation reduces the capital expenditure on the automation solution and, thanks to the reproducible processes, enhances process reliability and productivity.

Synchronized: Three Six-Axis Robots with 18 Axes

In the case of automation machines that are tailored to a particular application, it rarely makes sense to change components and to continue use when production requirements change. The great degree of freedom offered by a six-axis robotic system offers clear advantages over a linear system and renders it valuable and value-adding in subsequent production, even after amortization.

An example of a product-specific production cell in which three six-axis robots, i.e. 18 controller-integrated axes, operate synchronized with an injection molding machine can be found at Rudi Göbel GmbH & Co. KG, where the system runs around the clock at the company's location in Helmbrechts, Germany (**Fig. 6**). The system produces connector carriers for a new type of automatic Stop/Start system in cars. The component, comprising a metal insert and pin contacts, is overmolded with PBT and no finishing work is required.

The requirements with regard to efficient high-volume production are therefore extremely high. The inserts are supplied by a feeder cell featuring a Scara robot. The two six-axis robots for handling the inserts are connected serially via a bus interface. The first six-axis robot removes the inserts, aligns them using the special "event-driven rotation" function and places them onto a transfer station. This function is programmed via the machine control system and replaces an expensive rotary unit. The second six-axis robot removes the finished parts and places inserts and contacts in the mold. During the injection molding process, the third six-axis robot in the control station passes the parts to camera inspection before placing the good parts onto a tray. »

Fig. 3. Practically based solution for short set-up and cycle times: a servo-electrical Integralpicker for removing sprue

Complex: Turnkey System with Five Integrated Robotic Systems

However, things can get even more complex without causing overall availability to collapse. H&B Electronic GmbH & Co. KG also employs complex turnkey systems for the production of hybrid parts for the automotive industry. In addition to an injection molding plant, the company also has its own stamping and mold construction workshops at its location in Deckenpfronn, Germany. Complex, waterproof hybrid connectors, which are used for the electric steering system in car engine compartments, are produced in a production cell (**Fig. 7**). The system comprises two stamping presses, a vertical two-component rotary table machine and a testing cell with several stations. Handling of parts in the various production stages is performed by three six-axis robots as well as two linear robotic systems traversing on a cross head.

In the design of the system, the focus is on a reliable overall process, from the manufacture of the stamped parts through to the inspected finished product. An all-embracing operating philosophy for the injection molding machine and automation solution, as well as a single control logic for the entire interlinked system are major advantages. Communication between the stamping presses, the injection molding machine and robotic systems takes place via the central control system. Thanks to the “Part status” function, the machines and robotic systems always know the position of the inserts, pre-molded parts and finished parts.

Two small six-axis robotic systems place the contacts, which have been detached and bent into shape by the stamping presses, onto a transfer table. The first linear robotic system carries the contacts to the rotary table on a cross head. The second linear robotic system turns the pre-molded parts over, removes the finished parts and transfers them to the testing station, which can also operate autonomously. There, a third six-axis robot performs all further handling operations. After several checks, a DM code is printed on the good parts before these are placed in blister packs and removed. It is expected that in the next expansion stage, the system will produce a million parts a year.

Flexible: Robotic System Performs Additional Tasks during Waiting Times

The fact that a six-axis robotic system can not only securely handle injection molded parts, but also make rational use of the residual cooling time of the injection molding machine is demonstrated by Erco GmbH at its lighting factory in Lüdenscheid, Germany, with the production of thick-walled high-tech lenses for LED lighting systems. By investing in fully automated production and linking several process steps, the company has succeeded in further optimizing quality, as well as the price/performance ratio of the digital architectural lighting system.

The system is used in the production of a large variety of lenses and so-called collimators, which focus the light beam. Handling is provided by a six-axis robotic system which shares the same control philosophy as the injection molding machine and which is comparatively easy to program. The gripper can be quickly adjusted to the relevant product variant by means of interchangeable mold platens with product-specific mountings. The complete production cell is controlled centrally by means of the machine control system and operates extremely precisely. This enabled Erco to reduce the reject rate as well as the costs of transport and storage significantly.

The main products are 30 mm thick lenses with a diameter of around 80 mm. The six-axis robotic system removes these from the mold, places them in a turning station and positions them appropriately for the laser station, where the sprue is removed. Finally, it removes the lens and sprue and places both

Fig. 4. For high-speed applications, a linear robotic system with a fast-action mold-entry axis may be a better option than a specially designed automation solution

Fig. 5. Interactive operation reduces investment costs for the automation solution and, thanks to the reproducible sequences, enhances process reliability and productivity

on a conveyor belt. During the long residual cooling time involved in the injection molding process when producing optical components, the robot places disc-shaped microprismatic lenses from a drawer system into the laser station, which then cuts different geometries on these as required. The additional action can be repeated several times, depending on the cycle time. This ensures that the robotic system and the laser station are well utilized despite the long cycle time of the overall process (**Fig. 8**).

Even though, as the two examples have shown, it is worthwhile investing in complex systems in many cases, the integration of upstream and downstream process steps only makes sense to a certain extent. The limit is reached when the individual processes affect the availability of the system excessively and the required output can no longer be ensured. In these cases, the installation of buffer sections or complete separation of the processes is a better alternative. »

Fig. 6. Synchronized trio: a six-axis robot delivers metal inserts with positional accuracy, the second robot takes the inserts and contacts and places them in the mold, while the third robot is responsible for the inspection of the finished parts by camera

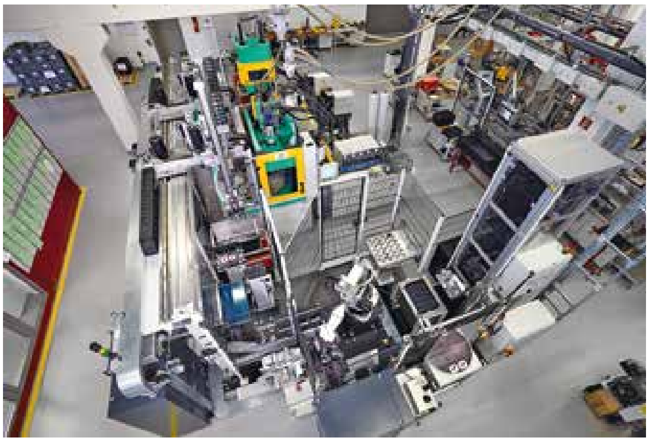

Fig. 7. H&B Electronic uses a complex turnkey system. Handling is performed by three six-axis robots, plus two linear robotic systems traversing on a cross head. All communication is handled by the central machine control system

Integrated: One Data Record for Robotic System and Machine

Especially against a backdrop of increasingly complex processes, a modern control system must provide the operator with the most convenient and efficient support possible. Otherwise, control of the complex processes is inadequate. A user interface that has been consistently designed for the entire injection molding sequence enables, for example, process data storage, statistical evaluations and the complete integration of robotic systems and other peripheral equipment, which can thus be centrally programmed and monitored. For the operator this means: only one data set, a familiar approach during programming and perfect synchronization of robotic system and machine.

A simple programming process is a key requirement in order to make best possible use of the high flexibility of the robotic systems. A "teach in" function means that linear robotic systems can be programmed very easily. Menu-based set-ups take only a few minutes. Conversion processes are also efficiently shortened, the overall handling sequence is more reliable and training expenses are reduced significantly.

Integrating the intuitive, graphics-oriented user interface into the control system for six-axis robotic systems has simplified the complex programming of these systems. This means that operators can enter and adjust all the movement sequences and functions themselves, on-site, without the need for an external programming service. Following the creation of the robotic program, all further actions can be controlled from the injection molding machine.

Mobile: Articulated-Arm Robot on a Linear Axis or Moving Platform

Where both high flexibility and high complexity are required, mobile robotic cells are the ideal solution. The fixed link between injection molding machine and robot is abandoned in favor of a modular, movable alternative, enabling a range of individual configurations. One example of this is a small six-axis robot that can also run on a seventh linear axis (**Title figure**). This enables more dynamic movements and faster entry into the mold.

The main advantages of this solution are short cycle times and a larger working area. The robotic system can therefore perform a wide variety of molded part production tasks. It is also possible to make flexible use of the mobile cell on different injection molding machines. If more than one mobile robotic module is available, completely new production concepts can result, involving one or several injection molding machines.

However, the wide range of new automation solutions is not due solely to the development of robotic technology. For example, new safety concepts allow man and machine to work hand-in-hand. For example, fluid automation and high flexibility enable the use of a six-axis robotic system without safety enclosure, which is technically equipped to allow the sharing of its workplace with a human operative. This includes a "smart" six-axis robot installed on a mobile platform. In addition to mobility and the associated high flexibility, the special feature of this automation system is that it allows man and machine to work together on an autonomous basis.

Combined: Injection Molding, Generative Manufacturing and Industry 4.0

The automated production of small batches without compromising on productivity or availability is a genuine challenge. Arburg will demonstrate the latest technology for the integrated and automated production of individualized and clearly traceable products at the Fakuma 2015 using two practical examples. Visitors can use a layering process to apply their name or a logo to an injection molded high-volume part – either a rocker-type light switch or a pair of office scissors (**Fig. 9**), producing a genuine "one-off" product. The process steps encompass order entry, injection molding of the "blank", industrial generative manufacturing for the individualization step and the display of the process parameters on a part-specific web page.

Using a PC station for order entry, visitors can choose between several different scissor blanks and personalize the product with their name. In order to enable flexible and fast product changes, human and linear robotic system work closely together. After the metal blades have been manually inserted in the injection mold, the plastic handles are overmolded; an individual

Fig. 8. While the thick lenses cool in the mold, the six-axis robot transfers more products for laser processing (rear right in the figure) (figure: Erco, Dirk Vogel)

Fig. 9. A generative production step is used to customize mass-produced items, for example through the application of three-dimensional lettering on a scissors handle

code is then applied by laser and individual lettering is added. The linear robotic system places the scissors in workpiece carriers, which are moved out of the injection molding cell on a conveyor belt. Then a 3-D lettering in plastic is applied in a generative process. A mobile robot handles the automatic loading and unloading of the Freeformer for generative production and finally hands the finished products over to the visitors.

Summary

A totally new world is opening up to the injection molding industry thanks to a wide variety of development. On the one hand this is thanks to complex turnkey systems. On the other hand, the automated manufacturing process also makes smaller batch sizes much more cost effective. Industrial generative manufacturing facilitates the cost-effective move from injection-molded high-volume production to the creation of finished one-off pieces in a generative process. Customer requirements are incorporated in the production process. Through the use of "Industry 4.0" technologies, the various process steps can be brought together in an end-to-end data and information chain that enables the specific individual parts to be traced accurately. ■

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