Flawless, scratchproof surfaces

The refinement of plastic surfaces, as carried out by GfO Gesellschaft für Oberflächentechnik mbH, involves very complex processes that require automated and highly flexible production facilities. Since these are cleanroom applications, the controller must perform both process-related and manufacturing tasks: the production facility, which is operated with a product mix, places MES demands on the controller with RFID identification, production control and recipe management. This also includes the computer coupling to subsystems, such as the coating station, camera-based surface inspection and robot system. All control tasks are PC-based and are implemented with TwinCAT. The process peripherals are coupled to Beckhoff Bus Terminals via various fieldbus systems.

In the pre-treatment station, the plastic parts are first pre-cleaned by brush (on the left in the picture) and then moved under the stationary plasma head for pre-treatment using atmospheric plasma. Both processes are performed dynamically by means of Servo Drive Technology from Beckhoff.

GfO Gesellschaft für Oberflächentechnik mbH in Schwäbisch-Gmünd, Germany, specializes in the refinement of high-grade plastic surfaces, such as those used for display panels in measuring, control and regulating equipment, medical devices, mobile phones, MP3 players, computers and navigation devices. The higher the demands on the function of a device, the greater the resulting demands on the product’s surface: it must exhibit a high-grade shine and be both smooth and, above all, scratchproof. Even in the automotive sector, where internal parts for displays and control devices or parts of the exterior (headlight covers, side panels, etc.) are made of plastic, physically and chemically resistant surfaces are indispensable.

In 2005, GfO opted to use a selective coating technique based on an inkjet process, which had been patented by a partner in the UK. In order to apply the refinement process, which takes place in the clean room, GfO developed a completely new production facility, with which the surfaces of plastic parts are activated fully automatically and surface-hardened after the application of the coating. “GfO develops its own production facilities, which means that we have our own equipment engineering department and also manufacture the holding devices and coating receptacles for the products that we process on our customers’ behalf. In principle, we bought only the cleanroom for the new plant, but even the planning of how the cleanrooms should be designed was conducted mainly at our company. We also assembled the plant equipment ourselves and developed the individual components, such as the processing stations for insertion and removal,” said Peter Wasgien, Head of Design at GfO.

High demand handled by TwinCAT

The complex plant was fully automated using PC-based control technology from Beckhoff. The automation technology was planned and implemented by APA-Tec GmbH. “In May 2005, we made the circuit diagram for the initial planning; after that we started building the plant control system,” said Eberhard Vaas, Managing Director of APA-Tec. This new plant for producing scratchproof surfaces was, however, not the first project that Eberhard Vaas and APA-Tec have tackled together with GfO. It is also not the first GfO system in which the Beckhoff automation platform has been used. “Due to the complexity of the production process, which includes both an extensive range of parts with mixed running, fully automated production as well as quality as-

PC Control enhances highly flexible production plant that refines high-grade plastic surfaces
surance measures, a flexible controller with horizontal and vertical integration capabilities was required,” said Eberhard Vaas. “The complete management of the production process, which includes the recognition of the workpiece carriers and the plastic parts to be processed along with the assignment of the correct recipes, is performed by TwinCAT.”

**Cleaning station is a highlight in the area of control**

The demands on the system are very high: a transparent protective coating is applied to the plastic surfaces by a special printer using the inkjet process. The printer recipe is dependent on the plastic parts being processed. To ensure that the transparent protective coating also adheres securely, the plastic parts are pre-treated in two work steps. First of all, the parts placed on the workpiece carriers are cleaned by brushing. Regarding this, Peter Wasgien said: “It is a wet brush cleaning process that also dissipates static charges.” “The brush cleaning and the subsequent plasma cleaning,” adds Eberhard Vaas, “already represent a highlight in terms of control: the brush consists of two longitudinal brush segments that move in opposite directions. The workpiece carrier (center of picture) is located directly under the printer head. The printing process is independent of the TwinCAT application, but is coordinated by the Beckhoff system.

A fully automatic and highly flexible production facility achieves the super-purification and activation of plastic surfaces by atmospheric plasma in cleanroom applications. The plastic surfaces are subsequently coated with a clear, special coating and made scratchproof by curing under UV light.

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**Beckhoff equipment used**

**Control**
- CP7201 Panel PC
- TwinCAT NC PTP
  - HMI connection via ADS OCX
  - Printer connection via Ethernet

**I/O**
- Bus Terminals with PROFIBUS DP Bus Coupler
  - Integration of the stepper motors via KL2541 Bus Terminal
  - Integration of the RFID reader via KL6201 Bus Terminal

**Motion**
- AX2500 Servo Drive with Ethernet interface
- AM3xxx series servo motors
piece carriers are driven under the brushes following a precise pattern and at a precise distance. This means that the distance between the brush and the workpiece is numerically controlled, as is the speed of the workpiece carrier. Subsequently, the workpiece carrier is blown off with ionized air and driven under the stationary plasma head for surface activation. In order to achieve an even pre-treatment of the surface, the workpiece carrier must be moved in the x, y and z directions in the atmospheric plasma. Eberhard Vaas comments: “The head is fixed and the TwinCAT system moves the workpiece. This pre-treatment process represents a servo application, which was implemented using Beckhoff control technology. This allows any position under the plasma head to be manipulated reproducibly in accordance with the recipe.

Peter Wasgien explains the control principle for the plasma treatment as follows: “This is a cleanroom application, so we avoid having moving parts above the workpiece carrier. Therefore the plasma supply line is rigid.” Both the inkjet print head and the cross table mounted below it, on which the workpiece carrier is placed by a pneumatically actuated fork lifter system, are controlled, along with the camera system, by their own controllers. A Linux-based controller receives information from TwinCAT directly via Ethernet regarding the correct recipe to use for the plastic parts to be coated.

**Control technology and stepper motor drives for complex edge hardening**

The element that connects the entire system is the circulating conveyance system. Empty workpiece carriers circulate freely. From here they are taken into manual equipping stations and loaded with plastic parts. They subsequently enter the main circulation, where they are transported first to the pre-treatment station and then to the coating station. After the application of the transparent protective coating, the workpiece carriers are driven into an infrared (IR) heat stage, where defined pre-drying takes place by means of IR heat sources. This is followed by transport into the ultraviolet (UV) curing station, which is in turn followed by a second free circulation for the removal and checking of the finished, coated parts.

The drying process has its own highlights in terms of control. As Eberhard Vaas reports, these begin with the infrared coupling. “The required IR power for heating is controlled by specifying the relative power value of the IR sources: this can be, for example, 25 percent of the available power. In addition, the duration of the power input is controlled. After that, the IR power is initiated. This process can be varied, depending on the plastic parts.” As Peter Wasgien remarks, the infrared station is required in order to optimize the flow of the coating process.

In the curing station, the surface is cured by UV light shining vertically from above. “This is similar to the drying process,” said Peter Wasgien: “We can precisely specify the burner power by calling up the stored recipe. For a certain product, for example, 75 percent of the UV burner power may be required along with a defined speed with which the workpiece carrier passes under the UV burners.”

However, because some of these plastic parts have lateral edges or web surfaces, with coating that is not cured by the vertical UV light, special edge layer hardening is required. “The edge hardening is a special solution that we retrofitted,” explained Eberhard Vaas. “In order for the UV light to also strike the lateral edge surfaces, the UV sources must be adjusted by a defined angle. The workpiece carriers thereby rotate under the inclined UV light source, so that all of the edge surfaces are uniformly hardened all around. The UV lamp is inclined by two Beckhoff stepper motors, which are controlled directly by an associated Beckhoff Bus Terminal for stepper control via I/O.

**Quality assurance in the control network**

After curing, the workpiece carriers are transported into a cell equipped with several camera systems and light sensors for surface inspection. These cameras observe the interference fringes projected onto the surfaces by the sensors in accordance with the triangulation principle. These are compared with the stored values of the object surfaces by a separate computer. A downstream SCARA robot removes rejected parts. The cell computer and the robot controller communicate with TwinCAT, which controls the synchronization of the test sequence.

Following the surface inspection and sorting by the robot cell, the workpiece carriers are transported to the manual unloading stations. There, the finished plastic parts are removed, subjected if need be to a final visual inspection and packed into appropriate containers. The empty workpiece carriers are placed in the free circulation and integrated once more into the previously described process sequence when required.

**PC Control easily manages automation and IT tasks**

The TwinCAT application integrates not only the surface treating process, but also complete control of the facility’s air conditioning according to class 10000 or 1000 cleanrooms.

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**Picture of the IR heating station**
Mixed operation with different plastic parts represents a particular challenge. To this end, all workpiece carriers are equipped with RFID transponders and identified via 16 readers mounted in the plant. The readers are coupled with TwinCAT through an AS interface integrated via the Bus Terminal I/O system, and supply information regarding which workpiece carrier is located at which point in the process sequence. This way, TwinCAT always knows where each workpiece carrier is located in the plant and with what load and can select the appropriate processing recipes. The operator at the feeding station in turn reports which plastic parts were placed on the workpiece carrier. Currently around 10 different parts are processed simultaneously in the plant. The average number of parts processed per shift is about 3,000.

This relationship alone illustrates that a conventional hardware PLC would not be able to cope with the complexity of the control task. The identification of the workpiece carrier, its insertion into the process circulation and the administration and assignment of the recipes to be applied, from the pre-treatment and the application of the transparent coating to the heating and curing, is actually a classic MES application from the point of view of data handling, which TwinCAT can easily cope with.

**Room control integrated into the system**

Air conditioning represents another complex task handled by TwinCAT. The processing plant itself is a complete small factory embedded in a subsection of the overall factory facility. Regarding this, Eberhard Vaas said: "The facility is fully encapsulated and consists of different rooms with different usage goals, including air locks for the personnel, a preparation room and various cleanroom areas, which are supplied with air according to the respective tasks. From the point of view of air conditioning and regulation, all rooms such as those for pre-cleaning, the printer room, the air exhaust zone, the infrared zone, etc. are supplied by one air conditioning unit. The air is filtered and cooled by three air-conditioning compressors, then heated again, set in motion, filtered again and finally moistened." To this end, appropriate temperature, pressure and humidity sensors are connected to the Beckhoff Bus Terminal I/O system. The air conditioning is to be adjusted using an analog technique; i.e. the power of the air-conditioning compressors is set by an analog signal. The analog values are 4 to 20 mA and 0 to 10 V; both types of signals are used. Furthermore, PT100 inputs for temperature measurement are available on the input side. Since vacuum systems are also used in the plant, pressure sensors are similarly integrated for this purpose. "We have full air conditioning in the production area," explains Peter Wasgien: "We can humidify and dehumidify, heat and cool, so that we maintain constant temperatures and constant humidity the whole year round. TwinCAT takes care of the entire control concept." The air conditioning is also documented. Regarding this, Eberhard Vaas said: "We represent the temperature curve graphically. This also includes the temperature curve outside the production area, as well as the humidity. All climatic values and all other collected data are stored in the form of logbooks with a time and date stamp, so that they can always be matched to the respective processed lot at any time later on."