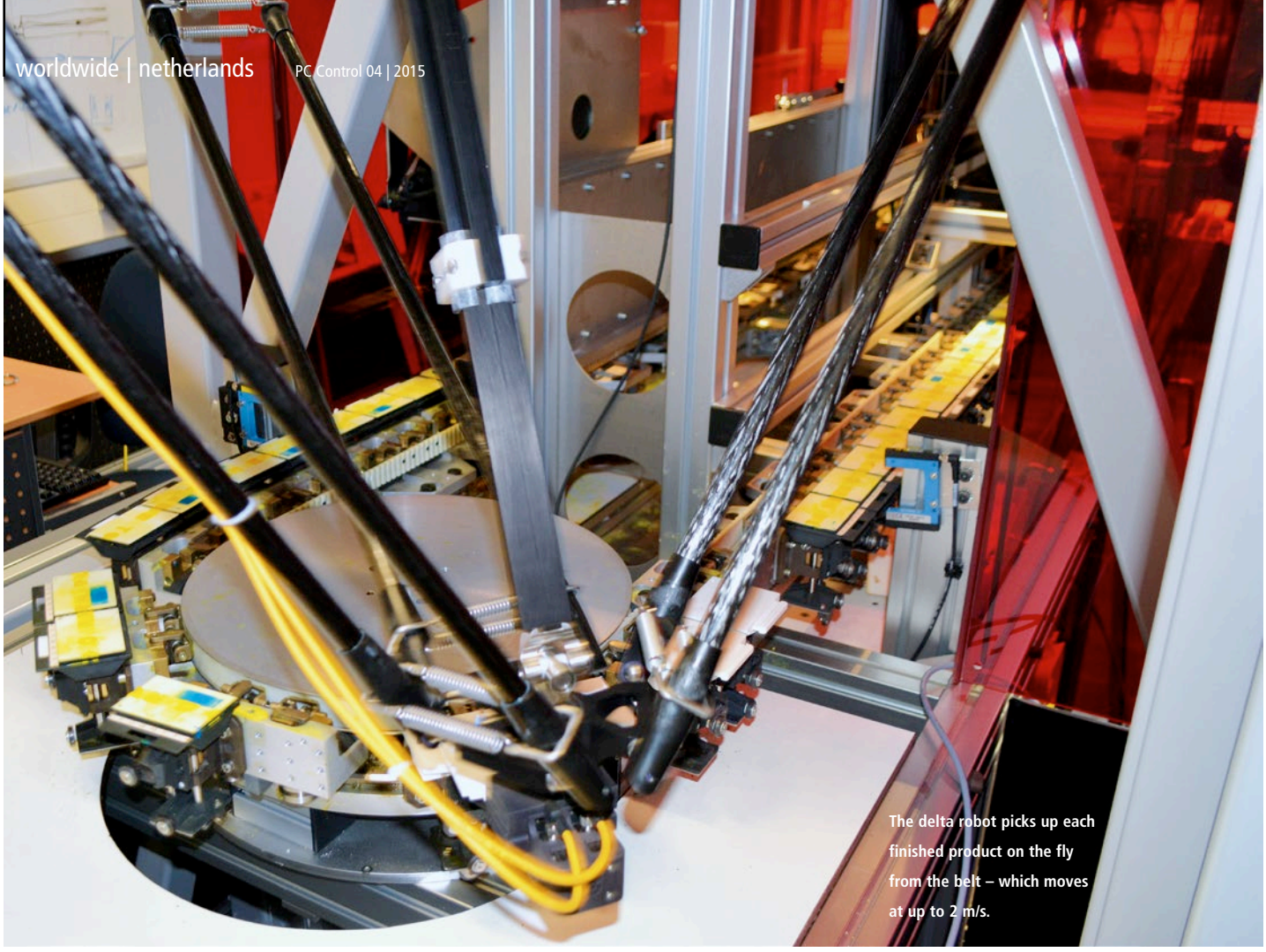

The delta robot picks up each finished product on the fly from the belt – which moves at up to 2 m/s.

Customized mass production in the factory of the future

High-speed production line combines 3D printing with precision machining

The development of additive manufacturing is progressing rapidly. One of the main advances in the progression of this technology is 3D printing of metals. To enhance this trend, TNO's additive manufacturing department in Eindhoven, The Netherlands, is developing "Hyproline", a "High Performance Production Line for Small Series Metal Parts" which consists of an integrated production line that incorporates printers and modules for finishing small metal products in various designs.

Up to now, the 3D printing process was limited to stand-alone machines that delivered products in small quantities, such as prostheses or non-standard machine parts. The ability to produce "batch size 1" quantities is one of the great benefits of 3D printing, and is often mentioned in discussions on Smart Industry or Industry 4.0.

To meet the demand for mass customization, i. e. the desire of modern consumers for a singular product at an affordable price, it is necessary to combine a large variety of products with high production figures. For this reason TNO, the Netherlands Organization for Applied Scientific Research, has developed "Hyproline". This high-speed production line makes 3D printing an integral part of the overall process, thus increasing the production output along with product variety and quality at the same time. "Hybrid manufacturing", which is based on the PrintValley concept, enables a combination of 3D printing and precision machining of 100 different product variants at high speed.

Hyproline begins as a European research project

Arguments in favor of the Hyproline were endorsed by the European Union, which supports the Hyproline research project to the tune of 4 million euros. (Hyproline was financially supported by the European Union's Seventh Framework Program under Grant Agreement no 314685) The "Equipment for Additive Manufacturing" division of TNO in Eindhoven is one of the key partners in this project. Other partners include the University of Birmingham (United Kingdom), the Swerea research center (Sweden), as well as the

companies CCM (Centre for Concepts in Mechatronics, The Netherlands), Höganäs (Sweden), and ITI TranscenData (United Kingdom). Frits Feenstra, Senior Project Manager, Frits Verhoeven, Research Engineer, and Herbert Fiedler, Control and Automation Developer at TNO, have been working on Hyproline for four years and plan to complete the project in 2015. Frits Feenstra comments: "With Hyproline, we address two key points: First, we want to considerably speed up the production of complete, individualized metal products, and second, we want to make 3D printing an integral part of a complete production line." Although the metal products are currently not yet produced on the Hyproline platform itself, the process of finishing 100 different metal components is an important step towards fast, high-quality production of 3D-printed parts.

A continuous conveyor is the solution

"We have to say goodbye to the idea that 3D printing always takes place in batches," Frits Feenstra explains. "At present, we still work in successive steps, as is customary with 3D printing. Our goal, however, is to produce several, perhaps completely different, products at the same time, and, to that end, we developed Hyproline." Bearing a striking resemblance to a toy train that keeps going round and round, the Hyproline implements an endless belt system with an overall length of 8 m, on which 100 carriers/pallets are mounted. The belt can move at a speed of up to 2 m/s, passing various processing stations. The individual machining steps are executed by modules mounted above the belt. Installed modules include measurement of the height (of the pallet and the printed layers), 3D scanning of metal products, laser processing (ablation, grinding and polishing), the printing itself, and flash curing as a final step. In each round, the pallet is set to the correct height for the next processing steps. "Due to the length of the belt, we can mount a large number of printers and other modules above the belt. The supplied parts are made by printing on metal powder (titanium, stainless steel 316L, or copper) followed by a sintering step," according to Frits Verhoeven. A 3D scanner determines the roughness of the applied metal. If the surface is too rough, it is polished by a laser beam. The processing steps are then repeated until the product is complete and ready to be removed from the belt.

TNO values control system openness

An integrated delta robot picks the pallet with the finished product from the belt "on the fly". "Our goal is a top speed of 2 m/s, although the currently realized speed of 1.3 m/s is already a remarkable achievement," Herbert Fiedler points out. A Beckhoff CX2020 Embedded PC controls the robot, and two further controllers provide instruction for the conveyor belt and the cleaning and filling mechanism of the print heads. "TwinCAT 3 is used as the integrated automation software," says the Control Developer. "We have been using hardware and software solutions from Beckhoff for five years. The main reason is the openness of the system, which gives us free choice of controllers and protocols. Also, when compared with control systems we used in the past, the Beckhoff system is much more maintenance-friendly. Openness and maintenance are important aspects for us, not least because we want to continue using machine control systems we developed in the past in the new lines. For programming the functionality we use TwinCAT and for motion control hardware, the Beckhoff AX5000 Servo Drives. The EL6692 EtherCAT bridge terminal is used for synchronizing the robot with the filling mechanism of the printer."

Conveyor belt with lift for quick height adjustment of the pallets

The TNO team with Hyproline in the background: Frits Feenstra, Senior Project Manager, Frits Verhoeven, Research Engineer, and Herbert Fiedler, Control and Automation Developer (left to right)

Integrated safety

Machine safety for the Hyproline system is ensured using TwinSAFE I/O modules from Beckhoff, providing IP 20 and IP 67 rated protection. "TwinSAFE enables machine safety and machine control to communicate via the same fieldbus and the same cable," states Herbert Fiedler. "This eliminates the need for external wiring." Safety functions of the AX5000 Servo Drives are integrated through AX5805 safety option cards. The two CX2020 Embedded PCs are directly linked with the EL6900 TwinSAFE Logic Terminals for controlling these safety functions. The sensors for the monitoring screens and the emergency stop buttons communicate directly with the machine control via eight EP1908 TwinSAFE IP 67 modules mounted directly on the machine.

A new maximum speed

"Today, Hyproline is able to simultaneously print and process 100 products with totally different shapes," notes Senior Project Manager Frits Feenstra. "The speed of Hyproline is crucial for its high productivity." With this in mind, the TNO developer team aims to increase the production capacity to about 10,000 parts per day.

Further information:

www.tno.nl/en

www.beckhoff.nl