PC-based CNC solution for machining and handling small parts

Quantum leap in micromachining with open, high speed CNC

With the 701S machining center, Willemin-Macodel has introduced a quantum leap in the machining of small parts by fully exploiting the dynamics and rigidity of the delta kinematic for the first time. This was achieved through the reduction of moved masses and by leveraging powerful PC-based CNC technology from Beckhoff. This has enabled a 90 % reduction in energy consumption and a reduction in the machining time by as much as a factor of ten, depending on the workpiece.

The basic idea: During the machining process the small mass of the workpiece is moved instead of the heavy tool carriage..

The Delémont, Switzerland-based Willemin-Macodel company specializes in machines for small part machining. The systems are used in the watch making industry, medical technology and the aerospace industry, among others. Technical director Denis Jeannerat explains: "Our core competency is in high-precision machines for full-process machining. Because fixing small workpieces has always represented a challenge, the same machine now performs all machining steps – without the traditional division of processes into turning, milling and grinding. The machine also takes care of the parts handling, i.e. the careful insertion and removal of the workpieces. A prime example of this is the 701S machining center, which was introduced at the EMO 2013 trade fair."

A simple idea revolutionizes micromachining

On the face of it, the idea behind the new machine sounds simple: The 701S micromachining center features a delta robot that has been inverted – placed "upside down", so to speak. This robot moves the workpiece – a task usually handled by the tool carriage. Denis Jeannerat explains the thinking behind this concept as follows: "There is a strong tendency toward component miniaturization in our markets. Therefore, we sought to design a machine with an enhanced ratio of parts size to machine size, because when you're machining a 2 g or 20 g part, it makes no sense to move a tool carriage weighing 100 kg in a 3 m long machine that weighs 12 metric tons. It is much better to move the small mass of the workpiece instead of the tool. In this way, the mass that must be moved is reduced immensely, from perhaps 500 to 800 kg for a conventional shaft to only around 2 kg. These low moments of inertia can also be mastered using a delta robot."

Accordingly, the basic concept of the new machine is based on parallel kinematics with a delta structure, and has been implemented in form of a workpiece carrier connected by three arms. The machining strategy of the 701S, which is designed for machining small workpieces (Ø 52 x 32 mm), focuses on compu-

The machining center is operated via a customized CP7912 "Economy" Control Panel with 15-inch touch screen.

The 701S micromachining center has a footprint of approximately only 1 m^2 .

tationally intensive "circular interpolation". The key characteristics include path accuracy better than 0.2 µm, low sensitivity to temperature fluctuations as well as very high precision and repeatability. A specially designed high-performance motor spindle, with a maximum speed of 80,000 rpm and without tool holders, additionally provides increased static and dynamic rigidity, very high balancing quality and a low radial runout (less than 1 µm at the tool tip).

PC-based control technology masters machine kinematics

Achieving what sounds so simple, however, requires a great deal of engineering effort and know-how with regard to both design and control technology, as Denis Jeannerat explains: "It was a very long project for us, having started over five years ago. Above all, the mechanical systems and drive technology required a great deal of development effort so that we could enhance and finally master the dynamic behavior."

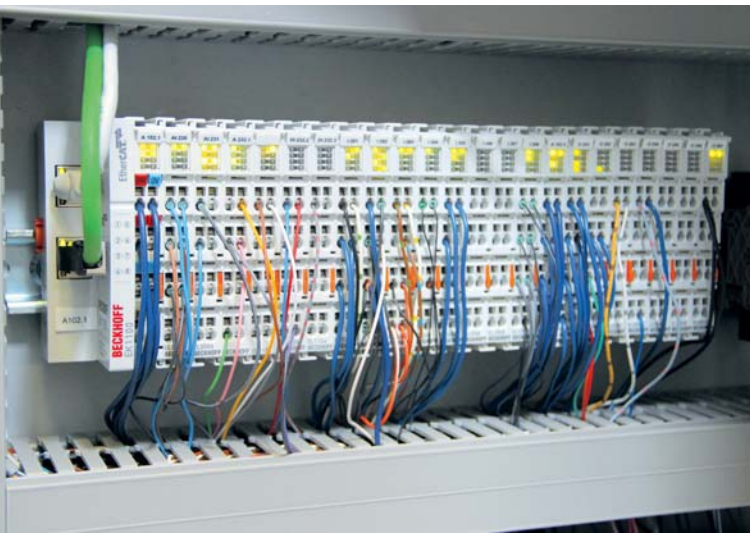
The decision to use PC-based control technology was taken right at the beginning of the project, because it was clear from the outset that this would be the only way to sufficiently realize the complex circular interpolation and fast control loops. Denis Jeannerat says: "After all, the goal was to develop an extremely dynamic machine. The highly dynamic rigidity needed from the system can be only achieved with a powerful Industrial PC that can calculate the control loop parameters extremely quickly. This is especially significant considering the reduced masses that must be moved."

PC Control: powerful, proven and open

Following the decision in favor of efficient PC-based control technology, a fitting supplier was also found quickly. Denis Jeannerat says: "We evaluated various industrial control architectures and were immediately impressed by PC Control. This was not just because of the technology, it was also important to us that Beckhoff has a great deal of know-how and industrial expertise in applications like ours."

According to Denis Jeannerat, Willemin-Macodel attaches particular importance to high flexibility in machine design: "To make our machine design as flexible as possible, we need a system that is open in every respect – with a multifaceted I/O solution, connectivity to various communications subsystems and software versatility. Communication with the necessary handling or robot systems, for example, is very important. On the one hand, we benefit from the kinematics that are already integrated in the TwinCAT software, while on the other we can also integrate our own solutions very easily if necessary." Not only that, each individual machine is adapted precisely to the application, which would be virtually impossible without an open control system. In addition to a modular toolkit of automation hardware that enables flexible machine configurations, dynamic control software – like TwinCAT in this case – must also be modularly structured and offer a great deal of programming freedom.

In the 701S machining center, the openness of PC control has also proven helpful in the simple connection of a special vision-based tool measuring system. With its help, the tools can be measured at full speed, including radial runout. The measuring system can be integrated into the Beckhoff control computer simply by using appropriate PCI plug-in cards, thus providing the computer with large quantities of data directly and very quickly. In addition to its high computing power, the C6920 Control Cabinet Industrial PC (IPC) with 1.9 GHz Intel® Celeron® processor employed in the machine offers a further important advan-



The EK1100 EtherCAT coupler integrates the numerous EtherCAT terminals into the control system, e.g. EL3202 2-channel input terminals for resistance sensors and EL5101 incremental encoder interface terminals.

The C6920 Control Cabinet Industrial PC with its Intel® Celeron® 1.9 GHz dual-core processor offers ample computing power for demanding circular interpolation functions.

tage in Denis Jeannerat's view: "The C6920 Industrial PC from Beckhoff is very compact and therefore requires little space in the machine's control cabinet."

CNC-specific software and operator interface

Apart from complex path calculations, the tasks of PC control also include controlling the speed and position of the high-performance spindle. A total of four axes – the delta robot and the spindle as an additional axis – are controlled extremely quickly. This makes it possible to perform special machining operations with the spindle, such as planing or deburring. This is implemented using TwinCAT CNC, i.e. by means of a pure software solution running on an IPC with complete CNC functionality. TwinCAT CNC can operate with up to 64 axes/controlled spindles, which can be distributed to up to 12 CNC channels. In a CNC channel, up to 32 axes can be interpolated simultaneously, solving even the most difficult motion tasks.

With TwinCAT CNC, users also benefit from the openness to the I/O periphery and to the drive system, which is unusual in the traditional CNC world. The most diverse I/O assemblies can be connected via all common fieldbus systems. The drive systems can be connected with the CNC entirely in accordance with application needs both via an analog/encoder interface and directly via a digital drive interface. The I/O system of the 701S machining center consists of 44 EtherCAT terminals, the information of which is transferred to the control system via two EK1100 EtherCAT couplers. The data are primarily acquired via EL1124 or EL1008 digital input terminals, EL2008 digital output terminals, EL3064 or EL3202 analog input terminals, EL4002 analog output terminals and via EL5101 incremental encoder interfaces.

For a CNC operator interface, the 701S features a customized CP7912 "Economy" Control Panel with a 15-inch touch screen as well as integrated DVI/USB-Extended technology which allows separation from the IPC by up to 50 m. In a sturdy aluminum housing with IP 65 protection, the panel for mounting arm installation features an added keyboard shelf and offers 12 function keys and 10 LED-illuminated special PLC keys. In addition, there is a key extension with emergency stop button, six illuminated pushbuttons, gray code switch (23 positions) and incremental encoder. Denis Jeannerat concludes: "The Control Panel makes the operation of the machine extremely convenient. Numerous functions are directly integrated, for example, via the electromechanical pushbuttons, which enables intuitive and very simple operation."

Highly efficient micromachining solution

The combination of intelligent design and efficient automation has resulted not only in a particularly compact machine with a footprint of only around 1 m^2, but also in a highly efficient machine. Due to the reduced moved masses, it requires only 2 kW of power to machine a small part. A conventional machine requires 20 KW or more for this. Denis Jeannerat adds: "With very high path accuracy within 0.2 µm – even at full speed – the 701S also achieves a value that is better than conventional machining centers by a factor of 10. A further advantage is the immense time savings in parts machining. Depending on the complexity of the workpiece, the machining time is reduced by a factor between 3 and 10. The machining of a copper electrode, for example, now takes only eight minutes instead of over an hour previously."

Further Information:
www.willemin-macodel.com
www.beckhoff.com/CNC