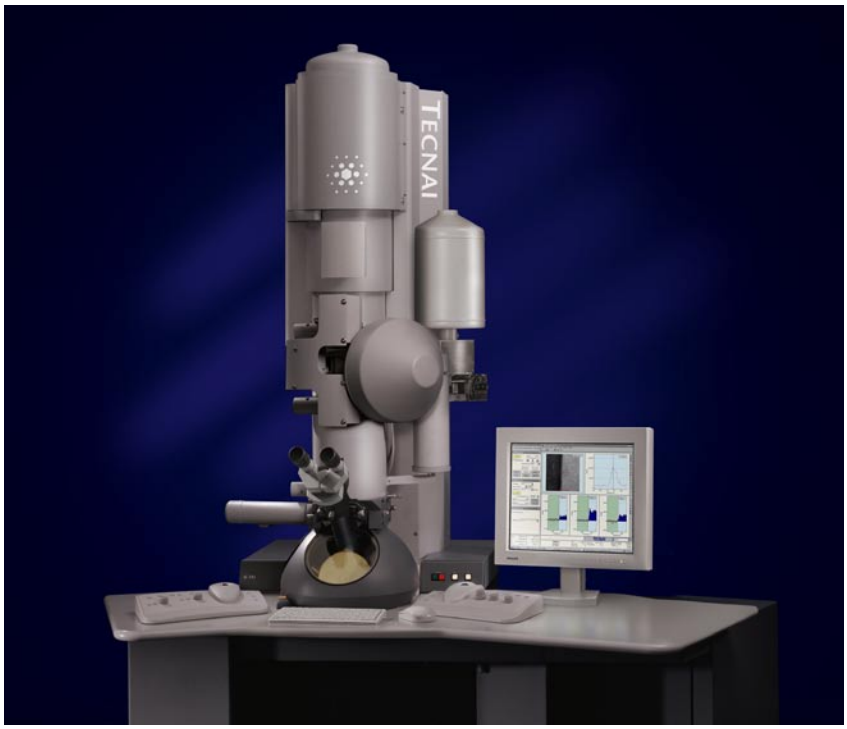
Drive & Control **profile**

Bosch Rexroth Controls Motion in the Nanoworld



Electron microscopes from FEI use highly sophisticated computer-controlled mechatronic technology.

Hillsboro, Oregon-based FEI has been in the microscopy business since 1949, when it produced the world's first Transmission Electron Microscope (TEM). Today, FEI manufactures a full range of microscopes, including scanning (SEM) and TEM types, plus dual-beam lab-based and related equipment. The company's tools, featuring focused ion- and electron-beam technologies, deliver 3D characterization, analysis, and modification capabilities with resolution down to the sub-Ångström level.

Joint Development Project

With one of its major development facilities in Eindhoven

Challenge

Implement extremely slow and steady stage control — at the nanometer level — in electron microscopes

Bosch Rexroth Solution

NYCe 4000 motion control system

Benefits

- Reduced integration costs by 50%
- Increased motion accuracy at the atomic level
- Fluid, accurate, repeatable motion in the nm/sec range
- Literally move specimen stage at the speed of the growth of human hair
- Compact motion control design reduces cabling and system footprint
- Measurement speed may be increased by a factor of five to ten

(Netherlands), FEI is a close neighbor of Bosch Rexroth, which develops motion control systems for various applications in high-tech markets that include wafer handling in the semiconductor industry, the assembly of electronic components, special robots and handling systems, production systems for solar cells and the production of Micro-Electronic Mechanical Systems (MEMS). FEI began working with Bosch Rexroth because of its close proximity and in-house capabilities. Ten years later the relationship has led to a breakthrough in both performance and cost reductions for FEI.

The two companies have embarked on a project called "NewMotion," which targets a modular motion control system comprising various hardware and software packages from Bosch Rexroth's NYCe4000 industrial motion control system. The Technical University of Eindhoven (TU/e) is aiding the project with research into the necessary new control techniques.

FEI will equip high-precision mechatronic systems with the NewMotion system NYCe4000 and integrate them into electron microscopes. TU/e's role is to study and develop new measurement and control algorithms in the field of motion control technology. With fundamental applied scientific research, they will develop new measurement and control principles that will be used in the motion control systems to increase the motion accuracy at the atomic level and achieve fluid motion in the nm/sec range.

Speed Paradox

At the heart of an electron microscope are mechatronic specimen-manipulator stages, which FEI develops. The company is developing new stages that will make it possible to work in the 1nm world in three dimensions (one nanometer corresponds to a millionth of one millimeter). This new manipulator demands a movement and positioning accuracy down to the atomic level, which will be realized through a combination of special stage mechatronics and the new motion control system.

"Paradoxically, the small world we are entering demands a different approach than the one required by manufacturers in other branches who normally want high positional accuracy at the fastest possible speed," said Dr. Maarten Buijs, director of R&D Europe at FEI. "Samples must be handled with extreme precision. In this instance, rather than scanning at high speed we require low-speed behavior for our application, which uses a fairly new type of actuator called an ultrasonic piezo motor." At 1 nm per second, the slow but smooth motion required to achieve the high positioning accuracies that FEI will implement in its latest machines can be compared with the growth of a hair.

More for Less

Although accurate positioning, speed of placement, and the ability to overcome vibration generated by the machine itself are important, machines capable of working on the nanometer scale are increasingly

Compact Rexroth NYCe4000 high-performance motion control reduces project costs.

sold to customers in the industrial sector. And in this respect, Bosch Rexroth's NYCe4000 motion control platform with integrated amplifier technology is both robust and priced low enough to have broad appeal. With everything necessary for controlling a complex machine contained in a single unit, the NYCe 4000 takes up a small amount of space and reduces the amount of cabling and the number of PCBs in a machine. This means that system and integration costs are reduced while availability and service level are increased.

All of these aspects are increasingly important as the electron microscope continues to evolve into an industrial measuring machine. "Achieving a breakthrough in cost reduction is the main driver," admitted Buijs, "but factors such as ease of use, high reproducibility of manipulations, and high throughput of samples all play an increasing role in our business."

At the same time, the company is pursuing new developments

that will measure up to new requirements in five to ten years time. On the motion control front, the NYCe4000 will be at the core of FEI's new generation of products.

"Price pressure is obviously a big driver these days," said Ad Scheepers, Bosch Rexroth sales manager. "On top of delivering better performance with each generation, customers expect a lower price, or more for less."

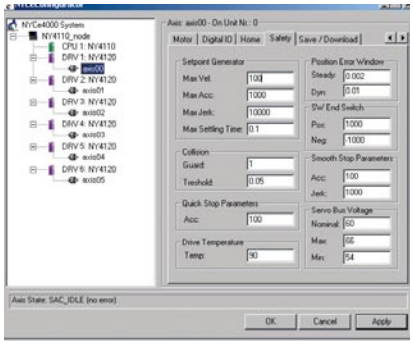
One of the first customers to use Bosch Rexroth's NYCe4000 motion control system, FEI is proving to be a valuable launching customer, according to Scheepers. "Our intensive customer/supplier interaction is leading to new and profitable products, including a very extensive set of tools for diagnostics, tuning, and system configuration. Until now, these were very time consuming processes for the customer."

Pushing the Limits

The expectations from this project center on a new generation of motion control systems whereby reliance will shift from electronic hardware to software and system components. There will also be significant improvements in terms of performance, functionality, and price savings.

"Compared to previous motion control solutions, the integration of drives and motion control in a single unit will save 50 percent on costs," confirmed Buijs.

Similarly, a new generation of manipulators with multiple axis coordinates will improve



NYCe4000 safety settings.

the performance of the motion system and the dynamic behavior by a factor of ten in all respects. This will be largely the result of new, balanced mechatronic constructions that make use of thermal compensation, vibration damping, and a new type of linear measurement scale coupled with play-free transmission. In concrete terms, this will deliver a positional accuracy in the magnitude of 100 nm with a relative accuracy of 10 nm and a drift of 0.1 nm/min. To achieve this extremely high level of stability, a special balanced thermal-compensation system is being developed whereby temperature as a function of time is held constant.

The movement accuracy of a sample using the multi-axis manipulator on a TEM, for example, is critical for the quality of the electronic scan. This demands very slow movements at speeds of no more than 1 nm/s. In turn, this requires a high resolution with a step size of 1 nm. With this project, the targeted speeds are a 15-fold improvement on current capabilities. A big challenge to overcome is the achievement of shock-free movement. Since just a small number of encoder steps are made per increment of time, huge demands are placed on the regulator in the control unit. This must be able to generate a homogenous speed profile so that the actual speed of the sample being manipulated remains constant. In addition, there is always a certain amount of vibration in a mechatronic system that can affect the end position accuracy—a factor that is being taken into account in the design and construction phase.

Although slowness of motion appears more relevant than speed in microscopy applications, the measurement speed of the manipulator will be improved by a factor of five to ten compared with existing systems. This raises the possibility to carry out measurements on multiple products in a reduced number of operations. The measurements in this case would take place sequentially, but samples would be placed in the measurement room in a single charge. All thermal and movement-critical effects would thus be much smaller than in the existing situation where just a single measurement sample is loaded.

In addition, new possibilities for simulation and tooling will inevitably emerge from the NewMotion project. These will offer better and faster ways of reaching an end result and/or solving a motion problem.

Motion Control Platform

For its part, Bosch Rexroth is supplying hardware modules for various application areas, such as low power, high power, and piezo

control—all with the electronic drive and the control in a single unit. The hardware architecture enables the required functionality to be developed with software. Similarly, software modules for applications, configuration, tuning, simulation, path generation, testing, and measurement are being developed to support the customer in implementing motion in a machine. A FireWire communication bus forms the backbone of the architecture, whereby the generated motion commands are fed to the appropriate motion controllers at high speed.

This platform targets applications where speed and accuracy, combined with low cost and fast time to market, are essential. The NYCe4000 is less than the size of a compact industrial PC, yet it provides multi-axis motion control and configurable safety functionality. A single control system supports a standard eight axes per unit, with a maximum of 62 units in a network.

Compliant with both UL and EMC standards, the NYCe4000 includes integrated drives that make it possible to control a machine or a machine subsystem with up to ten axes and with a total of 110 digital inputs/outputs and 20 analog input/outputs. Measurement systems supported include traditional S0/S90 encoders, SinCos encoders, analog position signal, EnDat and others. All related motion, input/output, and digital/analog interfaces are onboard.

The integration of a flexible, universal drive with the motion control system makes it suitable for low-power servo axes and stepper axes (driven by motors up to 500W), opening up the possibility of controlling all motors in a machine with the same drive type. Because it is easy to integrate a customer-specific connector board into the system, no additional external connector panels are required, since the sensor connectors in a machine can be plugged directly into the motion control system itself.

The combination of high-speed motion control with the drive and inputs/outputs in one box reduces cabling, extends uptime and improves serviceability while lowering system and integration costs. Moreover, using one compact system to replace a separate control system, separate drives, separate input/output blocks, and separate distribution boards saves space.

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