Application Story: QED

COMPLIANT TOOLING *+ IMPROVED CONTROLS = SUPERIOR FINISHING*

We all learned it in math classes. "QED" meant that which was to be proven. At a growing young company by this name, founded in 1996, the development of high-precision finishing/polishing machinery for the optics, telecom and semiconductor markets centered around one very provable theory. Namely, by developing advanced precision manufacturing technology, aided by state-of-the-industry CNC platforms, could superior finishes be achieved in significantly lower production times?

The first challenge was the materials being processed. Typical applications for the QED machines involve very brittle or hard substrates such as optical glasses and assorted glass ceramics, including fused silica, borosilicate and Zerodur. Single crystals (sapphire, calcium fluoride, silicon), IR materials (AMTIR-1), metals (EN) and various polymers (acrylic) are also routinely machined on QED equipment. The applications can involve virtually any optical or electro-optical system, including miniaturized micro-optoelectromechanical (MOEMS) systems, megapixel recording devices, optical communications, computer storage devices, integrated circuit fabrication and other emerging technologies that could substantially benefit from more cost-effective production of highly precise optical components.

Optics are also utilized in a wide variety of manufacturing environments, from photolithography for semicon chipmaking to optical sensors that monitor high-speed production lines. Generally, these in-process uses are grouped in two categories, the use of light to perform the manufacturing (rapid prototypes, photolithography) and process materials (laser welding or machining) OR the use of optics to control manufacturing, including metrology, machine vision or various parameter sensors. Optical lithography is essential in the semiconductor and flat panel display industries, with specific end uses including ultra-high quality lens elements, spherical or aspherical optics for imaging, prisms, plano mirrors, corrector plates and substrates for telecommunications applications.

At the heart of the QED formula is a concept of using CNC-based polishing machines that use a magnetic (or magneto-rheological) fluid (MRF) to finish workpiece elements in minutes, replacing manual technologies that required hours, weeks or even months. MRF-based manufacturing enables rapid, deterministic and repeatable surface shape corrections in minutes to levels of precision and surface finish previously considered impossible.

MRF machining was created in a university lab and QED developed it into an industrial platform as the company's original mission. Currently, the company employs a staff of 40 at its headquarters in Rochester, NY. Here, machines are designed, built and assembled, while research on MRF, software development and a customer/user facility with precision metrology capabilities for prototype lens production and machine demonstrations are also conducted. QED also operates a branch in Japan to meet the customer service and support needs of its Asian clients.

The company relies on its core competencies for design and application engineering, while outsourcing large component manufacturing, system integration and the CNC's used onboard QED machines. It is in this capacity that QED has partnered with Siemens to supply much of the critical motion control components and CNC equipment. On several of its machinery lines, QED buys or retrofits a standard grinding machine or machining center, modifying the original design to accommodate the unique and highly particular needs of its customer applications. Standard QED Q22 Series machines now polish parts or

material workpieces up to 750mm (29.52") as spheres, flats, aspheres, mirrors, windows, prisms, cylindrical surfaces and more. The latest innovation is QED's Subaperture Stitching Interferometer, a six-axis, CNC interferomatic workstation enabling the capture of precise metrology data for larger (up to 200mm diameter) parts or strongly curved (convex or concave) parts.The CNC most often found on QED machines is the Siemens SINUMERIK 840D, with HMI Advanced MMC (Machine Monitoring and Control). Proprietary C++ application data from QED software passes information onto the HMI Advanced MMC. Typically, a five-axis CNC with Siemens 611 drive packages is utilized with Siemens 1FT6/1FK6 motor on each axis. An auxiliary Siemens 611U is often used to control additional servomotor components. These components can be controlled through the CNC programs or the integrated PLC provided with the Siemens 840D. All machine digital and analog I/O are remote and connected via Profibus to the PLC for machine safety, monitoring and control.

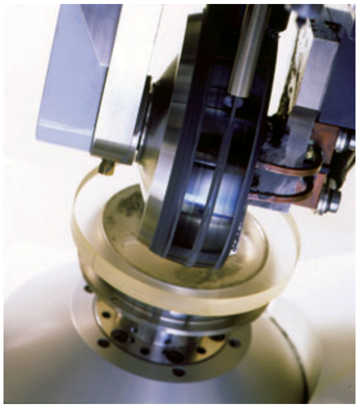
QED alliance manager Steve Hogan, who works closely with Siemens account manager Guy Fagerlund, comments on the benefits of this CNC and motion control component supplier. "The open architecture offered in the Siemens environment provides us with substantial possibilities in setting up our machine controls. Our process uses a compliant tool (MRF) to polish optical surfaces to extreme precision, where the form error on a surface of eight inches (200mm) in diameter is typically less than one to two millionths of an inch. We accomplish and maintain this accuracy by optimizing the servo tuning on the machine tool and taking advantage of the many extended functions available on the Siemens control package, such as beam sag, friction, backlash and other compensations. The competitors' controls we evaluated simply do not offer this level of OEM intervention to give us our desired flexibility."

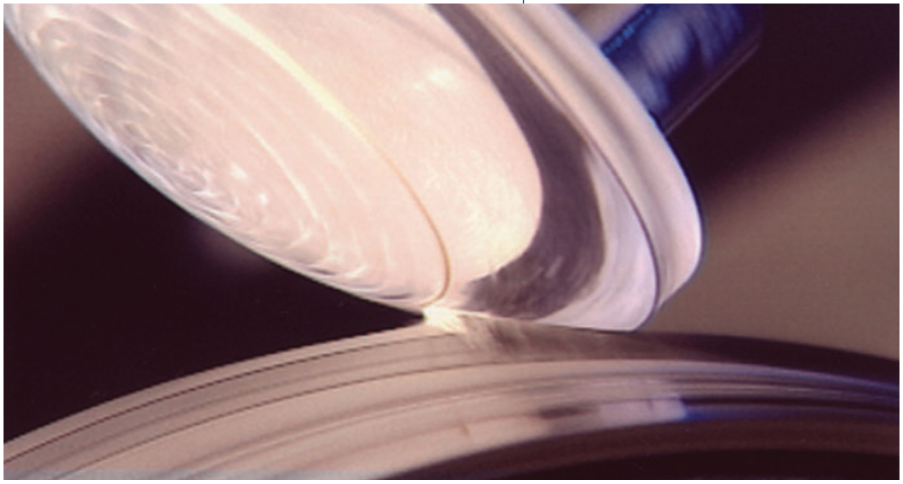
Typically, a QED machine employs two or three linear axes, two rotary axes and up to four servo drives running at a constant RPM. The company has a custom C++ User Interface with "the CNC running in the background," says Hogan. "Our UI is created for easy use in the optics industry, so our customers do not need to learn machine tool language. Several CNC subprograms are selected and run via this custom UI. They're used to position the axes for easy part loading or probing, prior to process running. After entering all the critical lens information, a part program is automatically created which generates the tool path of the lens or workpiece as it moves through the tool, that is, the MR fluid."

The MRF process uses a magneto-rheological fluid as a polishing tool. The workpiece is installed at a fixed distance from a spherical wheel which rotates about its horizontal axis. An electromagnet located below the wheel surface generates a radiant magnetic field in the gap between the wheel and the workpiece. The MR fluid is delivered to the rotating wheel, pulled against the wheel's velocity and becomes a subaperture polishing tool. The sophisticated computer program precisely controls the "dwell time" or how long the optic is immersed in the MR fluid and determines a schedule for varying the position of the rotating workpiece through the fluid.

Before beginning a polishing sequence, both the surface to be processed and the material removal function of the MR fluid tool are very precisely characterized. The surface is characterized using various types of interferometric metrology, thus producing a highly accurate map of the surface. The removal rate of the MR fluid correlates to its viscosity, which is controlled to ± 1 percent. A key to the MRF process is that the tool does not change, essentially creating a machine tool that never dulls. A spiral (round part) or raster (rectangular part) toolpath is then created by "de-convolving" the tool (MR fluid) with the desired removal function. The process truly self-programs to compensate for any variables or machine misalignment to achieve the desired outcome of surface finish and shape.

The extreme stability of this polishing tool, then, creates a deterministic process which allows the user to very accurately predict the results of the polishing run, before the cycle begins. The fluid stability, combined with a robust machine platform, allows the MRF tool to be almost perfectly compliant, creating an



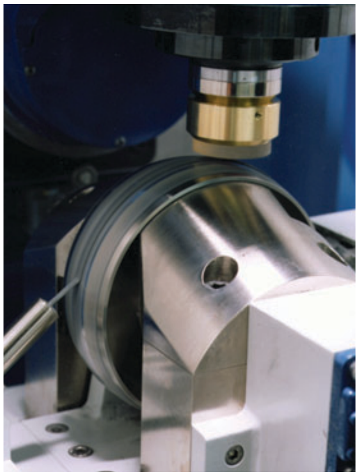


unmatched level of deterministic polishing on precision surfaces. As Hogan concludes, "The Siemens control package provides the critical flexibility necessary for QED's software to allow our machines to self-program, based on the advanced knowledge gained during the characterization phase."

Hogan also noted QED is able to integrate many of its machine measurement devices into the SINUMERIK 840D, such as cameras, height probes, pressure transducers and flowmeters to achieve faster set-up and reduced changeover times. The Siemens platform further allows a five-axis system with enabling/disabling of the fifth axis, as needed. Onboard power modules can accept either dual- or single-axis controllers and the use of dual-axis modules helps reduce electrical panel space, Hogan observed.

Siemens supplied technical support to QED from its Elk Grove Village, IL (Chicago) headquarters. Drive and CNC Engineers, including Dave Kazda, Dave Plews and Lutz Michel were cited by the customer for their assistance, as was Siemens account manager Guy Fagerlund.

Additional information for this article was supplied by Marc Tricand, QED director of business development and Carolyn Russell, QED business development specialist. ■



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