Microtechnologies: Art or Engineering?

Recent developments in micromachining are showing that much more can be achieved at acceptable costs than may have previously been thought possible. One of the biggest challenges, says the author, is unleashing the engineers' imagination. This article tackles some of the problems found in making and using machined microcomponents and offers some solutions.

Les récents développements qui sont intervenus dans le micro-usinage montrent qu'il peut être réalisé beaucoup plus à des coûts acceptables que cela ne l'a été pensé possible. L'un des plus grands défis, affirme l'auteur, c'est de faire en sorte que l'ingénieur se laisse emporter par son imagination. Cet article aborde quelques uns des problèmes rencontrés lors de la fabrication et de l'utilisation de microcomposants usinés et propose quelques solutions.

Neuere Entwicklungen im Bereich der Mikrogeräte zeigen, dass sehr viel mehr unter annehmbaren Kosten erreichbar ist, als zuvor für möglich erachtet wurde. Eine der grössten Herausforderungen, so sagt der Autor, besteht darin, die Phantasie des Ingenieurs von Fesseln zu befreien. Dieser Artikel behandelt einige der Probleme, die in der Herstellung und dem Einsatz angetriebener Mikrokomponenten begründet sind und bietet einige Lösungsmöglichkeiten an.

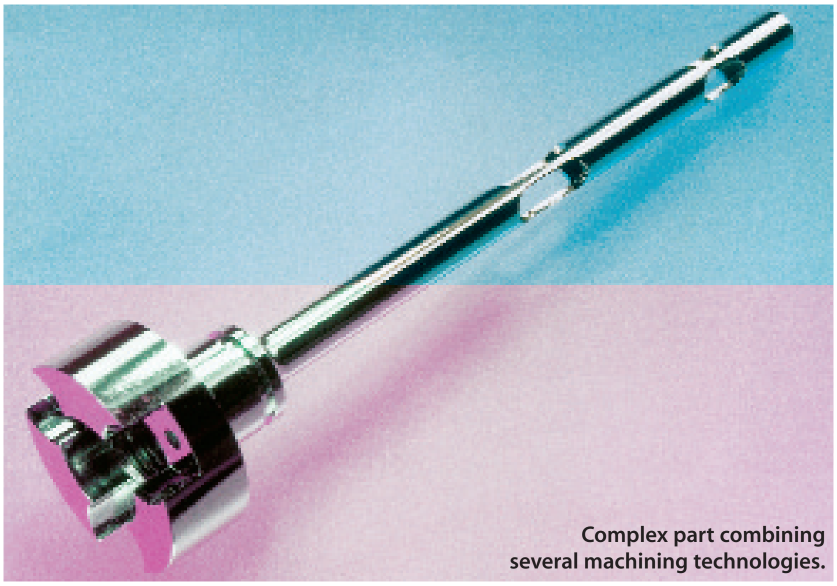
Mark Turner
Medical Engineering Technologies Ltd, Ashford, UK

Making the seemingly impossible

The trend towards ever more sophisticated medical equipment is driven by the desire to produce products that differ significantly from those that are currently on the market, and of course, the continuing drive to improve patient treatment. Specialist manufacturers are developing seemingly impossible components. Burr-free parts as small as 0.5 mm along their longest dimension are being made on a production basis. These parts can still be furnished with a detailed structure and a particular surface finish. When traditional machining methods such as milling and turning have been pushed to their limits, laser cutting can be applied. This has some limitations, but can give features such as holes with diameters down to 0.05 mm.

Micromachining technology

Traditional methods, such as milling, grinding, prismatic milling and turning, can be applied on specially built and adapted computer numerically controlled machines to produce parts with incredibly small sizes and even smaller tolerances on a production scale. These parts can have wall thicknesses as small as 0.1 mm, and holes can be drilled at diameters down to 0.12 mm. Complex surfaces can be machined with diameters in the region of 0.15 mm. The tolerances on these parts can be controlled to 0.0025 mm. Other machining processes such as electrical discharge machining also have applications in micromachining. This is a precise method of metal erosion often used for mould making and for shapes that would be impossible to machine. ➔



Complex part combining several machining technologies.

All these processes can be performed using statistical process control (SPC) to improve yield. The crucial factor is to measure these parts to an accuracy that complements the production capabilities. This is achieved using some of the better automated vision systems, which have a resolution of 1 µm. An additional advantage of using these systems is that the image can be transmitted via the Internet to allow remote inspection of parts.

A typical part

As a general rule, spinal implants, which are used to treat conditions such as degenerative disc disease, are machined from titanium. Implants are often held in place by bone screws. These screws have a preset torque value at which the head breaks off; this allows the surgeon to simply control the force on the screw. Thus, an accurately machined screw and well produced head will lead to a consistent, and known, holding strength. Typical problems encountered in machining spinal implants and potential solutions are shown in Table I.

An atypical part

Because of the need to safeguard commercial secrets, a fictitious example of an intravascular tumour removal and repair catheter (IVTRRC) is used to demonstrate current technology. This product is typically used for unblocking cardiac or cerebral arteries and can be inserted via the femoral or subclavian arteries. It needs to be flexible throughout its length, and to be able to accurately deliver a focused beam from three optical fibres and collect any debris after the cutting operation. The process involves the excision and removal of internal growths in vessels using laser cutting technology and suction. The problem is how to focus sufficient laser power at the correct place to cut the flesh and collect all the debris to prevent secondary blockage or infection. Any parts used must be either flexible or extremely small.

A rigid system is generally required to provide accurate positioning. The position of the tumour is accurately marked by the injection of a monoclonal antibody (MCA). The surgeon inserts the catheter to the approximate position using X-ray guidance. Eight metal clamps are then released to press against the vessel wall and stabilize the catheter position. These clamps are 2-mm long and 1-mm wide and are specifically machined to match vessel wall curvature and be completely atraumatic. The fibre optics illuminate the tumour and cause the MCA to fluoresce. The catheter position is finely tuned to maximize the fluorescence and then the cutting laser is fired. During cutting, suction is applied to one catheter lumen that terminates in a nozzle close to the cutting area.

Fluid-handling microcomponents, the black dot is a 10-point full stop.

Table I: Problems associated with machining larger parts.

Problem	Solution
Holding exacting tolerances	Company ethos of operator training and quality in production. In-depth application of SPC. Specially adapted and maintained machining equipment. Having the quality of measurement equipment in place that can detect trends in extremely small tolerances.
Burr removal	Application of a well thought out machining programme to minimize burrs. Post-machining burr removal by hand.
Large-scale production	Investment in capacity and effective production planning.
Coping with fluctuating demand	Efficient application of rapid change systems.

Table II: Production problems with machining the IVTRRC.

Problem	Solution
Machining of accurate complex surface on stabilizer clamps.	Use of 5-axis microgrinding with complete removal of burrs in situ.
Accurate targeting of optical fibre tips.	Production of a fibre guide to focus the beams requires 3D prismatic milling leaving a part 5-mm long and 2-mm wide with 3 fixation orifices 0.5-mm wide.
Holding parts during the milling process.	The fibre guide is milled from a cube 10-mm wide. The first operation is to drill the alignment holes while they are well supported and heat dissipation is evenly distributed. The final part is fitted to the catheter while it is still in the chuck; this aids handling and final alignment.
Machining of tiny turbine blade and ensuring sharpness.	Intricate tool path programming to ensure sharp edges on the tips of the blades with no burring.
Handling of machined parts.	The parts machined are often no larger than the swarf (the waste from machining). One elegant way of handling them is to leave them attached to the original metal bar at the end of machining. This part is then easily handled for later operations.

Multi-axis Swiss machining showing typical cutting tools.

Debris is sucked into the nozzle. Blockage of the catheter is prevented by the use of a turbine in the nozzle to finely chop the debris. This turbine has four accurately defined blades with a total diameter of 1.5 mm. Production problems and potential solutions for producing the IVTRRC are shown in Table II.

Think laterally

Active medical devices that perform some interventional action, such as cutting, crushing, closing or scraping, have been in existence for some time. The development of new technologies and the improved application of existing technologies are expanding the range of active devices that can be realized. Micromachining is an important part of this continual development of technology. Product designs are now viable with the tiniest metal or ceramic components in the most complex of shapes. This is engineering that allows the designers' art to flourish; all they need to do is to give their imaginations the freedom to think laterally. mdt

Mark Turner
Business Development Manager
Medical Engineering Technologies Ltd,
Webster House, Jesmond Street, Folkestone, Kent
CT19 5QW, UK, tel. +44 (0)845 458 8924
fax +44 (0)8700 562153
www.met.uk.com