Rapid manufacturing's rise

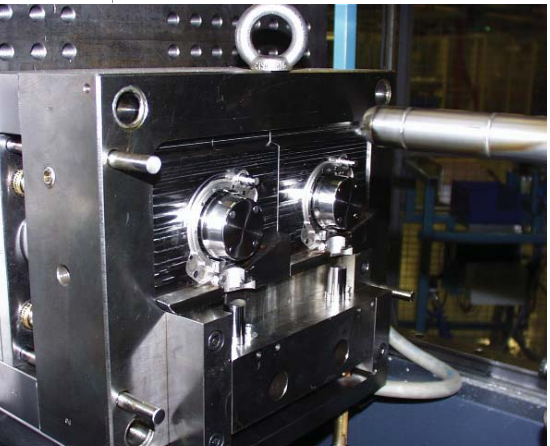
Is the time coming for rapid manufacture of metal parts? Andrew Allcock looks at recent developments and events and sees signs that it is. Metalcutters should know the score, he says

The rapid manufacture of parts by melting metal powder has been possible for years, but in the UK remains a minority pursuit. However, there is a new burst of activity that seems to indicate that we are approaching a critical point.

Rapid manufacture typically, but not exclusively, sees powders melted with lasers in controlled atmospheres, to 'grow' parts. Two basic routes are: melt one layer of powder, and then another, and then another, etc; or introduce powder to a molten pool. The latter delivers a more dense build-up. Unfortunately, a bewildering array of process names implies a multitude of process possibilities to the novice – a situation, which Liverpool University's Laser Group's Dr Eamonn Fearon believes works against building trust in rapid manufacturing.

The manufacture of tooling, typically mould tooling (often called Rapid Tooling) – has been discussed and possible for some years, but is hardly commonplace.

EOS' DirectTool is one such process and is used by Finnish company Alphaform RPI (UK operation Alphaform UK). In one example the laser/powder process was able to produce a small series of injection moulded parts from 2D drawings within just 15 hours using the EOS Direct Metal Laser Sintering (DMLS) process.



A production mould tool made via the Arcam electron beam/powder process

SERIES PRODUCTION

And, reports EOS, DirectTool is being increasingly used to support series part production. QuickTools, Belgium produced mould tool inserts and then made 20,000 covers in PBT (polybutylene terephthalate) +30GF (30 per cent glass fibre), this achieved in just two weeks.

Sweden's Arcam (UK agent HK Technologies) and Volvo reported on a test in late 2002 on the manufacture of a production tool for injection moulding of camshaft sensor housings for Volvo Car Corporation. Arcam's technology is an electron beam/powder process. Inserts for both tool halves were made in Arcam H13 Tool Steel and featured a conformal circular cooling channel that followed the geometry of the part. Compared to a traditional tool, lead-time was reduced by about a third – from 15 weeks to 10 weeks – while the injection moulder saw a productivity increase of 25 per cent due to the conformal cooling channels.

And in May last year, Arcam received an order for an EBM S12T from FIT (Fruth Innovative Technologien) in Parsberg, Germany. The company offers a rapid prototyping/tooling service, and its system will make steel parts for advanced tooling, as well as for direct part manufacture.

A material development that impacts rapid tooling viability was revealed by 3D Systems in late 2003 – LaserForm A6 steel. Parts made from this can have a surface finish of 5-10 μm Ra, can be machined just as traditional steels, can be hardened to HRc 39, while polished 'raw' parts are up to HRc 29. Surface coating can boost hardness further, incidentally. And with thermal conductivity almost twice that of most tool steels, cooling is 20 to 40 per cent faster it's claimed.

In Europe, 3D instances only a handful of companies using rapid manufacture to produce mould tools inserts, either from A6 or its predecessor materials. In Germany, 4D Concepts is highlighted (*www.4dconcepts.de*): this company offers prototype mould tools in three weeks. In the UK Milton Keynes-based KV is another. A manufacturer of pneumatic and fluid control products, its adoption of the process for its internal use has spawned a new business which has seen it make mould tools for the production of moulded parts for aerospace use, for example. It is investigating A6 use.

High Wycombe-based CRDM uses EOS technology for its commercial rapid tooling service. Based at the Buckinghamshire Chilterns University College, it is a specialist in rapid prototyping/manufacturing processes, taking in laser sintering of metal powder to produce mould tool inserts and, increasingly in the future, components as part of its services. The supply of rapid tooling has grown from nothing to represent 50 per cent of its business over four years or so – the remaining half is rapid prototyping, which was 100 per cent of its work.

CRDM upgraded its EOS equipment last November and installed a M250 Xtended. This can use 20 micron versus 50 micron powder and has steel capability versus nickel-bronze. Density has improved from 85 per cent to as high as 98 per cent, with no surface machining now necessary for cavity details, only finishing processes such as micro shot peening or polishing. The increased density now delivers surface finish quality suitable for more demanding applications, such as medical and packaging companies, while longer production runs can also be supported – in excess of 30,000, says CRDM UK sales manager Andrew Mitchell.

Tolerances are unchanged –50 microns; while the process is slower due to the increased number of layers – multiples of 20 and not 50 microns, although 20, 40 or 60 micron increments can be employed in some areas, he says.

Limited to 250 by 250 by 185 mm - length, width and height (although multiple parts can be dovetailed) – and a slow process, it is not a serious challenge to metalcutting for simple tasks, but comes into its own for complex detailed areas, he explains. So the use of hybrid tooling including both machined (steel or aluminium) and rapid manufactured elements is an approach taken by CDRM and its customers.

But over the past four years, convincing toolmakers to go down the rapid manufacturing route has been difficult. Normally, CRDM approaches OEMs who then 'talk' their toolmakers into making use of CRDM to the benefit of the OEMs.

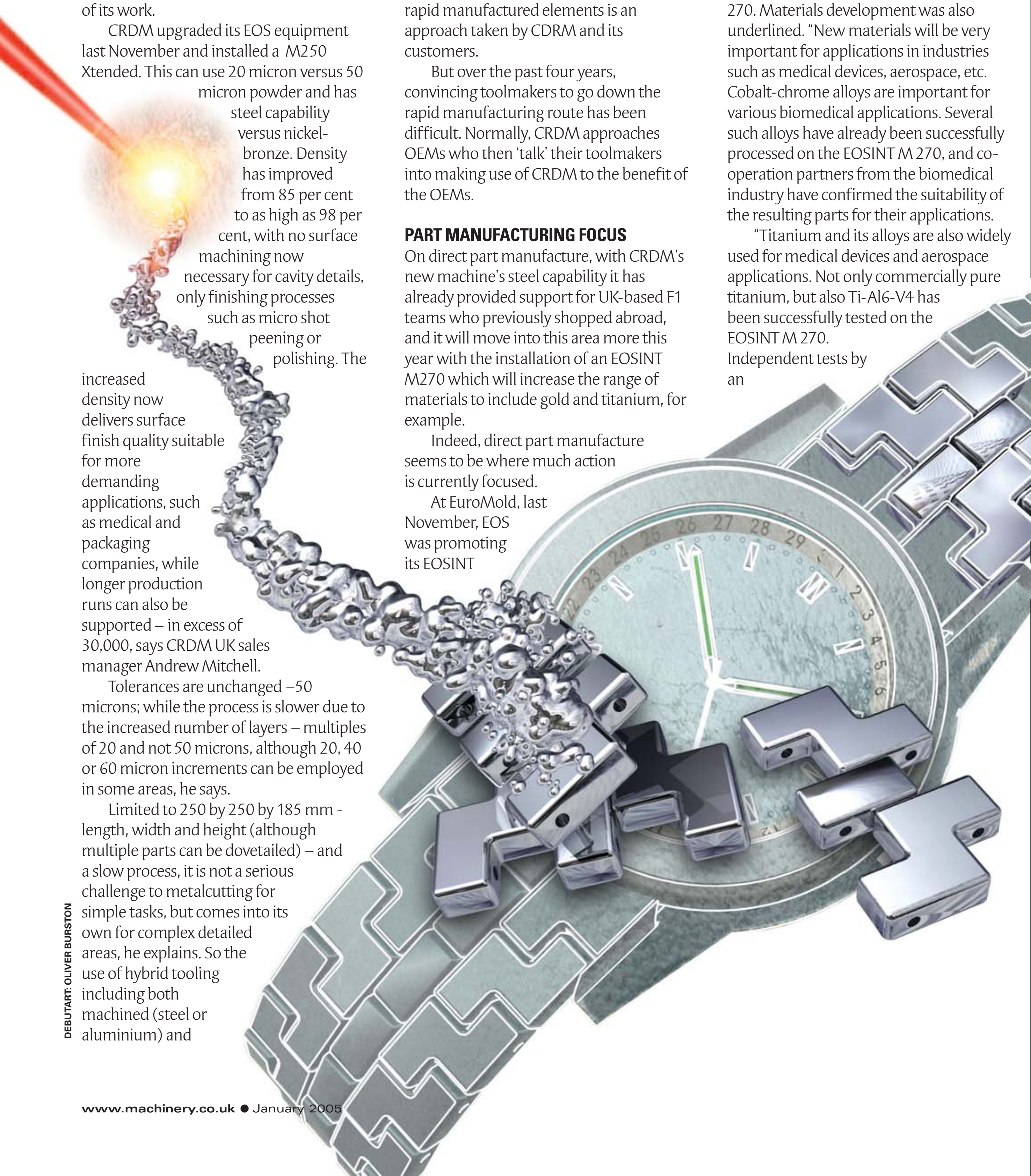
PART MANUFACTURING FOCUS

On direct part manufacture, with CRDM's new machine's steel capability it has already provided support for UK-based F1 teams who previously shopped abroad, and it will move into this area more this year with the installation of an EOSINT M270 which will increase the range of materials to include gold and titanium, for example.

Indeed, direct part manufacture seems to be where much action is currently focused.

At EuroMold, last November, EOS was promoting its EOSINT 270. Materials development was also underlined. "New materials will be very important for applications in industries such as medical devices, aerospace, etc. Cobalt-chrome alloys are important for various biomedical applications. Several such alloys have already been successfully processed on the EOSINT M 270, and co-operation partners from the biomedical industry have confirmed the suitability of the resulting parts for their applications.

"Titanium and its alloys are also widely used for medical devices and aerospace applications. Not only commercially pure titanium, but also Ti-Al6-V4 has been successfully tested on the EOSINT M 270. Independent tests by an



DEBUTART: OLIVER BURSTON

This chess piece was fabricated via Arcam's electron beam-based process

industrial partner have shown that a part density of more than 99.5 per cent and a purity corresponding to CP-Titanium Grade 2 specification has already been achieved," says EOS, adding that stainless steels and Inconel alloys have also been tested on EOSINT M systems.

In July last year, 3D Systems announced its Sinterstation HiQ SLS system. Able to process plastics and steels, "this represents a significant step forward in providing users with an alternative solid imaging solution that meets the demands and requirements of end-use parts manufacturing," said the company's Abe Reichental, president and chief executive officer. And KV of Milton Keynes is, in addition to mould tools, already making metal parts, semi- and fully finished, for its own internal short batch run purposes to avoid the time and cost of investment casting. The company says that were there to be an external demand, then it would offer the service.

Other examples of direct part manufacture come from Sweden's Arcam. Last August, the company received an order for an EBM S12T system from Boeing Phantom Works in St Louis, USA for the building of titanium aerospace parts. An order for an unnamed medical device manufacturer – again an EBM S12T – followed, this time for the direct manufacturing of parts for titanium medical parts.

One month later and another EBM S12T order came from Detroit-based Synergeering Group for the direct manufacturing of high-performance titanium parts. Synergeering is a service bureau with a wide customer base in Detroit automotive and "aggressively diversifying".

And last year Warwick University's rapid manufacturing department installed an Arcam EBM S12 lab system and showed it off at a Direct Parts Manufacturing seminar in October.

MCP, Stone, Staffordshire places emphasis on direct part making rather than rapid tooling with its recently introduced Selective Laser Melting (SLM) process. Hailed as "the first ever process which could build up to 100 per cent dense metal parts direct from CAD data", it is a laser/powder system and the SLM Realizer can build parts, inserts and components in stainless steels (including 316L 14440 and 14410) cobalt chrome and TI AL 6 V4 (medical/aerospace grade titanium).

Two UK universities are using MCP's SLM process. Liverpool University's Manufacturing Science & Engineering Research Centre is applying it to help its research into the manufacture of micro-heat exchangers, ultra light components for aerospace applications and implantable medical devices.

More recently MCP SLM was installed at PDR in Cardiff, a leading supplier of medical models. PDR identified the process as being able to provide accurate, strong and durable surgical guides that can withstand contact with aggressive surgical instruments such as drills and oscillating saws. The use of SLM in the direct production of custom-designed reconstructive implants is to be

Rapid military manufacturing, US and UK

In the US, AeroMet (*www.aerometcorp.com*), offers its powder/laser Laser Additive Manufacturing (LAM) process and was awarded SAE AS9100:2001 ANSI/ISO/ASQ Q9001-2000 certification last August, meaning it can produce rapid manufactured titanium parts for the aerospace industry under sub-contract. Established in 1997, AeroMet says it had "aerospace certified LAM parts in production and flying in 2004." Military use seems to be the driver.

US company Optomec offers its LENS process and once again military interest is high. In 2002 Optomec reported that the US' National Center for Manufacturing Sciences had submitted a report to the US Department of Defense concerning LENS repair of Abrams M1 Tank gas turbine engine parts. An annual saving of over $6 million was cited.

In June last year, the US House of Representatives authorised support to the tune of $1 million for an Air Force manufacturing technology programme for the rapid production of low volumes of complicated, difficult to obtain and expensive metal parts. Research is to be carried out by On Demand Manufacturing (ODM), Camerillo, California. ODM is, in fact, a Boeing spin-out company, having been established in September 2002. ODM makes both plastic and super alloy parts by laser sintering using 3D Systems technology.

Technology that competes with, for

investigated, too.

SLM is already used commercially to manufacture dental crowns, caps and bridges in cobalt chrome, says MCP. Up to 100 caps, crowns and bridges can be built in one fully automated 5-6 hour session. And a McLaren Formula 1 engine exhaust manifold has also been produced using SLM, reports MCP.

KNOWLEDGE TRANSFER

So who's spreading the word to manufacturers? Well, Warwick Manufacturing, as already highlighted. And earlier last year, precision engineering companies were invited by the Lairdside Laser Engineering Centre (LLEC), Birkenhead to a seminar to hear about the manufacture of 3D metallic parts by depositing molten metal in a series of layers. The LLEC has a technology transfer remit and while focused on helping local firms, it is a national facility. The result was that there is follow-up activity between LLEC and some attendees, but generally, interest was such that a larger, follow-up seminar is planned for this year.

More recently, the TWI is also now promoting additive manufacture to its membership (see *Machinery* 5 November 2004, page 35). Using a Trumpf DMD 5050 unit, deposition of projections onto large components to reduce machining and material cost is a future theme (Trumpf has licensed the US' POM Group's technology – *www.pom.net*). TWI's Dr Robert Scudamore believes the potential the process is "huge".

And a national organisation, the Direct Writing Association (*www.directwriting.org*) was established last summer following a DTI-commissioned report – see *Machinery* 2 July, 2004, page 29). Its remit includes rapid manufacturing and one of its aims is to "co-ordinate industry-led direct writing R&D activity". The Association's Advisory Panel is meeting this month, plans a technology mission to US companies and R&D centres in April and a conference and exhibition in July.

So what's the state of play today? With a confluence of machine and material development, research activity supported by latest technology targeting commercial products, a national association that aligns industry need and UK research activity, together with the transfer of knowledge to industry, it seems that metal powder-based rapid manufacturing's time is surely approaching.

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example, LENS is also interesting to the UK's defence establishments. In 2001, the Division of Manufacturing Engineering at Liverpool University's Manufacturing Science & Engineering Research Centre was awarded £900,000 by the Engineering & Physical Sciences Research Council to fund the first three years of an eight-year development programme, designed to further develop the Cold Gas Dynamic Manufacturing (CGDM) process and apply it in the additive manufacture of near net shape metallic objects. The programme was to be carried out in conjunction with BOC Gases, BAE Systems and the then Defence Evaluation & Research Agency. High temperatures currently required to melt metal particles can undermine the integrity and stability of the resulting deposition and CGDM offers an alternative, 'non-melt' approach (*http://mserc.liv.ac.uk/research/cgdm/index_html*).

IN BRIEF

Alternative rapid manufacturing processes

Shaped Metal Deposition

Shaped metal deposition (SMD) is a rapid manufacturing process based on the direct deposition of metal using TIG welding technology and Kuka robotics. It supports production of near-net shape complex parts without the need for tooling and also allows the construction of hybrid components – the use of small forgings, which can be built up to larger structures, for example.

The SMD process, initially developed and patented by Rolls-Royce, has to date been applied in production by Rolls-Royce to titanium alloy outlet guide vanes for Trent series engines. Nottingham University's Agile Technology Unit aims to extend SMD's use outside of Rolls-Royce and is working with interested parties, *Machinery* was told. Next March, an SMD cell will be installed at Sheffield's Advanced Manufacturing Research Centre (AMRC – see *Machinery* 5 November, page 19). The cell will support near-market application studies.

High volume powder

Metal Injection Moulding

Powder-based Metal Injection Moulding (MIM) is ideally suited for high-volume production of intricate components, ranging from laparoscopic instruments for the medical industry to optic modulators used in fibre-optic networks, plus watch bracelet links and watchcases.