Halving machining times

Vacuum company’s R&D facility makes dramatic improvements to the milling of pump chambers

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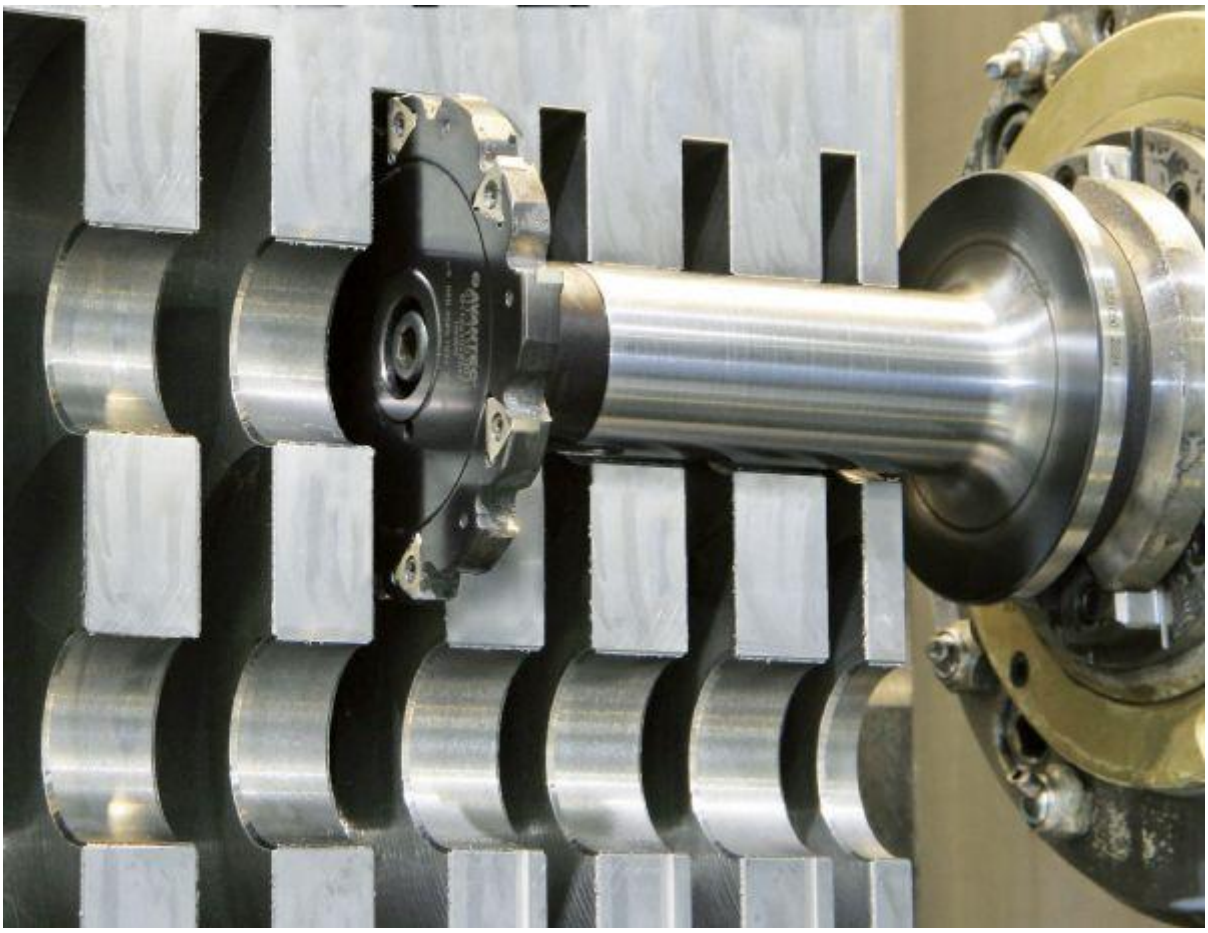


The production and assembly of vacuum equipment designed by Edwards Group plc (formerly BOC Edwards) have been transferred from the UK to South Korea and the Czech Republic. Meanwhile, the company’s former factory in Burgess Hill has been transformed into its Group Technical Centre; this is now a world-leading vacuum science R&D facility and includes a Machining Process Development cell.

A notable success of this centre in early 2013 was the development of an alternative process for machining the chambers of a new, multi-stage vacuum pump that allows semiconductor, pharmaceutical, petrochemical and other manufacturers to use considerably less power in their production operations.

Reuben Day, a senior manufacturing engineer at Edwards, says the time needed to rough- and finish-mill the chambers in the two halves of the pump’s SG cast-iron stator has been reduced by 94% (the process has been validated on a Makino horizontal machining centre, of which there are three in the development cell).

Edwards has had a long relationship with Makino’s UK agent, NCMT Ltd, Thames Ditton (www.ncmt.co.uk), which was called in to advise on how to reduce the

unacceptably long cycles required for milling the chambers in the new pump.

Coincidentally, NCMT was appointed last year as the UK agent for Kaiser boring bars, which Edwards has been using for many years. Engineers from both NCMT and the Swiss company Kaiser visited Burgess Hill under strict non-disclosure agreements. Discussions centred on the single-point cutting tools that were being used to machine the radius and faces of the swept volumes that form the chambers in the inlet and exhaust castings.

Bespoke tooling

Kaiser also works closely with the German milling tool and indexable-insert manufacturer AVANTEC, which specialises in producing bespoke cutters for difficult machining applications; these cutters often involve high-positive-rake tooling to reduce cutting forces and produce top-quality surface finishes. It was clear that such a tool would be ideal for machining the swept volumes in Edwards' vacuum pump.

Three side-milling cutter bodies of different diameters were supplied to accept 10mm-wide, ground, coated-carbide indexable inserts for either roughing or finishing, the latter inserts being developed especially by AVANTEC for the application. The smaller cutter accommodates five inserts on each side, while the other two bodies have six inserts per face, all secured in deep pockets that expose only the edge of the inserts.

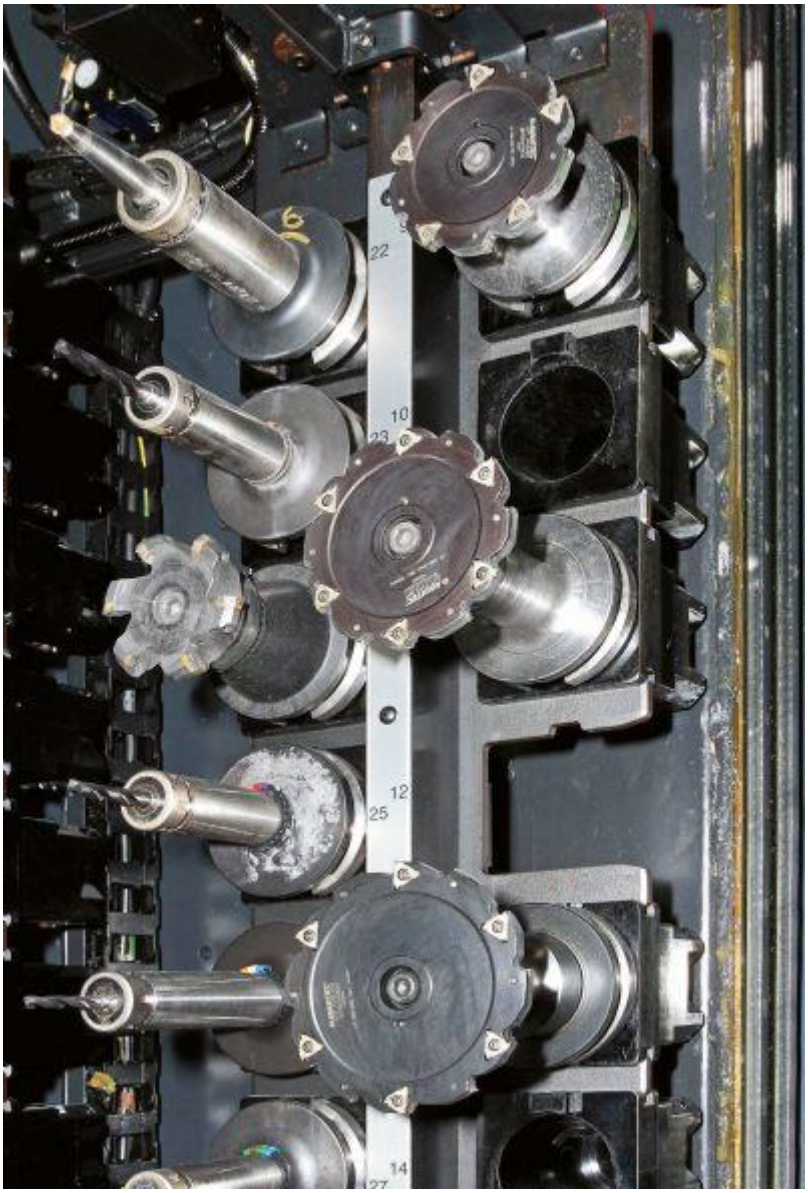
The top cutter face contains right-handed inserts for machining one side of a chamber, while the reverse of the tool has left-handed inserts for machining the opposite side of the chamber. To avoid an insert being placed on the wrong face of the mill, AVANTEC has coloured the right-handed top inserts gold and the others black. All finishing inserts have a

special wiper geometry to achieve the 1.6Ra surface finish required in the chamber.

AVANTEC applications engineers also visited Burgess Hill to conduct trials on the Makinos; these lasted three days and ascertained how best to mill the two faces and diameter of the chambers, each of which is a different size. Surface finish was important, but dimensional tolerance was even more important in order to achieve sub-100µm clearance between the chamber surfaces and the rotor that is subsequently fitted. The final optimised results, after Mr Day redesigned the tool-holder's back end to be a one-piece unit, were a cycle time reduction of 96% to rough the chambers from cast and a 93%
reduction in the time required to finish them.

Avoiding chatter

Previously, roughing using a conventional side- and face-milling cutter capable of holding three 6mm-wide inserts per side took 30% of the total cycle time. The problem was that inserts had to be removed to leave one on each face, as only in this way could chatter be avoided and surface finish preserved; essentially, the tool was fly-cutting each side of the chamber. The finishing cycle was 34% of the total cycle time, and again a fly-cutting method was employed; this used a tool with a single brazed carbide insert made at Burgess Hill.



The new process using the AVANTEC cutters consumes just 6% of the original cycle times. As chamber milling (roughing plus finishing) used to account for around two-thirds of the total program run time on a casting, the 94% reduction translates into a 60% reduction in the overall cycle.

Mr Day says: "After the process has been transferred to our Korean factory, machining will be carried out using our tooling package and programs on new Makinos, so capability is assured. Moreover, Edwards has the same Zeiss co-ordinate measuring machines in Korea as we use here in the UK, so 100% inspection of the production castings will be carried out to the same

standard as in our R&D facility."

In developing the new machining process, what really focused the minds of the team at Burgess Hill were the tight tolerances that have to be held in a shopfloor environment. In addition to sub-100µm stator/rotor clearance, they include: ±30µm on the overall length of the casting; ±16µm on dimensions from the datum face; 25µm squareness; ±30µm on the bores; and ±10µm on dowel hole positions (the latter two features are machined with Kaiser tools).

Access problems

In traditional multi-stage, dry vacuum pumps, separate stages each containing one chamber
are dowelled and bolted together. Edwards' one-piece design comprising two mating castings avoids the risk of cumulative errors as well as the cost of assembling the stages. However, it creates the problem of how to access the internal chambers with long-reach tooling while avoiding deflection, vibration and consequent loss of accuracy.

On the shopfloor in Korea, the tolerances will be maintained by the robust tooling solution developed at Group Technical Centre in Burgess Hill combined with strict maintenance regimes and the inherent accuracy of the Makino horizontal machining centres, which have temperature-controlled ballscrews, slideways, spindle and coolant. In conclusion, Mr Day says: "This application is an example of innovation and engineering efficiency excellence. We have developed a high-added-value machining process for cost-effective production.

Moreover, having a dedicated, fully equipped R&D facility to carry out this type of development work avoids the need to borrow valuable time on production machines. Under those circumstances, we would almost certainly have commenced production of our new pump with a significantly longer cycle time and a less-capable process for machining the casing. That would have meant additional capital investment further down the line as production volumes ramped up, which would have ended up costing us a lot more money in the long run."

The next project Mr Day and his team will undertake in the Machining Process Development cell will be to optimise the production of two key components for the pump rotors, which will be machined on multi-axis CNC mill-turn centres in Korea.