Well done in one

Five-axis machining doesn’t just mean machining centres or freeform surfaces to Yamazaki Mazak, as Andrew Allcock discovered during a visit to the company’s Worcester Technical Centre

A visit to Yamazaki Mazak’s Worcester Technical Centre to get to grips with 5-axis machining will see the visitor not only shown vertical machining centres from the company’s Variaxis range, but will also take in its b-axis fitted mill-turn Integrex. In fact, the all encompassing machining philosophy is Mazak’s done-in-one approach.

But a first example is that of a part machined in a single operation on, in this case, a Variaxis 730-5X. The part in question is an aluminium cable conduit connector (pictured) for aerospace applications. Not an actual part, underlines senior applications engineer Graham Rash but one that resembles current components.

The alternative process for such a part is die-casting plus machining of certain features. Benefits over die-casting for this part which took some 3.5 hours to machine are, suggests Mr Rash, high component quality due, for example, to no casting porosity and no die manufacture which also makes design changes easier to handle. The cost of casting such parts is also rising, he
adds. "A lot of people are moving away from casting because it is not as cost-effective as it used to be." Add to that the problems of lead time and work-in-progress, of course.

Part programming took about two days, including proveout, using Delcam’s PowerMILL solution. If this had been a customer part, then the likelihood is that CGTech’s Vericut would have been used to confirm the output. The program makes use of about six tools, including ballnose, square edge endmill (for bore shoulder features) and lollipop cutters, the latter for machining around the bend of the bore. Importantly, because 5-axis machining allows the part to be orientated to give best access, standard length cutters were employed, underlines applications manager Richard Drohan. The Variaxis machine’s a-axis movement of +30° to -120°, which effectively tips the part upside down, provides access to the underside of some features. Mazak claims some 100 Variaxis machine installations in the UK.

MOVING TO MILL-TURN

Moving to another 5-axis part, this time an impeller of some 150 mm diameter (pictured) for an aerospace fuel pump, the chosen method of manufacture is an Integrex 200-IV mill-turn lathe. Once again, it replaces casting and machining on special-purpose machines, says Mazak. Jet engine blades and vanes in aerospace alloys are also fodder for this machine, as are blisks (machined from solid). In the case of blades and vanes, the parts can be machined complete without the need for finish grinding. There are some 400 Integrex machines installed in the UK.

Deputy applications manager Lawrence McCann points out that although ballnose cutters are often chosen for 5-axis tasks, in the case of the turbine blade and vane aerofoil surfaces, an endmill offers a better finish while also allowing faster material removal in parallel with better tool life. The impeller example, however, requires a ballnose cutter for reasons of access.

An interesting observation concerning the impeller is that although a surface feedrate of around 5 m/min is programmed, as the cutter goes round the leading edge (the b-axis swivelling through over 90°) x-axis and z-axis traverse rate is as high as 16 m/min. It is worth noting that the drive system for Integrex b-axis movement is not worm and wheel but a cam and roller follow arrangement, this system can support axis speeds four times greater than can worm and wheel, while also delivering lower backlash. This is a feature of the latest generation of Integrex machines and is particularly important in impeller machining where the greatest dynamic range of movement is seen in the b-axis. In the case of turbine blades, which effectively lie on centre along the z-axis as opposed to the impeller’s x-axis blade direction, it is c-axis where the greatest call is made on rotary axis performance.

Not so obvious candidates for 5-axis milling are prismatic bracketry (see picture, page 26) such as a missile release mechanism for the Eurofighter in work hardening stainless steel. Here the emphasis is on machining features which require five axes, although not simultaneously. In this example, raw material was turned to rough out the part with milling taking over to machine the prismatic features.

A hidden benefit of 5-axis/one-hit machining is that where the removal of material in such a component leads to movement of the workpiece due to stress relieving, the order of material removal can be controlled within a single operation such that this movement is allowed with its effects subsequently eliminated by machining after the movement has taken place, underlines Mr McCann.

Allied to the various machine types
available, there’s Yamazaki’s latest CNC—
Matrix—which has features and
functions to help would-be 5-axis users.
For those where the requirement is for
3+2 programming—positional 5-axis
machining—on-board conversational
programming is and has been supported
for some time since the launch of the
previous Fusion 640 Control, says Mr
McCann. And Mr McCann does not rule
out the possibility of on-machine 5-axis
continuous programming in the future,
based on parameterised standard
component types—something already a
feature of some CAD/CAM systems.
But features recently introduced with
the Matrix control include the ability to
change the diameter of the cutter used
to machine, say, an impeller blade
surface at the control itself, during
simultaneous 5-axis machining. The
machine will effectively offset the tool
diameter direction vector of the tool
each time the program is run.
This, Mr McCann says, would have
required reprogramming offline in
previous times. Indeed, within a CAM
system it is typically necessary to run the
cycle again to generate new cutter paths
if a cutter diameter is changed: the
Matrix control allows this to be edited on
the shopfloor.
The latest control also allows a figure
for surface speed to be specified;
working back from
this requirement, all axis feedrates will
be controlled to deliver this, as in the
impeller example. This makes
programming easier without the need
for “inverse time” feedrate
programming.
Users can change machine
parameters within a program, too. For a
particularly demanding area of the
component, say the leading edge of the
blades on the impeller, the dynamics of
the machine can be tuned. This might be
useful as a ballnose cutter goes over the
leading edge of a blade and as large axis
movements are required in a short time.

**TIGHTEN UP FOR PATH FIDELITY**
By tightening up the dynamics, the
programmed path is followed as
accurately as possible, but the trade-off
is that maximum feedrates will be kept
below a lower maximum figure. In the
case of the impeller, however, this could
also mean a limitation imposed on axis
speed, say, limiting x-axis to 10 m/min.
Interestingly, it is possible to upgrade
the latest Mazak 5-axis machines from
3+2 to full 5-axis control through a
software upgrade. This function does not
have to be specified at the time of
machine purchase.
A final example of complete
machining using five axes within the
Mazak Worcester Technical Centre is a
field-replaceable recoil damper for the
M777 Lightweight 155 mm Howitzer
(LW155). This 2 m long component (two
per gun) is made from aluminium and is
machined complete on an Integrex e
series (moving column mill-turn),
including boring using a 1 m long by
80 mm diameter boring bar. End-to-end
bore concentricity of 50 microns is
achieved with wall thickness
down to
5 mm. External location and fixing
details plus ports are part of the
design, and material removal
involved high speed milling strategies
as part of the less than 20 hour cycle.
While larger companies are
convinced of the benefits, many smaller
companies counter argument is usually
one of cost, believing 5-axis machining
to be too expensive and too complicated
for their requirements, offers Mazak.
“This is not a balanced assessment,”
says Tony Saunders, Yamazaki Mazak
UK’s sales director, “because it places too
much emphasis on the initial machine
cost and ignores the considerable
productivity gains that will be quickly
realised.”
But even if a company recognises the
potential of 5-axis, it will need help
deciding between, say, a machining
centre or an Integrex machine, says Chris
Goodall, regional sales manager, adding:
“It can be quite technically involved.”
Yet having acquired the technology,
the learning curve is not as steep as it used to
be, offers Mr McCann.
And the frequency with which
purchasers go on to buy the same again
is surely a strong argument that it has
delivered benefits. As Mr Goodall
highlights, many sub-contractors that
buy their first Variaxis, often
speculatively, soon come through with
an order for a second unit.
* Yamazaki Mazak will be speaking at
Machinery’s 5-axis seminar at the Heritage
Motor Centre, Gaydon, Warls, Tuesday, 22
May. Get all the angles on 5-axis machining
by attending. Sign up for the event now at
www.machinery.co.uk/5axis

Not classic 5-axis parts, but their production in one hit on an Integrex machine brings them into the 5-axis fold