In the third in this series of articles on a systematic approach to process improvement we look at how on-machine part and tool setting help us to make the first crucial steps towards process automation. By Marc Saunders

Part and tool setting - the first steps to process automation

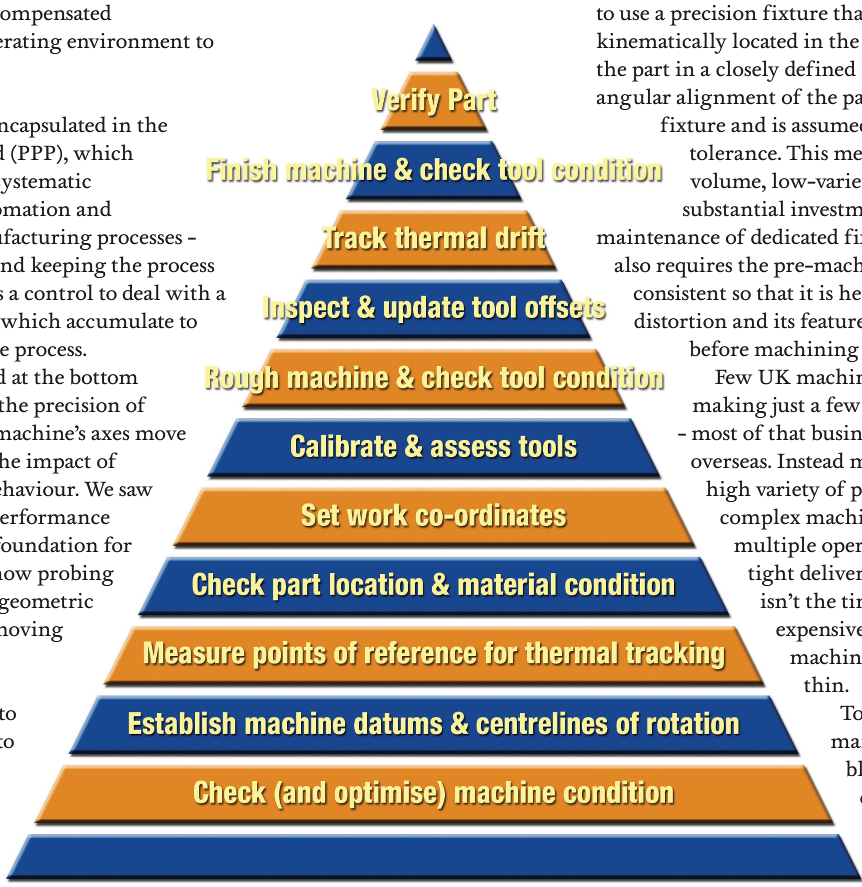
IN the previous articles, I noted how UK manufacturers are concentrating on their core strengths: precise, sophisticated machining coupled with innovation and responsive service. Specialisation, however, cannot fully shield you from the fierce force of global competition, which demands a relentless focus on productivity, quality and costs. To improve competitiveness, I would suggest tackling four main areas:

- automate manual processes to increase throughput and eliminate operator error
- systematically eliminate process variation to increase process capability
- introduce process control to ensure that any remaining process drift is compensated
- maintain a consistent operating environment to ensure process stability

These initiatives are all encapsulated in the Productive Process Pyramid (PPP), which represents an eleven-stage systematic approach to increasing automation and reducing variation in manufacturing processes - making the process right, and keeping the process stable. Each layer represents a control to deal with a source of process variation, which accumulate to deliver a productive, capable process.

In the last article I looked at the bottom three layers, which govern the precision of machine motion, how the machine's axes move relative to each other, and the impact of temperature on machine behaviour. We saw how laser calibration and performance health checking provide a foundation for precision machining, and how probing can establish and track the geometric relationships between the moving elements of the machine. Understanding these relationships and adapting to changes in them is critical to precision 4- and 5-axis machining, as they govern the paths through which the part and the tool will move.

The Productive Process Pyramid was developed by Renishaw to underpin waste reduction, and to help control variation in its manufacturing processes



We're now ready to introduce parts and tools into the system, so this month I will add a few more layers to the Pyramid, focussing on flexible automation of setting processes. Let's start with part setting...

Aligning machining to the part

Before we get into the details of process design and adaptive machining, we need to bring the component and the tools together into the same frame of reference so that the first cut is where we want it to be. We also need to understand where the part is in relation to any rotary axes on the machine so that we know where it will move to if it is re-orientated.

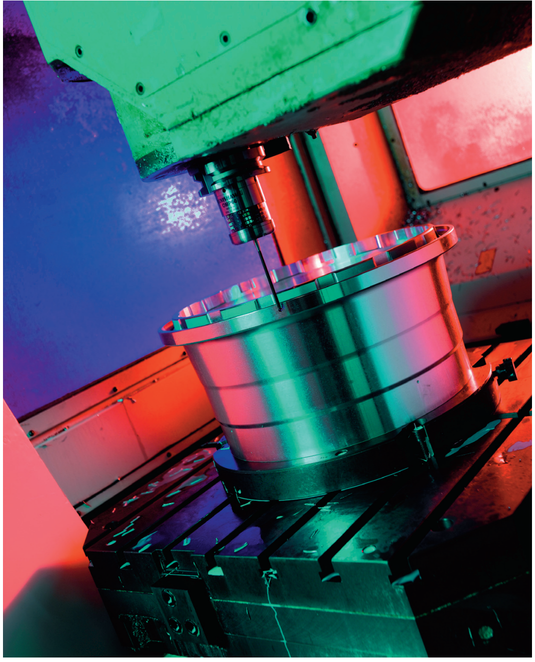
There are two approaches to setting parts. The first is to use a precision fixture that is either permanently or kinematically located in the machine, and which holds the part in a closely defined location. The position and angular alignment of the part is controlled by the fixture and is assumed to be within the required tolerance. This method is suited to high-volume, low-variety production, where a substantial investment in the development and maintenance of dedicated fixturing can be justified. It also requires the pre-machined component itself to be consistent so that it is held in the fixture without distortion and its features are positioned correctly before machining starts.

Few UK machine shops have the luxury of making just a few parts in very high volumes - most of that business has already moved overseas. Instead most shops must turn out a high variety of parts, often requiring complex machining, sometimes needing multiple operations, and always to meet tight delivery schedules. There simply isn't the time to design and procure expensive fixtures, and yet machining tolerances are wafer thin.

To compound the problem in many first operations, the blank component - billet, casting or forging - can exhibit significant variation, often more than the machining tolerances. This means that, even with a precision fixture, the part cannot always be correctly located in the machine. More importantly, the part may suffer distortion if clamped against unyielding stops. This can result in perfectly good machining being ruined as the component springs back when the clamping forces are removed, upsetting the relationships between features.

With these concerns in mind, the second approach to part setting involves finding the part location and then adjusting the datum for the machining operation to that actual position. Modern machine tools do not require the part to be perfectly positioned and aligned with the machine axes to make it right. By using work co-ordinates and co-ordinate rotations, the machining frame of reference can be aligned with the part itself. So the fixture can be designed to simply hold the part rigidly, with sufficient compliance to allow for variation in the size or shape of the pre-machined part. All that we need to do is to find where the part is positioned and set up our co-ordinate system to suit.

Part setting is the classic application for touch probes on CNC machine tools. The task is generally very simple: to find the location of a datum feature on the part - often a corner or a bore centre - and use this position to set a work co-ordinate. In contrast to traditional techniques such as clocking the part or using a 'wobble bar', probing cycles can be fully automated and, as such, are subject to far less variation than manual methods. Furthermore, the calculation and application of work co-ordinate changes are also automatic and therefore immune to human error.



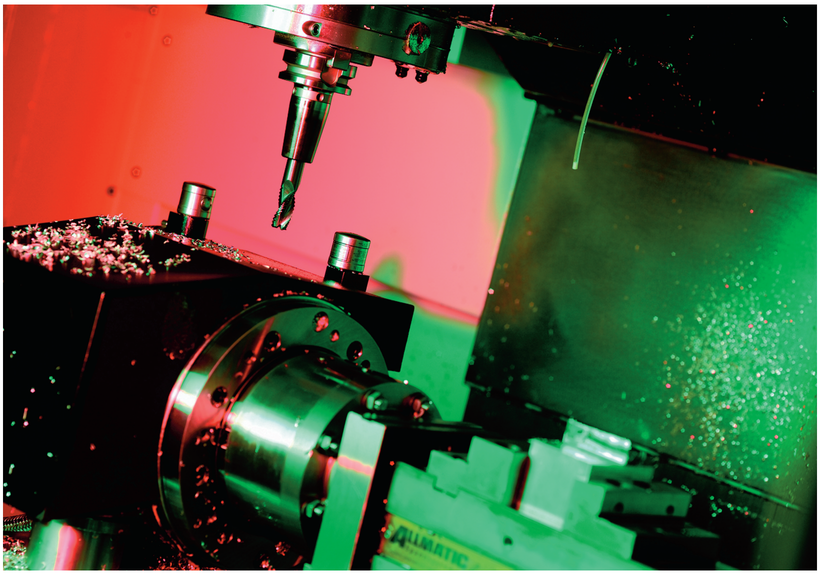
Part setting is the classic application for touch probes on machine tools

Where large variations in raw material condition can occur, it is often necessary to remove excess stock using a variable number of roughing passes. With a probe and a bit of simple program logic, it is easy to find the material condition and compute the number of passes required to cut the part down to size, avoiding 'fresh air' cuts.

In many instances, the component must be mounted on a rotary axis to allow access to multiple faces, where the position of the part relative to the centre-line of rotation is crucial. For the reasons outlined above, it is not always possible to position the part perfectly, but the relative displacement of the part and the rotary axis centre-line can be probed on the machine. Modern CNCs can then track this eccentricity as the rotary axis moves, adjusting machining to the right position on the part.

Setting tools in situ

The second aspect of process set-up is to establish tool dimensions and record this information in tool offsets in the control so that the tool can be brought accurately



Setting tools on the machine means you can measure the tool in situ - performing as it will when it cuts metal

to the component. The traditional method was to make a trial cut and measure the result, an approach that does not sit well with the modern drive towards automation and efficiency.

The key advantage of setting tools on the machine tool rather than using off-line pre-setters, is that you can measure the tool in situ, performing as it will when it actually cuts metal. Placing the tool in the spindle and spinning it introduces several dynamic effects, including pull-up where the shank settles in the spindle nose. Where the tool and/or the spindle experience a degree of run-out, this will also be detected as the tool spins.

Probing once again provides the key advantage of automation - both the cycles and the feedback require no manual intervention or interpretation, eliminating a major source of crashes, concessions and scrap.

Tool setting need not be limited to just length and diameter measurement. On form tools, a tool setter can be used to establish a series of points along a profile, checking whether each is within tolerance. It can also check for tool projection and stop the process if a tool assembly has been built incorrectly - vibration and chatter can be induced in tools that are over-extended, adversely affecting process capability.

Scaling the pyramid

So are we ready to start machining yet? Yes - we know that the machine can move accurately, we know how the axes move relative to one another, we know where the part is positioned and we've datumed our tools. The topic of the next article in this series will be the process of cutting metal, using adaptive machining techniques to combat the sources of variation that can afflict the cutting process. After that, we'll move on to on-machine verification and maintaining a stable environment. Additional material to support this series of articles can be found at **www.renishaw.info/pyramid**

Marc Saunders is General Manager of Renishaw's UK & Ireland Sales Division. He has a first-class masters degree in engineering, and played a leading role in the development of RAMTIC, Renishaw's award-winning automated manufacturing system