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Dynamic re-machining

Problem

When undertaking a machining process, the outcome in terms of dimensional accuracy may not always be predictable. Process capability may be influenced by other factors occurring within the manufacturing process that are inconsistent, or that are subject to change over time.

Using external, off-line or 'after the event' methods of process control may not address these causes of variation. In fact, the part-to-part variation may be such that using a previous part measurement to adjust the process may introduce further variability.

As a result, the achieved levels of process capability may not meet the targets required to minimise or eliminate defective parts.

In applications where high-value parts are machined, this scenario leads to low productivity, increased manual intervention and design concessions where parts are 'crafted' by skilled operators reacting to part specific variation.

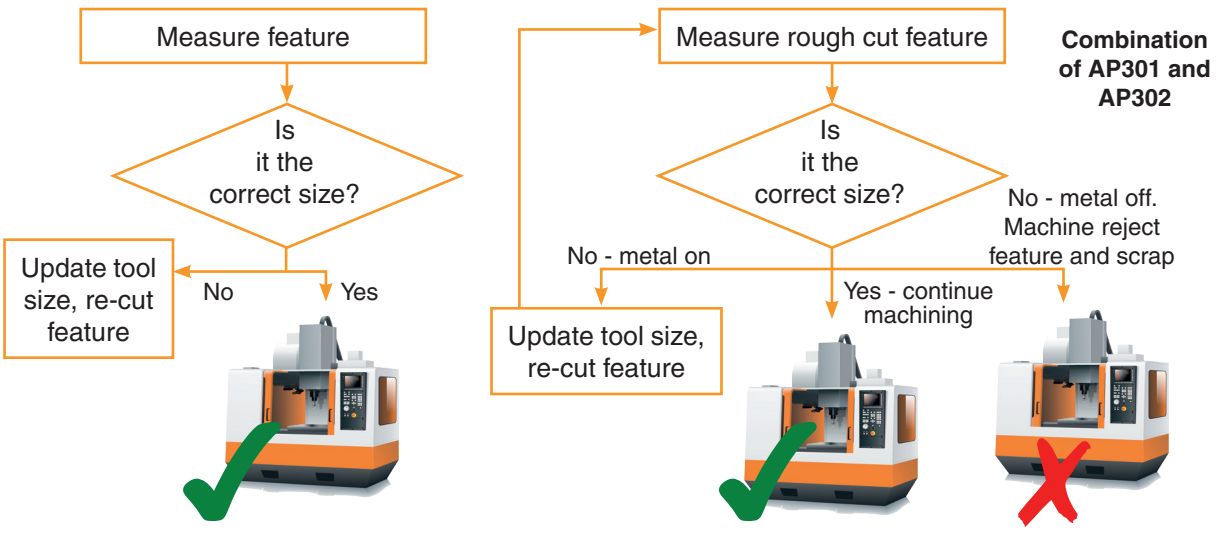
Expected sources of natural variation include:
- part distortion influenced by input material condition
- tool deflection caused by material/machined feature condition
- thermal effects of environment on part and/or machine
- significant tool wear during machining of a single part (long cycle times or exotic materials)

Solution

The CNC machining process uses semi-finishing cuts or test cuts (slave features) that are representative of the subsequent finishing cut. The probing system on the machine is used to measure the cut feature and adjust the process through tool offsets to improve final part accuracy (using pattern *AP301, Cutter parameter update*). Decisions are then made as to whether the feature needs to be re-cut, if the feature is OK, or if it should be rejected.

The elapsed time between taking a test cut and the final cut may have an influence on the accuracy achieved. For the highest accuracy, the measurement and final cuts need to occur in quick succession.

- The machining of 'slave' features in sacrificial material (material to be removed as part of the normal process) is one way of fine-tuning or adjusting the process to increase confidence in final part accuracy.



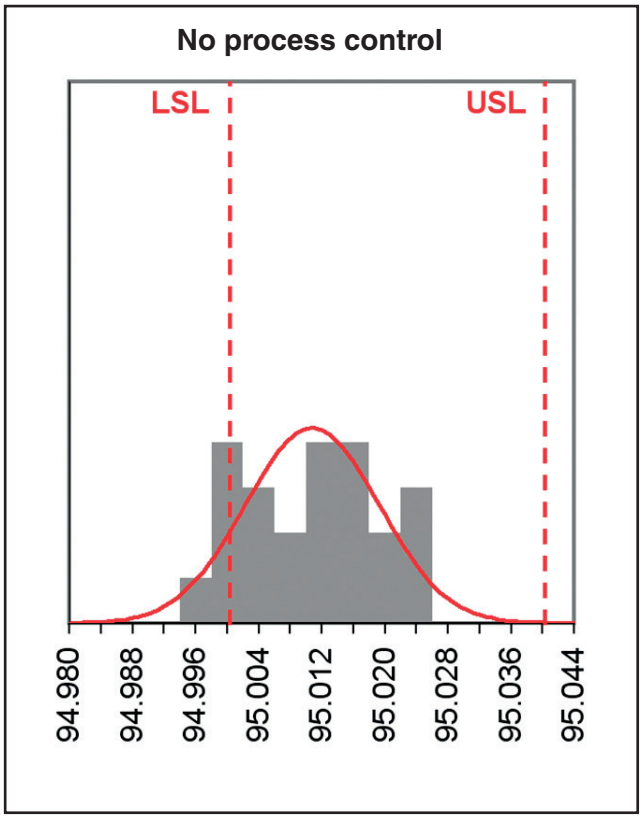
Benefits

- Adjusts the process accurately despite part-to-part variation
- Allows closed loop, cut-measure-cut process control without manual intervention
- Improves process capability compared to off-line, post machining process control
- Allows prevention of scrapped parts by stopping a process safely before excessive errors are introduced to the finished part

Case study

Rotary encoder rings are machined on a mill-turn machine. Three rings are machined in sequence from a single billet. An internal bore with a 95.00/95.04 mm diameter is required. Post-process quality checks revealed unacceptable defect levels.

Baseline capability was established by running 23 parts straight off the machine.

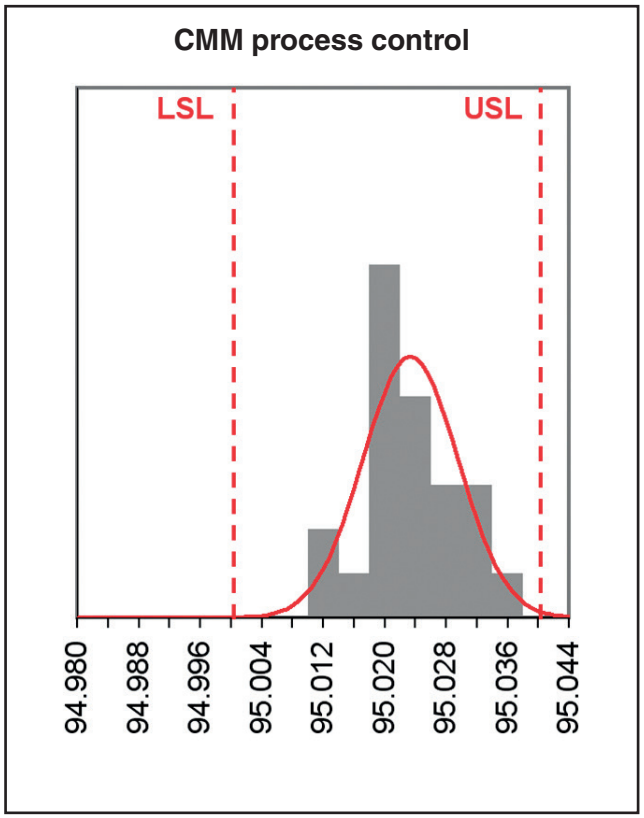


Process data	
Sample mean	95.0103
Sample size	23
Standard deviation	0.0106786

Capability	
Cp	0.62
CPL	0.32
CPU	0.93
CpK	0.32

The process showed a very poor CpK of 0.32 resulting in approximately 12% scrap levels.

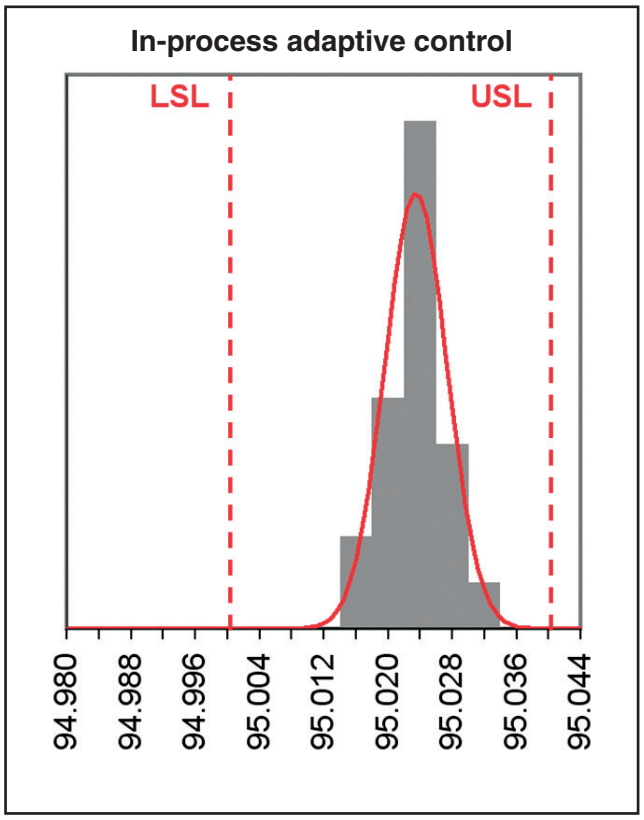
A second capability study was carried out using a feedback regime whereby the result of every finished part was used to adjust the process for the next part in the batch (this process is analogous to using post process CMM style inspection as a means of process control).



Process data	
Sample mean	95.024
Sample size	48
Standard deviation	0.00618681

Capability	
Cp	1.08
CPL	1.34
CPU	0.81
CpK	0.81

A third batch was produced using a semi-finishing cut which was measured on the machine to update the tool offset before final finish cutting. This method of control compensates for any part to part variation.



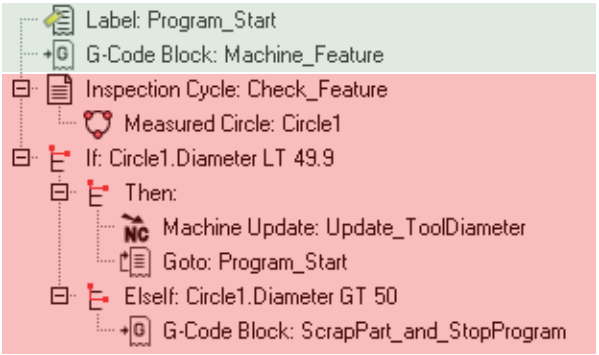
Process data	
Sample mean	95.0221
Sample size	48
Standard deviation	0.00358382

Capability	
Cp	1.86
CPL	2.06
CPU	1.66
CpK	1.66

The process now indicates a capability of CpK1.66 which equates to 0.0002% scrap.

Example: inspect feature dimensions and tool diameter update

Sample Productivity+™ probe software program



Machine feature: circle of diameter 50 mm.

Inspect diameter of machined circle.

If the diameter is less than 49.9, a tool diameter update operation is performed. Program then jumps back to the Start label and re-machines the feature.

If the diameter is greater than 50, too much material has been removed. The program is stopped and the part is scrapped.

Sample Inspection Plus software program

Tool in use is a 10 mm end mill.

N10	
	Machining process of 50 mm bore using tool 10
N20	
T1 M6	Select the probe
G54 X0. Y0.	Start position
G43 H1 Z100.	Select length offset
G65 P9810 Z-10. F3000	Protected positioning move to Z-10
G65 P9814 D50. T10	Cycle checking a 50 mm diameter bore. Update the tool 10 offset by the difference
IF[#138LE50.]GOTO30	
#3000=90 (PART OVERSIZE REJECT)	Alarm
N30	
IF[#138LE49.9]GOTO10	If bore size is less than 49.9 “jump” to beginning of program and re-machine
G65 P9810 Z100.	Protected positioning move to Z100
G91 G28 Z0.	Return to home position
G90	
N30	
	Finish machining of component

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Products include:

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- Probe systems and software for job set-up, tool setting and inspection on CNC machine tools
- Raman spectroscopy systems for non-destructive material analysis
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- Styli for CMM and machine tool probe applications

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