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Adaptive machining

Problem

A manufacturing process may dictate that the form of a finished component is dependent on the form of the input material for that process. This may occur where distortion of the part during machining varies from part to part (for example, owing to fixturing effects), or where the actual workpiece is a unique item and depends on uncontrollable effects (for example, in a remanufacture task where the lifetime history of the component has affected its form).

In these circumstances, it is necessary to measure the form of the input component and use the measurement to produce a customised cutting program which is unique to that component.

Solution

There are many different production scenarios which may present this problem, for example machining a highly toleranced feature relative to a variable profile, repairing old or damaged parts, or producing a smooth blend between variable forms.

These scenarios require:

Assessment of input forms and conditions *

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Generation of customised tool paths based on form measurement

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Upload new program to machine tool and run CNC program

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Use a workpiece inspection probe to characterise 3D forms for generation of customised tool paths.

On-machine measurement brings several advantages over off-machine methods:

- there is no need to translate datum systems
- workpiece set-up and fixturing requirements are minimised
- overall measurement cycle times are optimised

Measurement data is processed to generate customised tool paths for the adaptive machining process. (This may take place on or off the machine tool control.)

The new tool paths need to be processed into program code which is executable on the machine tool, after which machining can continue using the customised program.

Run the CNC program to use the newly customised tool paths.

* It is often necessary to collect a high density of data points to describe complex forms so consideration should be given to the suitable choice of probing and programming technology.

Benefits

Adaptive machining offers adjustment and automation of CNC machining processes beyond the possibilities of conventional setting processes. The ability to collect and process high density data relating to form and condition brings new technical abilities to machining processes and makes complex operations more accurate and time-efficient. Adaptive machining brings significant benefits to the accuracy and time requirements of blending operations. It also allows various other metal forming processes to be used prior to machining where the outputs of those processes were previously considered too complex or variable to machine reliably or efficiently.

Examples

Machining welds on remanufactured components

When remanufacturing parts such as turbine blades and turbo turbine wheels, worn blade tips are machined back to known good material, and then weld is applied to rebuild the tip. The weld needs to be machined back to match the original blade profile exactly in order to create a correctly machined blend and leading edge profile.

Edge profiling

Where component specifications include tightly toleranced edge profiles (for example, chamfered or radiused edges) between variable surfaces, the precise form and position of the surfaces must be known in order to accurately machine an edge profile between them. The machining tool path needs to be able to accommodate surface variation caused by factors such as distortion owing to clamping forces.

Mould tool refurbishment

Where mould tools may be subject to repairs such as welding, there can be a requirement to machine the repaired area to blend with existing hand-finished profiles. In such circumstances, the finished profile needs to be smooth rather than produced to a nominal specification, so the machining process must be capable of adapting the tool path to blend with existing profiles.

Matching components

There can be situations where part of an assembly has a variable profile which must be matched with a component which is produced by a process over which there is more control. It is possible to characterise the variable profile and create a cutting program to machine a matching component for the unique assembly.

Aero engine blade and disk assemblies

When building blade and disk assemblies, blades are often joined to hubs using a welding process which generates welding flash. The flash needs to be removed and blended smoothly from the variable blade profile to the nominal blade root blend profile.

Turbine blades

For some new turbine blade designs, the blades are forged or formed but require the machining of the leading edge to give it a specific profile. The machining tool path needs to blend from the variable forged profile to the required nominal leading edge profile.

Example: edge chamfering

A machined chamfered edge on a component is affected by clamping forces. Adaptive machining is used to produce the desired profile despite part distortion.

Two alternative probing technologies may be used to enable this adaptive application.

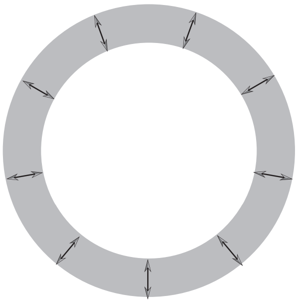

Figure 1: sample component, uniform thickness

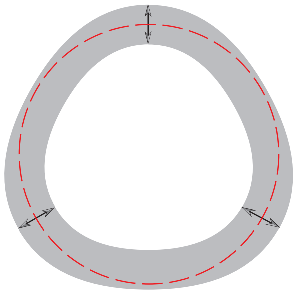

Figure 2: affect of clamping forces on material, and chamfering tool path

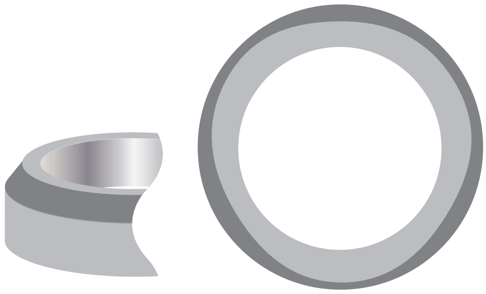

Figure 3: variance in chamfered edge without adaptive machining

1. Touch-trigger probing technology

- A touch-trigger probe is used to measure a series of 121 points on the outer circumference of the feature (figure 4)
- XY location data of measurement points is stored to macro variables on the machine control
- A macro program on the control is used to manipulate the XY data, offsetting by the tool diameter to generate the required cutting path in G-code
- A second macro program executes the cutter path generated by the first program

2. Scanning probe technology

- A scanning probe is used to determine feature surface characteristics (figure 5)
- Results are saved to a data file
- Form data is processed and used to generate a cutting path in G-code
- The generated part program is executed in order to machine the feature to required dimensions

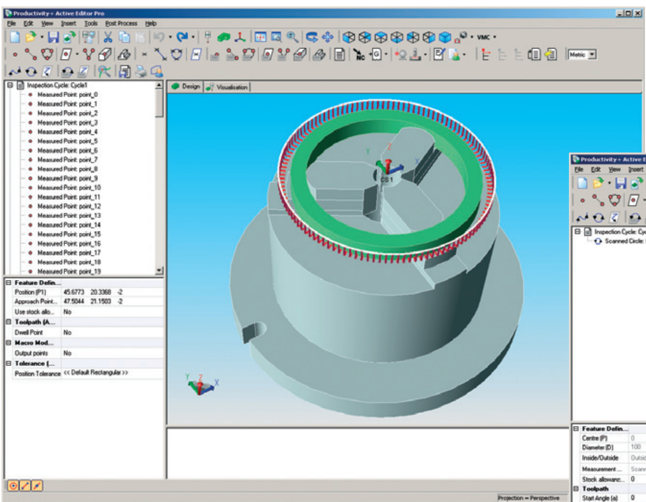

Figure 4: touch-trigger method with individual inspection points

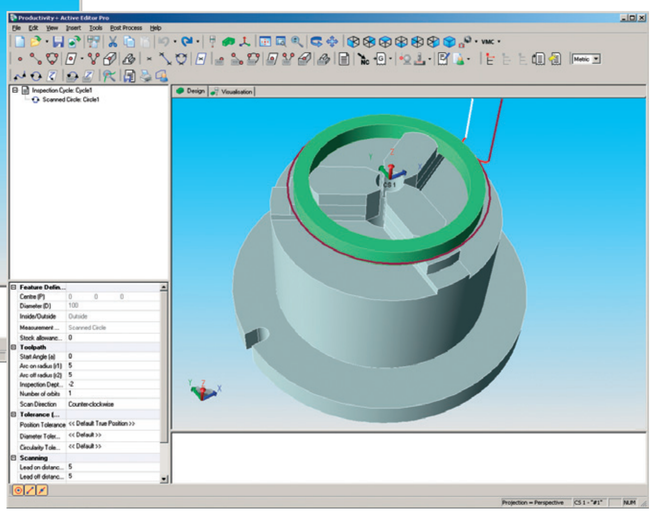

Figure 5: surface scanning method with single probe scan path

Screenshots are taken from Renishaw Productivity+™ Active Editor Pro and are provided for illustration purposes only.

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- **Styli for CMM and machine tool probe applications.**

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