



Scanning capability notes

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3D feature measurement

Scanning capability for CNC machine tools

The Renishaw OSP60 on-machine scanning probe with SPRINT™ technology provides a rapid and highly-accurate solution for a wide range of measurement applications. Automated part setting, in-process verification, and adaptive machining, can all benefit from the adoption of on-machine scanning. This capability note looks at using the OSP60 probe for high-speed inspection of 3D features such as spheres, cylinders and cones.

Accurate measurement of 3D features can be a difficult and time-consuming process using a touch-trigger probe. Collecting the vast quantity of data required for accurate form determination can be cycle-time prohibitive for all but the most high-value materials and workpieces. Minor defects can easily be missed, interrupted features (such as incomplete circles) can be difficult to program, and combining the information from such features can be challenging.

As a scanning solution, the OSP60 is uniquely positioned to capture the high volume of data required to accurately model full 3D features. Up to 1,000 3D data points per second at feedrates of 15 m/min (590 in/min) are possible. This provides significant cycle time advantages and a uniquely accurate, detailed understanding of true part form.

The Productivity+™ 3D Feature Toolkit is a dedicated software application for use with the OSP60. It allows 3D features such as cones, cylinders, spheres and circular sections to be programmed and inspected with ease. Simply select wire geometry from a component solid model (or program manually using supplied custom macros) to generate the required scanning toolpaths. Data obtained can be referenced in reporting statements or written to variables for machine update operations.

Resulting geometric information can also be used to perform a fitting operation before machining commences. For example, data from two circular scans can be fitted to a cylinder which can then be used to align the component to a specified machine axis.

The software contains several flexible scanning strategies allowing even interrupted or incomplete features to be scanned. Using these strategies, the results of multiple partial feature scans can be used to 'construct' a complete feature. For example, a series of arc features which together form an interrupted circle, can be scanned, and their individual results combined to 'construct' a complete circle or sphere.

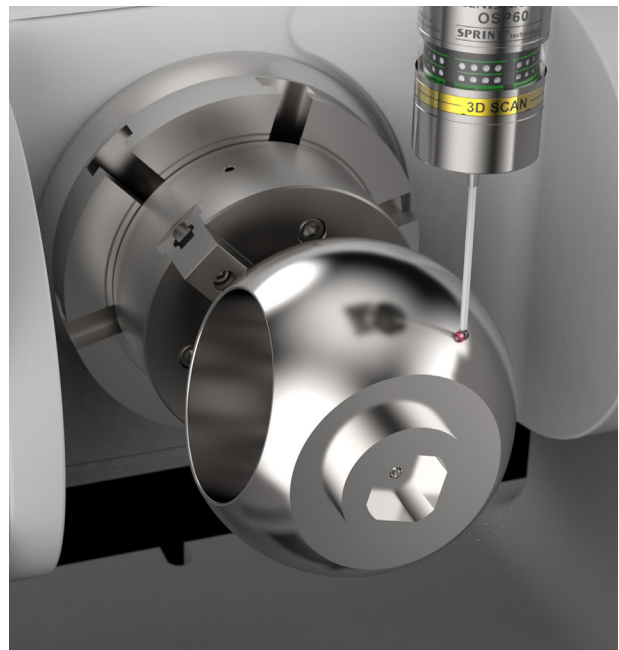
Benefits of on-machine scanning

On-machine scanning is an intelligent, automated, enabling technology that offers numerous operational benefits.

- Significant reductions in part setting, inspection cycle times and scrap.
- Data-dense inspection results. The OSP60 captures up to 1,000 3D data points every second.
- Automated setting and updating of machine parameters.
- Comprehensive feature information including dimensional data, geometric data, positional offset, angular offset and true feature form.
- Perform multiple applications such as part setting, on-machine component verification, surface condition monitoring, and machine performance verification, with a single probe and stylus configuration.
- Absolute confidence in measurement results due to continual communication between the scanning system and machine tool position data.
- Improved manufacturing capability, productivity and process optimisation.
- Complementary software solutions providing application-specific inspection capability.

Adoption of on-machine scanning solutions can introduce game-changing capability for companies in high-value manufacturing sectors. These include automotive, consumer electronics, medical, mould and die, and power generation.

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3D surface capture

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Measurement of intricate and highly curved free-form surfaces can be a difficult and time-consuming process. Collecting the vast quantity of data required for accurate form definition with a touch-trigger probing system can be cycle-time prohibitive for all but the most high-value materials and workpieces.

As a scanning solution, the OSP60 can measure undulating component geometry, including surfaces with double curvature – blades, bladed disks, turbines, and impellers for example – at exceptionally high speed. Up to 1,000 3D data points per second at feedrates of 15 m/min (590 in/min) are possible. This provides significant cycle time advantages and a uniquely accurate, detailed understanding of true part form. Scan data obtained can then be used in applications such as high-precision adaptive machining, or for advanced part setting, and pre-machining alignment operations.

On-machine scanning can provide significant advantages over alternative measurement techniques.

- Reduced cycle times in comparison with traditional touch-trigger probing systems.
- Improved accuracy compared with both touch-trigger and optical measurement systems. Particularly the capability to scan around leading and trailing blade edges.
- Data from different areas of the component surface – measured in different machine orientations – can be captured, 'stitched' together, and reported in a single work co-ordinate system.
- Manual handling errors, and the complexities associated with the transfer and multiple set-ups required when moving components from machine tools to offline measurement devices, are eliminated.
- Allows the operational benefits provided by a closed-loop control process.

Results data including surface position (XYZ), normal vectors (IJK), and material condition are output to machine variables. Data can be used directly or via integrated logic functions to control subsequent processes. Data can also be exported to a .csv or text file for further analysis or for use in third-party metrology applications. Scan data and the nominal component model can also be used to generate a corrected model surface which can be exported back to a CAM system.

A complementary software application, Scan Data Viewer, displays data representing machine points and probe tip centre positions. This application can be used to optimise part set-up, and to highlight measured part form variation from nominal.

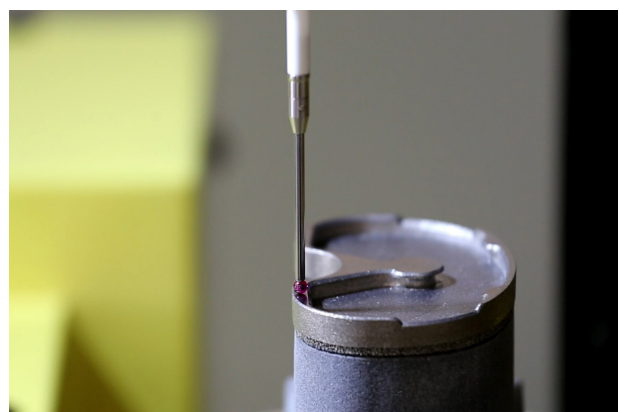
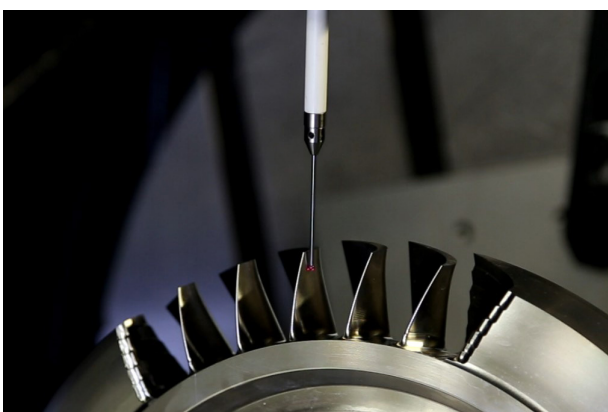
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- Comprehensive feature information including dimensional data, geometric data, positional offset, angular offset and true feature form.
- Perform multiple applications such as part setting, on-machine component verification, surface condition monitoring, and machine performance verification with a single probe and stylus configuration.
- Absolute confidence in measurement results due to continual communication between the scanning system and machine tool position data.
- Improved manufacturing capability, productivity and process optimisation.
- Complementary software solutions providing application-specific inspection capability.

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Adaptive machining

Scanning capability for CNC machine tools

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Components that are cast or forged are frequently subject to significant part-to-part variation. A manufacturing process that can react adaptively and account for these variations is a key enabler for automated, lights-out manufacturing. This in turn increases productivity and profitability.

Collecting the amount of data required for adaptive machining with a touch-trigger probe system can be incredibly time consuming. This can make the process unsuitable for all but the most high-value materials and workpieces. As a scanning solution, the OSP60 collects high volumes of measurement data at exceptionally high speed. Up to 1,000 3D data points per second at feedrates of 15 m/min (590 in/min) are possible, providing a rapid and detailed understanding of true part form. Data is analysed by accompanying software to automatically adjust the nominal cutting program, point-by-point, in real time. A new cutter toolpath, tailored precisely for each individual scanned part, is automatically generated and loaded to the controller. This ensures that even the most challenging workpiece can be manufactured to tolerance.

The OSP60 puts high-end adaptive machining capability directly into the hands of the end user. It can eliminate the requirement for external equipment, such as industrial robots and third-party software, for a fraction of the price of some alternative solutions.

The benefits of adaptive machining offered by the OSP60 can be utilised in numerous applications. These include: chamfering of near-net-shape parts; edge-breaking and deburring; surface engraving; and copy-cut production of mating parts.

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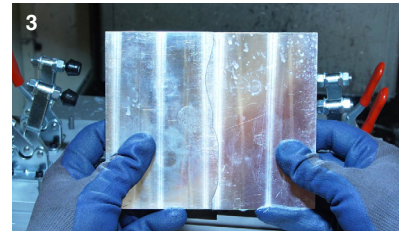
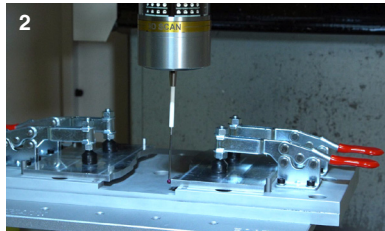
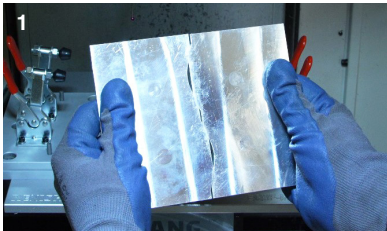
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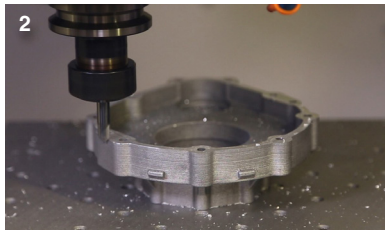
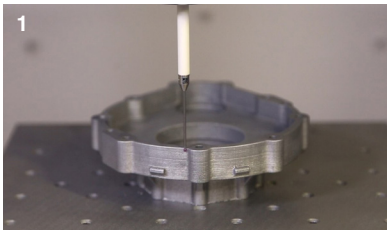
Copy-cut example

1. Master and nominal blank part.
2. Master part is scanned. Software analyses the master part form and generates an adaptive machining toolpath.
3. Nominal blank machined to match the master part resulting in a high-quality match.



Chamfering example


1. Part is scanned and adaptive cutting program, based on the true shape, is automatically uploaded.
2. Run the cutting program.
3. Uniform chamfer cut around the part, matching its true form.



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High-accuracy diameter measurement

Scanning capability for CNC machine tools

The Renishaw OSP60 on-machine scanning probe with SPRINT™ technology provides a rapid and highly-accurate solution for a wide range of measurement applications. Automated part setting, in-process verification and adaptive machining, can all benefit from the adoption of on-machine scanning. This capability note looks at using the OSP60 probe as a solution for exceptionally repeatable workpiece diameter measurement.

Highly accurate turned components are required across numerous industries including aerospace, automotive, oil and gas, and power generation. Accurately determining workpiece diameter – and the ability to consistently produce components to tolerance – can be critical for winning and maintaining supply contracts, fulfilling quality assurance requirements, and maintaining supply chains.

Workpiece diameter measurement with the OSP60 probe is provided via a dedicated scanning cycle. This cycle utilises the unique 3D scanning capability of the probe to collect measurement data from every part of the component surface whilst the workpiece is rotated.

Potential measurement errors are eliminated in several ways. The rotating profile is measured multiple times; measured points are then averaged, reducing measurement noise. The optional use of a reference artefact reduces the effects of thermal changes to the machine structure or component on-centre error. Measurement accuracy of less than 5 µm (and repeatability of ±0.5 µm) can be achieved.

Using an on-machine scanning system can provide significant advantages over alternative measurement techniques.

- Provides a highly repeatable measurement of diameter, part run-out, machine centrelines, and circularity.
- Eliminates errors caused by machine axis drift or off-centre errors.
- Enables 'cut-measure-cut' processes based on automatic closed loop process control capabilities, eliminating the need for tool length updates based on manual measurements of turned diameters.

Measurement results – diameter, rotation centre, runout, on-centre error, and circularity – are written to machine variables. Results can be used directly or via integrated logic functions as part of a go/no-go check, or for updating tool parameters within the NC program. Optionally, export data to a .csv file for further analysis or for use in third-party software applications.

Benefits of on-machine scanning

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- Data-dense inspection results. The OSP60 captures up to 1,000 3D data points every second.
- Automated setting and updating of machine parameters.
- Comprehensive feature information including dimensional data, geometric data, positional offset, angular offset and true feature form.
- Perform multiple applications such as part setting, on-machine component verification, surface condition monitoring, and machine performance verification, with a single probe and stylus configuration.
- Absolute confidence in measurement results due to continual communication between the scanning system and machine tool position data.
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High-speed part set-up and verification

Scanning capability for CNC machine tools

The Renishaw OSP60 on-machine scanning probe with SPRINT™ technology provides a rapid, high-accuracy solution for automated part setting and on-machine component verification. It significantly and consistently outperforms the capabilities of traditional touch-trigger probing solutions, offering reduced cycle times and increased data density. Although probing cycle time savings will always be application dependent, reductions of up to 90% have been achieved.

As a scanning solution, the OSP60 can measure features such as arcs, circles, and planes at exceptionally high speeds. Feedrates of 15 m/min (590 in/min) are possible without compromising accuracy. This allows almost any existing touch-trigger set-up or inspection routine to be replaced with scanning cycles, returning more detailed information – up to 1,000 3D data points per second – in a fraction of the previous cycle time.

Prismatic data collection is key in many applications. For example, automotive engine block refurbishment where probing is typically used to determine the lowest point of corrosion. A tool length update is then applied before a skimming operation is performed across the face of the engine block.

Prismatic inspection routines can be generated using a variety of programming techniques. G-code macro programming, CAD/CAM-style programming (where probe toolpaths are generated through the selection of component solid model geometry), parameterised programming, and complementary Renishaw apps (including Set and Inspect and GoProbe) are all supported. Dependent on the programming method selected, additional functionality such as probe path visualisation, crash detection, on-screen reporting, and graphical representation of real-time feature scanning, is also available.

Measurement results returned can be used for a wide range of purposes including:

- setting or updating work co-ordinate systems and machine variables;
- tool length and geometry updates;
- logic (control) statements to intelligently determine if and how the machining program should proceed;
- simple go/no-go checks;
- quality assurance purposes and report generation.

In addition, the system provides comprehensive geometric data, including circularity, flatness, straightness and material condition.

Associated scanning software features enhanced data handling capacity and analytical capability when compared with traditional software offerings. Functionality includes user-selectable fitting routines – such as least squares and minimum circumscribed – allowing tailored form analysis for individual applications.

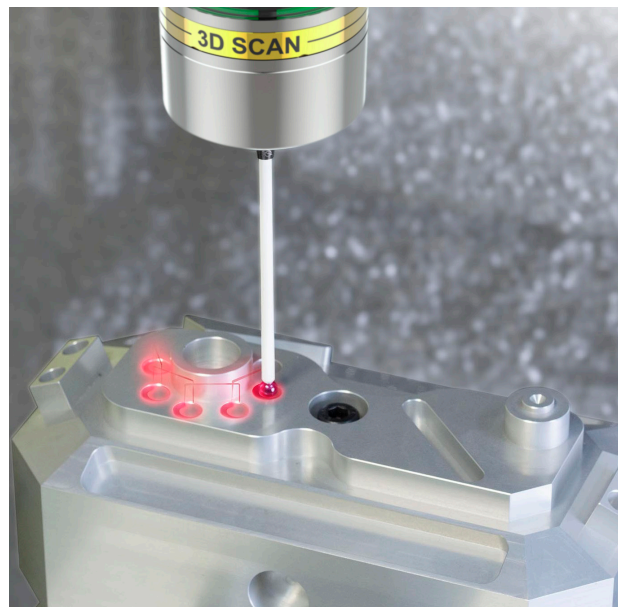
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Machine performance verification

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Determining performance capability will confirm whether an individual machine tool is capable of accurately manufacturing the parts required. Regular monitoring of machine capability will identify performance drift over time. This allows predictive, preventative maintenance tasks to be scheduled before machine performance reaches unacceptable levels. Such checks are especially important in industries that use high-value raw materials, and where components require significant machining time.

The Productivity+™ Machine Health Check cycle utilises the exceptional measurement capability of the OSP60 probe to deliver a simple, sub-60 second, performance verification check of a CNC machine tool's linear and rotary axes.

The cycle can be integrated into existing machine code and executed automatically, making it an ideal, rapid go/no-go check before critical machining begins. Operator intervention, disruption to machine uptime, and therefore impact on productivity, are minimal, but the benefits are significant.

- Test 3-axis machines and 5-axis table/table machine tools in under one minute.
- Integrate the cycle into existing production processes to maximise the likelihood of successful, right-first-time, manufacturing processes. A significant step in the road to process automation.
- Improve manufacturing capability, productivity and profitability.
- Reduce scrap, rework, and machine downtime required for unscheduled maintenance operations.
- Utilise your existing scanning probe hardware to perform the test. Only a single additional test artefact is required to perform both 3-axis machines and 5-axis table/table machine tool tests.
- Suitable for use by machine tool OEMs, resellers, installers, and end users.
- If performance issues are identified, further investigation can be performed using AxiSet™ Check-Up, or the QC20 ballbar.

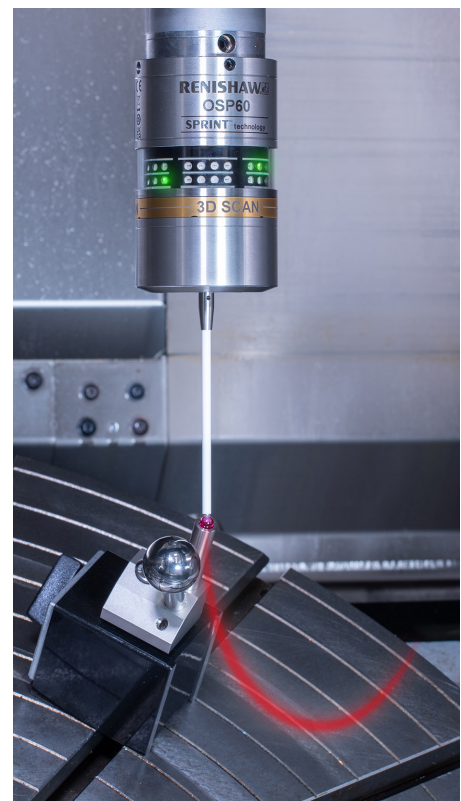
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- Perform part setting, on-machine component verification, and determine machine capability with the same probe and stylus configuration.
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Surface condition monitoring

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Surface condition errors are frequently responsible for cosmetic and functional failure of components, and can be a significant cause of rework. Early identification and resolution of these errors are therefore critical.

Surface condition monitoring with an OSP60 measures waviness (W_t) values and can detect:

- periodic errors – indicated by a repeating pattern on the workpiece surface, and typically caused by worn tooling, or machine vibration.
- surface peaks – due to chipped, or worn tooling.
- steps on the surface – caused by unexpected differences between cutter dimensions, tool push-off, part deflection (when the workpiece is subjected to cutter forces), or thermal changes in the machine tool.

Surface condition measurement has traditionally involved the use of hand-held sensors, or has required the workpiece to be moved to a dedicated measuring machine. Use of an on-machine solution such as the OSP60 offers several significant user benefits.

Automated on-machine scanning using an OSP60 to capture surface condition data is more reproducible than using hand-held equipment as it eliminates human error. Data collection while the component remains in the machine tool eliminates repeated manual handling and the complexities associated with the transfer, and multiple set-ups required when moving components from machine tools to offline measurement devices. On-machine monitoring ensures that tooling is used for the duration of its useful life. Sister tooling can be called as soon as it is determined necessary, allowing process adjustments to be made before workpieces are machined beyond salvage, particularly important when machining high-value materials. The same probe and stylus configuration used for part setting and on-machine verification can also be used for surface condition monitoring. This can reduce or eliminate the need to invest in costly, dedicated offline inspection equipment and devices.

Waviness parameters calculated by the OSP60 are saved to machine variables allowing them to be analysed and used to control downstream processes. Data can also be exported for analysis in external software packages such as OmniSurf.

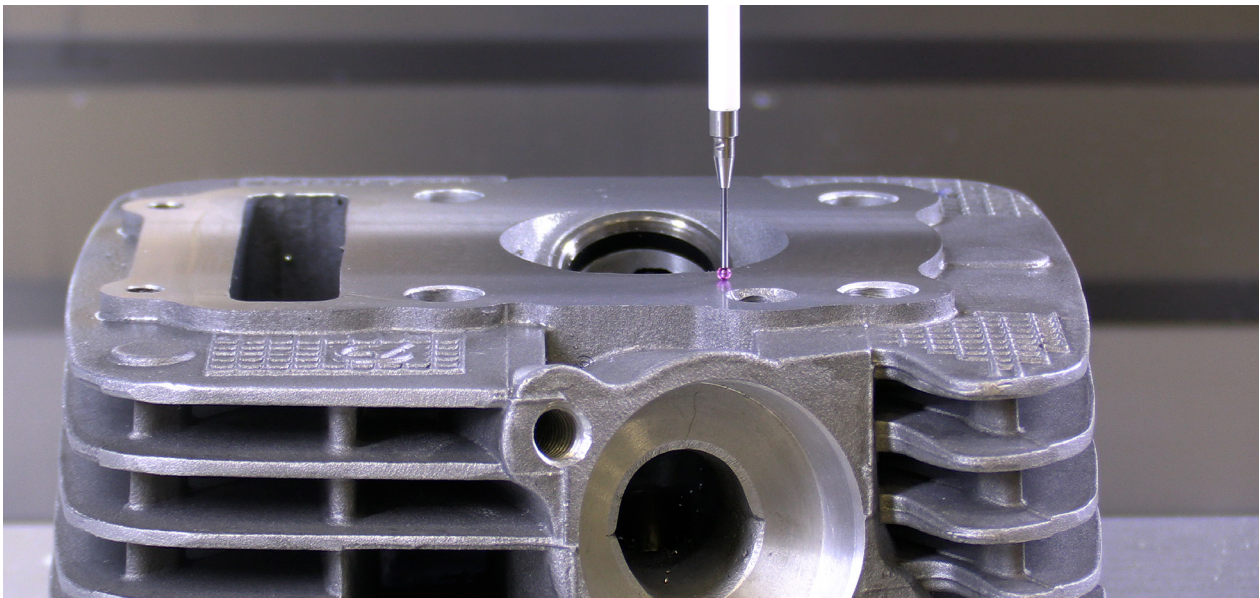
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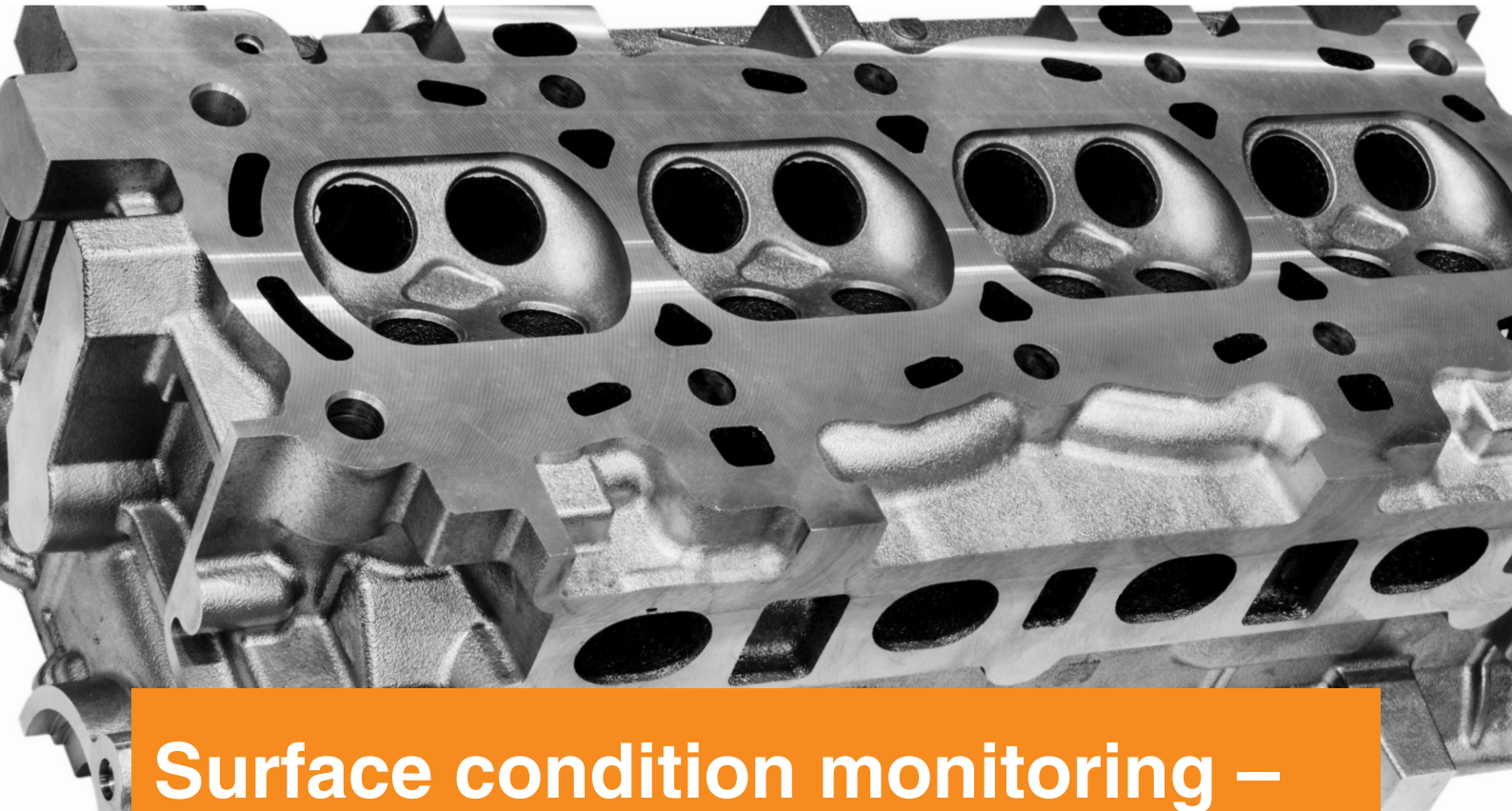
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Part no.: H-5465-8313-01-A



Surface condition monitoring – technology demonstration

Scanning capability for CNC machine tools

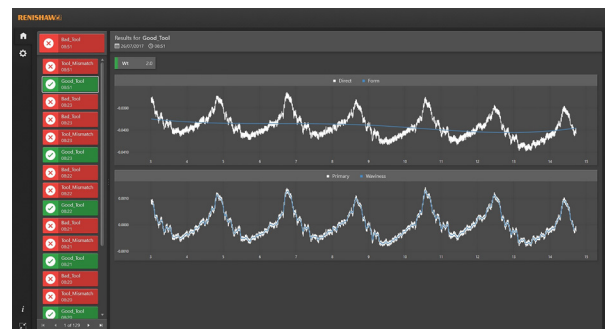
The OSP60 on-machine scanning probe with SPRINT™ technology provides a rapid and highly-accurate solution for a wide range of applications. Automated part setting, in-process verification, and adaptive machining can all benefit from the adoption of on-machine scanning. The OSP60 is also capable of monitoring the surface condition of nominally flat surfaces while the component remains in fixturing on the CNC machine tool.

This document outlines a surface condition monitoring technology demonstration which shows how surface condition monitoring with an OSP60 scanning probe compares with a traditional off-machine inspection system.

Technology overview

The output of OSP60 surface condition scans is total waviness (W_t). This value is passed into a machine variable and can be used to control subsequent processes or exported to file for further analysis.

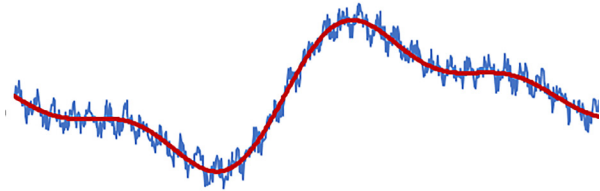
A visual trace of the surface profile can be displayed in Surface Reporter, a free-of-charge PC-based app. Its real-time, colour-coded display of surface condition results allows users to quickly and easily determine whether a component surface is in or out of tolerance.



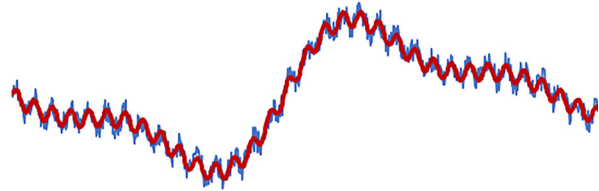
Surface waviness profiles in the Surface Reporter app

Surface condition monitoring for process control

Once a surface scan is completed, associated software filters the form profile from the raw surface scan data, and then filters the waviness profile from the remaining data. Users can customise how the waviness profile is filtered by adjusting the value of the λ_c cut-off wavelength. A setting of greater than 0.08 mm is recommended for process control applications.



Filtering waviness profile (red) from primary profile (blue) using a larger λ_c cut-off value



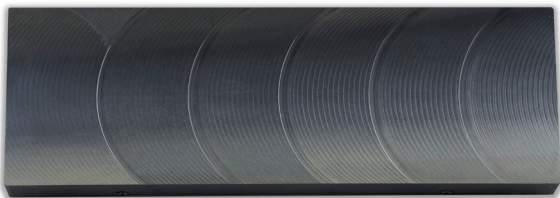
Filtering waviness profile (red) from primary profile (blue) using a smaller λ_c cut-off value

The OSP60 can be used to measure surface condition in any direction. Surface peaks, typically caused by chipped or damaged tooling, and scratches, potentially caused by material build-up on the tooling, can be measured accurately. Steps on a component surface, indicative of unexpected differences between cutter dimensions, tool push-off, part deflection under cutting forces, or thermal changes in the machine tool, can also be detected.

Surface condition measurement requires use of a 2 mm diameter stylus ball. This same configuration can also be used to perform additional probing tasks such as workpiece set-up, feature verification, and post-process inspection.

Technology demonstration

To demonstrate surface condition measurement capability of the OSP60, we have produced an aluminium test piece exhibiting different levels of wear. Six cuts were made on the test piece using tooling with varying levels of wear. As the wear levels of the tool performing each cut was different, a different surface condition was produced on each section of the test piece. Section one was cut with a new tool, section six which was cut with the tool exhibiting the highest level of wear.



Test piece with six cuts representing six different levels of surface condition

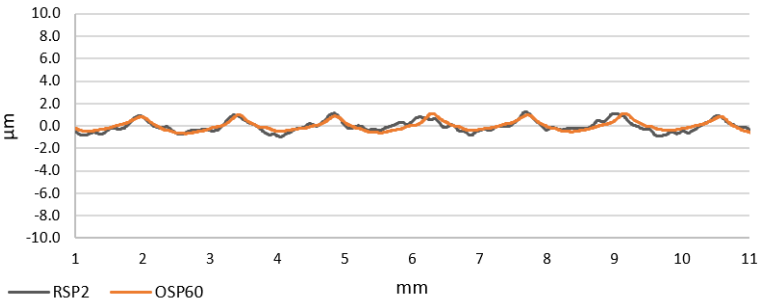
The following charts show the waviness profile of each section of the test piece as measured by:

- a machine tool with an OSP60 probe (with a 2 mm diameter stylus ball and a scanning feedrate of 500 mm/min);
- a CMM with a Renishaw REVO® RSP2 probe (with a 1 mm diameter stylus ball and a feedrate of 120 mm/min).

A λ_c value of 0.25 mm was used to filter the waviness profiles from the roughness profiles.

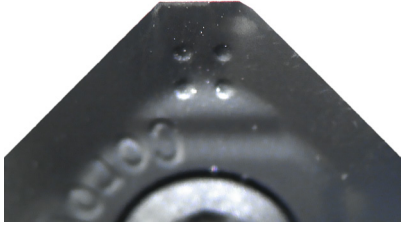
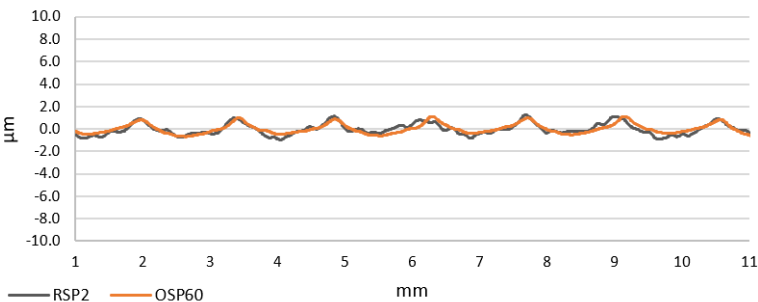
Tool images show a tool with a wear level representative of that used for the corresponding section of the test piece.

Section 1 waviness profile



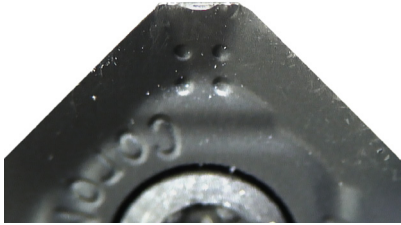
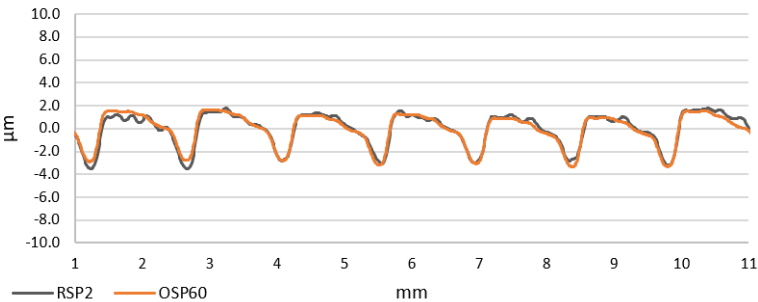
Waviness values reported: RSP2 $W_t = 2.560 \mu\text{m}$; OSP60 $W_t = 2.575 \mu\text{m}$.

Section 2 waviness profile



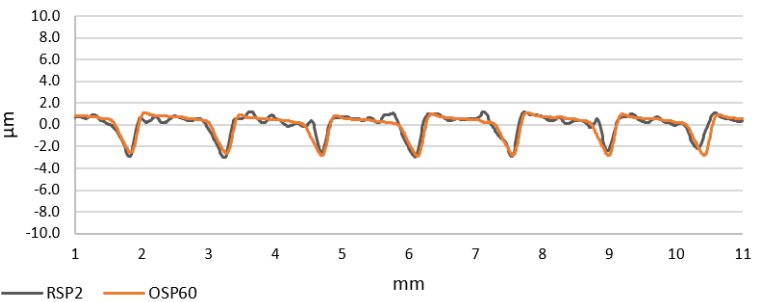
Waviness values reported: RSP2 $W_t = 2.203 \mu\text{m}$; OSP60 $W_t = 2.086 \mu\text{m}$.

Section 3 waviness profile



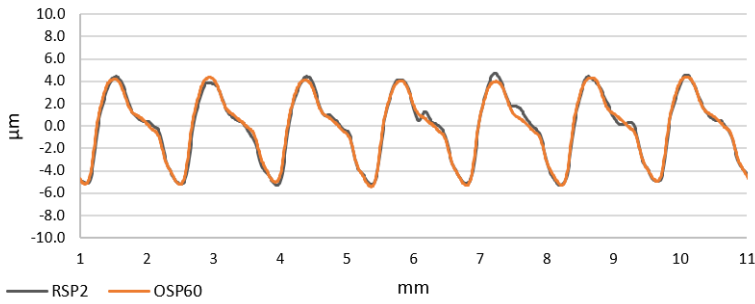
Waviness values reported: RSP2 $W_t = 5.294 \mu\text{m}$; OSP60 $W_t = 4.985 \mu\text{m}$.

Section 4 waviness profile



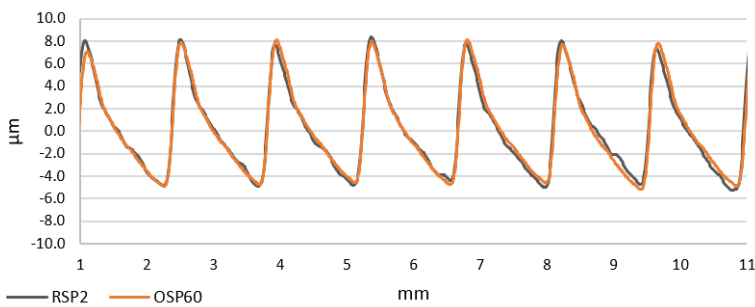
Waviness values reported: RSP2 $W_t = 4.245 \mu\text{m}$; OSP60 $W_t = 4.109 \mu\text{m}$.

Section 5 waviness profile



Waviness values reported: RSP2 $W_t = 10.028 \mu\text{m}$; OSP60 $W_t = 10.067 \mu\text{m}$.

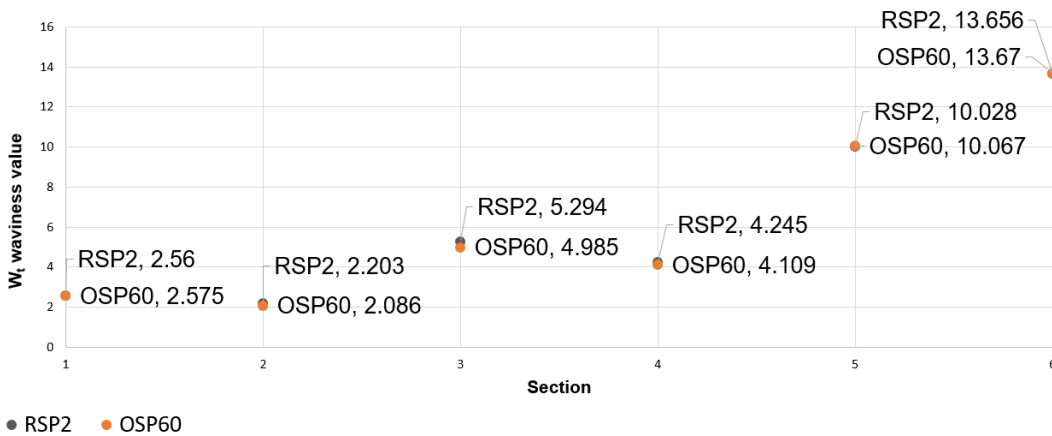
Section 6 waviness profile



Waviness values reported: RSP2 $W_t = 13.656 \mu\text{m}$; OSP60 $W_t = 13.670 \mu\text{m}$.

Conclusion

Results show a good correlation between the waviness profiles detected by the OSP60 on-machine scanning probe and the RSP2 CMM probe across each section of the test piece.



Correlation between W_t values from RSP2 CMM probe and OSP60 on-machine scanning probe