When Other Measurement Methods Fail

How to ensure the quality of tiny planetary gears in micro-drive systems? The combination of a multisensor coordinate measuring machine, a **FIBER PROBE**, and specialized software makes it possible – using scanning operation, even tooth flanks can be measured quickly, accurately and in accordance with the strictest standards.

Image 1. Measurement technician Ralf Nutto operates the Werth ›VideoCheck HA‹ multisensor coordinate measuring machine, equipped with a telecentric 10X lens and Werth Zoom Optics, the ›TP200‹ touch trigger probe, and the ›WFP‹ fiber probe. The ›WinWerth‹ software program and the integrated ›GearMeasure‹ software are used for operation and analysis

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Extreme temperatures from -100 to +200 degrees, vibrations, and impacts – drives from Maxon Motor, based in Sachseln, Switzerland, get the job done with absolute reliability under the toughest conditions. This makes them the first choice for unusual and especially challenging industries and applications. In space exploration, for example: The NASA Mars Rovers ›Spirit‹ and ›Opportunity‹ are each equipped with 39 Maxon drives. For over ten years they have been steadily doing their job under difficult conditions on the red planet.

Drive Elements Are Getting Smaller and More Precise

Back on Earth, Maxon DC motors function with up to 90 percent mechanical efficiency. They are used in antennas, radio masts, ships, and aircraft to provide smooth communications. They enhance driving safety in shock absorbers, advance automation in industrial production, help to correct vision problems in eye surgery, and even provide exact dosages of insulin for diabetes patients.

The trend toward miniaturization can be seen across every industry. This means that drive element have to get smaller and smaller. Maxon motor offers a modular series of motors, gearboxes, sensors, and control electronics under the name ›micro drives‹ that can be combined into tiny drive units just 6 mm in diameter.

Even these miniature units and their microcomponents still need to meet the highest quality requirements – a tradition at Maxon. In 1988 the company obtained ISO 9001 certification. Today the drives

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Images: Werth/Maxon

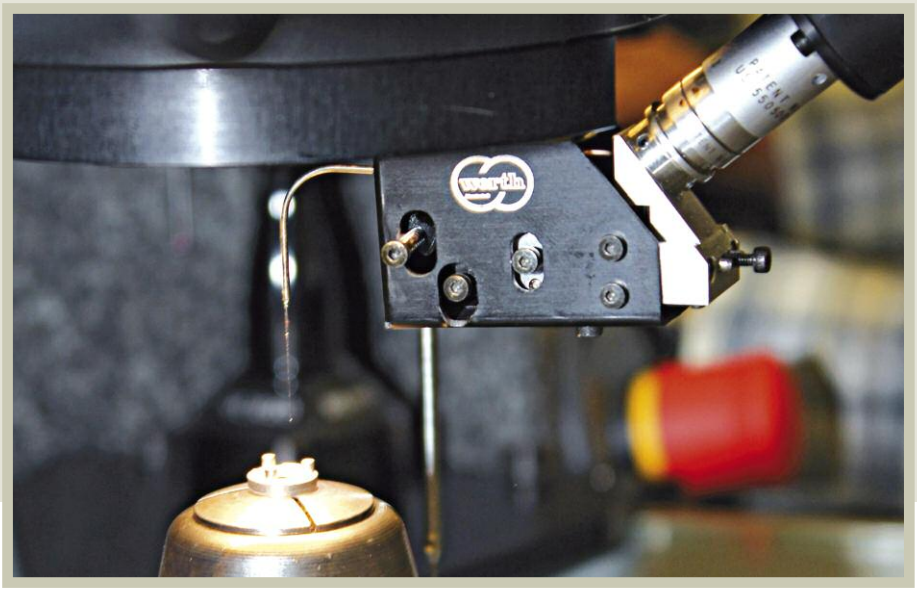

Image 2. The ›WFP‹ fiber probe is a microprobe for high-precision applications. It makes it possible to perform contacting measurements of extremely small geometries, with very small contact forces, at high precision

manufacturer also meets various other quality standards, including EN 9100, conceived for companies that develop and produce components for the aerospace industry. The ›Maxon medical‹ business unit is certified to the ISO 13485 medical standard, which confirms that all processes and procedures are documented and that traceability is guaranteed.

The Challenge: Gears with Module 0.12

Roland Rossacher has been responsible for quality assurance at Maxon Motor for over 20 years. He explains: »Our certifications mean that we are obligated to test even the smallest drive components. Measuring the injection-molded plastic gears used in our 6 mm diameter ›GP6‹ planetary micro-gearbox, which have a module of 0.12, presents a particular challenge.«

A few years ago, the head of quality and his team had to find suitable measurement equipment and methods in order to be able to check the design requirements for these tiny toothed components in detail. Adrian Burch, manager of quality assurance for assembly testing, dedicated himself to this task. The skilled precision mechanic outlines the requirements: »We need measurement results that our mold shop can use to make effective corrections and produce a series-capable injection mold with the fewest possible modification cycles. The measurement must also be suitable for first article inspections of microgears and for sample testing of production lots.«

The molding, production, and measuring these microgears are core competencies of Maxon Motor, which means they are located at the main plant in Sachseln, near Lucerne, Switzerland. A micro-EDM machine in the production area uses wires with diameters from 0.02 to 0.2 mm to shape the mold inserts to the desired tooth contour. Molds with as many as eight cavities are used to produce the plastic gear in their micro-injection molding process.

Typical Methods Fail for Small Plastic Gears

Previously, tooth measurements at Maxon Motor mostly used standard double flank gear rolling inspections. This is a conventional inspection method for spur and planetary gears, described in the VDI/VDE 2608 guideline. A special master gear is required for every tooth pattern. The master engages with the test gear with low force, and then they are meshed and rotated together. The two gears then roll through their entire circumference with no clearance. Changes in the distance between the centers and the uniformity of the motion are then measured and analyzed by software. For the small plastic gears with module 0.12, however, the double flank rolling inspection was problematic because even the slightest pressure caused the teeth of the tiny gears to deform, yielding false results.

For Adrian Burch, it was clear that conventional tactile measurement using a touch trigger or scanning probe also had no chance. »Here again we would need contact pressure for the measurement, in order to generate the probe signal. The diameters of such probe spheres are also too big to measure the tooth flanks down to the root circle.« Optical methods would be fundamentally suitable for the measurements, but the flanks of microgears are not accessible with optical sensors.

The quality team ultimately found a suitable solution for reliably measuring microgears at Werth Messtechnik. The company from Giessen is the leader in coordinate measuring technology, with optical sensors, multisensor systems, and X-ray tomography, as well as in the measurement of microfeatures.

The Solution: Measurement with a Fiber Probe

The quality team at Maxon Motor decided on the Werth ›VideoCheck HA‹ high-precision 3D multisensor

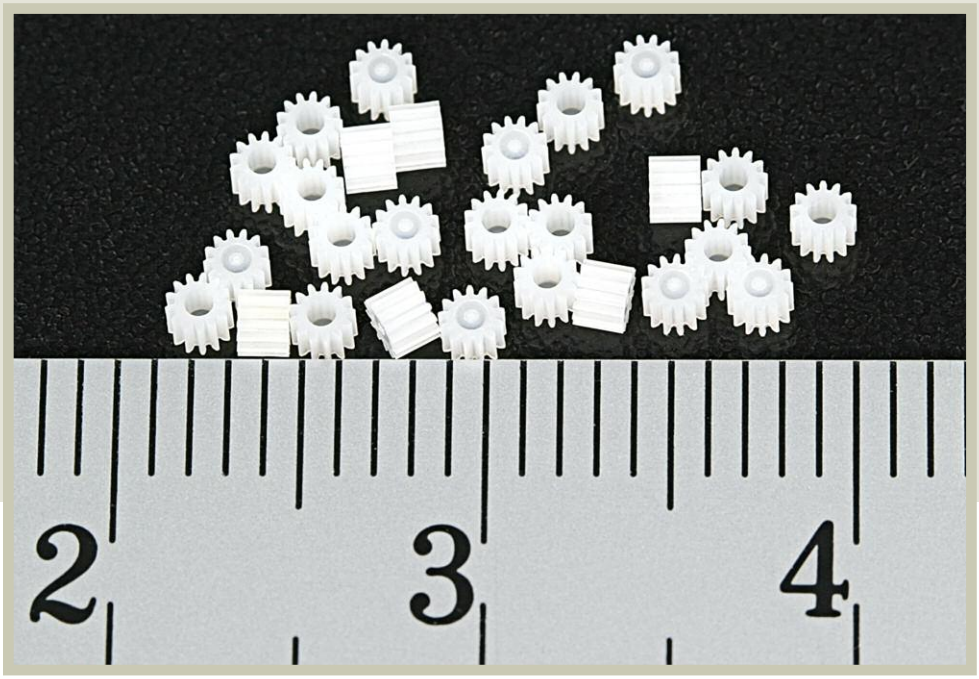

Image 3. Tiny planetary gears like this are found in the ›GP6‹ planetary gearbox. Measuring them is a challenge: Gears with module 0.12 (tip diameter 1.908 mm, root diameter 1.347 mm, number of teeth 13, material Delrin 100)

measuring machine **(Image 1)**. The choice was clear since this machine has a bidirectional maximum permissible error specified of just (0.5 + L/900) µm when using the image processing sensor under quality laboratory conditions. They selected a telecentric 10X lens, ›TP200‹ touch trigger probe, Werth Zoom Optics, patented ›WFP‹ (Werth Fiber Probe), and the ›WinWerth GearMeasure‹ software package. »The primary driver for our decision was the Werth Fiber Probe«, explains Roland Rossacher. »We have been able to use it to perform standardized measurements even on the flanks of microgears, including in scanning mode.«

The WFP consists of a glass fiber with a probe sphere on the end with a diameter as small as 20 µm **(Image 2)**. In contrast to tactile measurement with a conventional probe, the fiber probe operates on a tactile-optical basis. Instead of serving to transmit a mechanical signal to the probe head, the probe shaft of the WFP only serves to position the tiny probing sphere. The sphere position is captured optically by the image processor through the telecentric lens. This makes it possible to use tiny probe geometries with correspondingly high precision (contact deviation ≤ 0.3 µm). As with a conventional probe, the software uses the probe sphere radius to calculate the corresponding measurement point. Because of the thin probe shaft, the contact forces are negligible, even for the smallest probe sphere. Thus, even the most sensitive plastic gear will not be deformed.

Contour Comparison for Mold Correction

Another advantage is that no complex fixturing is required, since the force exerted on the workpiece is virtually zero. Ralf Nutto, measurement technician, has been responsible for measuring with the Werth ›VideoCheck HA‹ for two years. He explains: »We just fix the little gear to a pedestal with a piece of tape and set it up on the measurement plate. Then we use the optical sensor to capture the tooth profile contour.« The ›WinWerth‹ measurement software package uses the 2D data to calculate the path that the fiber probe will travel during scanning. While a nominal path is not strictly necessary, because the fiber probe can also scan unknown contours, scanning along a predefined path is faster. Because the height of the gear is about 1 mm **(Image 3)**, the measurement technician sets the depth of the fiber probe to 0.5 mm, where the contact area of the gears is greatest, for the scan of the tooth profile contour. This area cannot be reached by any other method. Finally, the runout of these gears can also be measured, simply by measuring the shaft seat diameter using the same approach.

Scanning provides a high point density for the contour, with precisions better than 1 µm. This actual contour can then be visualized in a 3D-CAD comparison, as a color-coded deviation plot based on the CAD data set. This analysis is of primary interest to the mold shop, in order to be able to correct the mold, in case of deviations, precisely on the problem locations.

Simple Procedures, Precise Data

The ›GearMeasure‹ measurement program for gears is completely integrated in the ›WinWerth‹ software package. After entering nominal and measurement data, the measurement sequence, including travel paths, is generated and executed fully automatically. The software calculates the typical tooth profile

Images: Werth/Maxon

Image 4. Roland Rossacher (L), Quality Manager at Maxon Motor, and Adrian Burch, Manager of QA Assembly Inspection, evaluate the measurement results using a printout with a color-coded deviation plot

deviations, such as involute and flank deviations, single and cumulative pitch, surface tomography, tooth thickness deviations, and runout.

The manager of QA for assembly inspection, Adrian Burch, is also very satisfied with the time required for the measurement. »The measurement time per sample is about ten minutes, while one-time programming for each type of gear takes a little more time. We can then analyze the data offline.« For him and for Quality Manager Roland Rossacher **(Image 4)**, there is no doubt that expanding the measurement expertise at Maxon Motor to include gear measurements using a fiber probe has been worthwhile. Ultimately, the correction cycles in the mold shop have been reduced, and the inspection efforts during series production have been cut back greatly due to both improved first article inspections and process assessment. Roland Rossacher is very satisfied: »We have several thousand of these gears in use, and the measurements work perfectly.« ■

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Images: Werth/Maxon