CMM INTERNATIONAL

COMMERCIAL MICRO MANUFACTURING

THE MAGAZINE FOR
MICRO, HIGH-PRECISION AND
MEMS MANUFACTURERS

IN THIS ISSUE

02
20

Blohm Jung employs IBS' Rotary Inspector wireless probe system in development of volumetric compensation process for 6-axis grinding machines

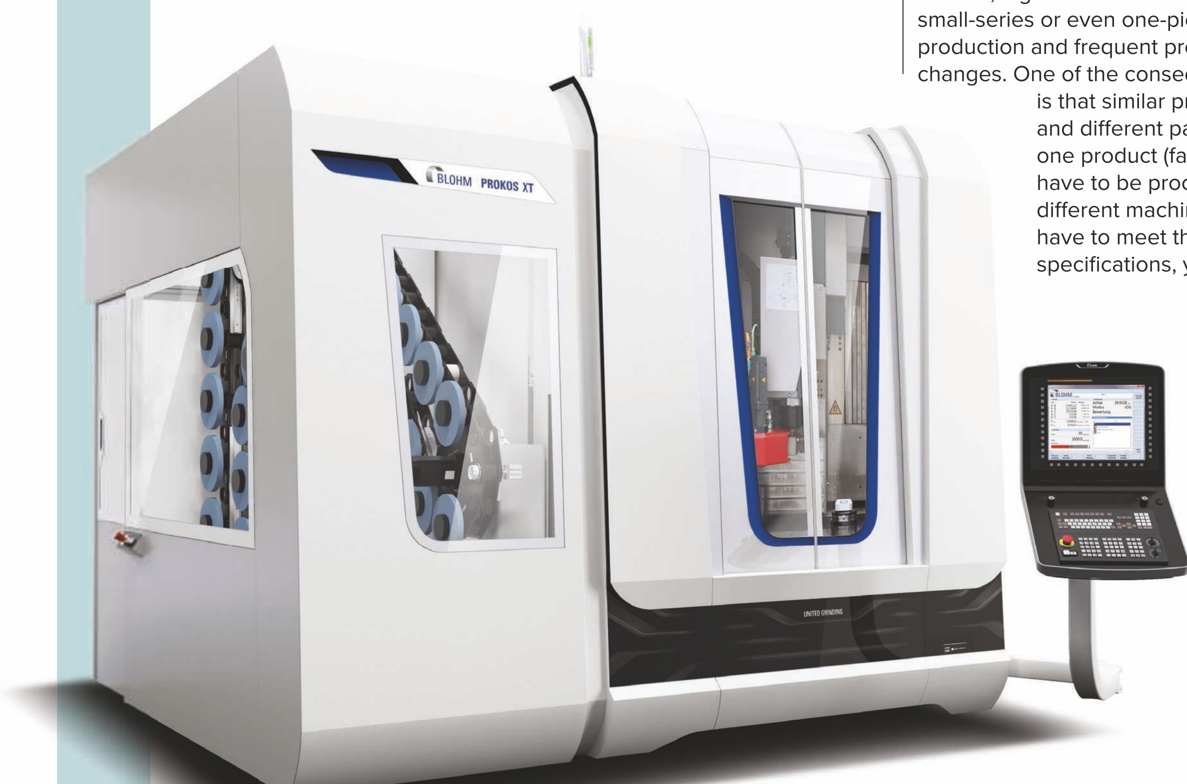
▶ *Turbine manufacturing at MTU Aero Engines is a high-complexity, high-precision process, requiring true 6-axis grinding.* ◀

Blohm Jung, a Germany-based manufacturer of surface and profile grinding machines, built the PROKOS XT 6-axis grinding machine to simultaneously address complexity, flexibility and quality issues in modern manufacturing. However, one of the biggest challenges in operating this machine has been maintaining its required volumetric accuracy of +/–25 µm. To solve this, Blohm Jung has extended its volumetric compensation process for conventional 5-axis machines to accommodate 6-axis machines. The new, 6-axis volumetric compensation process minimises geometric errors on all six of the PROKOS XT's axes

Blohm Jung enlisted the help of Netherlands-based IBS Precision Engineering (IBS) in developing the process using its Rotary Inspector wireless probe system, which measures the three rotational axes. MTU Aero Engines (MTU), a Germany-based manufacturer of aircraft engines, was the PROKOS XT launch customer and uses Siemens' volumetric compensation system (VCS) software on a number of the machines for producing turbine components.

Challenges

Complexity and precision are two of the biggest challenges of modern manufacturing, not only in terms of the products but also the machine design, given the increasingly tight demands pertaining to the accuracy of machined products. Typically, precision is specified in the tens of microns range. In addition, flexibility is a dominant characteristic of modern, or smart, manufacturing. This refers to, for instance, low-volume, high-mix manufacturing, with small-series or even one-piece flow production and frequent product changes. One of the consequences is that similar products and different parts of one product (family) have to be processed on different machines but have to meet the same specifications, yielding



▶ *The PROKOS XT 6-axis grinding machine.* ▶

consistent quality and allowing machine-independent workpiece assignment. Combined, these challenges demand a qualification procedure that ensures precision during the operation of multiple machines.

> The addition of a sixth axis allows for the machining of complex products in one run, without changeover in clamping.

Volumetric accuracy

The PROKOS XT is a recent addition to the Blohm Jung portfolio of surface and profile grinding machines. It is designed for the automated machining of complex workpieces and can execute drilling and milling as well as grinding operations. The addition of a sixth axis allows for the machining of complex products in one run, without changeover in clamping.

Axes of a grinding machine inevitably have geometric errors originating from production and assembly of the machine itself, wear during its lifetime (backlash and bearing problems) and environmental factors in operation. The errors include radial, tangential and tilt errors in the rotational axes and guideway errors in the linear axes. Blohm Jung has developed a volumetric compensation process that minimises these errors via the control software and achieves maximum volumetric accuracy in the interaction between all six axes. This process uses Siemens' VCS software to apply compensation functions to Siemens' SINUMERIK CNCs.

The volumetric compensation process has been used on 5-axis machine tools for a number of years. After a machine tool has been installed, all degrees of freedom of all axes are precisely measured. Compensation values are determined for the geometric errors that are shown up and stored in the machine control. If the VCS software function is activated in the control, it uses these values to compensate for the errors and improve the precision of the machine. This process can be repeated during the operational lifetime of a machine.

However, applying the volumetric compensation process to the PROKOS XT 6-axis machine presented two challenges, namely the acquisition of the error data and

3D MICROMAC

Micromachining Excellence

Whether Standard System or Special Solution:

High-Performance and Reliable Laser Micromachining Solutions Made by 3D-Micromac

New: Laser Contract Manufacturing

3D-Micromac AG

sales@3d-micromac.com

www.3d-micromac.com

the algorithms for converting these data into compensation settings for the machine. In terms of suitable measuring systems for precise acquisition of error data, Blohm Jung selected a straightforward solution for the linear axes; a laser measurement system capable of measuring errors in six degrees of freedom along linear axes. However, measuring of the three rotational axes had no precedent. For this, MTU recommended the Rotary Inspector, which can provide confirmation of the true positioning accuracy of a tool relative to the workpiece for (normally) 5-axis machines under dynamic conditions. By mimicking the normal operation of a machine, the Rotary Inspector can check the volumetric accuracy of all machining axes by moving them simultaneously.

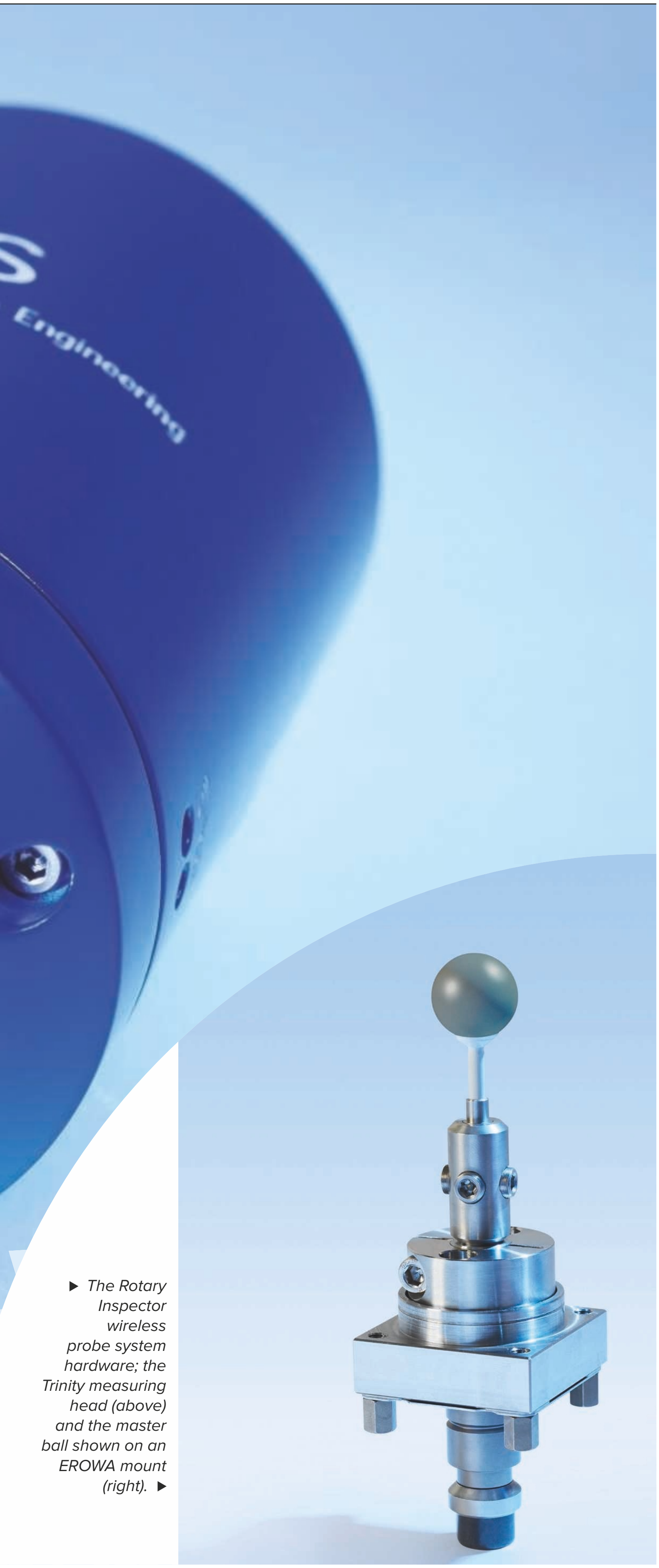
Rotary Inspector

IBS designed the Rotary Inspector to determine (and correct) critical geometric and dynamic performance parameters of 5-axis machines. Based on measurements according to *ISO 10791–6 Test conditions for machining centres—accuracy of speeds and interpolations*, the Rotary Inspector measurement software can determine the total 5-axis machine tool accuracy in minutes as well as calculate the pivot line offsets and squareness errors. Extensive measurement results can be condensed into two characteristic numbers: the Q value as the maximum geometrical error, providing an upper boundary for the dimensional accuracy; and the P value as the largest dynamic error, representing the surface finish.

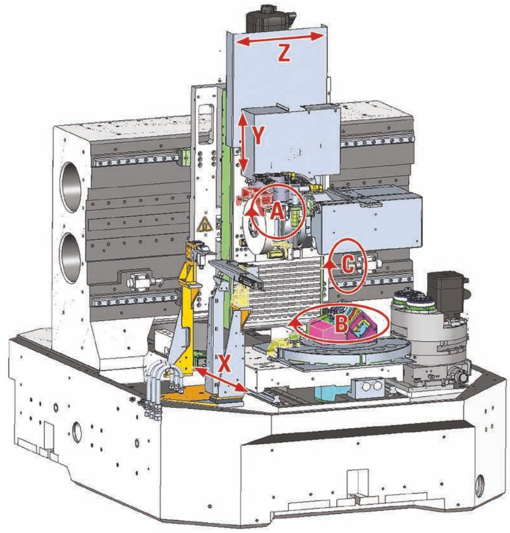
The Rotary Inspector includes a Trinity wireless measuring head, which is placed in the spindle, and a master ball, which can be placed on the product table using an optional EROWA mount for accurate positioning.

Coordinate transformations

The biggest challenge in developing the 6-axis application was not only the measurement of all six axes, but the interpretation of the measurement results and their translation into compensation values, which required a thorough understanding of the construction of



▶ The Rotary Inspector wireless probe system hardware; the Trinity measuring head (above) and the master ball shown on an EROWA mount (right). ▶



▶ *A schematic of the PROKOS XT, showing the three linear axes (X, Y and Z) and the three rotational axes (A, B and C).* ▶

the machine. The Rotary Inspector covers 21 standard 5-axis machine types/configurations. This was the first application of the Rotary Inspector for measuring a 6-axis machine.

The PROKOS XT configuration features three linear axes (X, Y and Z) and three rotational axes (A, B and C); it can be considered as a 5-axis machine with an additional tipping axis (C) sitting on the B-axis, under a 45° inclination angle. Naturally, this adds to the complexity of defining the required coordinate transformations. Errors measured in the measuring head coordinate system have to be transformed to errors in machine coordinates (such as squareness and position errors of the rotary axes) and subsequently converted into an optimisation of the kinematic chain in the machine.

An additional challenge was posed by the PROKOS XT's bulky grinding tool mounted on a short spindle, which is in contrast with the conventional milling machine's slender tool mounted on a long spindle. This means that the various linear and rotational axes have a limited range and not all standard motion sequences are accessible, as the measuring head under certain conditions could collide with the index table and workpiece carrier. Therefore, some of the measurements have to be performed in non-standard situations.

ISO philosophy

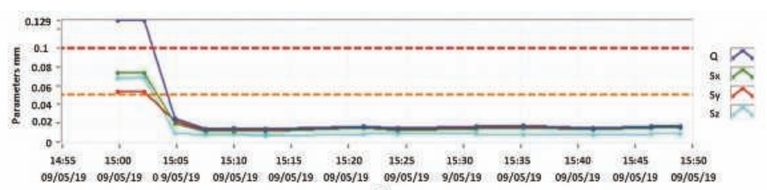
In the Rotary Inspector formulation, the PROKOS XT has been defined by the combination of two 5-axis types that best represent the 6-axis configuration. The measurement procedure then combines the standard tests for these two types, covering the A and B and the A and C axes, and finishes with a comprehensive ABC test. Based upon the reasoning behind ISO 10791–6, the various elements of this test, for example, one rotary axis moving at double the speed of the other axis or one axis moving in positive direction and the other in negative direction, have been merged into the 6-axis test. This does not mean that the 6-axis test is ISO-certified, as there is no 6-axis ISO standard, but it represents the best approach following the ISO philosophy. In this way, a major step towards the reliable qualification of 6-axis machines has been taken. ●

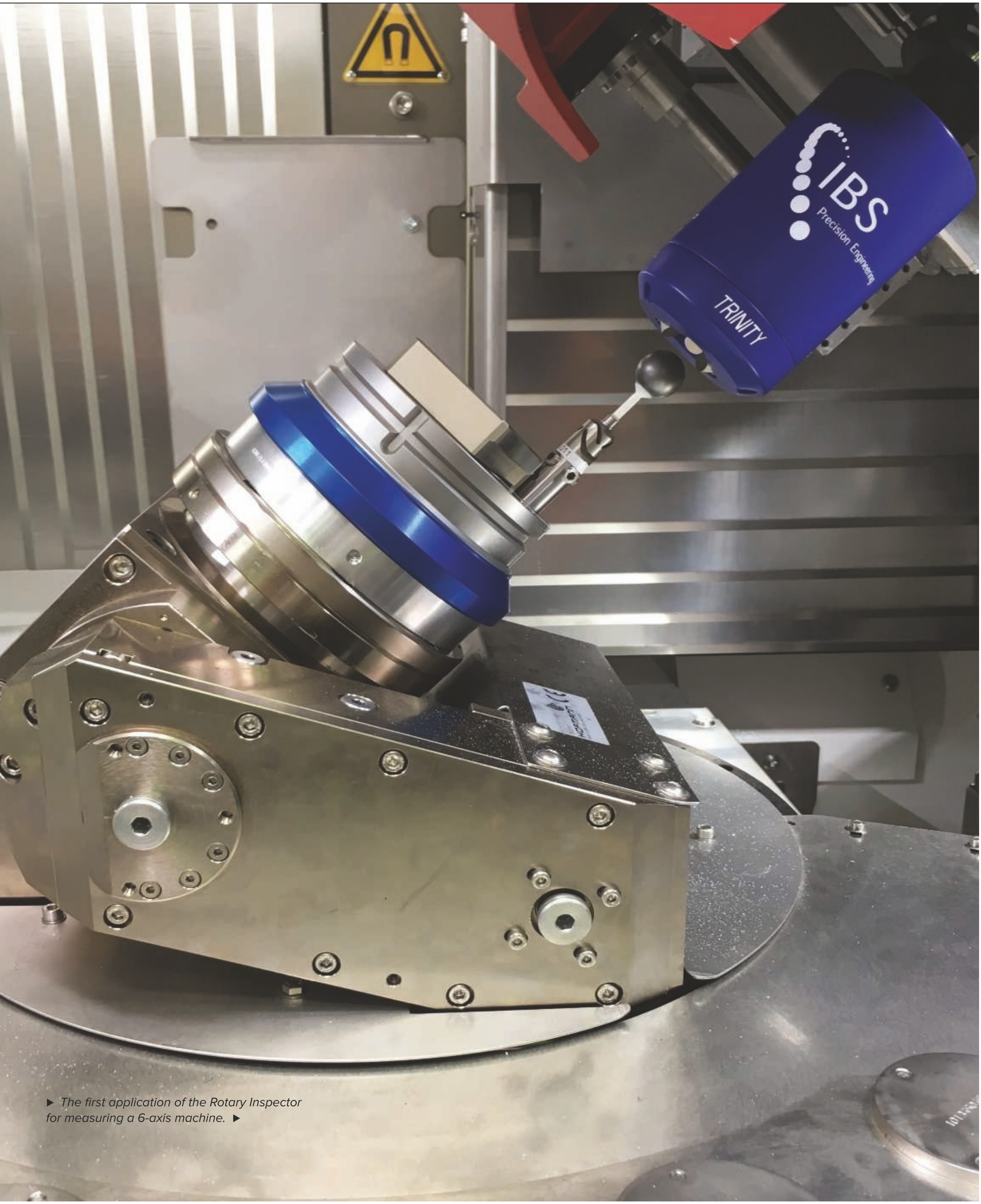
Blohm Jung
www.blohmjung.de

IBS Precision Engineering
www.ibspe.com

MTU Aero Engines
www.mtu.de

▶ *A graph showing typical Rotary Inspector output, namely the evolution of the Q value, i.e. the maximum geometrical error, and the underlying maximum individual axis errors (Sx, Sy and Sz). The sharp decline in all values reflects the error compensation taking effect.* ▶





▶ *The first application of the Rotary Inspector for measuring a 6-axis machine.* ▶

Machine Tool Qualification Tools

- Dynamic 5-axis test & compensation
- Volumetric & linear qualification
- Results in under 1 minute
- ISO 10791-6

Analyzer for advanced users. Inspector for production.

www.ibspe.com

IBS
Precision Engineering