

Separating spindle motion error and target form error in high-accuracy spindle measurement

The Spindle Error Analyzer (SEA) measures and analyses the dynamic error motion of high-accuracy spindles using a non-contact measurement principle. It captures radial and axial error motions to provide detailed insight into spindle performance. For ultra-precision applications requiring deeper analysis, IBS Precision Engineering developed the Multi-Probe Analyzer (MPA) extension kit for the Spindle Error Analyzer to help achieve even more precise spindle characterisation.

Spindle Error Analyzer

The machine qualification product portfolio of IBS Precision Engineering includes the Spindle Error Analyzer (SEA), a system designed to measure and analyse the dynamic and thermal error motions of high-precision spindles. The SEA enables detailed characterisation of spindle behaviour under realistic operating conditions, supporting both machine qualification and process optimisation.

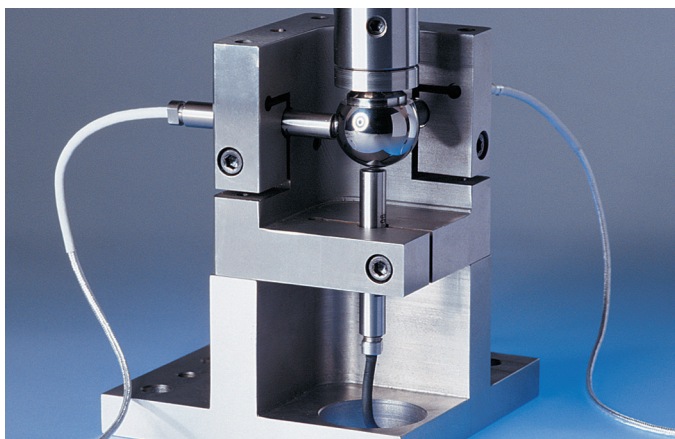


Figure 1: Spindle Error Analyzer set-up

The SEA configuration consists of three displacement sensors that measure the radial (X/Y) and axial (Z) error motions of a target mounted on the rotating spindle. When the target geometrical error is significantly smaller than the spindle error motion, the measured variation can be reliably attributed to the spindle, making the SEA highly effective for machine qualification, condition monitoring and performance verification.

Measurement need for ultra-precision spindles

Advances in spindle technology have significantly reduced error motion levels in specific high-accuracy spindle applications. In high-precision manufacturing with e.g. high-quality bearings and improved thermal and structural stability, the typical error motion averages about 1–3 μm . In ultra-precision machining with e.g. air

bearings and metrology spindles, the typical spindle error motion is $<0.1 \mu\text{m}$.

At these levels of precision, the relationship between spindle error motion and target form error changes. The target geometrical error is no longer negligible and becomes a significant component in the measurement, contributing directly to the overall uncertainty. As the error magnitudes grow closer, the need to distinguish between the individual contributions of spindle motion and target geometry increases.

For ultra-precision applications requiring deeper analysis, IBS developed the Multi-Probe Analyzer (MPA) extension kit. Designed for spindles with error motions of 500 nm and below, the MPA separates target geometry from the measurement, revealing true spindle performance at nanometer level.

Multi-Probe Analyzer for SEA

The Multi-Probe Analyzer (MPA) is an extension-kit for the SEA system. The key innovation is the implementation of the multi-probe method, enabling separation of spindle error motion and target geometrical error within the measured signal. This allows accurate spindle characterisation, when both contributions are approaching the same order of magnitude.



Figure 2: Multi-Probe Analyzer set-up.

The MPA uses the same probe nest base, sensors and measurement software as the SEA plus a further MPA app. The system operates with three displacement sensors mounted in the MPA ring around the rotating target at optimised angular positions. These sensor positions make it possible to separate the target geometrical errors from the spindle error motion.

Although the hardware, software and measurement setup are largely shared with the SEA, the underlying data analysis approach is fundamentally different. By processing the measurement data in the MPA software, the individual contributions of spindle error motion and target geometry can be separated. This enables reliable extraction of harmonic content up to 150 UPR, well beyond the range typically encountered in practical spindle applications.

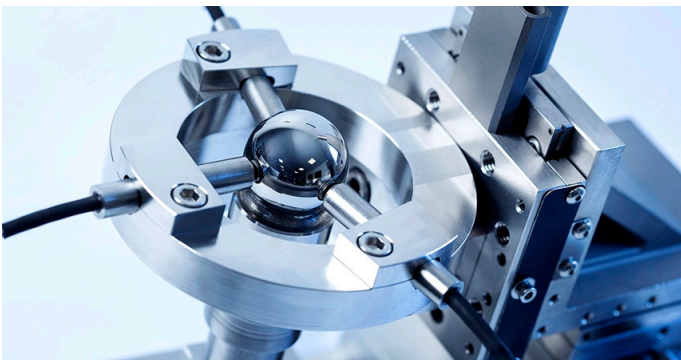


Figure 3: MPA: three sensors at different angles facing the target

MPA key advantages

By combining multi-probe measurement with advanced signal processing, the MPA system provides several key advantages:

- Accurate separation of spindle motion and target geometry
- Reduced dependence on ultra-precise reference targets
- Reliable measurements in the nanometer range
- Simple add-on kit to SEA
- PDF report showing true spindle and target form errors
- No extra capacitive sensors needed

This enables precise characterisation of ultra-precision spindle performance under realistic operating conditions. The separated MPA data can subsequently be imported back into the Spindle Error Analyzer software for further in-depth spindle analysis.

Reliable spindle characterisation at nanometer level

Multi-probe error separation independently determines target geometry and spindle error motion from a single measurement, enabling reliable spindle characterisation even when both error sources are of similar magnitude.

Read more

- [Multi-Probe Analyzer webpage](#) (part of SEA)

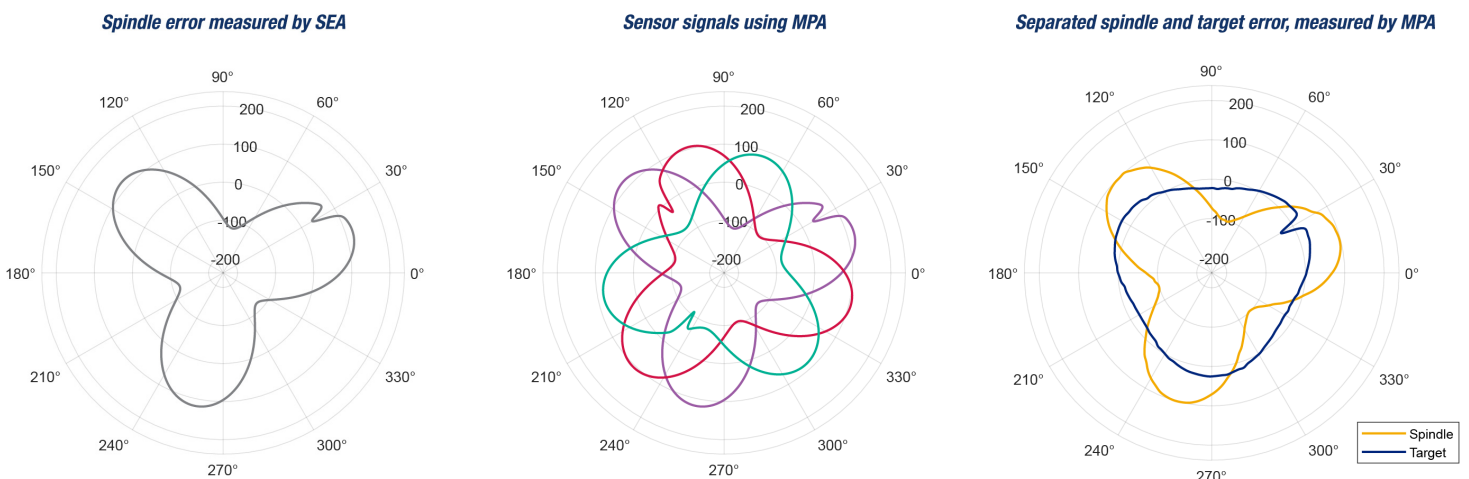


Figure 4 – Example measurements: SEA measured error, Sensor signals using MPA and MPA-error separation

The SEA measures a combined spindle motion error and target form error from two probes at 90° angles. The MPA measurement uses three sensor signals, and with a separation algorithm the MPA distinguishes spindle error motion from target form error.