LEVICRON

NON-CONTACT PRECISION MOTION

ShakesBear (Spindleanalyzing and testing systems)

Levicron

The development, manufacturing, and sales of motor spindle solutions with non-contact bearing technologies for ultra-precision and CNC machining are Levicron's core businesses.

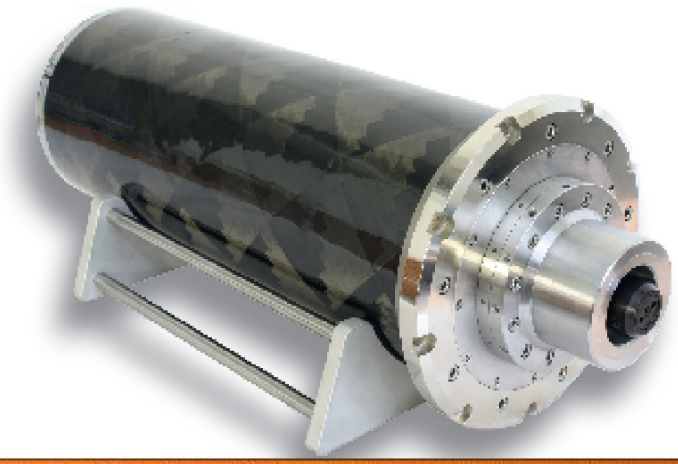
At Levicron, bespoke proven analytical methods and simulation tools for structural analysis and fluid dynamics complement sound practical experience of spindle development and production. Together with the first-ever aerostatic tool spindle comprising an industrial taper interface (HSK) and full CNC functionality, products from Levicron are now used for CNC-machine precision parts with optical surface finish all around the world.

Our requirements for our products and those of our customers prevent the use of off-the-shelf components. Therefore, not only the patented bearing technology and patent-pending spring-free HSK taper clamping systems can be found in our motor spindles, but also in-house developed motor, encoder and tool clamping solutions.

A vertical manufacturing integration of more than 90 % incorporates CNC turning, -milling, -diamond machining, -cylindrical/ bore grinding, -wire cut EDM, and bespoke machining solutions. You can find all our sophisticated production tests and dynamic balancing methods under one roof.

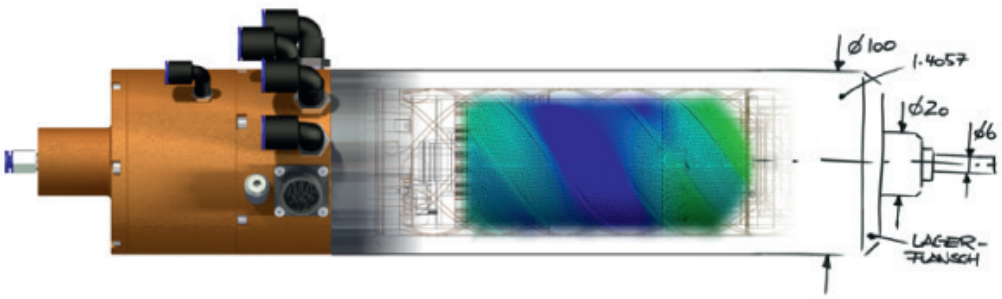
The quality, speed, and accuracy of Levicron spindles and the requirements coming from the applications are used to make it necessary to develop bespoke encoder and motor solutions as well as solutions for HSK tool clamping, HSK tool holding, and others. Because of their unique performance and functionality, some solutions have been made available for our customers as off-the-shelf items.

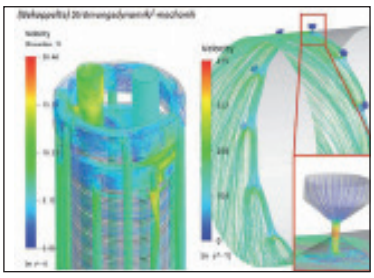
Although Levicron had to reinvent the wheel more than once, our customers can confirm that our wheels run smoother and faster than others. As a result, tool and work-holding spindle solutions for turning, milling, and grinding can provide the customer with unique thermal stability and robustness at shaft dynamics, errors in shaft motion, and speeds that have not been available so far.

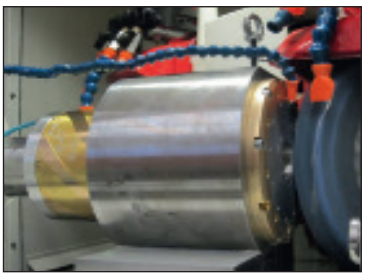


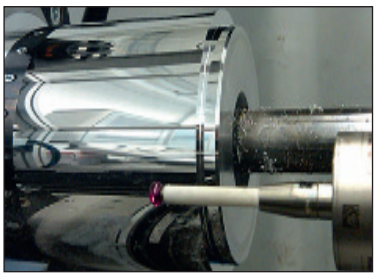
Levicron

All in house developed and manufactured Ultra Precision Technology for CNC Machining









ShakesBear

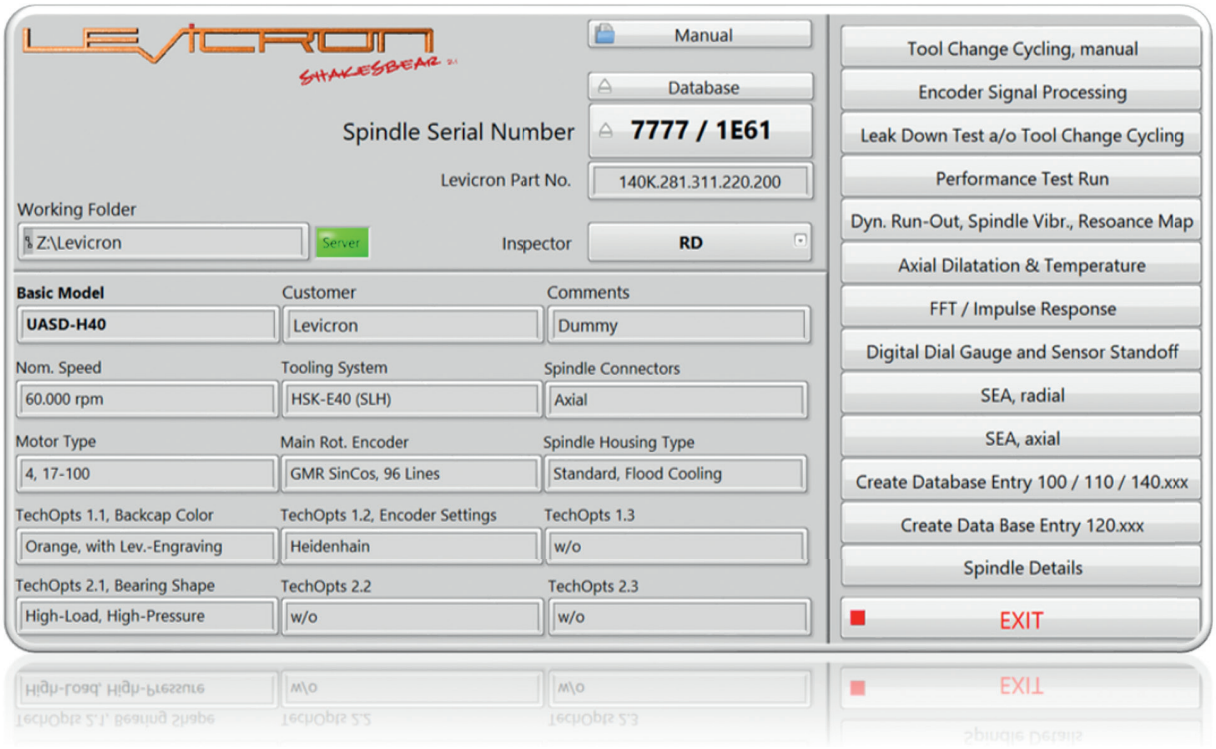
Spindle analyzing and testing systems with nanometer resolution for speeds of to 100,00 rpm.

Description

Where other spindle manufacturers can rely on suppliers, Levicron forces to develop key spindle components to achieve and guarantee the quality and performance of their spindle products. As such components are not commercially available, their development often leads to new products. The same applies to the technology to analyze, test, and verify the properties and quality of spindles that Levicron has been developing since the beginning. They are also unique regarding resolution, sampling rate, and use.

With our spindle analyzing and testing systems **„ShakesBear, Hamlet“** and **„ShakesBear, Othello“**, Levicron can now provide all-in-one spindle analysis and testing systems up to 100.000 rpm on a nanometer level.

Measurements of dynamic tool run-out, spindle errors (SEA), vibrations with speed, and spindle/ system resonance maps are stored as reports and raw data in a local or server-based spindle/ machine database that can recalls at any time required.



All-in-one spindle analyzing systems

The advantages of using the application

Our all-in-one spindle analyzing system „ShakesBear, Hamlet“ has specifically been developed to acquire spindle errors (error-motion) in radial and axial directions at a nanometer level up to 100,000 rpm.

The integrated direct error-separation of spindle synchronous and artifact shape errors allows measurement in a single test setup without changing the system or the spindle.

The mobile rack includes the amplifiers, filters, connectors for the sensors, and a PC connection.

The benefits for the spindle designer

The all-in-one spindle testing system „ShakesBear, Othello“ targets the machine and spindle dynamics like dynamic tool run-out and vibrations, thermal shaft growth, and spindle/ machine resonance maps.

Here the spindle can be used as an excitation to the machining system where a waterfall FFT with spindle speed generates to identify system resonances.

This system allows quick and mobile use at the customer site or in your test field with an optional, integrated PC and a touch screen.

Also, for the Othello system, all amplifiers, filters, and connectors are part of a mobile rack to which the sensors can be connected.

Spindle Error analysis

Hamlet

Excursion

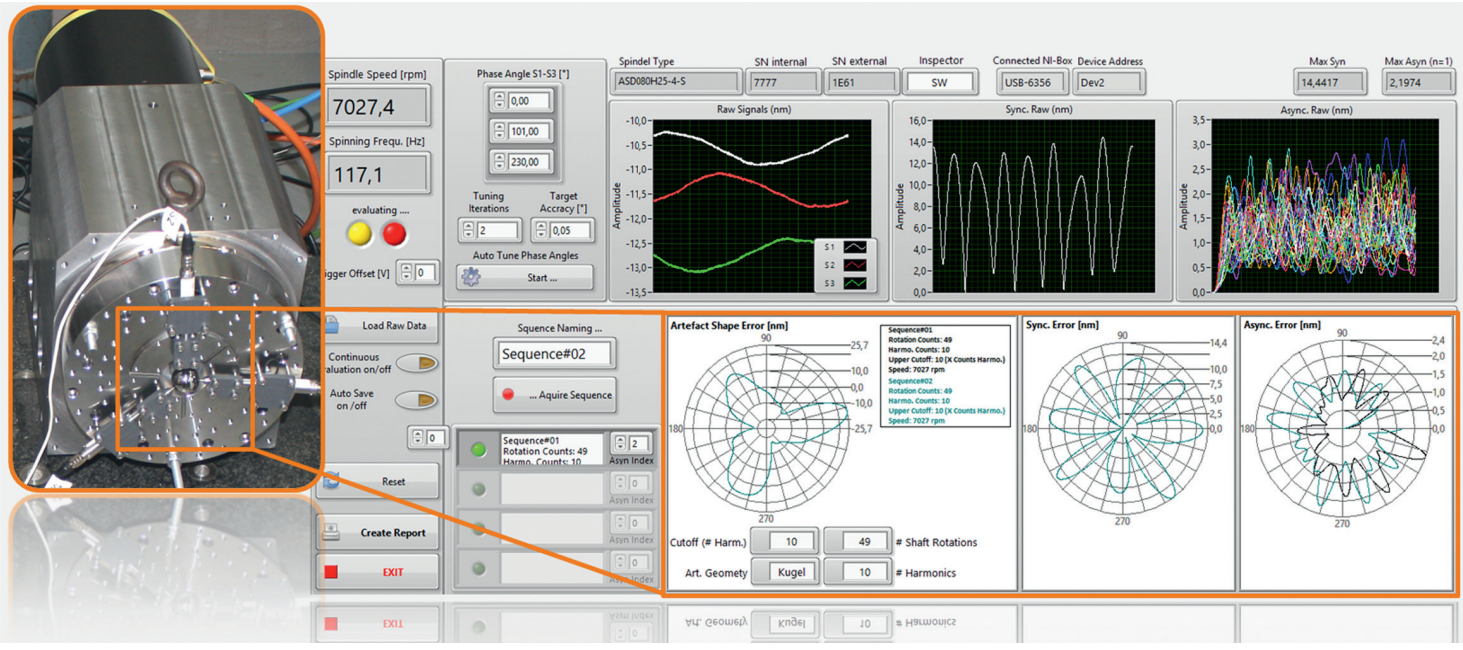
Spindle errors can be distinguished between Synchronous Errors and Asynchronous Errors. The most significant deviation of the shaft spinning axis in radial or axial direction from an ideal axis defines as Error-Motion. The perfect spinning axis has the least averaged overall deviation measurements in this case.

» **Synchronous Error**: Repeat during shaft rotation at the same angular position.
» Asynchronous Error: Are not repeatable between shaft rotations.

The Run-Out (fundamental) is a perfect spindle error polar plot circle and represents an off-centered tool. Thus run-out is not a spindle but a tool error.

Therefore the spindle error (Error-Motion) in the radial direction is defined as:

∑Sync.Errors + ∑Async.Errors - Fund. (run-out)



Direct (auto) error-separation

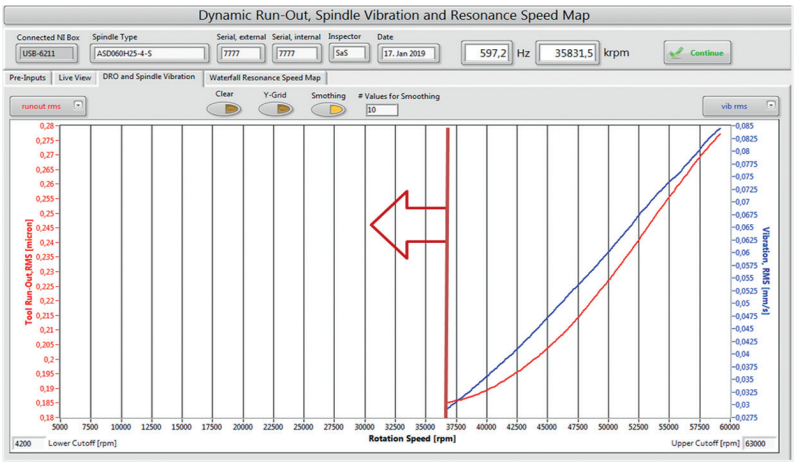
Any measurement of radial spindle errors takes against the spindle shaft or any object attached to it, preferably perpendicular to the equator of a precisely lapped sphere. However, any roundness error of the equator repeats with the shaft rotations and would be detected as a synchronous spindle error.
Although there are methods to separate the target shape error from the spindle synchronous errors, those require two measurements and a change in setup between two measures and are significantly error-prone.

Our solution:

By using at least three radially arranged distance sensors around the spinning axis, it is possible to separate spindle synchronous errors from the target shape errors by solving a complex transposed equation system before converting the signal back into the time domain.
Levicron has included the direct error separation into their SEA treatment so that synchronous, asynchronous, and target shape errors can be measured and separated in one setup and a single measurement.

Dynamic tool run-out, Resonance speed map and Axial shaft growth

Othello, Module



Dynamic tool run-out and Spindle vibrations over Spindle speed

The included low-noise capacitive distance sensor with 2 nm resolution and 100 kHz sampling rate allows a sound measurement of the tool run-out at spindle speeds of up to 100,000 rpm. At the same time, a piezo-mass accelerometer detects spindle vibrations. An external trigger or the laser-tacho gives the spindle speed to create a continuous dynamic run-out, and spindle vibrations chart over speed.

Resonance and natural frequency map

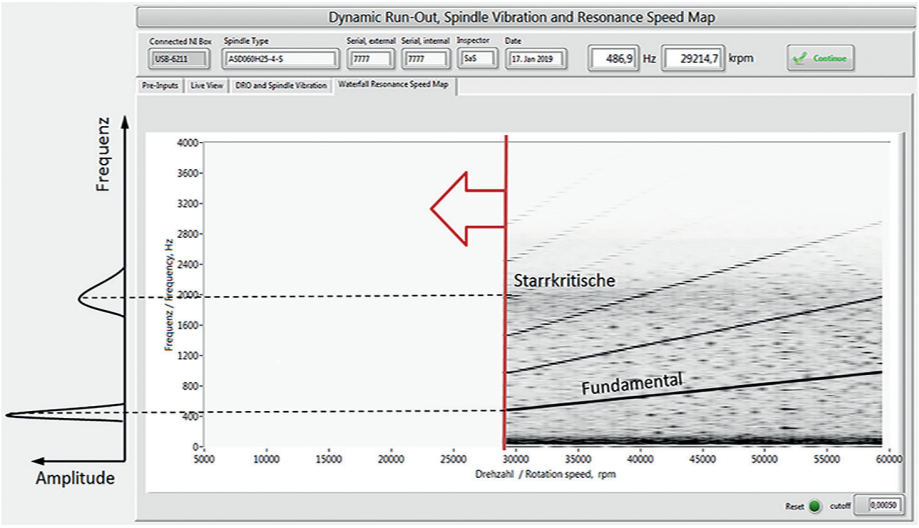
Due to its high resolution and sampling rate, the capacitive distance sensor is capable of detecting the amplitude of the fundamental (spinning frequency) and any frequencies up to 4 kHz.

As vibrations can be measured as a change in the distance, the capacitive gauge can be used to create an FFT spectrum at discrete spindle speeds. Changing the speed from stand-still to top speed, or vice-versa allows the creation of a continuous Waterfall-FFT chart where the single FFT charts are lined up and arranged with speed.

The resonance speed map feature represents a 2.5-D Waterfall-FFT (looking top-down on a 3-D Waterfall diagram) where dark areas mean higher and light areas lower values.

As a result, identifying spindle and system natural frequencies and resonances where the fundamental frequency (spindle frequency) crosses a natural system frequency is possible.

When the capacitive gauge is used as the source spindle, natural frequencies are measured dominantly. Using the included accelerometer instead gives natural frequencies of the entire system, including pumps, hydraulics, and chillers e.g., Placing the accelerometer anywhere in the system can thus be used as a tool to identify natural system frequencies with the spindle as a vibration source.



Axial shaft growth, Temperature, and Spindle speed over time

When used axially against the spindle shaft the capacitive gauge enables a measurement of the thermal shaft growth with time.

Along with an optional temperature sensor which can be placed on any part of the machining system, the thermal shaft growth, temperature, and spindle speed can be measured with time where the spindle speed can be detected using either an external trigger or the included laser-tacho

Impulse response, Drag-pointer diag gauge, spindle/ machine tool database

2-Channel-FFT with Peak-Hold (Impulse Response)

The FFT module offers an easy-to-use tool to measure and display the vibration amplitudes of the frequency spectrum and thus identify spindle or natural system frequencies while running the spindle or as a response to an impulse (Dirac Impulse). All this happens during the use of the included accelerometers or cap gauges.
A Dirac-Impulse, also known as step response, can be re-assembled as the sum of all harmonics within the frequency spectrum. It means that a gentle hit at the spindle nose or anything in the system would excite all frequencies, and thus the spindle or the entire system would respond with larger amplitudes at its natural frequencies.

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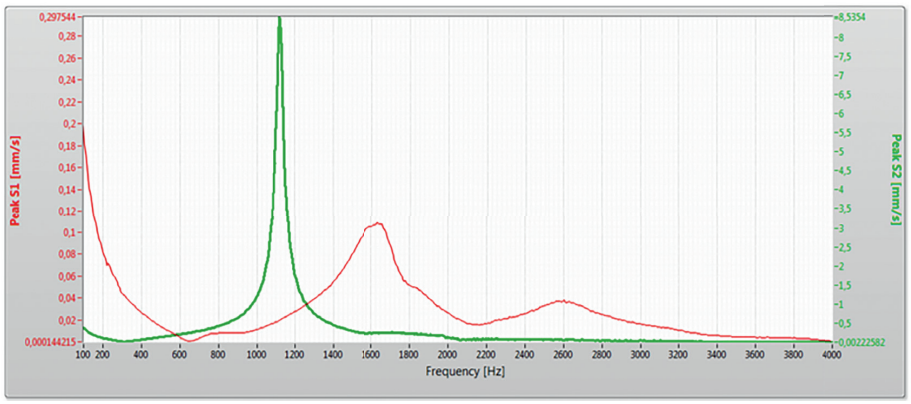
Spindle Details:

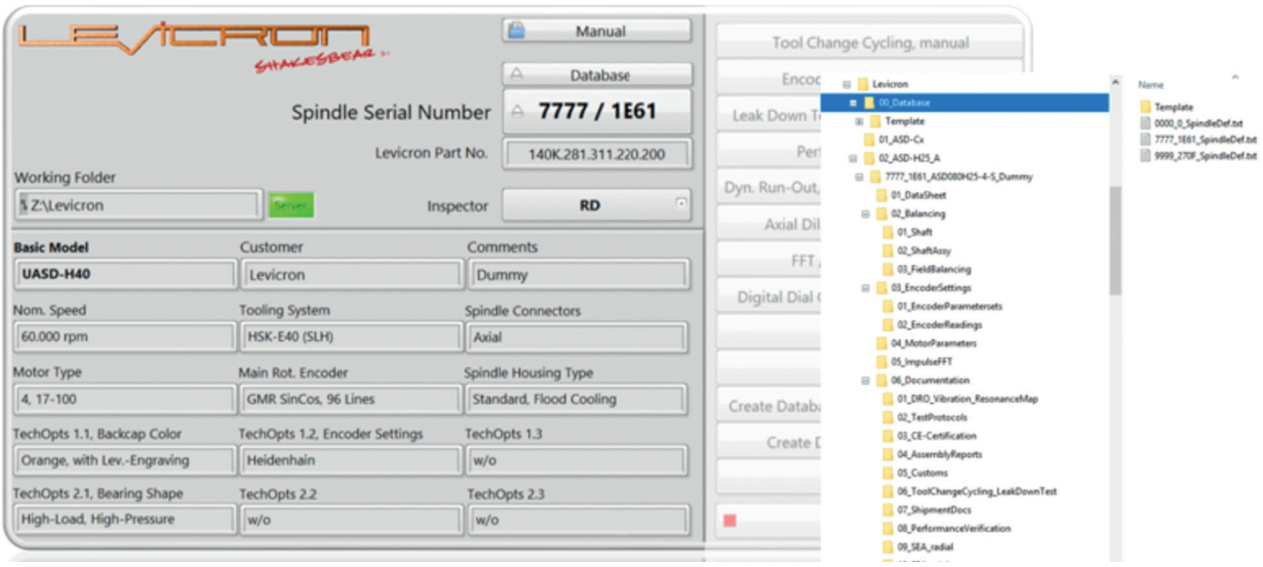
Spindle Type	ASD060H25A-2-ST
Serial	1414
Serial, internal	0415
Customer	LCR
Inspector	RD
Date	07.08.2019, 09:51

Impulse Response FFT:



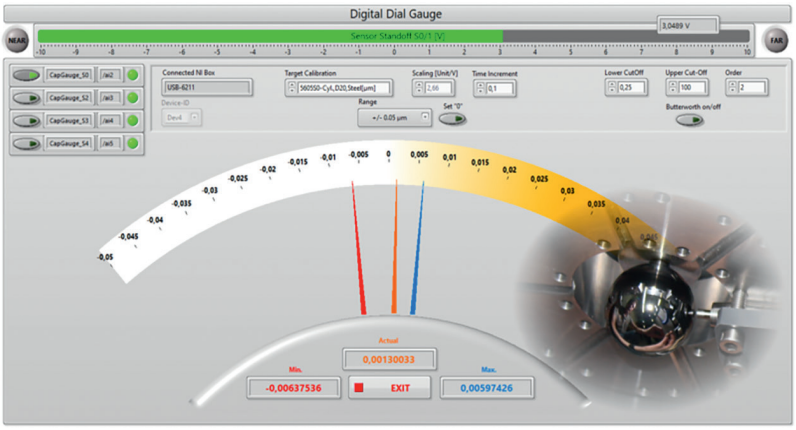
Spindle/ machine tool database

For an ISO certification in particular, but also for tracking the quality of the spindle products for internal use or customers, all measurements and results must be recorded and stored electronically. Our ShakesBear Software is designed to work with server systems and is based on a spindle or machine tool database in which all reports and raw data are stored.
Whether connected to a server or working locally, the database module generates a folder structure for each serial number in which all reports and raw data are stored that can be recalled at any time.



4-Channel drag-pointer diag gauge

To set up the standoff of the included cap gauges and to radially align the spindle artifact, the cap gauges measure against the included 4-channel, digital drag-pointer dial gauge can be used. It can also measure the artifact's static run-out when turning the spindle by hand or at low speeds.



Overview ShakesBear

ShakesBear, Hamlet

The all-in-one spindle analyzing system „ShakesBear Hamlet" was developed to measure, analyze and report spindle errors. With its four low-noise, high resolution, and fast capacitive distance sensors, the radial and axial shaft error in motion can be measured at spindle speeds of up to 100,000 rpm on a nanometer level along with a direct separation of the spindle synchronous and the target shape errors. All data and results are stored in a spindle/ machine database and can be recalled at any time. Bespoke fixtures can be supplied to match your application and spindle type.

ShakesBear, Othello

The all-in-one spindle analyzing system „ShakesBear Othello" targets a portable and flexible use at customer sites or your test fields to measure, analyze and report spindle and machine dynamics. Besides pure spindle properties, the user can analyze machine dynamics and system natural frequencies with the spindle as a vibration source.

With an optional Raspberry Pi and a touch screen instead of a USB connector, the Othello system is well prepared for mobile use. Also, bespoke fixtures can be supplied to match your application and spindle type.

Data Sheet ShakesBear, Hamlet and Othello

		ShakesBear Hamlet	ShakesBear Othello
General	Power Supply	240 VAC	240 VAC
	Internal PC, touchscreen	n.v.	n.v.
	USB 2.0 (or higher) connector	ja	ja
A/D Converter	Digital resolution	16 bit	16 bit
	Number of channels	8	8
	Evaluation	differential	differential
	Sampling rate per channel	1.25 MS/s	250 ks/s
	Analog signal	+/- 10V	+/- 10V
Distance sensing	Physical principal	capazitive	capazitive
	Working distance	50 µm	50 µm
	Resolution	1.7 nm	1.7 nm
	Sampling rate	100 kHz	100 kHz
	Number of sensors	4	1
Vibration sensing	Physical principle	Piezo-Mass	Piezo-Mass
	Cutoff frequency	18 kHz	18 kHz
	Sensitivity	1 V/g	1 V/g
	Number of sensors	0	1 (2 optional)
Software modules	Spindle/ machine data Base	X	X
	Server connection via Ethernet	X	X
	Dyn. run-out, spindle vibration,s and resonance speed map		X
	Axial shaft growth, temperature, and spindle speed with time		X
	FFT impulse response		X
	Digital drag pointer dial gauge (Cap. gauges)	X	X
	Spindle Error analysis (SEA), radial	X	
	Spindle Error analysis (SEA), axial	X	

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