NON-CONTACT PRECISION MOTION

News 13/03

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- NEW **ASD010P/ASD012P** – Ultra precision air bearing work head capable of operating to speeds of up to 10.000 / 12.000 rpm
- **ASD-H25 / ASD-Cx** – Not commonplace sealing air test
- **Myth Error Motion** – Backgrounds and modern measurement methods
- **ASD-H25** – First industrial opportunity for CNC machine tools to get closer to ultra-precision and vice versa
- **Air Bearing Applications** – Bespoke air bearing systems from Levicron for balancing high-speed turbo compressors
- **ASD-H25 / ASD-Cx** – New product brochure available

ASD010P /ASD012P – Ultra precision Air bearing work head capable of operating to speeds of up to 10.000 / 12.000 rpm

Along with the technical and commercial success of our spindle types ASD-H25 and ASD-Cx customer driven thoughts came up for a direct driven air bearing work head which should lead our patented bearing technology and experiences about air bearing motor spindles to a new level. After an intensive market research and preliminary calculations these thoughts became an inherent part of Levicron's business plan and development roadmap. After the first prototype has been finished the pilot batch of twelve spindles is being produced.

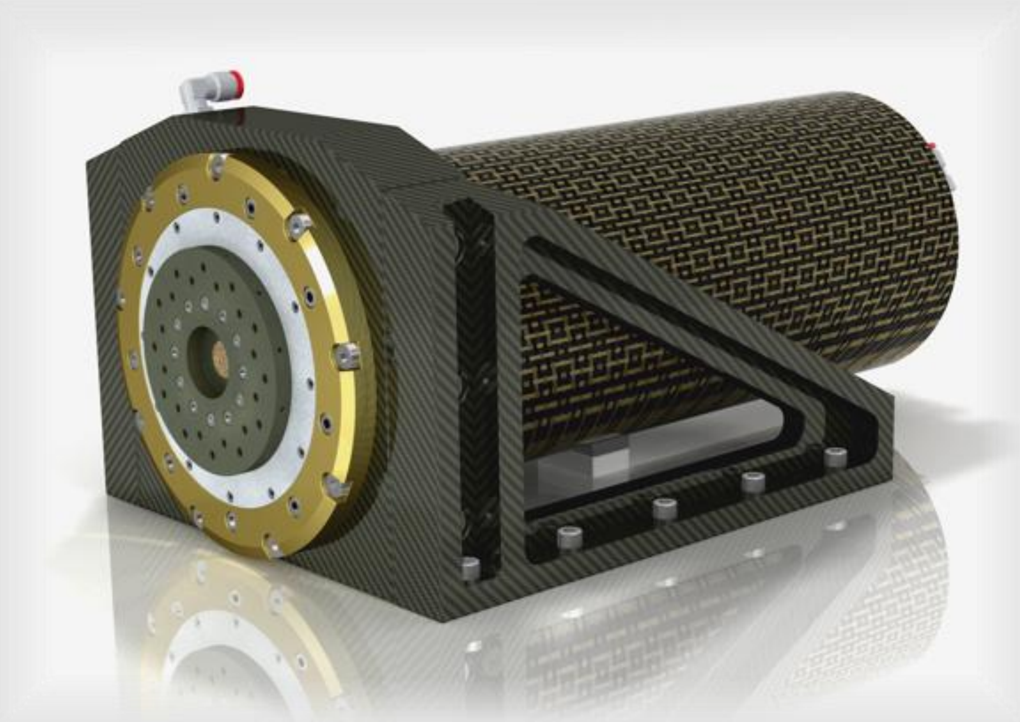


Fig. 1: New addition – air bearing work head ASD010/012P

The demand on ultimate radial/axial load capacities to exceed 1500 N (800 lbs), the radial/axial stiffness to exceed 200 N/µm, a thermal stability of better than 0.5 µm and error motion values (asynchronous errors) of better than 15 nm had been ambitious aims where the thermal stability in particular was the main focus of the design and optimization.

A parameterized CFD simulation of the bearing gaps as well as a comprehensive and coupled FEA model had been established to determine the axial and radial thermal behaviour and were used within several iterations to optimize the bearing gaps as well as the thermal design together with analytical calculations for the air bearing characteristics.

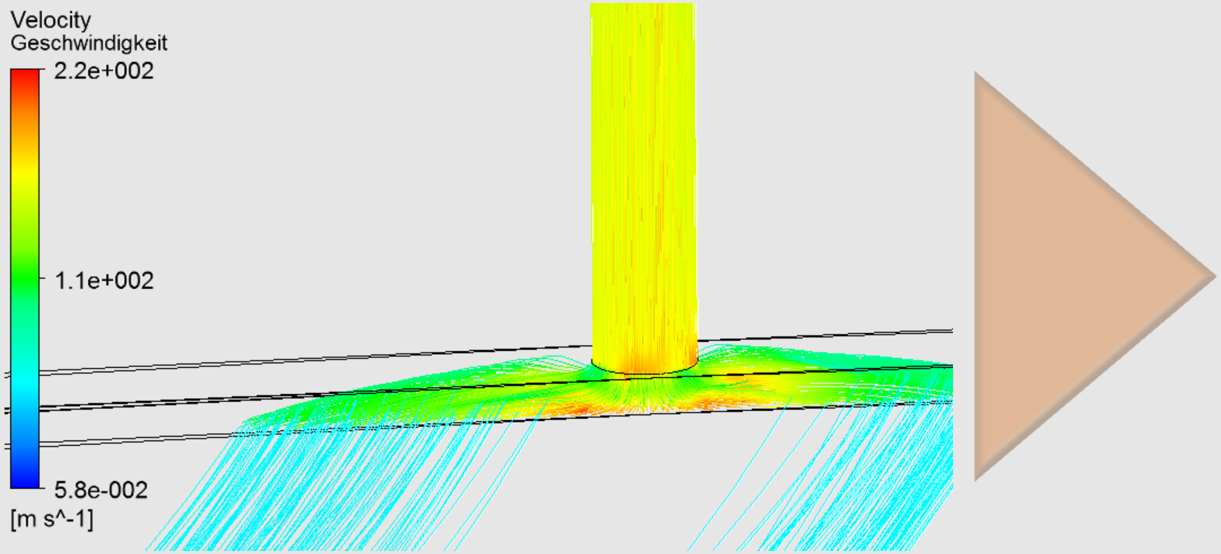


Fig. 3: CFD-simulation of jet and bearing gap flow

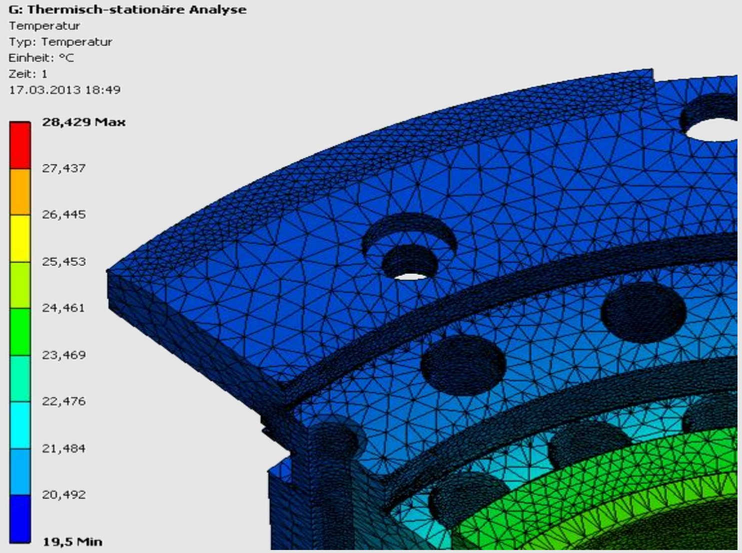


Fig. 2: Coupling of CFD temperature and heat transfer coefficient fields with thermal FEA Simulation

After an excessive analytical optimization the required performance data could even be exceeded and the first spindle batch is being made. Despite the higher speed with respect to other market players even a higher ultimate load capacity and stiffness in radial and axial direction could be realized. Beside an outstanding permanent magnet synchronous motor with air gap winding and a nominal motor torque of 6 Nm an air bearing feed through for oil-air-mist and vacuum at the same time was developed and adapted.

Fig. 4: Pre-machined parts of pilot batch

At a glance:

- Speed : 0 - 10.000 / 12.000 rpm
- Ultimate load capacity / stiffness : see table
- Continuous motor torque : 6 Nm S1|100%, permanent magnet synchronous motor with air gap winding
- max. async. error (error motion) : 15 nm
- rotary encoder : 1VSS SinCos with 16.400 lines and Index or absolute encoder with BISS2 standard, 26 bit

- patented bearing technology with service friendly cartridge solution
- Thin-film liquid cooling to thermally separate spindle from machine
- Availably as spindle cartridge or with bolt-on head stock

	radial, at face plate			
	static (standstill)		**10.000 rpm**	
	stiffness	ultimate load capacity	stiffness	ultimate load capacity
	N/µm (lbs/in)	*N (lbs)*	*N/µm (lbs/in)*	*N (lbs)*
cold	225 (1.280.000)	2.100 (470)	250 (1.420.000)	approx. 3.300 (740)
warmed through	320 (1.830.000)	2.000 (450)	410 (2.340.000)	approx. 4.100 (920)
	axial			
	270 (1.540.000)	2.400 (540)		

all values at 7 bar / 100 psi supply pressure

available from August 2013

ASD-H25 / ASD-Cx – Non common sealing air test

Some customers keep asking whether or not the sealing air and labyrinth function of our spindles were sufficient. Instantly we had the idea to check these function by operating a spindle under water. “Sushi“, our orange specialist from inspection, confirmed a flawless sealing function. Meanwhile he’s back with his friends in the pond and it appeared that he enjoyed the day out in the spindle world.

Click on the picture to see that this not a Photoshop creation.

Myth asynchronous errors (error motion) – Backgrounds and modern measurement methods

Definition: The asynchronous error (error motion) of a rotating shaft is the geometrical deviation from the spinning axis (radial) or wobble (axial) that doesn't repeat every revolution at the same angular position of rotation.

Impact: Asynchronous errors in tool-spindles are a measure of the achievable surface finish and partly for the amount of tool wear. The lower the better.

Root Causes: For roller bearing spindles it becomes clear that shape errors of the roller elements as well as their dynamics and especially the bearing cage are root causes for asynchronous errors. But also natural frequencies of the bearing-shaft system or even non-rotating systems, draw-bars e.g., cause asynchronous errors as such always get excited. The ultra-thin air film in air bearings on the other hand gives an averaging effect which allows the shaft to rotate more precisely than the sum of the single errors actually would allow. As a result asynchronous errors in air bearing spindles are substantially smaller due to this averaging effect and the missing metal-to-metal contact. For these reasons asynchronous errors in air bearing spindles are generally 5-20 times, synchronous errors generally 2-5 times smaller than in roller bearing spindles and are thus the most suitable spindle type to machine optical components and micro structures with.

Sources for high-frequency asynchronous errors: Beside multiples of the shaft bending critical or bearing induced natural frequencies electrical drives with high switching-frequencies generally cause a distinct portion of high-frequency asynchronous errors. These frequencies are attended by multiples and permutations of the count of motor poles, stator turns and slots and – of course – the turning frequency. To get rid of such high-frequency asynchronous errors caused by electrical drives and motors in Levicron a new motor stator technology with air gap winding is used which generates a homogeneous magnetic field and thus eliminates the effects described.

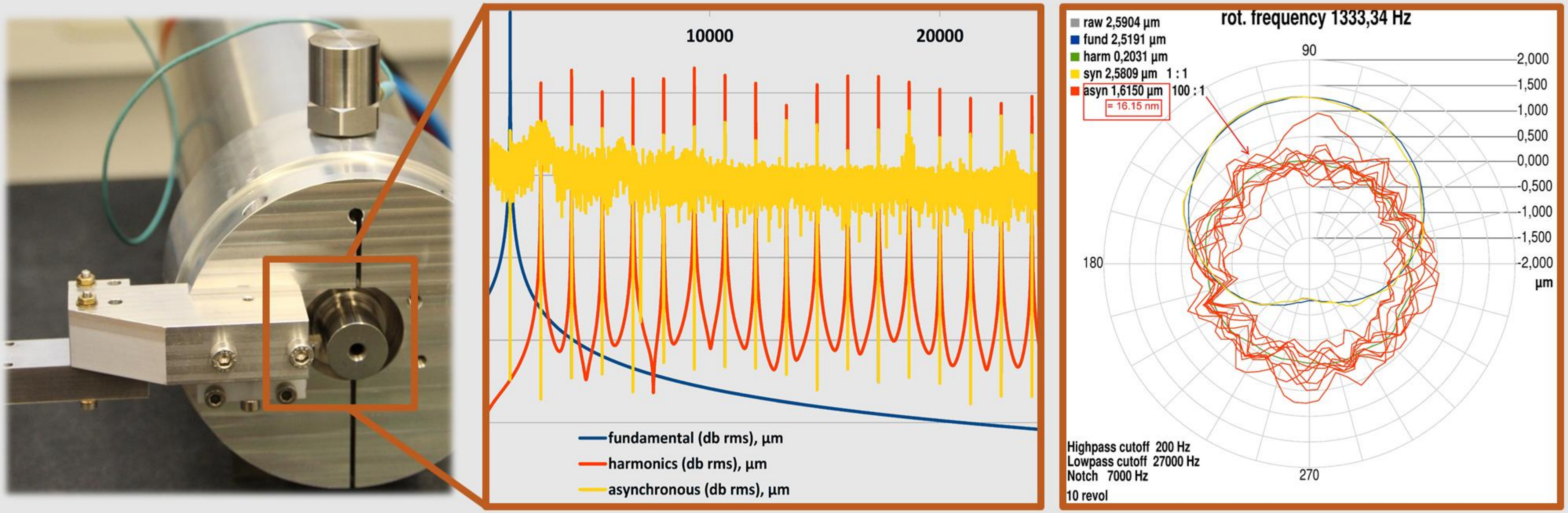


Fig. 5: set-up, data separation and evaluation

Measurement principles: Based on the need to measure the deviation from an ideal rotation a distance information depending on the angular position is required. It's obvious that with the current state of the art in sensor technology and signal processing there is no reasonable way to do this. A way better method is it to record as many distance information by angular position as possible – regardless at which angular position – over several rotations, to fold the time signal into the frequency spectrum (FFT), to identify and eliminate the synchronous portions, means the fundamentals and their multiples, and to unfold the so filtered information back into the time spectrum. With the synchronous portion eliminated the information left are the information about the asynchronous error of the rotations recorded.

Limitations then and now: Better resolutions and sample rates according to the technical progress and bespoke techniques in signal processing opened up new possibilities for Levicron to include higher frequencies in asynchronous error measurements which indeed have an impact on asynchronous errors. Sensor devices with a resolution of less than 2 nm and sample rates of more than 100 kHz are available and are used together with bespoke algorithms for this purpose.

Filter settings: Without a shadow of a doubt, using a low-pass filter with a low threshold leads to small asynchronous error values which was necessary using standard sensor devices and methods. To be able to make a sound and realistic statement about the asynchronous error of a spindle not less than twenty harmonics of the fundamental (=turning frequency) and all frequencies below 20 kHz should be considered to include high-frequent influences like multiples of bending and bearing induced natural frequencies as well as permutations of the motor and drive components. There might be the need to set a high-pass between 50 and 100Hz to avoid electrical interferences.

Easter egg – there's more to see: Having a closer look on the 3D-FFT chart derived from the time-based distance signal with speed (=waterfall FFT) you also can spot the bearing-shaft induced natural frequencies. These criticals again are a direct function of the actual bearing stiffness in radial or axial direction, depending on a radial or axial measurement. Taking the constants values of the rotor weight, bearing distances and moments of inertia into account this delivers to all data required to measure and calculate bearing stiffnesses with speed and thus the actual bearing gap. Knowing the bearing gap width with speed is crucial with air bearing spindles as they need to run with bearing gaps of only a few microns to deliver sufficient performance and are predominantly influenced by the heat input from shear losses and motor as well as centrifugal loads.

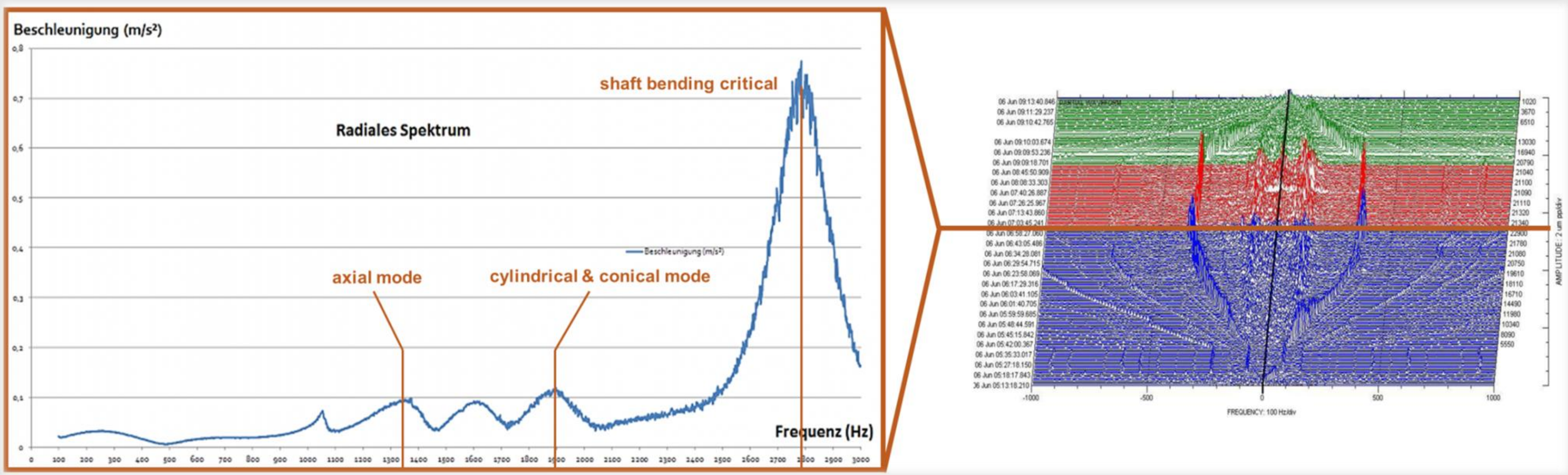
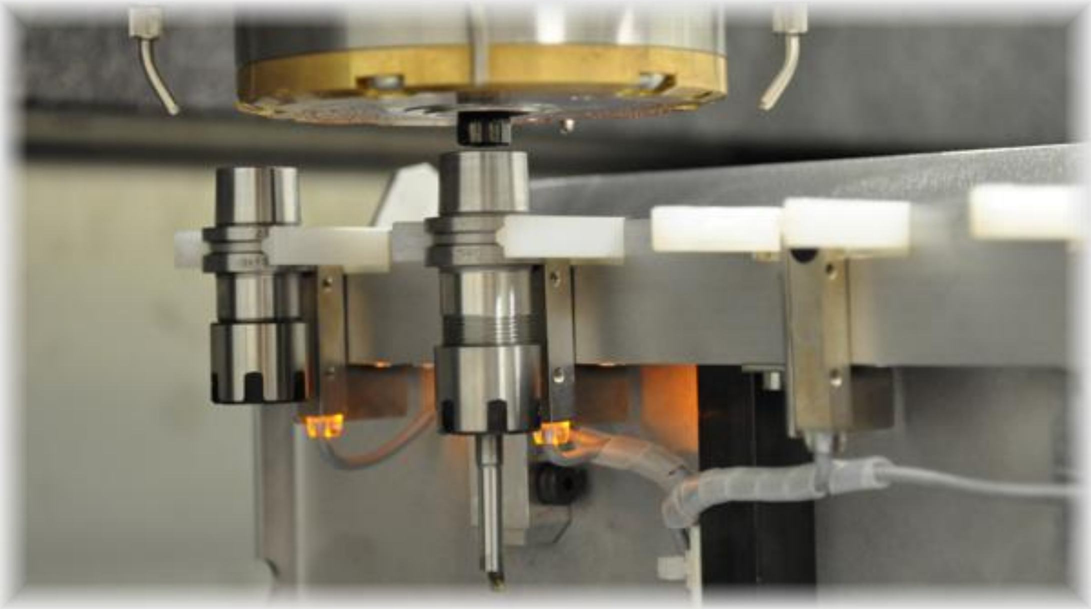


Fig. 6: Identification of natural frequencies in the folded FFT-signal and derivation of bearing stiffnesses and bearing gaps

ASD-H25 – First industrial opportunity for CNC machine tools to get closer to ultra-precision machining and vice versa

Current developments in the market of conventional CNC machine tools in combination with their excellent machine controllers, hydrostatic guides or outstanding thermal behavior are increasingly targeting on ultra-precise manufacturing and/or micro-machining, but are physically still limited on surface finish, rotation speed and continuous operation stability due to available roller bearing spindle solutions.

Due to their usage of air bearing spindle systems machine tools for ultra-precise machining on the other hand are superior with respect to surface quality, however the robustness and simplicity of these spindle systems prevent these machines to get over a certain level of automation and productivity.



Our milling/grinding spindle type ASD-H25 was explicitly developed to connect these two markets and to unite benefits from air bearing systems like high rotation speeds of up to 100.000 rpm, optical surface qualities and thermal stability with features of a state of the art milling spindle. Amongst others this includes the automatic HSK taper clamping system, clamping status monitoring, lubricant feed-through, a high-resolution rotary encoder, high efficient liquid cooling as well as robustness and ease of maintenance.

Our bespoke and comprehensive spindle production allows us to specify run-outs at tool of < 0.5 µm, error motion values of < 25 nm and thermal xy-stabilities of < 1 µm for this spindle type.

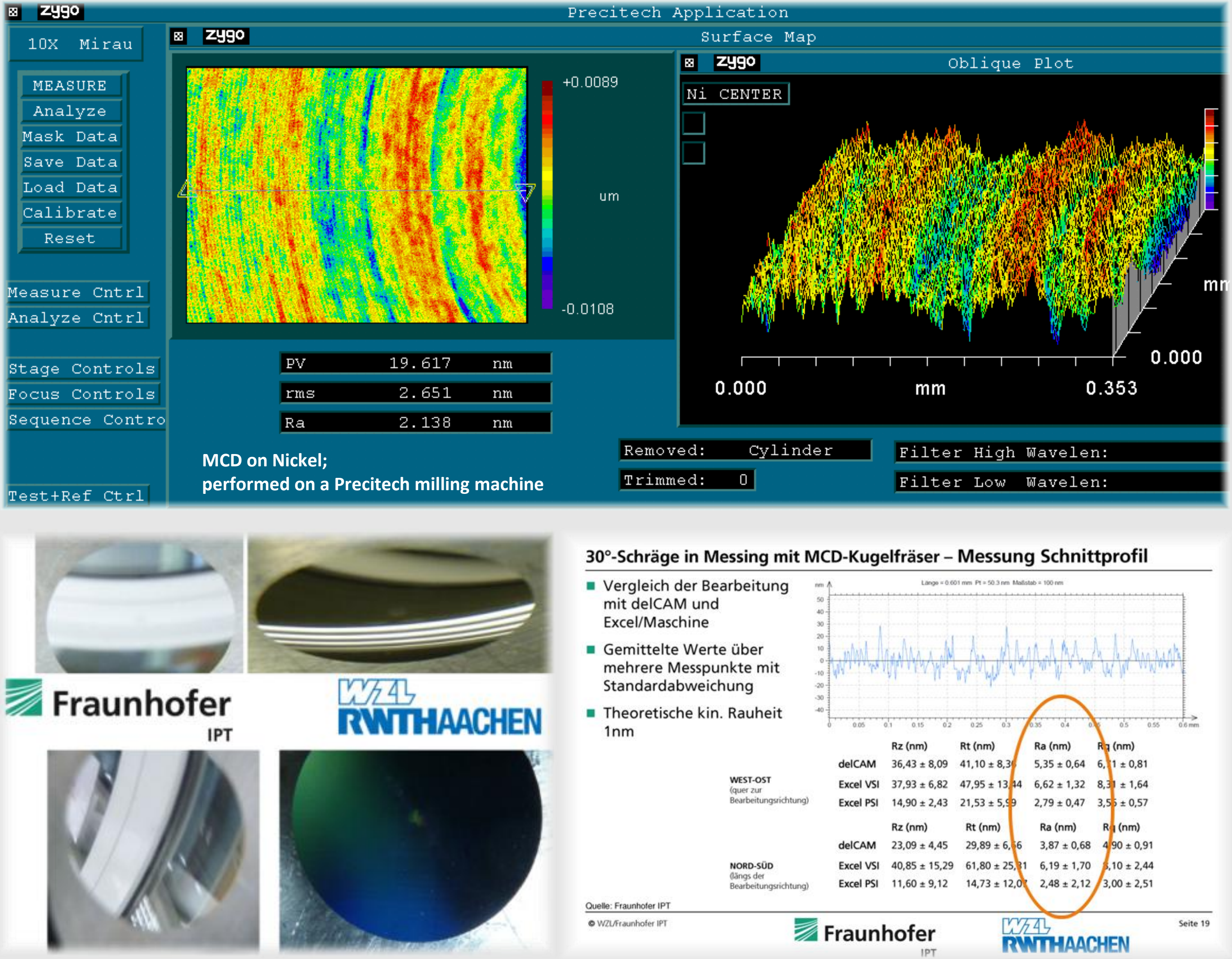


Fig. 7: Machining results for optical components

Air Bearing Applications – Bespoke air bearing systems from Levicron for balancing high-speed turbo compressors

Together with PMB as user Levicron developed aerostatic bearing systems for balancing micro-shafts and rotors of high-speed turbo compressors with a new quality and exceptional repeatability. Using roller- or V-supports for micro rotors significantly causes disproportional residual imbalances due to non-repeatable (asynchronous) errors. Here shape errors of the metal-to-metal contact and the roller elements themselves become visible. Furthermore they cause vibrations which consist of random frequencies within a broad band and can excite various system frequencies. The averaging effect of the bearing gap within air bearings on the other hand allows a much more precise rotation which is even better than the parts actually allow. As a result balancing a rotor in an air bearing system significantly improves the signal quality and repeatability.

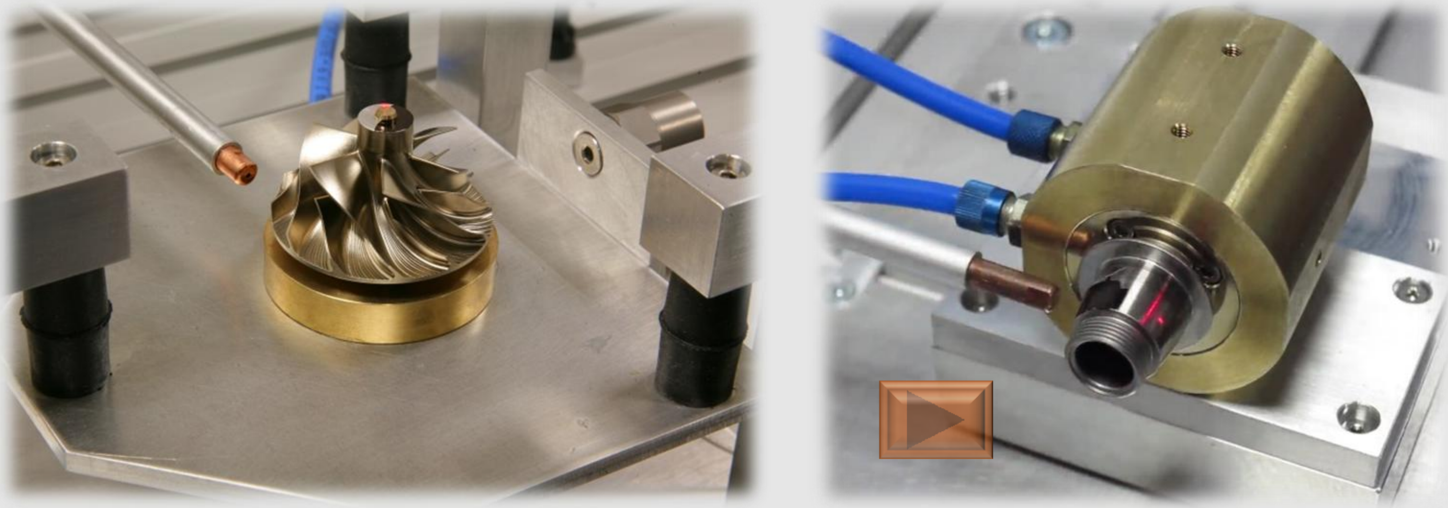


Fig. 8: Air bearing systems for balancing micro shafts and rotors of high-speed turbo compressors; with video

ASD-H25 / ASD-Cx – New product brochure available

The brand new product brochure of our milling spindle types ASD-H25 and ASD-Cx is available as PDF document and printed version. Please contact us if you wish to receive a printed copy, otherwise please download the PDF-document by using the download link underneath.