Contactless Frequency Analysis of Motor Vibrations with the Ultra Precise FPS3010

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Machine vibrations induce errors in parts manufacturing. Tiniest vibrations of a milling machine produce erratic motions of the workpiece with regards to the cutter and hence, may lead to contouring errors or bad surface finish. Yet, in state of the art mechanical manufacturing allowed tolerances are constantly narrowed down. Indeed, misshaped components can jeopardize the whole system's assembly or safe operation. In the end, such parts may fail quality criterions such as the 6-sigma standard – this quality process ensures that only two out of a billion manufactured parts may be outside the specifications. attocube now provides a perfect tool to efficiently and precisely characterize vibrations.

A few months ago, a customer needed to test a rotating motor embedded in his system. Simulations emphasized that the maximum vibration amplitude of the motor housing should not exceed 100 nm to comply with the overall system error budget. As the development project was approaching a deadline, our customer required a fast and accurate method to characterize the machine vibrations. But how to measure these?

Even minimal mass variations may induce dramatic shifts in vibration frequency / amplitude signature. This discards any contact sensing solutions (such as CMM probe calibration spheres or optical encoders). Moreover space configuration in our customer's setup imposed a cylindrical geometry for the motor housing, hence prohibiting the use of capacitive sensors. In fact, only a non-contact, high accuracy interferometric technology could work.

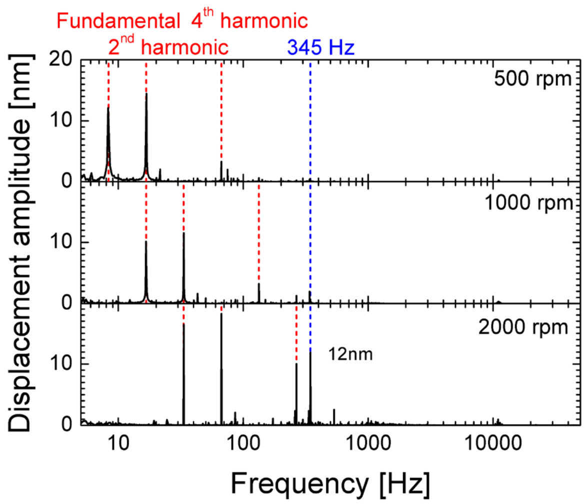

Figure 2: *FFT of the displacement signal monitored in a 100 kHz bandwidth. The spindle of the motor was rotated at 500 rpm (top), 1000 rpm (middle), and 2000 rpm (bottom). We evidenced vibrations at the fundamental rotation frequency as well as replicas at the 2nd and 4th harmonic (red dashed lines). At 2000 rpm, the 345 Hz (blue dashed line) system resonance is highly amplified.*

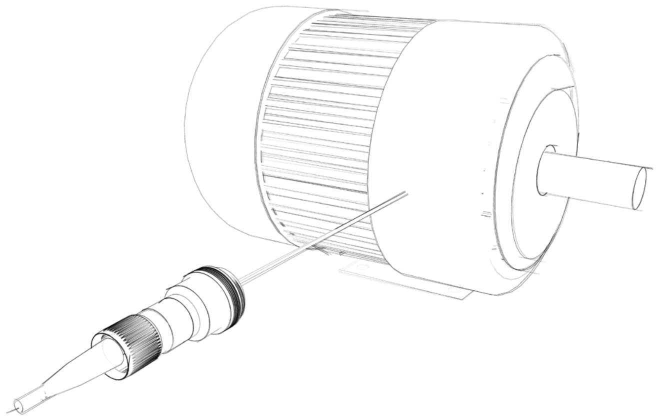

Figure 1: *Schematic setup for measuring an vibrating object. As the motor is actuated, its position changes, hence vibrations are monitored by the laser interferometer. Note that different sensor heads are available for objects of different size and different sensing distances.*

attocube then offered to perform a fast test measurement with its easy to use sensing solution (see sketch in Figure 1). We mounted our non-contact probe within less than five minutes and started recording the displacement of the motor housing. Our sensor's remote electronics performed a live Fast Fourier Transform (FFT) of the signal and allowed us to monitor the assembly's vibrations on the fly. Figure 2 shows the results of the measurements with the motor spindle rotating at 500, 1000, or 2000 rotations per minutes (rpm).

For the lower two rotation velocities, the system complied with the requirements. However, at 2000 rpm, the total vibration exceeded 150 nm overall amplitude. With our frequency analysis feature, we assessed that the system triggered vibrations not only at the fundamental frequency but also at its second and fourth harmonics (see Figure 2). We evidenced that when rotating at 2000 rpm, the motor generated vibrations at 270 Hz which in turn amplified a system resonance at 345 Hz, and therefore drastically increased the overall vibration amplitude. With this crucial information, our customer could take action (modify the design of the holder) to minimize the system response to vibrations and prevented potential failure.

The ease of use of attocube's sensor initiates in situ fast monitoring of vibrations even by non-experts in laser interferometry. The frequency analysis tool of the FPS3010 allows on-the-fly diagnosis of a machine in a production line: Hence, production managers can trace back unbalanced, misaligned, damaged, or loose components and trigger service or maintenance on time. This not only improves part quality, but also minimizes machine downtime. attocube's compact sensor design and high integration qualifies for the "Industry 4.0" challenges.

More detailed documentation on the FPS3010 can be found at www.attocube.com.