

Non-Cogging Motor with Air Bearing Spindle Eliminates Flat Spots when Micro Grinding OD's

Mating a non-cogging ThinGap motor with an ultra-precision air bearing spindle enabled a micro grinder spindle/indexing system for outside diameter (O.D.) grinding



and profiling of parts with diameters as small as 25 microns. The non-cogging motor eliminated flat spots caused by conventional brushless motor cogging, while improving accuracy, repeatability and surface finish. According to Brad Engel, president of Nelson Air Corporation, "The ThinGap motor greatly improved the roundness of the parts being ground by our customer. The motor accelerates smoothly and indexes with higher repeatability because it has zero cogging. Also, the servo is more stable, providing a better surface finish and better geometry."

The ThinGap motorized air bearing spindle is the key component of a computer controlled micro grinding system being developed by a customer of Nelson Air to grind extremely small parts in a proprietary manufacturing process. The parts are microscopic so the tolerances are an order of magnitude tighter than can be achieved with conventional equipment.

Three Nelson Air motorized air bearing spindles are mounted on ultra-high resolution positioning stages and the grinding and dressing operation is monitored using a high powered video microscope with machine vision system. The air bearing spindles include the grinding, dressing and tool spindles. The grinding spindle spins a 3-inch diameter diamond impregnated grinding wheel at speeds up to 13,000 RPM. The dressing spindle uses another abrasive wheel to dress and profile the grinding wheel. A tool spindle with a non-contact optical encoder rated at 8192 counts per revolution holds the part being ground. The tool spindle with encoder is used for grinding part

profiles down to 25 microns diameter, which is too small to be seen without a microscope.

Additionally, the tool spindle allows multi-tasking, spinning the part for concentric grinding and indexing the part to a precise position for grinding flat profiles at different angles, the micro grinder reduces cycle time and part handling. While the grinding and dressing spindles have a runout tolerance of +/- 20 μ inches, the tool spindle needed to achieve a tolerance of +/- 2 μ inches.

"When we first built the tool spindle, we used a conventional brushless DC motor to drive it. But when we looked at the parts ground with the conventional brushless DC motorized air bearing spindle under a microscope, we saw it had created a part that was not round but had flats where the cogging occurred," says Engel.

Magnetic attraction between the iron in the motor stator and the magnets in the rotor was causing a radial deviation of the spindle as it rotated past each motor pole. When the part in the spindle moved radially, the grinder took a deeper cut and it created a flat.

A ThinGap brushless motor achieves zero cogging with a coreless circular copper coil replacing the iron core and wire windings used by conventional brushless motors. The coil is a thin, freestanding composite structure made of copper sheet, glass fiber and polyimide. Since there are no magnetic materials in the air gap, there would be no magnetic attraction to cause radial motion of the spindle.

The motor also eliminates cogging due to the moving magnetic field. Generally, most brushless motors (iron core and ironless) rely on a rotating magnetic field, which causes hysteresis losses. ThinGap brushless motors eliminate relative motion between the rotor and housing return path by using a fixed magnetic field with a rotating return path, which results in hysteresis losses that are barely measurable. This eliminates cogging, which enables very precise control. The unique geometry of the ThinGap motor allows the rotor to be mounted directly to the air bearing shaft, eliminating the use of

ball bearings which would degrade the accuracy of the spindle.

Because the inside and outside surfaces of the coil are exposed to moving air, it quickly dissipates heat allowing more current to be used without burning up the motor. The maximum stator winding temperature is 100°C. By eliminating the iron core, eddy current losses are eliminated and efficiency is improved. The torque ripple is very smooth because of the higher inertia of the motor. This also reduces vibration and provides a wider dynamic range. These characteristics combined with very low harmonics enable the motor to deliver very smooth velocity.

A trapezoidal, 3-phase brushless motor Copley amplifier drives the motor part set, which features peak torque of 574 oz-in. and peak current of 70 amps. A single axis Galil control with RS-232 port provides the controller and interfaces with the customer's software. Engel adds, "Generally, a sinusoidal drive should be used with a ThinGap motor, but the system had already been built with a trapezoidal drive. It worked within the tolerances required by our customer, so we decided to keep the drive. We did use an inductance board because the amp couldn't supply enough inductance."



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