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Actuator/bearing technology is changing how grinding machines move.

The Overbeck L/T Super Precision grinder — developed in a partnership between the Massachusetts Institute of Technology and Overbeck Corp., Hauppauge, N.Y. — is perhaps the first production grinder that uses a combination of linear electric motors together with aerostatic linear bearings. This configuration not only provides high precision at a low cost, but it also ensures a great deal of modularity and flexibility. As a result, end users get grinders fully customized for their applications in a fraction of the time needed for more traditional systems.

The L/T pairs a PC-based CNC with "Axtrusion" actuator/bearing technology (so called because it appears as if the axis could be extruded). Essentially, air bearings ride on two intersecting perpendicular planes for simple and precise linear motion, while a linear motor at an inclined plane preloads the bearings. These two planes represent the most accurate and lowest-cost geometry to guide linear motion. And by placing the motor at a specific position and angle with respect to the air-bearing pads, any desired distribution of preload force is obtained.

The grinder takes advantage of the powerful attractive force of open-faced linear motors. This force, which is typically 5× the axial force with which the motors actually push an axis,

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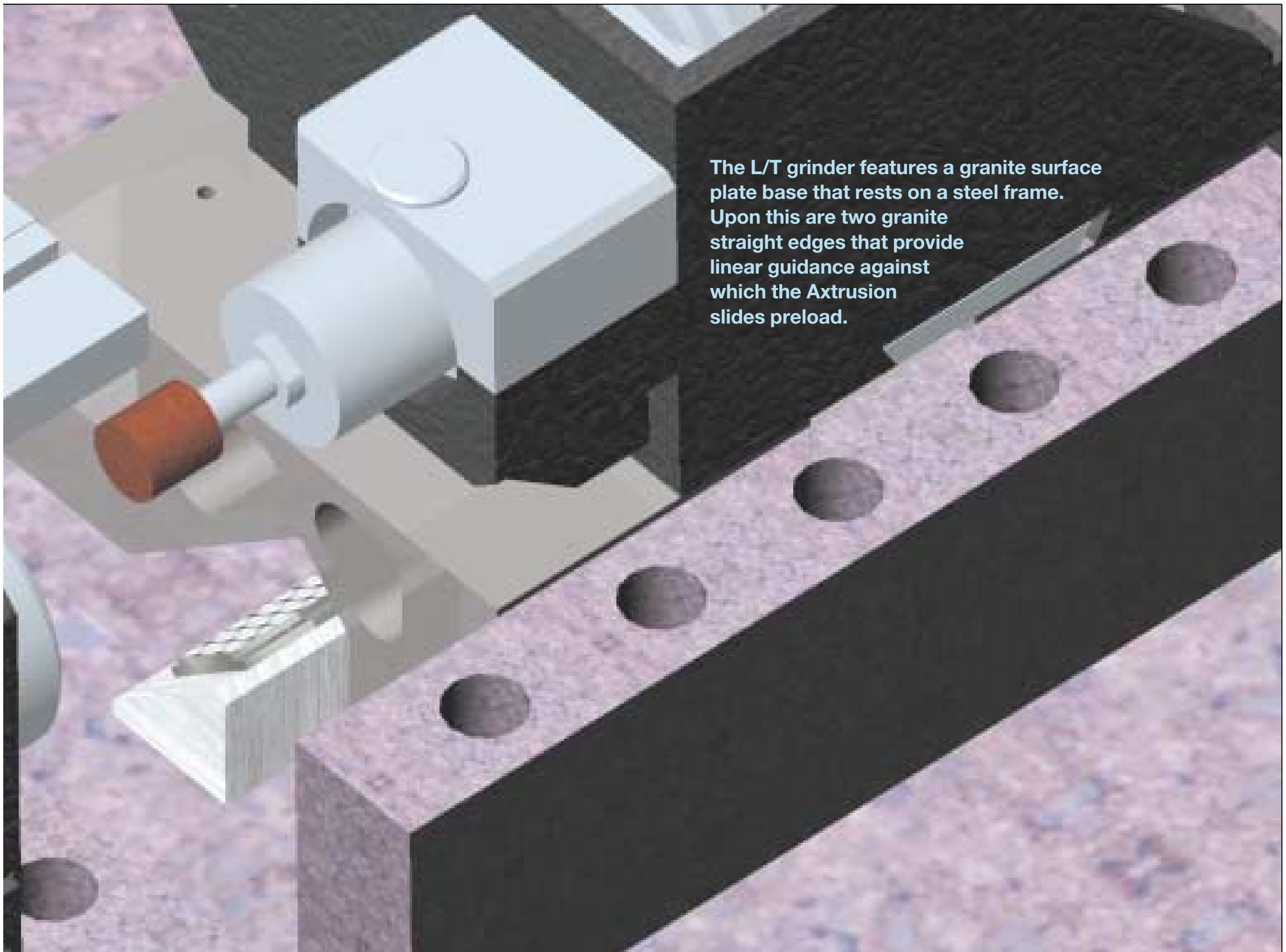
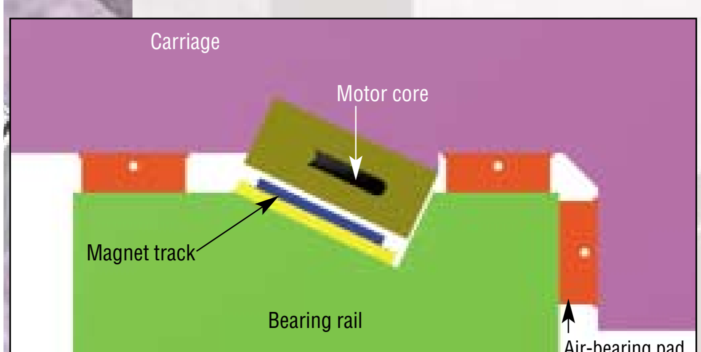


The L/T grinder features a granite surface plate base that rests on a steel frame. Upon this are two granite straight edges that provide linear guidance against which the Axtrusion slides preload.

can so heavily load conventional rolling-element or sliding-contact linear bearings that they heat excessively and quickly wear out.

To remedy this situation, many other builders configure two open-face motors back to back or use an ironless core motor. But this arrangement results in a more complex geometry, which escalates the cost of the machine. Instead, the L/T grinder uses this magnetic force to hold down the bearings, eliminating the need for an underside "keeper" rail and, thus, simplifying machine design. In addition, the magnetic force makes the L/T system inherently well preloaded and stable even in the presence of large externally applied forces that might induce pitch, yaw, or roll.



The Axtrusion concept uses linear motors at an inclined plane to preload air bearings arranged to provide elastic averaging and high pitch, roll, and yaw stiffness.

Using the motor's attractive force for preloading maintains air-bearing stiffness and damping, even when the machine is heavily loaded. The Axtrusion configuration also eliminates the need for costly and delicate wraparound preload mechanisms and lets the entire machine be essentially made from simple planar surfaces. Because one can virtually extrude an axis from simple planar surfaces to a desired length, ballscrews and linear bearings no longer constrain machine design.

In addition to open-faced linear motors, the L/T grinder uses New Way modular porous-carbon air bearings, which, when mounted and

Machine development

Overbeck's L/T grinder went from concept to build in just seven months. This aggressive development plan involved a peer-review evaluation process (PREP), in which Professor Slocum of MIT and Overbeck engineers individually developed machine concepts and then reviewed each other's ideas before brainstorming.

Among the early concepts for the new grinder were more complex models with round shaft bearings of roller or hydrostatic design. The MIT/Overbeck group also considered a stacked-axis version. But what quickly became apparent was that the best design was the simplest. And the Axtrusion concept was born.

Once the team finalized the design concept, it used an analytical model and spreadsheet to develop dimensions and determine system stiffness and the system error budget. From there, creating part drawings from the solid model was a straightforward task.

So that modular elements could rapidly come together, the team members independently precision machined components and then aligned them using fixtures. Members then went to work vacuuming bearings to the granite base, positioning carriages, and injecting epoxy to secure the bearings into place. The team also assembled sheetmetal elements to keep grinding fluid away from the granite base and the bearings. This also insulated the structure for better temperature control.

The final step, the electrical system, took less than a week. This was accomplished by implementing Overbeck's new plug-and-play electrical-cabinet design method. This system makes it possible to seamlessly integrate all electricals in a short period of time with a high degree of reliability and success.

MIT and Overbeck designed and built the L/T grinder in seven short months and launched it at IMTS 2002.

Novel designs of the past

From Whitworth's 3-plate scraping method, to Philip's kinematic arrangement of air bearings preloaded by a linear motor (U.S. Patent 4,817,930), to replicating in place an elastically averaged array of air bearings and then preloading them with the linear electric motor (U.S. Patents 5,488,771 and 6,150,740), the Axtrusion is a part of the continual evolution of machine tools. In fact, MIT is no stranger to designing such machines. Professor Slocum and then graduate students Nathan Kane and Eric Marsh once partnered with Weldon Machine Tool Inc. to build a CNC cylindrical grinder. American Machinist introduced it in an October 1994 article entitled "Out of the lab and into the shop" (p. 60).

That same year, the gang at MIT also built an all-ceramic grinding machine with hydrostatic (water) self-compensating bearings with CoorsTek, a ceramic-component manufacturer located in Hillsboro, Oreg. The bearings, combined with mounting the machine to the floor, give it near-critical damping. This was Paul Scagnetti's Ph.D. thesis.

pressurized correctly, provide near-critical damping for machine axes. To maximize stiffness and damping, six bearing pads per axis are actually used, where they are suctioned down to the planes first, and then epoxied into place to yield a rigid, damped, elastically averaged design. Critical damping prevents vibration in the machine structure. For further damping, the machine has a layer of viscoelastic damping material between its granite surface plate base and steel support frame.

The final piece of the modular puzzle is the machine's PC-based CNC, called MachineMate L2. This easy-to-program CNC, which offers both linear and circular interpolation, combines with the Axtrusion design to provide plenty of design flexibility.

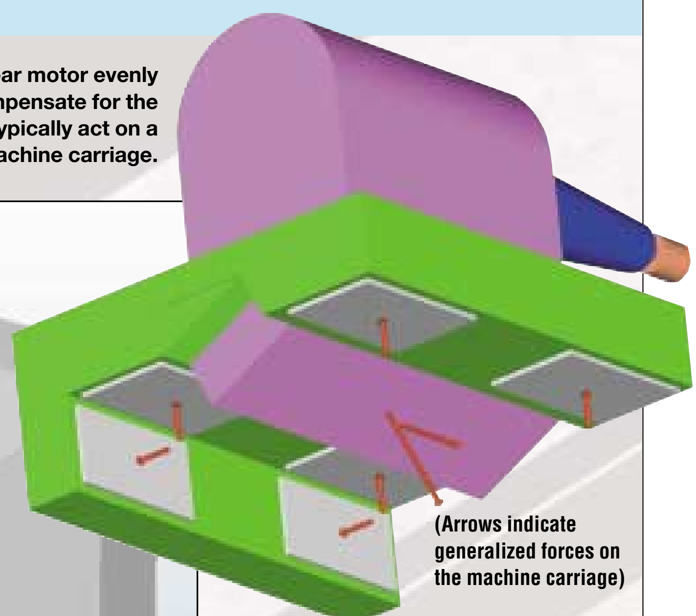
The first production version of the L/T debuted at IMTS 2002. This machine supports up to a 1,000-lb load on each axis and accommodates up to a 4-in.-diameter part. Its 20-hp spindle takes full grinding loads with only submicron deflections in the machine. Overbeck reports that it will customize the L/T to handle just about any load capacity. In addition, end users can specify the L/T as an internal, external, cylindrical, face, surface, center, centerless, or universal grinder. They could also request certain wheel spindles, dresser types, in-process gages, coolant-delivery systems, and many other features. AM

According to Slocum, the half-life of the other precision grinders at CoorsTek is about two years. After which, ceramic dust basically wears away cast iron structures. However, MIT's ceramic grinder has been running nonstop, three shifts a day, since 1994.

Reg Maas, senior engineer at CoorsTek — who worked closely with Scagnetti — confirms that this machine is a production workhorse, seeing about 18 to 20 hours a day of service in rough stock removal. He says the machine often runs unmanned, with operators loading parts at the end of a shift and taking them off the following morning.

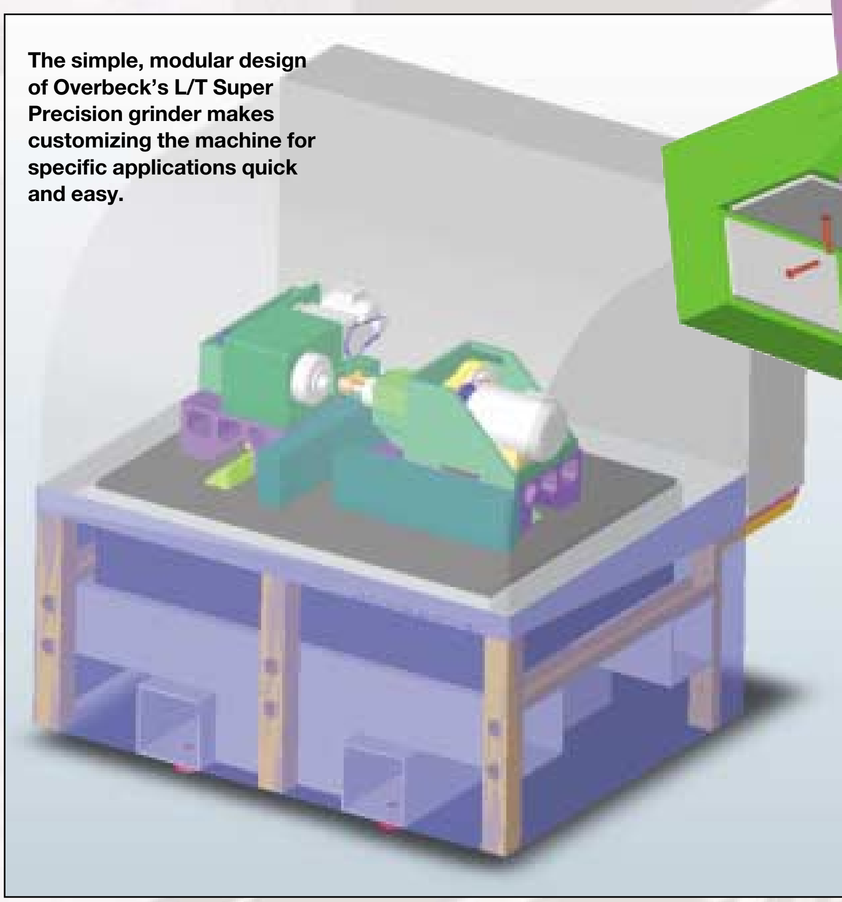
Interestingly, Maas was also involved in the peer-review process for the Overbeck L/T grinder. He suggested that the first prototype should use a granite surface plate. But future versions of the machine will likely offer a lightweight ceramic base.

An MIT-designed, all-ceramic grinding machine has been grinding ceramic materials at CoorsTek since 1994 — easily outliving its other grinders.



The Overbeck L/T grinder's linear motor evenly preloads the air bearings to compensate for the numerous forces that typically act on a machine carriage.

(Arrows indicate generalized forces on the machine carriage)



The simple, modular design of Overbeck's L/T Super Precision grinder makes customizing the machine for specific applications quick and easy.

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