How granite bases improve machine tool performance

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With its Danobat, Overbeck and Hembrug companies, Danobat has over 70 years of experience in building precision grinding and turning machines. With deep technical experience in designing every component of a machining system, Danobat chooses to use natural granite bases for its most demanding applications. Here's why.

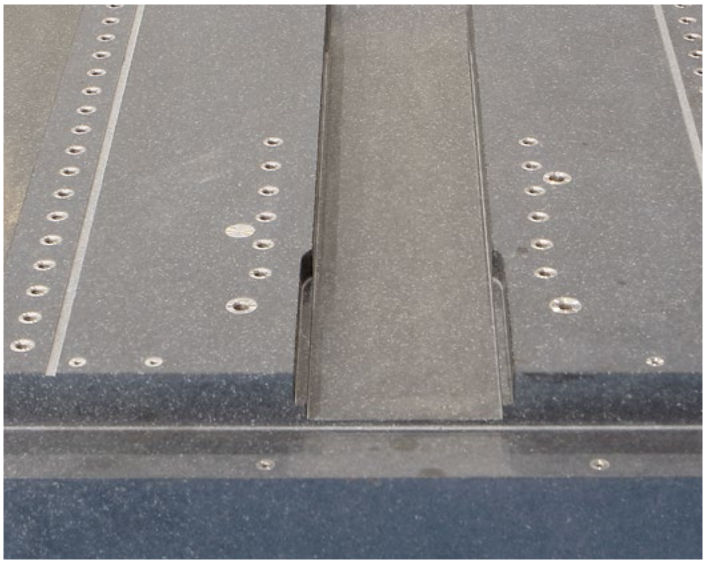
There are many elements that go into building a truly precision machine tool, and one that will maintain its accuracy over time. A range of add-ons can enhance a machine's accuracy, but none can compensate for a design that is structurally unsound to begin with. It all begins with the base which is perhaps the most important component of a machine tool.

A high functioning bed will be strong, stiff and absorb vibration induced by machine motion and machining forces. The mechanical design of the bed is certainly critical but so too is the material. For precision machine tools, that material has historically been cast iron, and the more of it, the better. However, with more than 20 years of experience with the material, Danobat engineers know that natural granite is a better choice for vibration and thermally sensitive applications. Particularly for as precision grinding and hard turning, granite is becoming the new material of choice for high performance machine beds.

Requirements of a machine tool bed

The structural components of a machine tool must ensure stability of the geometry, rigidity (stiffness) in the mechanism over time, and damp vibration in the system. This enables a machine to retain its accuracy across a wide range of machining conditions with the least vibration at the point of contact between the workpiece and cutting tool or grinding wheel. Lower vibration operation enables more aggressive machining processes, better surface finishes and superior tool life.

Danobat has found that the inherent properties of granite make it clearly better in vibration damping capability compared to cast iron; it is much more thermally stable; and, properly designed, stiffer as well. More on each below.



Stability over time

When it comes to accuracy, the best day for a machine tool is the day it was assembled. Straightness and squareness of machine axes are properly adjusted, and the machine is calibrated to be as accurate as it can be. But over time that accuracy will likely diminish for a number of reasons. One is the base which can warp over time due to internal stresses in the casting or distortion of plastic materials used in polymer concrete bases. Here's how the primary machine base materials compare in their ability to maintain shape over longer periods of time.

- ### Cast Iron and Steel

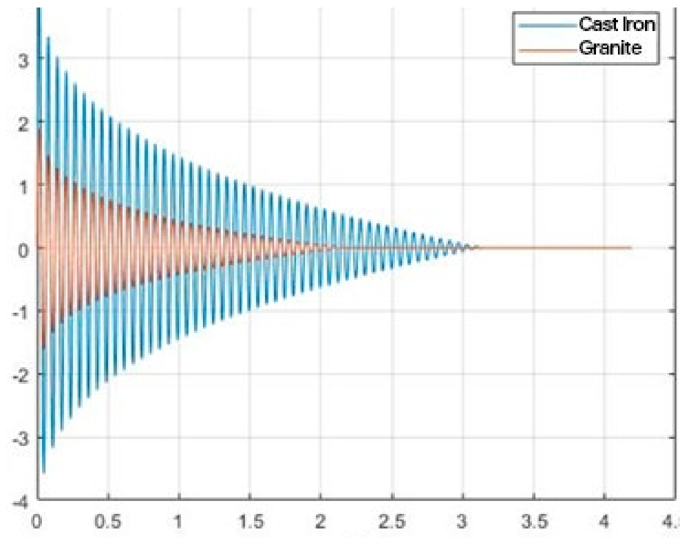
Parts manufactured with these materials have large internal stress values, even when releasing techniques are applied such as stabilization with actuators (vibration induced at critical modes) or leaving parts to "soak" in an environment across many day-night thermal cycles. As those residual stresses release over time, it will result in asymmetrical distortion of the base geometry.

- ### Polymer concrete

While more stable than cast iron and steel, polymer concrete parts can change geometry over time as well, mainly due to a creeping effect in polymeric materials.

- ### Natural stone (granite)

Natural granite has been stabilized on Earth over millions of years, so parts made with this material are free of internal stress. Granite manufactured parts offer the most stable geometry for engineering solutions, which is why it is the standard for highly demanding precision applications like metrology devices such as CMMs or ultraprecision machine tools.



Source: Danobat

Damping vibration

As said, the granite brings a degree of vibration damping ability that few other materials can match without significant compromises in strength and rigidity.

One way Danobat and other materials engineers measure damping ability is with the "loss coefficient" which indicates how long a material will vibrate after a shock. The higher value the greater the vibration. A metallic bell, for example, by design has a high loss coefficient which is why the ring lingers for an extended time. You want the opposite for a machine tool, and granite has a much lower value.

In the more direct measurement of damping coefficient, Danobat engineers have found that granite performs about five times better than cast iron and 10 times better than welded steel. While you can't take that value in isolation to compare two machine tools, because many other factors contribute to the overall vibration properties of a machine, it is safe to say that the amplitude and duration of vibration of a granite bed is much smaller than cast iron. In extremely vibration-sensitive machining applications that difference will matter.

Thermal stability

What happens to a structural component when it heats up has a major impact on a machine's inherent accuracy. Machinists know that as a machine warms up it "grows" larger. For low tolerance work on small machines that's not going to matter much. But as tolerances get smaller and machines get bigger, the thermal stability of the machine's structural components grows increasingly important.

There are three major sources of heat in a machine:

1. Friction from the machine's moving components (ballscrews, spindle, etc.)

2. Friction from the machining process itself

3. Ambient shop conditions.

There are numerous ways to mitigate these factors. For example, high precision machine tools are increasing being fit with component cooling (chiller) systems where cooled fluid is circulated through critical machine components such as ballscrews and spindles. And it is common for extremely high tolerance work to be done in temperature-controlled environments.

But the ability to fundamentally manage thermal effects on a machine tool begins with the base. Here too, granite offers significantly better material properties than cast iron or welded steel.

From an engineering perspective, there are two values that best define a material's thermal performance:

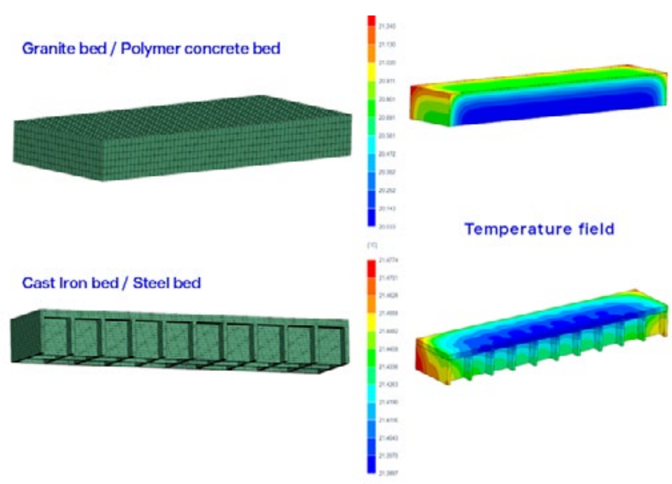
- Coefficient of thermal expansion:

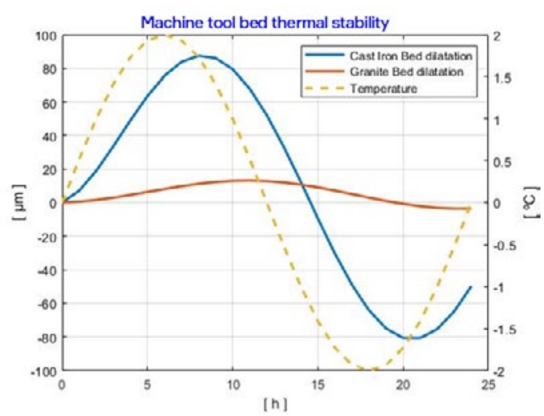
Danobat has found that while thermal expansion rate is the most used characteristic to compare materials, it is not always the most significant. Nonetheless, cast iron has an expansion rate almost two times greater than granite for the same temperature variation on a machine structure.

- Thermal response over time

How quickly a material responds to temperature changes is evaluated by thermal diffusivity, a ratio between thermal conductivity and heat capacity. Granite reacts 40 times slower than cast iron, therefore under thermal cycles like day/night or machine short stops (tool changes, parts loading, etc.) the machine keeps stable.

Inherent thermal behavior can be simulated through finite element analysis. Shown here is a comparison Danobat conducted of a typical





Source: Danobat

cast iron structure vs. a comparable solid granite bed. Both are designed with the same specific stiffness, and then exposed to a thermal variation of +/-2º C (35.6 º F) in a simulated 24-hour day-night cycle. In this case the simulation shows that granite exhibits a resistance to thermal expansion seven times better than cast iron.

The whole package

One advantage that cast iron does have over granite is greater inherent static stiffness as defined by Young's modulus. This is the property that quantifies how easily a material can stretch and deform under tensile stresses. With this measure the stiffness of granite (85GPa) is lower than that of cast Iron (125GPa), but the specific stiffness ratio between elastic modulus and density is better with natural stone, 28.3 vs 17.4. Therefore, for a properly designed machine component with the same mass, the static stiffness of granite can be up to 63% greater than cast iron.

There is still one more reason to consider natural granite bases over cast iron and polymer concrete: the environmental impact. A tremendous amount of energy goes into the mining, smelting and casting to make a cast iron bed. Polymer concrete is somewhat better, but making the plastics materials is also very energy intensive and presents emissions issues that must be abated. Natural stone is literally mined directly out of a quarry and then shaped to the final form. That's not environmentally "free" of course, but it is much more ecofriendly than the alternative processes.

As said at the outset of this paper, there are many things that go into making a more accurate machine tool, of which the bed material is just one. But without a bed that meets the highest standards of high-performance machining, there will be a steadfast limit as to how accurate that machine can be.

About Danobat

Danobat is a world leader in building customized solutions for production grinding and hard turning applications. Based in Elgoibar, Spain, Danobat has over 70 years of experience building turning and grinding systems for customers around the globe. Also included in the Danobat family of companies is Hembrug Machine Tools (The Netherlands) which manufactures high precision hard turning lathes and hybrid machines with hard turning and fine grinding capabilities. And the globally known Overbeck (Germany) specializes in high precision internal, external, face and radius grinding. Combined, the Danobat family of companies manufactures everything from individual machines to fully automated turnkey production systems.

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