Good Connections

The combination of a rigid machine tool and strong spindle connection is ideal for cutting titanium.

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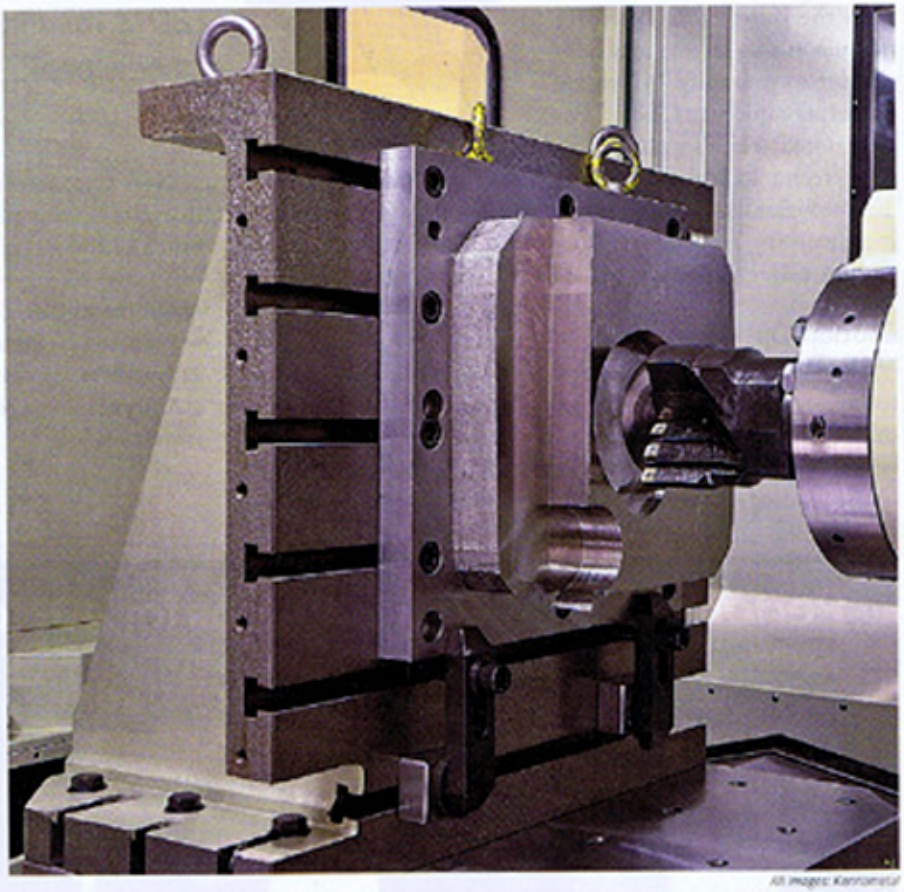
When sourcing capital equipment for machining specialty materials, many shops would do well to consider the 10-speed bicycle analogy. People shop for and buy a 10-speed bike for recreation or exercise, but when riding it rarely go beyond two or three of the most comfortable gears. Elite riders, on the other hand, both size and operate all their components (such as the frame, pedals, shifters and wheels) to maximize their equipment, whether climbing mountains or racing in the flats.

Machining high-strength, high-temperature alloys, such as titanium, is challenging. Machine tool builders have responded with stiffer milling and turning centers, damping spindles and sizable machine structures and motors, all to provide the significant horsepower, torque and thrust forces required while minimizing undesirable vibrations that lower part quality and tool life.

Achieving the ultimate system to precisely machine titanium at maximum metal-removal rates (mrr) requires close attention to the machine tool, the tool/workpiece interface and the spindle connection—the "handshake" between the machine tool and the toolholder.



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The Ti6Al4V machining tests using a Mitsui Seiki HPX63 CNC HMC equipped with four Kennametal cutting tools, each using the KM4X100 spindle connection, involved severe interrupted cutting. As shown here, that included drilling a flat-bottom hole, rotating the workpiece 45° and then drilling another flat-bottom hole through the edge of the first hole.

Tool Test Team

In April 2012, machine tool builder Mitsui Seiki (U.S.A.) Inc., Franklin Lakes, N.J., teamed with toolmaker Kennametal Inc., Latrobe, Pa., to conduct cutting tests on a Ti6Al4V workpiece using a Mitsui Seiki HPX63 CNC horizontal machining center equipped with four Kennametal cutting tools, each using the KM4X100 spindle connection.

Key design criteria for the HPX63 that allow it to machine titanium include a large work capacity with a swing diameter up to 1,050mm, an available work height (Y-axis) up to 1,050mm, an X-axis stroke of 1,000mm and a 900mm stroke in the Z-axis. The pallet is 630mm. The B-axis rotary table offers 12 rpm with high-torque, high-acceleration availability. Rapid travel rates are 32 m/min. with 0.5G acceleration/deceleration, and the cutting feed rate is 12 m/min.

Made for ultraprecision work, the HPX63's castings are metallurgically configured for a high level of stiffness, while its box way axis slides are hardened, ground and hand-scraped. Positioning accuracy and repeatability is 0.001mm.

The Mitsui spindle automatically compensates for thermal changes and does not require a warm-up period. The builder offers several spindle options to meet user needs for direct or gear drives and the amount of torque and spindle speed required.

Overall, the ruggedness, rigidity and precision of the HPX63 make it ideal for machining titanium, as well as Inconel, tool steel, stainless steel and aluminum.

The Spindle Connection

A spindle connection that makes the best possible utilization of available

machine power by efficiently transferring that power to the tool is key to achieving an optimal titanium machining system. With traditional toolholders, that can be difficult to accomplish in certain applications.

Most toolholders are solid, such as CAT, BT and DV styles. Face-contact versions of those holder styles are also solid. Most spindles used with these toolholders have a relatively low clamping force. This is because with a traditional steep-taper spindle, the drawbar and spindle provide the only force to clamp a tool, and a spring pack pulling that drawbar provides that force.

Therefore, connection stiffness is limited, as radial interference must be kept to a minimum. The tolerances required to achieve consistent face contact are thus very tight, which increases manufacturing costs. Hollow-shank toolholders, such as HSK, also fall short on clamping force and bending resistance because of their clamping design and lack of interference fit within the spindle.

The KM4X100 spindle connection from Kennametal represents an alternative technology for complex machining applications. Although some traditional systems might be capable of withstanding a considerable amount of torque, the cutting forces generate bending moments that typically exceed the toolholder/spindle interface's limits before reaching the torque limits. In contrast, KM4X100 provides three-surface contact for improved stability, with optimized distribution of the clamping force and interference fit, delivering three times the bending moment resistance vs. other toolholding systems.

In the test cuts, the HPX63 was equipped with a high-torque, high-power spindle with a maximum 26kW of power and 1,081 Nm of torque. The KM4X100 spindle connection generated 90 kN of clamping force, more than twice that of an HSK100 and three times that of a BT50 (40 kN and 25 kN, respectively).

The cutting tools employed in the Ti6Al4V machining tests were (left to right) a 203.2mm-dia. facemill tooled with seven square indexable inserts; a 203.2mm-dia. facemill with eight round inserts; a 76.21mm-dia., 228.6mm-long HARVI Ultra cutter with five helical rows of 11 inserts each; and a 125mm-dia., flat-bottom indexable drill with six indexable inserts.

Tools Put to the Test

The four different cutting tools employed in the tests were a 203.2mm-dia. facemill tooled with seven square indexable

inserts; the same diameter facemill with eight round inserts; a 76.21mm-dia., 228.6mm-long HARVI (Helical, Axial Rake, Variable, Indexable) Ultra cutter with five helical rows of 11 inserts each; and a flat-bottom indexable (FBI) 125mm-dia. drill with six indexable inserts.

As a result of the power of the machine tool and spindle and the enhanced clamping force of the KM4X100 spindle connection, the test results were strong across the board.

For example, the HARVI Ultra tool, cutting in the X-axis and Y-axis directions simultaneously, topped a 309-cm³/min. mrr at a spindle speed of 171 rpm, a feed rate of 101.6 mm/min., a 40mm DOC and a 76.21mm WOC.

The FBI drill made a flat-bottomed 125mm-dia. hole in the titanium workpiece at a 102-rpm spindle speed, a 10.2-mm/min. feed and a 125.2-cm³/min. mrr. The workpiece then was rotated 45° from the spindle to drill an angled hole that pushed through the edge of the first hole. In spite of the heavy, interrupted cuts, both the machine tool and drill performed well.

The HPX63 is able to reach from one-and-a-half to two times the mrr of general-purpose machine tools when machining titanium. The KM4X100 spindle connection also provides more-than-adequate rigidity, bending moment resistance and torque capacity to take advantage of the higher spindle speeds and torque offered by the HPX63 machine tool and spindle. As a result, the combination optimizes the productivity potential and cutting performance of the machine tool.

Moreover, a KM4X100 spindle connection will reach performance levels of an HSK125, while rendering the more costly requirements of a larger-footprint machine unnecessary, including the larger spindle, toolchanger arm, tool magazine and other accessories.

Sizing the right machine tool with the right tooling helps optimize the productivity of the entire metalcutting system. The KM4X100 spindle connection is capable of performing up to the machine tool's full potential, which drives the most out of the cutting edge, making milling, drilling and even turning more productive and cost-effective. CTE

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