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Harder with Silicon

By Joseph L. Hazelton, Senior Editor

Tool coatings harder than AlTiN coatings are applied via a process that combines AlTiN particles with an amorphous silicon nitride (Si_3N_4) matrix.

Seeing is believing, but it may require testing first. That was the case for toolmaker Melin Tool Co., Cleveland, when it was presented a coating called nACo, which the coating company said was harder, more wear resistant and had a higher hot hardness than AlTiN.

Melin Tool performed in-house tests on nACo, which refers to nanocomposite, applying the coating to a series CCMG 45 6-flute endmill for cutting hardened steel and comparing its tool life to the same-style endmill coated with AlTiN. "We found about a 27 percent increase in tool life with the nACo coating," said Mike Wochna, Melin Tool's president.

Also, the nACo-coated tool had a hardness of 45 GPa vs. 38 GPa for the AlTiN-coated tool. "It creates a harder surface," Wochna said of nACo.

Besides endmills, Melin Tool offers the nACo coating on its high-performance, through-coolant drills and ballnose endmills for making dies and molds. All three types of tools are made from 91 HRC solid carbide and are for cutting workpiece materials of about 45 HRC to 65 HRC. In all cases, the tools are usually for cutting hardened steel, cast iron, high-silicon aluminum and superalloys.

Moreover, nACo has a high hot hardness. As a nanocomposite coating, it can withstand heat up to 1,200° C before it starts to oxidize and break down.

Filling the Spaces

nACo's hardness results from its nanocomposite structure. The coating consists of nanocrystalline AlTiN grains embedded in an amorphous Si_3N_4 matrix. According to the coating and coating equipment company, Platit AG, Grenchen, Switzerland, this structure increases hardness partly because the matrix acts as a diffusion barrier, preventing the grains from growing. "The smaller the grains, the higher the hardness," said Bo Torp, sales manager of Platit Inc., Libertyville, Ill.

The matrix also contributes to the coating's hardness. Torp compared the grains and matrix to wet sand. On a beach, a person's feet usually sink into dry sand, but they won't sink, or won't sink as far, in wet sand. The reason is the space between the grains

Nanocomposite nACo coating on tungsten-carbide tools: suitable processes and workpiece materials.

	Drilling	Milling	Reaming	Tapping
Steels	X		X	
Hardened steels	X	X	X	
Cast iron	X	X	X	X
Aluminum (> 12 percent Si)	X	X	X	
Superalloys	X	X	X	

Source: Platit

Melin Tool

is occupied by water, not air. Consequently, wet sand has a higher resistance, is harder. Likewise, the matrix occupies the space between the grains and makes the coating harder.

nACo's nanocomposite structure can increase a machine shop's productivity and reduce its costs. "You can improve feeds and speeds, or you can start running dry," Torp said.

Melin Tool applies the coating in-house with a Platit π^{80} coating machine. Torp estimated that the coating is appropriate for 90 percent of carbide tools. He added that it's mainly unsuitable for HSS tools because the substrate usually isn't hard enough to sustain the coating. nACo, however, can be applied to other styles of cutting tools and can be used when cutting different workpiece materials (Table).

Standard Coatings Too

The π^{80} can apply TiN, TiCN, TiAlN and AlTiN and other coatings, too. Also, it can apply some of those coatings with monolayer, multilayer, nanogradient, nanolayer and

Inside the machine

THE π^{80} MACHINE CAN create nanocomposite nACo and other coatings via its LARC (lateral rotating ARC-cathodes) technology.

Platit states that LARC technology can use plasma-generating physical vapor deposition to apply coatings to tungsten-carbide cutting tools with greater hardness, wear resistance and heat resistance than other AlTiN coatings.

A LARC-equipped machine features two rotating, cylindrical, water-cooled cathodes that are laterally about 200mm from center to center. Inside the cathodes are coils and permanent magnets for generating a magnetic field. Each cathode's magnetic equipment can rotate independent of the cathode itself.

Before coating, the cathodes and magnetic equipment are rotated and turned on so the cathodes apply their initial AlTiN droplets, usually large particles, against one of the machine's interior walls. At the same time, the workpieces can be cleaned via the machine's plasma.

After the droplets become smaller, the cathodes and magnetic equipment are rotated again so the cathodes apply the AlTiSiN particles to the tools' now-clean surfaces. Simultaneously, the magnetic field controls the deposition rate, with the AlTiN and Si_3N_4 segregating at the tool surface.

Also, the cathodes' and magnetic equipment's movements allow the LARC machine to create a coating with a surface roughness of 0.07µm R_a to 0.15µm R_a.

Besides creating a nanocomposite structure, a LARC machine can contribute to the nACo coating's hardness through its ability to be programmed to create continuously changing nanogradients. For example, when first coating a batch of tools, the machine will apply titanium nitride first for maximum adhesion and then aluminum titanium nitride. As coating progresses, the aluminum content is continuously increased, which increases the coating's hardness, temperature stability and oxidation resistance.

—J.L. Hazelton

nanocomposite structures, and in their combined structures. The machine can coat tool steels at higher than 230° C, HSS at 350° to 500° C and tungsten carbide at 350° to 600° C.

Melin Tool itself used its π^{80} strictly for applying the more traditional coatings during its first 10 months of owning the machine, until this past September. The toolmaker knew it would eventually use the machine to apply the nACo coating, but it wanted to first learn to use the π^{80} for more traditional coatings.

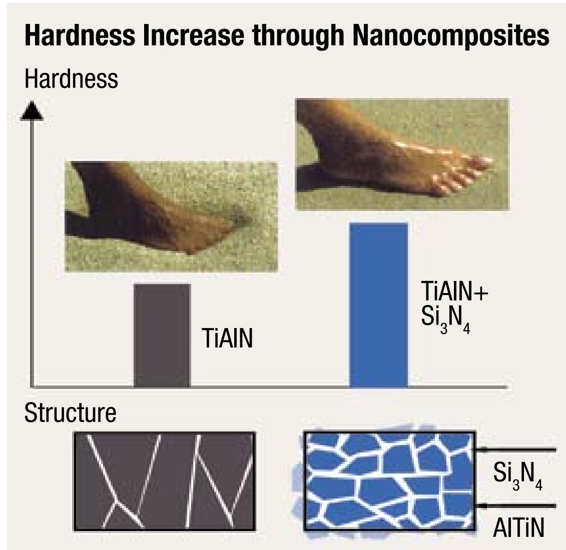
Wochna purchased the π^{80} after researching coating machines via printed literature, the Internet and conversations with coating equipment companies and other toolmakers. Wochna had narrowed the choice to two machines from two companies when he attended IMTS in September 2006, where both companies were exhibiting. After comparing the companies' displayed models, Wochna chose the π^{80} for several reasons, including its ease of use, flexibility and setup and changeover times.

Two months later, Platit installed the coating machine at Melin Tool's factory. By then, the toolmaker was ready with suitable fixturing and a separate clean room for the π^{80} on the shop floor so it could put the machine into production use quickly. After installation, Melin Tool technicians were trained on the π^{80} within a week.

"We have found it to be very flexible," Wochna said. He described the π^{80}'s changeover time as short, saying that the machine can switch between applying three different coatings to three different batches of tools in a 10-hour period. "We usually run three batches per day in one 9-hour shift," Wochna said. "The last batch goes in at end of shift and runs lights out."

Limited Use, A Solution?

However, the nACo coating has a limitation. "It is a brittle coating by nature," Wochna said. "That's probably the biggest limiting factor."



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Like water between sand grains, an amorphous Si_3N_4 matrix fills the spaces between AlTiN grains, making the coating less compressible and therefore harder.

Its brittleness means the coating can crack and flake off a tool's cutting edge. A rigid setup, such as used in high-performance drilling and milling, reduces vibration that can cause a cutting edge to chatter and thereby reduces the chance of cracking and flaking.

Melin Tool's goal is to extend the range of application so nACo can be a more universal coating, like AlTiN is. Specifically, Melin Tool is experimenting with application of a thin layer of AlTiN under a multilayer nACo coating to protect a tool's cutting edge. That way, if the nACo coating cracks and flakes off, the cutting edge will still have a protective coating.

For this multilayer strategy, Melin Tool will need a second π^{80} or a larger Platit machine to apply the AlTiN and nACo layers. With two π^{80} machines,

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Platit

Inside a coating chamber, two vertical, cylindrical cathodes apply the AlTiN grains of the nACo nanocomposite coating. Inside the cathodes are coils and permanent magnets that generate the magnetic field to support the chamber's ionized plasma, which creates the coating's amorphous Si_3N_4 matrix.

the toolmaker would be able to apply the AlTiN layer to one batch in one machine and then transfer the tools to the other machine to receive the nACo layers. With a larger machine, Melin Tool could apply both coatings in the one machine because it would be large enough to contain the nACo cathode and the AlTiN cathode at the same time.

A purchase wouldn't be a problem for Melin Tool because of its already considerable use of its coating machine. "We've kind of outgrown our π^{80} capability," Wochna said, adding that a new machine will be needed probably by summer. CTE

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