HOTSEAT

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You can't open a technical journal or online magazine without someone opining about carburizing, quenching, nitriding, distortion control, and all of the pre- and post-processing required for a successful outcome. But one very important process has a major impact on that success: Machining, or, more specifically, the tools that make removing metal

DECADES AGO THERE WAS ONLY ONE OPTION: High-speed tool steels such as molybdenum types M2, M4, M50, and the tungsten series T15 for example. The best heat treating process for these special tool steels was, at one time, molten salt, because of the precise time required for successful hardening. Due to the large quantity of alloying elements like vanadium, moly, tungsten, chromium, nickel, and titanium in the iron base metal, the soak times at 2200°F [1204°C] for M series tools and 2300°F [1260°C] for T series were very short—three to five minutes. The short time was long enough to allow the iron to transform to austenite or gamma iron because of the high temperature, but not so long that too much of the alloying elements were allowed to go into solution. An alloy-rich gamma iron resulted in too much retained austenite after quenching and not enough undissolved or free carbide to provide wear resistance complementing the martensite matrix.

Eventually vacuum furnaces replaced much of the salt pots, but vacuum processing lacked the precise short-time soak control: Enter metal/ceramic like silicon carbide and more common tungsten carbide inserts and, more recently, CBN [cubic boron nitride] materials have been developed. All of the circular saw blades manufactured today have tungsten carbide teeth inserts brazed to the metal disc. As machining science evolved and computer controls allowed extremely accurate dimension control, new ideas to manage distortion in gears started to emerge and this led to hard turning or hard machining (heat treating the gears first then employing final machining—not to be confused with final grinding). Hard machining has seen the evolution of the metal removal science because of the tremendous heat generated at the tool-metal interface causing a perceived "micro-melting" of the steel and the effort to understand what's actually happening. And even these high-tech tool materials must be heat treated to induce the qualities required.

All of these so-called composite materials start out as powder that must be blended with wax binders to hold the compacted insert's shape prior to sintering. Tungsten carbide inserts consist of tungsten carbide and cobalt particles, plus the binder compressed into the appropriate form that must be sintered to diffuse the particles into a solid form. However, as sintered they still lack the proper density, so hipping or HIP [hot isostatic pressure] is required to complete the process. The other parent of our sister company ALD-Holcroft, ALD Vacuum Technologies, GmpH of Germany manufactures over-pressure sintering or Sinter-HIP furnaces for this process. These furnaces are vacuum furnaces with graphite hot zones and heating elements, but they are also capable of increasing the pressure up to 90-bar [1305 PSI].

Prior to the development of the sinter-hip furnaces, composite inserts were sintered in vacuum furnaces, cooled and removed, and reheated and hipped in a separate autoclave. This process had one major drawback; after hipping, the inserts had what's been dubbed "cobalt lakes," islands of cobalt separating tungsten carbide particles, which lead to increased tool wear. Hipping immediately following the sintering process without cooling the insert drastically reduces the formation of cobalt lakes.

Sinter-HIP furnaces consist of an ASME-designed pressure vessel complying with section eight of the pressure vessel boiler code. The hot zone consists of a circular laminated graphite-felt foil-felt insulation sandwich that's sealed at each end so it can contain the wax vapor during the de-waxing process to remove the binder. Within the inner chamber, or hot zone, graphite heating elements are configured to accommodate the convection characteristics of 90-bar argon.

The sequence of operation consists of rolling the layers of graphite trays of inserts into the vessel on carbon-carbon or carbon composite rollers. Evacuating to about 100 microns (.1 torr) [.133 millibar] and heat to start the dewaxing process. Molten wax drains from the hot zone into a condenser followed by heating the load of inserts to 2400°F to 2600°F [1315° to 1427°C], then increasing the pressure to 90-bar with argon. After the appropriate soak time, the system cools. Hipping compresses the inserts, reducing their volume by 10% to 25%.

When Holcroft manufactured Sinter-HIP furnaces under license from Degussa in the late 80's, I had the opportunity to witness the inspection of a newly-fabricated pressure vessel. The process includes hydrostatically pressurizing the vessel with water to 125% of its working pressure, then 75-bar [1087 PSI].

Standing in a circle, dead quiet around the newly fabricated vessel with a dozen or so engineers and inspectors, "The African Queen" pumped, thumped, and hissed as the needle on the large dial gauge, painfully slow, showed the pressure rising. Suddenly, a pop, then another, then some creaking and I found myself inconspicuously looking to see if anyone else was looking for an exit sign. With false courage, I asked the guy next to me, "What's with the noise?" He said, "That's just the vessel becoming round."

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