Industrial Heating
THE INTERNATIONAL JOURNAL OF THERMAL TECHNOLOGY

Multiple Quench Options Move Low-Pressure Carburizing Closer to Universal Acceptance

Jack Titus – AFC-Holcroft, Wixom, Mich.

Low-pressure vacuum carburizing (LPC) has intrigued the heat-treating industry for 30 years. ALD Holcroft is expanding the application flexibility and market potential for LPC by providing seamless integration of high-pressure gas quenching as well as oil quenching, press quenching and intensive water-quenching capabilities.

Low-pressure vacuum carburizing (LPC) is a legitimate heat treatment that excels at eliminating intergranular oxidization in alloy steels. When used in conjunction with high-pressure gas quenching (HPGQ), LPC can dramatically reduce distortion caused by quench stress when processing precision parts like gears, shafts fabricated from hot-worked die steels, high-speed tool steels and alloy steels. However, there are many LPC applications better supported by oil or water quenching rather than HPGQ. This is why ALD Holcroft, Wixom, Mich., (manufacturer) is expanding its LPC capabilities by offering heat treaters a system with multiple quench options.

ModulTherm® – LPC/HPGQ Treatment System

ALD Holcroft currently markets the LPC/HPGQ systems in North America and NAFTA regions as ModulTherm®, a modular vacuum-based heat-treating system developed by ALD Vacuum Technologies AG of Hanau, Germany – a parent of ALD Holcroft.

ModulTherm is a LPC/HPGQ system designed for higher volume, semi-continuous operation. These systems consist of two to eight linked treatment chambers and a track-mounted vehicle that serves as both a transfer chamber and HPGQ chamber (Fig. 1). This configuration takes advantage of the fact that the LPC/HPGQ process is fast, and it requires only a fraction of the time needed to carburize vacuum-processed parts compared to atmosphere-based carburizing. An advantage of this design is that one quench unit can support multiple treatment chambers. There are significant cost savings associated with having to maintain one HPGQ system versus multiple quench units.

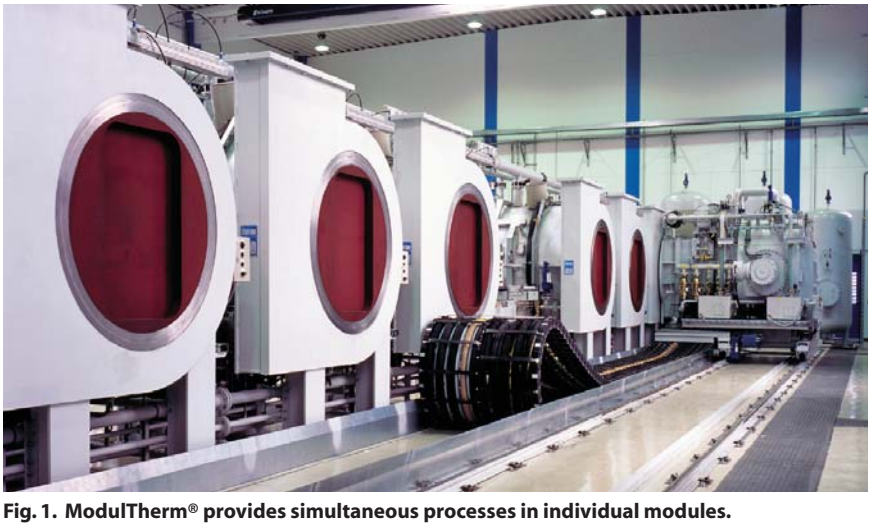

Fig. 1. ModulTherm® provides simultaneous processes in individual modules.

LPC and HPGQ Work Separately and Sometimes Together

Not all components benefiting from LPC require the superior distortion control provided by HPGQ. Likewise, not all parts benefiting from HPGQ require the intergranular-oxidation control associated with LPC (Fig. 2, 3). For example, the 20-bar helium-gas quenching provided by this system is capable of hardening alloy steels with an ideal diameter (DI = 50% martensite in core) as low as 2.5, depending on cross section. It is generally accepted, however, that alloy enhancement may be necessary to achieve acceptable core hardness in some automotive parts and other heavy components. In some cases, holding

Fig. 2. 2,200 pounds of capacity provides greater productivity.

Fig. 3. Even heavy gears can benefit from helium quenching.

the alloy to its upper chemistry limit may be sufficient. Depending on the value of a component, or lack thereof, if the DI is not sufficient for core strength and increasing alloy content is not a cost-effective option, conventional oil quenching may be the only alternative. Heavier, highly stressed gears are another example. Such parts can benefit from the increased fatigue strength provided by LPC. It may not be possible, however, to achieve an acceptable martensitic transformation using HPGQ. So, what is the heat treater to do?

The manufacturer is making the LPC process more flexible by introducing a second version of the system that provides at least three additional quench options. This additional quench flexibility makes LPC suitable for processing small precision gears, shafts and injector nozzles as well as large gears, saw blades and a variety of other components that do not require HPGQ.

ModulTherm® LPC Capabilities Expanded

Three key modifications to the architecture of a ModulTherm® system make it possible to seamlessly integrate any of four quench methods with LPC. The first modification replaces the shuttle-mounted HPGQ chamber used with a standard treatment-chamber arrangement with a shuttle-mounted heated transfer chamber and floor-mounted HPGQ chamber. Instead of bringing a quench chamber to the load, the load is now brought to the quench chamber.

The heated parts' transfer shuttle is equipped with a telescoping transfer fork housed within the open-ended transfer chamber (Fig. 4). The shuttle chamber is designed without graphite components to allow operation from atmosphere to vacuum in air, nitrogen or other atmospheres. This variable-pressure concept provides for multiple surface treatments, resulting in preselected coloration if desired. The hot-zone interior consists of oxidation-resistant radiant tubes and ceramic insulation. Loads can be transferred at carburizing temperature or reduced temperature for gas or oil quenching. Maintainability of the transfer fork is accommodated via the open end of the transfer chamber, allowing full-view access without opening doors or interrupting the carburizing process in any of the LPC treatment chambers. Trays are transferred from the in-feed conveyor to a LPC treatment chamber by the telescoping transfer fork. The heated shuttle is designed to mate and seal against the treatment chamber and all styles of quench modules. It will evacuate and transfer loads under vacuum for the HPGQ or nitrogen for the oil quench, holding chamber or intensive quench. All necessary energy and gas requirements are contained in a compact energy chain or flexible-track system.

Fig. 4. There are no doors or chambers to open to access the lift-and-place material-handling system.

The second modification to the patented LPC system is mounting treatment chambers on both sides of the transfer-shuttle track instead of linking LPC treatment chambers in a straight line. This parallel-line layout is possible because the heated transfer-shuttle vehicle is capable of 180º rotation. This reduces floor-space requirements and allows maximum layout flexibility.

In many generally accepted applications, load weight is limited to 500 Kg (1,100 pounds), ModulTherm's capacity is 1,000 Kg (2,200 pounds). Load volume is 600 mm (24 inch) wide x 1,000 mm (39 inch) long x 750 mm (29.5 inch) high.

The Advantages of HPGQ

The new package offers HPGQ, oil quenching, press quenching and water quenching (Fig. 5). All quench chambers are floor mounted, and they are loaded and unloaded by the heated transfer shuttle. Each quench method offers distinct benefits.

Because gases have only one quenching or heat-transfer phase – convection – there is no progression through different heat-transfer rates. But at high pressure, such as 20 bar (290 psia), the heat-transfer rate of gases has unmatched cooling uniformity. Compared to nitrogen, helium is the preferred quenching media because of its ability to transport five times the heat gained from the load to the heat exchanger. The thermal conductivity of helium also is 5.9 times that of nitrogen. The specific heat of helium is 5.19 J/g K, compared to 1.04 J/g K for nitrogen. The thermal conductivity of helium is 0.00152 w/cm K, compared to 0.000259 w/cm K for nitrogen.

Because helium is so expensive, it must be recovered, cleaned and reused to be economically feasible. At prevailing costs, it is actually less expensive to replace the

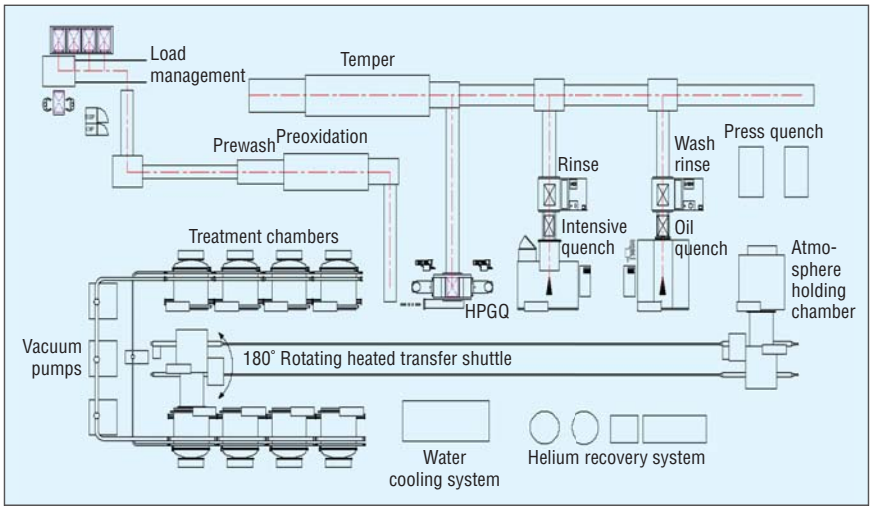

Fig. 5. Every component of an assembly, no matter the quenching requirement, could be heat treated in the versatile quench system.

0.5% helium lost in the recovery process than to discard all of the nitrogen used in a 20-bar quench. At $0.40 per 100 cu. ft., nitrogen will cost about $8.40 per load. Helium, by contrast, at $25 per 100 cu. ft. when recovered at 99.5% will cost about $2.40 per load. The bulk of the helium can be reused and recovered indefinitely.

The Advantages of Oil Quench

In the U.S., oil quenching comprises about 90% of all quenching processes for case-hardened, ferrous metals. Due to its large margin for error, oil quenching will likely be with us for decades to come. It is well known that oil quenching progresses through three phases: a vapor surface layer, boiling at the part surface and convection with boiling, creating the highest heat-transfer rate. It is less well known that the oil-vapor-film phase contributes to the most nonuniform quenching action. Laboratory video studies show that under certain circumstances vapor can be trapped beneath parts and contribute to nonuniform heat-transfer rates. Increased oil agitation can be used to improve heat transfer by disturbing and breaking up the vapor film. And because the load is completely immersed in the quench oil, acceptable heat-transfer rates generally still occur and provide adequate hardness. Thus, the higher the agitation level, the better the quenching uniformity. Because LPC is conducted in the absence of oxygen, the process is ideal for integration with oil quenching. In addition, no explosive endo gas or flame screens are required. This facilitates the move into the manufacturing pipeline.

The Advantages of Press (Oil) Quenching

Although HPGQ seems to be the ideal quenching process for LPC, a relatively small percentage of carburized parts benefit from its advantage. Gears, shafts and similarly shaped parts are ideal candidates for HPGQ. However, they must have a hardenability quotient high enough to obtain the desired microstructure. If the part value justifies the alloy cost, the hardenability can be enhanced to meet the need. However, if the part is too large for gas quenching but can benefit from the time savings offered by LPC plus lack of intergranular oxidation, the flexible-quench system becomes an ideal processing solution. With addition of the atmosphere holding chamber for press quenching, all parts of diverse shapes, sizes and chemistries can be processed simultaneously. The major disadvantage of press quenching is the cost of tooling for individual parts. Development has been under way to address this shortcoming by employing "range tooling," a concept by which many parts share in a common setup.

The Advantages of Water Quenching

IntensiQuench® is a patented water-quenching process licensed by IQ Technologies of Akron, Ohio. This process subjects the surface of quenched parts to compressive versus tensile stress. The result is a fully martensitic case structure with high wear and fatigue strength – as much as the ever-present endo-produced IGO will allow. Specialized software computes the precise time parts are immersed in a highly agitated water quench prior to removing from the water for a predetermined time before final quenching. With correct timing, the heat remaining in the core reheats and tempers the surface martensite, resulting in the compressive stress. The process is especially suited to one-at-a-time part quench, but batch loading can be successfully performed with attention to loading with very uniform and high water velocities. The process is primarily attracting symmetrically shaped parts made from lower-alloy steels. Higher alloys, however, can also benefit from the process. Combined with LPC, intensive quenching can provide parts with extremely high strength and unmatched fatigue resistance.

System Maintainability Without Furnace Shutdown

Like the current ModulTherm®, the new system is designed for easy maintenance. Each treatment chamber and all quench modules can be maintained from the rear of the unit away from the heated transfer shuttle. This allows continuous processing during routine and most unscheduled maintenance tasks. For example, if the telescoping transfer fork requires maintenance, the heated transfer shuttle can be driven to a maintenance position and the unit replaced without interrupting production.

The new multiple-quench LPC system has positive implications for captive and commercial heat-treating operations. In the U.S., as manufacturing moves to "lean itself" or moves back to its core business model, identifying areas for cost reduction is topic number one, and heat treating becomes a candidate for outsourcing. One alternative to outsourcing for captives is to move heat-treating operations closer to machining operations or integrating the process directly into the manufacturing pipeline, thereby improving overall process effectiveness by increasing heat-treating flexibility. Vacuum furnaces, with their low emissions, are well suited to these relocation options. ALD Holcroft's ModulTherm® with multiple-quench options supports this approach. **IH**

For more information: ALD Holcroft Vacuum Technologies Co., Inc., 49630 Pontiac Trail, Wixom, MI 48393-2009; tel: 248-624-8191; fax: 248-624-3710; e-mail: info@ald-holcroft.com; web: www.ald-holcroft.com.

Fig. 6. Production can continue even through routine and many unscheduled maintenance operations.

ALD Holcroft at a Glance

ALD Holcroft Vacuum Technologies Co. is a joint venture of ALD Vacuum Technologies AG, Germany, developers of Modultherm® LPC and HPGQ systems, and AFC-Holcroft, Wixom, Mich. The joint-venture company was formed to further develop and market vacuum heat treatments in North America. ALD Vacuum Technologies has 90 years of vacuum-technology experience with numerous installations worldwide. AFC-Holcroft has 90 years of atmosphere furnace and quenching experience and is one of the world's largest manufacturers of thermal-processing equipment.

Technology Spotlight

ALD-Holcroft

Flexible, Vacuum-Based Heat-Treating Systems Designed for the North American Market

ALD-Holcroft designs and manufactures fully integrated, vacuum-based thermal-processing systems that meet the performance and flexibility requirements of manufacturing and heat-treating companies in the United States, Canada and Mexico. In addition to vacuum chamber furnaces, ALD-Holcroft provides multiple quench options, pre- and post-processing equipment, load storage and retrieval systems, transfer automation, and the computer controls necessary to integrate equipment with upstream and downstream manufacturing operations.

Flexible, Multi-Tasking Capability

The ModulTherm® system is the core of ALD-Holcroft vacuum-processing technology. Equipment can be con-figured for vacuum aging, vacuum annealing, case hardening, through hardening, vacuum nitriding, vacuum normalizing and vacuum sintering, as well as low-pressure carburizing (LPC) with from 2- to 20-bar high-pressure gas quenching (HPGQ). To accommodate the production levels of North American plants, ModulTherm furnaces feature a large, 40-inch-long x 24-inch-wide x 30-inch-high treatment chamber with a 2,200-pound load capacity. In LPC/HPGQ applications, a shuttle-mounted HPGQ chamber supports up to eight ModulTherm vacuum treatment chambers. For greater flexibility, the shuttle-mounted HPGQ chamber is replaced by a heated transfer shuttle (HTS) designed to move loads to multiple floor-mounted quench systems.

Multiple Quench Options

The HTS supports up to 12 ModulTherm treatment chambers with high-pressure gas, oil, press quench holding chambers or water quench systems. It allows operation from atmosphere to vacuum in air, nitrogen or other at-mospheres at carburizing temperature or reduced temperature. This processing flexibility significantly increases equipment utilization levels.

Proven Products and Performance

ALD-Holcroft has the in-house capability to tailor vacuum-based thermal-processing systems to the production requirements and manufacturing practices common to North American automotive, industrial, aerospace and gear-manufacturing facilities. ModulTherm systems also can be tailored to the needs of commercial heat-treating firms. This allows the benefits of LPC/HPGQ to be offered without sacrificing heat treatment and quench flexibility.

The processing options and layout configurations available with a ModulTherm system are unlimited. ALD-Holcroft can provide vacuum furnaces, quench systems, thermal cleaning systems, pre-wash and rinse systems, pre-oxidation systems, batch or continuous tempering furnaces, and work-handling automation for seamless integration with other manufacturing operations.

Turnkey, Single-Supplier Support

ALD-Holcroft is a North American company serving North American manufacturers. It designs, engineers, manufactures and supports every installation on a turnkey, single-supplier basis.

ALD-Holcroft can trace its thermal-processing heritage back to 1916. Its parent companies are ALD Vacuum Technologies AG of Hanau, Germany, and AFC-Holcroft, LLC of Wixom, Mich. ALD is a global leader in vacuum heat-treating and furnace systems. AFC-Holcroft is one of the world's largest manufacturers of atmosphere furnace systems. Both companies have more than 80 years of heat-treating experience.

ALD-Holcroft ModulTherm vacuum furnace systems are available with a shuttle-mounted high-pressure gas quenching chamber or a heated transfer shuttle for moving loads to floor-mounted gas, oil or water quench stations.

For more information on flexible, vacuum-based thermal-processing systems, contact: ALD-Holcroft, 49630 Pontiac Trail, Wixom, MI 48393-2009; phone: 248-668-4130; fax: 248-624-3710; e-mail: sales@ald-holcroft.com; website: www.ald-holcroft.com.