Vacuum carburizing offers shorter cycle times and better quality control compared to traditional heat treat methods (courtesy of Ipsen).

Why Vacuum Carburizing?

HEAT TREAT ALTERNATIVE OFFERS ADVANTAGES OVER CONVENTIONAL METHODS

Matthew Jaster, Associate Editor

While a majority of heat treating in the gear industry is done using conventional atmospheric carburizing methods, vacuum carburizing continues to gain market share due to its reduced process time and more environmentally-friendly technology. In 2010, the focus of vacuum carburizing—also known as low pressure carburizing (LPC)—is the minimization of heat treat distortions, improvement of furnace equipment and the development of high temperature and low temperature techniques. Many companies are increasing the pressure levels of gas quenching and providing multiple quench media within a single furnace or multi-cell system.

"According to different sources, LPC is currently between 10–15 percent of the carburizing market," says

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Rafal Walczak, vacuum furnaces team leader, Seco/Warwick Corp. "Compared with data from 10 years ago when LPC was 1–3 percent of the market, we can see much progress. This growth will continue at the same rate in the future driven by the latest material developments in vacuum carburizing."

"Future growth will reach roughly 30 to 40 percent in the next five to 10 years based on a variety of reasons," says Bill St. Thomas, sales manager at Ipsen. "Rising energy costs, shorter cycle times and better quality control will make electrically heated vacuum furnaces far more attractive than gas fired furnaces. New steel grades are being developed for a variety of industrial markets as well."

Vacuum carburizing is particularly useful for gear applications because parts carburized in vacuum furnaces and quenched in inert gas have fewer deformations compared to traditional technology.

"High velocity, directional flow of quenching gas creates a uniform cooling environment for all parts located through the furnace chamber," Walczak says. "A series of tests with gears, followed by measuring their geometry, showed that there is a trend in deformations after vacuum treatment and high pressure gas quenching (HPGQ). Both direction and level of deformations are repeatable. This allows gear designers to adjust the primary shape in a way which results in minimal tooth deformations after the heat treat process."

For the heat treat of large gears, Walczak says Seco/Warwick supplies double chamber furnaces with oil quenching. "With LPC, such equipment allows for the application of vacuum carburizing technology to steel grades with lower hardenability as well as parts with thick sections, which cannot be positively quenched under gas."

William Gornicki, vice president of sales and marketing at ALD-Holcroft, says vacuum carburizing has gained a significant market share for the new generation of transmissions such as dual clutch (DCT) and six- and eight-speed automated transmissions.

AISI 9310 bevel gear set up for low pressure vacuum carburizing (courtesy of Solar Atmospheres).

"Also, some gear components are assembled directly after heat treat because no hard finishing is needed after vacuum carburizing. There's no intergranular oxidation, no washing after heat treat," Gornicki says. "It's the integration of heat treatment into the manufacturing line."

"Shorter cycle times and far less machining are needed with vacuum," St. Thomas says. "Small gears, dense loads and blind holes are processed with ease versus conventional methods."

The ability to process other higher alloyed materials will allow the gear industry to branch out into more exotic steels that may result in superior mechanical properties, according to Trevor Jones, project engineer at Solar Atmospheres, Inc. Jones adds that there are also advantages to root-to-pitch case depth ratio.

"The root-to-pitch case depth ratio obtained in vacuum carburizing is over 90 percent where conventional carburizing methods is under 70."

Of course these companies don't expect customers to just take their word on each feature or capability in vacuum carburizing. Most market players offer free testing to anyone considering this form of heat treating and will educate customers on the vacuum process and recommend the optimum heat treat to fit specific needs.

"It's a challenge to get the word out to potential customers on the benefits of this process and encourage them to switch from their current conventional carburizing methods," Jones says. "Older specifications often dictate the use of conventional methods and will not allow for vacuum carburizing unless authorized by a qualified engineer."

What might help the cause is the continued push for green technology in manufacturing. Green heat treating is plausible in vacuum carburizing and an easy sell regarding the environmental impact this method has over other forms of heat treating.

"Vacuum carburizing doesn't emit any harmful gases, and most of the furnaces we install have a closed water system to cool the furnace, thus saving clean water," St.

Thomas says.

Jones says from an industry standpoint, vacuum furnaces generally have a smaller carbon footprint on the environment over atmospheric furnaces. "There is a fair amount of antiquated equipment in our industry that consumes more energy than is required because of out-dated control systems."

And the green benefits in heat treating directly correspond with cost benefits, Gornicki adds.

ALD-Holcroft, in fact, is taking new steps to further widen the ecological benefits of its vacuum carburizing systems. "Our new generation furnace systems include energy saving options such as automated start-up and automated shut down procedures. Our furnaces are also equipped with a smart electrical power management system, which avoids unnecessary consumption peaks."

R&D efforts at ALD-Holcroft to minimize heat distortion will lead to lower cycle times, and the development of high temperature vacuum carburizing will lead to lower energy consumption.

ALD-Holcroft furnaces are equipped with energy saving options to promote green manufacturing (courtesy of ALD-Holcroft).

"Both LPC and HPGQ are environmentally friendly technologies," Walczak says. "In the case of FineCarb (*Ed's note: See product spotlight on page 34 for more information*), more than 90 percent of the gas emitted to the atmosphere is hydrogen. Nitrogen and helium used for quenching are also inert gases, which do not pollute our planet."

One area that Solar continues to focus on is the use of electricity. "We're constantly reminding our technicians to turn off equipment if it's not being used. Items such as shop fans, excessive hold times on furnace bake-outs and leaving the diffusion pump on when it is not needed are all items that waste electricity," Jones says. "Our electric bill is by far our most expensive utility due to the fact that all our furnaces are heated via electric graphite heating elements. We have no gas-fired furnaces nor [do we] utilize combustion to heat our customers' parts."

With all of the capabilities in vacuum carburizing, why exactly is the market share so low compared to other heat treating methods?

Price has always been one issue. The initial capital investment costs are much higher in vacuum carburizing than atmospheric carburizing.

"Rather than purchasing a new vacuum carburizing furnace, some heat treaters would prefer to keep their current equipment online," Jones says.

"The biggest challenge, in reference to the gear industry, is overcapacity and the financial situation many gear producers are facing, especially in the North American market," Gornicki says. "High temperature vacuum carburizing is also a challenge. It requires new fine grain stabilized steels to avoid unwanted grain growth during heat treat. However, the availability of these new micro-alloyed steel grades is difficult, especially for gear companies with globally distributed manufacturing sites," Gornicki says.

Another challenge is to comply with CQI-9 regulations without creating unnecessary costs while operating the equipment, Gornicki adds. "CQI-9 was issued by the Automotive Industry Action Group (AIAG), in March 2006, as a specification evaluation for the automotive industry.

"ALD-Holcroft is working on several committees to define practical CQI-9 regulations for vacuum carburizing," Gornicki says.

"Current specifications need revising to allow vacuum carburizing to advance in the industry," Jones says. "The progression in technology of HPGQ has evolved over the last several years to adequately quench certain steels. Outdated drawings, however, will not allow gas quenching because the drawing or specification dictates liquid quenching."

While challenges exist, major markets, including aerospace, automotive, agricultural, wind, mining and commercial

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heat treating, are using vacuum carburizing today and see potential growth in the future. It's an area that will continue to attract attention as more technology unfolds, either as the preferred method or as a complement to atmospheric furnaces.

"Most companies that require heat treating are considering equipment for in-house processing mainly due to high cost of transportation and turnaround time," St. Thomas says. "Vacuum carburizing has many benefits that should be considered in the future."

Product Spotlight

Here's a few of the vacuum carburizing systems currently on the market. For more information on vacuum carburizing, heat treating equipment and services, visit *www.geartechnology.com*.

FineCarb–Seco/Warwick

For almost 10 years, Seco/Warwick has been supplying its FineCarb technology to vacuum systems. This consists of a mixture of gases where the carbon carrier is ethylene and acetylene mixed with hydrogen and ammonia at a specified volume ratio, protected by the patent.

The FineCarb method eliminates negative effects while preserving all qualities that are typical of the particular carbon carriers. This way even, well-formed carburized layers are obtained on all surfaces of workpieces treated, including deep non-through holes, inner and outer gears, preserving a clean surface of the workpieces in question. In addition, the whole process is being accomplished successfully with low industrial gas consumption.

"The need to accelerate the surface layer saturation with carbon was the motivation to continue to develop LPC technology. In spite of the high cost of machinery, the technology became competitive with gas processes due to the speed and repeatability of the cycle. The LPC of steel using FineCarb technology provides carburizing cycles with a shorter cycle time than gas carburizing, with full control and repeatability of the processes," Walczak says.

Additionally, the company provides a simulation software tool called *SimVac*, which determines the carburizing process limits according to specified carbon case parameters. "Results can be printed and attached to the batch report, and the created recipe can be easily transferred. The software has a built in database of steel grades according to different international standards."

ModulTherm 2.0–ALD-Holcroft

ModulTherm is a highly flexible and fully automated concept in vacuum thermal processing technology. It combines three basics into one linked multi-chamber vacuum furnace system: heat treatment, quenching and material handling. The quenching and hot vacuum transfer chambers are integrated into a rail-mounted shuttle module that can service two to 12 or more independent treatment chambers. This modular design makes it easy to adapt the system to meet particular production requirements with direct integration.

ModulTherm has several features and options including high equipment availability, larger volume treatment chambers, 2,200 pound gross load capacity on original system, 7,000 lbs capacity on the new large size, convective heating to reduce cycle times, identical "time-to-quench" for every load and reversible quenching gas flow that improves uniformity and reduces distortion and dynamic quenching. In addition to thermal processing equipment, ALD-Holcroft provides all parts storage and retrieval systems, load transfer automation and computer controls for integration.

Processes include vacuum carburizing, carbonitriding, neutral hardening, normalizing, annealing, spheroidize annealing, stress relieving, vacuum brazing, high purity copper annealing and sintering. ModulTherm has been utilized for drive and axle components, transmission components, shafts, fasteners, precision machine components, castings and forgings, brake lines, hose fittings and tools. The company has developed dozens of configurations compatible with production used by manufacturing and heat treating facilities in the United States, Canada and Mexico.

LPC–Solar Atmospheres

Solar Atmospheres offers "Low Torr Range Vacuum Carburizing" (also known as LPC) for optimum case hardening. The benefits are wear resistant part surfaces with case depth uniformity, maximum case integrity, minimal distortion and clean parts. Solar carburizes in a single chamber with a newly developed *in situ*, gas pressure quenching system. The advantages include reduction in part distortion and precise temperature control, optimal case depths with acetylene gas mixtures. Single chamber carburizing means less part handling for cost effective processing. Metallurgically, this method prevents surface intergranular oxidation (IGO) and decarburization. The avoidance of IGO provides high case integrity for improved wear life compared to traditional carburizing. Additionally, the presence or absence of carbides can be controlled according to specification requirements. The process also produces compressive residual stress for improved fatigue life.

Advantages of this method include, minimal distortion, efficient part handling for improved quality and turnaround, furnaces ranging from lab sizes to six feet long, shorter cycle times for reduced costs, uniform case depth including improved gear root to pitch ratios, automation of specific cycles to insure repeatability, customized cycle development for specific applications and the ability to efficiently carburize blind holes. Because of furnace and processing capability, Solar offers specific cycle development for a range of alloys. New cycles are being developed for new materials and new applications, including powdered metal parts.

Super TurboTreater and TurboTreater–Ipsen

The Ipsen Super TurboTreater is a HPGQ vacuum furnace designed for larger load capacities for the processing of dies, tools and parts with complicated geometries. It's effective for larger, heavier loads with features including multi-directional cooling and isothermal hold functionality, a reliable water-cooled motor to improve hardening performance for heavy loads, convection-assisted heating combined with trademarked Flapper Nozzle technology that reduces cycle time and improves temperature uniformity during heat up and quench speed to allow heat treatment that exceeds the latest GM die block heat treatment specifications.

The Flapper Nozzle, a cooling gas injection port, is simple and reliable. It requires no complex linkage or actuation mechanism. This design reduces heat loss from the hot zone while improving temperature uniformity during heating. Convection heating has been demonstrated to dramatically reduce cycle time, especially for large cross sections or dense loads. These technologies decrease energy consumption, saving both time and money in addition to reducing maintenance worries and expenses.

For hardening, tempering, brazing, sintering, annealing (and AvaC and SolNit) high speed steels, titanium or the latest super alloys, Ipsen delivers fast cycle times and improved workload results with TurboTreater. Features include Ipsen's patented gas quenching system, a compact cooling system design and three zones of heating with Digital Trim control ensure temperature uniformity throughout the hot zone.

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