Heat Treating 4.0

Bringing Mature Technology into the 21st Century

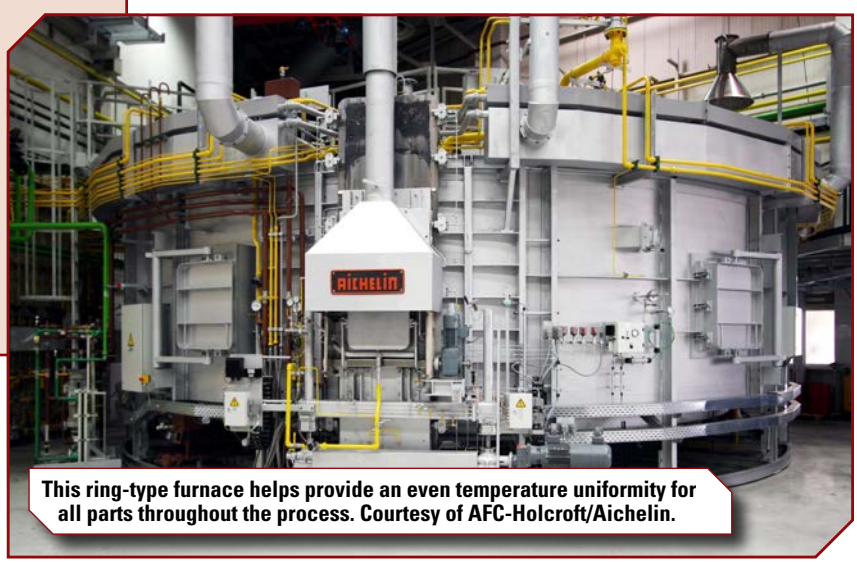
Randy Stott, Managing Editor

The basic concept of heat treating has been around for a long, long time. And even though the technologies have changed considerably, and even though our understanding of the various processes continues to improve, many in our industry still view heat treating as something of a black art.

You take great care cutting your parts to spec. Then you send them out to heat treat, close your eyes, cross your fingers and hope for the best, right?

Well, not so fast. Suppliers are working hard to make sure their equipment is controllable, repeatable and efficient, and manufacturers continue to incorporate technology that gives heat treaters—and their customers—more information about what's going on inside the magic box.

We interviewed several of the leading equipment suppliers for heat treating gears, in order to give our readers a feel for how the technology is changing. Participating in the interview were William "Bill" Disler, president and CEO of AFC-Holcroft; Anne Miner, sales and marketing manager for Diablo Furnaces; Dennis Beauchesne, general manager for ECM USA; Jim Grann, senior technical manager for Ipsen; Aymeric Goldsteinas, product development manager for Ipsen; and Janusz Kowelewski, director of business development for Ipsen's ARGOS brand.



This ring-type furnace helps provide an even temperature uniformity for all parts throughout the process. Courtesy of AFC-Holcroft/Aichelin.

What are the most significant recent advances in heat treating technology for gears?

(ECM-USA) — "Recent" is to be defined. If you are looking at the last 15 years, than you have to point to low pressure vacuum carburizing and high pressure gas quenching, as it has dominated the automotive industry for high production systems. However, if you are talking about the last year or two, this technology is such that it is now bringing products to the market that offer "in-line" heat treating. This subject is bringing the world of heat treating into the reality of processing smaller loads to customers on an in-line basis. Low pressure carburizing, while utilizing higher temperatures and lower processing times, can satisfy the high demand for in-line processing by supplying completely heat treated gears at the speed of associated machining with very little work-in-process.

(Ipsen) — There is a growing share of low-pressure carburizing (LPC) technology for heat-treating gears. One such LPC technology is our AvaC process (acetylene vacuum carburizing), which produces excellent carbon transfer into the parts, thus helping ensure extremely homogenous carburizing – even for complex geometries and high load densities. Ipsen has also developed new technology for multi-chamber LPC: the ARGOS heat-treating system. This vacuum furnace represents a significant milestone in the growing trend to operate LPC lines in combination with inert gas quenching. One of its many benefits is that it provides enhanced temperature uniformity throughout the hot zone, resulting in minimal part distortion.

(AFC-Holcroft) — Although there has been considerable focus regarding low pressure carburizing and gas quench processes for smaller gears throughout the last decade, we have seen a significant increase in manufacturer interest in alternative technologies. Over time, as many users have become more experienced with these technologies, concerns regarding cost and the ability to reliably deploy this technology in evolving markets as needed to be part of a true global bill of process seem to have become more common conversation points. Many gear manufacturers justified the added cost of LPC and gas quench with the assumption that hard machining would be totally eliminated. Since in most situations this is not the case today, the overall cost-to-benefit model takes on a new look. We see considerably more interest in alternative methods of achieving the results needed to meet the strength and distortion objectives of the gear manufacturers. One specific area that has significantly renewed interest is quenching in salt. Although salt has an old-school, dirty image, the reality is that new processing methods make salt a viable alternative that provides single-phase quench benefits like gas but with superior heat

transfer. It is arguably the best quench solution available when it comes to gears, and salt can be 99% recovered. It is much less expensive than gas quench and more forgiving, hence better for evolving markets, and much safer and more environmentally friendly than oil. As manufacturers package heat treat equipment in new ways to handle salt cleanly, it continues to gain attention.

(Diablo) — Although we only concentrate in atmospheric technology, the advancement of one-piece flow allows us to process small batch sizes, while keeping a continuous product-flow between soft-machining, heat treatment and hard-machining.

How are heat treating equipment providers adopting Industry 4.0?

(AFC-Holcroft) — In my opinion, heat treat equipment manufacturers tend to be much slower moving on the higher tech side of things than many other industries such as automation and machine tools. Some heat treat equipment suppliers seem to be engaging with new ideas, while others seem slow moving in this area. Within AFC-Holcroft and the Aichelin Group we have many progressive activities in motion. Our equipment now provides much higher fault diagnostic data than ever before via new networking tools and technology. We also provide a cloud service for our customers where equipment events and fault data are automatically retrieved from furnace equipment and then filtered and organized to provide high-level reports to help our engineers improve our equipment as well as help our customers improve how they operate it. Pareto charts indicating top downtime offenders and mean-time-to-repair become powerful tools and are automatically generated for customers on each piece of equipment monitored. This is only part of our initiative to provide advanced services to our customers via our web-based, secure customer portal. As we continue to better utilize the advanced fault data that is avavilble on devices, such as VFD drives, our web service tools will become more and more powerful. We have the foundation blocks in place and the pyramid is growing.

(Diablo) — Requests for smart industrial ovens and furnaces occur regularly with new equipment quotations. From our standpoint, the ability to control and monitor the heat treating equipment remotely through dial in from engineer or operator is a feature being built into our controls for safety and ease of monitoring productivity. Alerts can be e-mailed or texted, and reviewed and remedied on-line based on the situation. A robust PM operating manual on-line with intuitive questions and answers guides an operator to debug and solve a problem prior to calling an OEM service technician.

(Ipsen) — As Industry 4.0 and other digital technologies continue to grow and advance, we have begun to see the development of heat-treating systems that can manage process variables, enhance productivity and optimize heat treatment operations. Here at Ipsen, our *PdMetrics* software platform for predictive maintenance uses the Internet of Things (IoT) and Big Data to optimize equipment performance and production efficiency. The *PdMetrics* platform securely connects to a network of integrated sensors on your furnace to gather data, run algorithms and provide real-time diagnostics that help improve the health and integrity of your equipment. Overall, the adoption of Industry 4.0 can decrease the cost of heat treatment, as well as improve safety and production efficiency.

(ECM-USA) — Industry 4.0 is nothing new to heat treating equipment, as many manufacturers have provided systems that can monitor and maintain themselves as well as feed key information to other processes downstream. It allows gear manufacturers to have better understanding and control of the process parameters used in heat treating the precision gears produced today. All high production low pressure vacuum carburizing systems in use today in capacity automotive plants have the ability to interact with other portions of the assembly lines and maintenance personnel on that line.

How has heat treating equipment changed to adapt to smaller batch sizes?

(AFC-Holcroft) — Heat Treat equipment has always had the ability to run smaller batch size loads. In the past, the issue has been that the smaller the batch size load, the more expensive it is to heat treat. This has not changed. Depending on the mix of production, any number of technologies can be scaled to larger or smaller load sizes. A smaller load size tends to be easier to quench if the quench media has limited heat transfer rates, such as gas. Having said that, I think that most people have forgotten some of the basics with heat treating in batch loads vs. continuous operations as they relate to uniformity and quality. The simplest way to look at this is to consider carburizing. Carbon diffuses into steel at a rate that is very dependent on temperature, regardless of LPC or conventional process. In fact, for every 100°F increase in carburizing temperature, the time needed to reach a desired case depth is cut in half. Consider, then, a small batch load in a furnace with a temperature uniformity spec of +/- 10°F. That means from one corner of a load to the other you could have up to a 20°F total temperature spread and be within the furnace specifications. In a batch process, the load never moves, so you will definitely have parts throughout the load carburizing at different rates. The effect of 20°F on carburizing case depth at a given cycle time can be verified via simple calculation or via published charts. I believe that it will surprise many people how significant this can be. In a continuous system, or the Ring Furnace system that is becoming much more popular in Europe, the temperature uniformity of the furnace will be the same but the load is moving throughout the process. This means that the load never sees the same non-uniformities of the furnace for very long. The continuous movement though a non-batch system provides a self-averaging effect that ultimately leads to parts having much tighter temperature uniformity throughout the carburizing process. So although small batch loads are desirable to many, to others who process

larger volumes, I suggest looking closely at the alternatives. With batch equipment it is also important to look beyond the standard temperature uniformity specification that all suppliers offer – in addition, ask to see temperature uniformity survey (TUS) results from installed equipment. Some equipment may survey at much tighter uniformity, providing it is maintained properly.

(ECM-USA) — In the last few years, the ECM Nano furnace has been developed to adapt smaller batch sizes. This design allows for smaller loads with much better part-to-part deviation for case depth, core hardness and distortion results. This system uses a 20-bar high pressure gas quench system that is very efficient in quenching most steels used in carburizing. This allows the customer to provide small batch sizes based on their production runs. The system can be turned on and off like a CNC and can also be maintained on the fly by a method where half the system can be shut down and the other half can maintain processing gears or parts.

How has heat treating equipment changed to bring the process closer to the manufacturing cell?

(AFC-Holcroft) — The movement to LPC and gas quench has allowed equipment to be nested into manufacturing areas. The clean aspects of the equipment make this more viable than with older style equipment. The equipment is also perceived to be safe to install in the middle of a manufacturing floor; however some recent events with vacuum and pressure vessels have prompted a few more questions in this area. Everyone is interested in smaller, cell-compatible units, but real-world challenges may be difficult to overcome. Heat treat equipment is different than other machines in cells such as gear cutting machines, automation and washers. The mean-time-to-repair (MTR) is much longer due to the internal temperature that the equipment operates at. Not that we plan on equipment failing, but if it does, then cell manufacturing requires short MTR since the entire work cell is down when any part of the cell faults. The time it takes to cool a system furnace to gain access, assess problems and do the repair is going to be a difficult part of this cellular equation of needed uptime availability. True repair and maintenance numbers may be difficult to achieve, or manufacturers may have to decide to accept slightly lower cell uptime in trade for the integration of the heat treat. I think that it will be interesting to see companies explore the benefits and downsides of bringing heat treat into cellular manufacturing. It is very desirable, but the basic nature of the processes may make this solution costly and complicated. We are watching the evolution closely and exploring options within our group.

(Ipsen) — The development of a one-piece flow concept with better traceability allows production to be organized according to the cell manufacturing principle. The ARGOS heat-treating system, for example, is a multicell system with a modular structure and software flexibility that makes it adaptable to a variety of plant configurations and changing production processes. The multi-chamber ARGOS furnace line also offers several distinct opera-

tional advantages in manufacturing. With synchronized movement between each process and real-time sensors implemented in each process stage, the intermediate buffers between heat treatment operations can be eliminated and the transfer of loads between different modules (e.g., washing, carburizing, hardening, tempering) can be monitored.

(ECM-USA) — Over the last 20 years, low pressure vacuum carburizing has done just that. In many automotive and some aerospace plants, the heat treat is lost in the sea of CNC machines on the open floor. This helps with lean manufacturing flow, and the furnaces can be dedicated to particular gear manufacturing cells. The heat treat cells can be validated or de-validated as needed for daily heat treating capacity. It is no longer necessary to keep a long pusher furnace running 24/7 in the back corner of a building to shuttle parts to and from the machining cells and have to keep it running for 365 days a year.

What is the next thing coming in terms of heat treating technology?

(AFC-Holcroft) — Hybrid solutions.

(Diablo) — From our standpoint, the ability to control and monitor the heat treating equipment remotely through dial-in from engineer or operator has been a large request. The other key aspect of these furnaces is safety due to oil deployment for cooling, and ensuring that safeties and alarms are deployed in every major component of the furnace.

(ECM-USA) — The next thing is here with the ECM Nano in-line processing system. This is where the future of heat treating is going. Processing parts in-line at the speeds of your machining cells is the new requirement in the industry. The industry can no longer sustain the large batching of parts, as this is a costly process with so much work in progress waiting to be heat treated. In addition to the in-line versatility, the process gives precise case depths, load after load, along with reduced distortion through the possibility of gas quenching. This is the future.

(Ipsen) — We will see better materials with improved hardenability and lower quenching pressure requirements. We will also continue to see the development of advanced, innovative heat-treating systems, such as the ARGOS multicell system and the ATLAS atmosphere furnace. In addition, with the increased focus on connectivity and integrating heat-treating equipment with Industry 4.0, we will continue to see new digital technologies emerge. Take our *PdMetrics* predictive maintenance software platform, for example. This innovative system utilizes the Internet of Things (IoT) to provide real-time monitoring and diagnostics. Yet we are continuing to push the boundaries of what is possible by incorporating augmented reality into the platform, transforming the way operators experience their equipment and perform maintenance.

What are the biggest concerns gear manufacturers have about bringing heat treating in-house?

(Ipsen) — The biggest concerns gear manufacturers tend to have about bringing heat treatment in house are the availability of skilled workers and the logistics of heat treatment. To help address these concerns, we offer comprehensive training both on-site at Ipsen U and at customers' facilities. This three-day course provides attendees with a broad, hands-on overview of furnace equipment, processes and maintenance. Our *VacuProf* controls software on our heat-treating systems also allows a user without any special prior knowledge to select the correct process for the type of steel to be treated. The user simply needs to enter the characteristics of the steel, the load geometry and a few other details, such as desired hardness or the heating and quenching characteristics. The *VacuProf Expert* software will then recommend a possible heat treatment recipe for the entered material.

(ECM-USA) — Mostly, safety, operating costs and maintenance of the equipment are of the main concerns for the gear manufacturer bringing heat treating in house. However, the most decisive reason to bring heat treating in-house is to have control over the timing of the parts to be processed. Transportation costs run a hard second to this aspect. Looking back over the years, the only solution was to have a furnace that used a flame curtain and had to be watched by an employee 24/7. With the latest equipment supplying low pressure vacuum carburizing and high pressure gas quenching, the safety concerns are minimized. This technology doesn't require these systems to be monitored 24/7, nor do they require open flames as flame curtains did. In addition, in most cases, the advancements made in high pressure gas quenching and the advancements in quenching capabilities of modern steel products, allow the use of gas as the quenching media. This provides a much safer, cleaner and much more capable of distortion control. Overall, the combination of low pressure carburizing and high pressure gas quenching makes perfect sense for the gear manufacturer to bring heat treating in-house now. The systems

The ATLAS line of furnaces help boost efficiency with intelligent controls. Courtesy of Ipsen.

can be shut off on the weekends and can be idled over holidays with no risk of explosion or need of supervision. The lack of oil quenching provides a clean installation, and the parts are clean as well. The smaller "in-line" system also lend themselves to be the stepping stone for gear manufacturers to start slowly with smaller product to begin with while allowing for optimum control of heat treat design specifications such as tighter case depths and core hardness control.

(Diablo) — The cost of the equipment and talent to maintain it. Diablo Furnaces is manufacturing equipment at a lower price point. Efficiencies are gained with newer methodologies and savvier approaches. Working on a team level basis, all employees have value and input to mitigate costs and waste.

(AFC-Holcroft) — I believe that some are concerned about having the expertise to support the equipment, as it tends to be much different than other traditional gear machining equipment. Providing manufacturers select a strong supplier of heat treat equipment, I believe that the support that manufacturers can provide can significantly lessen the risks and concerns. In addition, with many of the new automation and process monitoring tools such as those described above, the old world of heat treat equipment has changed considerably. We have deep engineering and support capabilities within our global group. We have to make our customers successful. Our future depends on it.

Do you have anything else to add regarding the technology of heat treating gears?

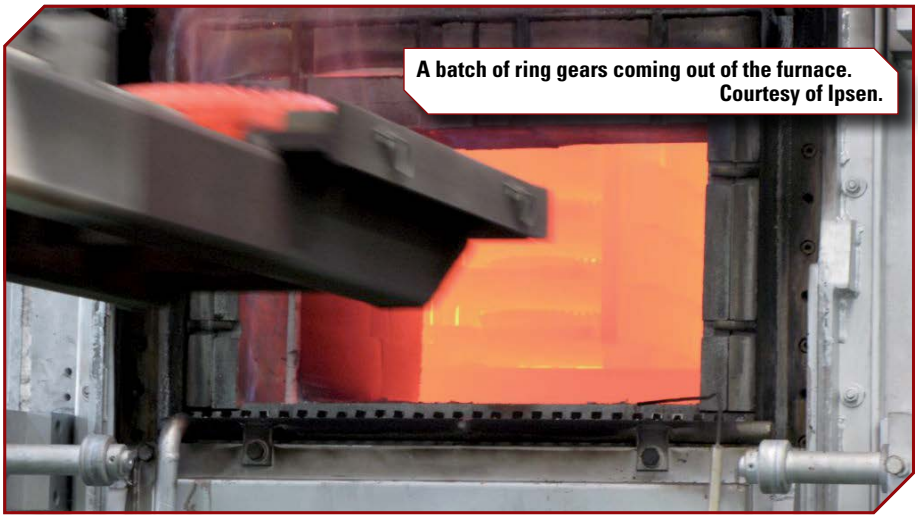
(AFC-Holcroft) — There are many alternatives and methods to optimize the heat treatment of gears. It is not one-type-fits-all. Our group provides a large range of equipment for heat treating everything from windmill gears to gears for Swiss watches and everything in between. I suggest that everyone take the time to evaluate all their options and seek advice from the many quality heat treat equipment suppliers in the marketplace. The right supplier can openly discuss the options that are best for each unique situation. Suppliers with experience in the full range of process alternatives will be the most objective. Often you may have to weigh the pros and cons of multiple solutions, but always take the time to evaluate your options.

(Diablo) — Nowadays, all heat treatment technologies have incorporated modern controls. This in turn offered opportunities for gear design and manufacturing engineers to specify more precision heat treat requirements without added cost, be it hardness range, carburizing depth, timing, or other specs.

(Ipsen) — According to a recent study, there will be tremendous consolidation in the gear industry. This trend is connected with consolidation in the car industry and changing customer evaluations of car utility. The cost of gear heat treatment will influence who will be a survivor of this consolidation. Ipsen's *PdMetrics* software platform is key to lowering the cost of operation by analyzing per-

formance and efficiency and minimizing unplanned downtime. As the gear industry looks at heat treatment, they should consider not just the physical equipment design, but process cost, connectivity and repeatability.

(ECM-USA) — Heat treating gears has come a long way even in the last 10 years with the advance of higher hardenibilty steels and the use of high pressure gas quenching. It's no longer the smoky, soot riddled oily floor, wear your lucky shirt industry. Reducing distortion and making stronger gears are always at the center of gear manufacturing, and that is what low pressure vacuum carburizing has brought to heat treating of gears. Heat treating is not only about the furnace system and how it works for you, but it starts with the design and processing of the material at the design level. Annealing, heat up rates and fixturing are all aspects of the heat treating process that are mostly overlooked and yet these are critical items for gear manufacturers.



A batch of ring gears coming out of the furnace. Courtesy of Ipsen.

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