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Heat Treat Today

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We take a look inside the automotive heat treat industry.

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Nitrocarburizing for Automotive and Large-Volume Production

By Mark Hemsath

Conventional wisdom says that batch processing is for smaller volumes. Anytime large volumes of 1 million or more parts per year are envisioned, for instance with ferritic nitrocarburizing, the go-to technology is a roller hearth or other continuous system like rotary retort or mesh belt furnace. Mark Hemsath urges end-users and engineers who use, or specify, continuous systems to not undervalue automated batch processing for large volume production.

There are a number of trends in the automotive arena:

- More parts are being light-weighted. This means they need more precise and repeatable heat treating.
- Parts need to be cheaper and lighter. The trend we see are increased and more sophisticated stampings.
- The trend is away from carbonitriding and toward ferritic nitrocarburizing due to less distortion on lighter parts.
- Gears and such are smaller and require exact carburizing, minimized quench distortions, and less hard machining.

A deep discussion of all of these is beyond this article, but we will touch on each as we focus on nitrocarburizing for large-volume production.

Batch v. Continuous

What is the difference between a classic "batch" furnace and a classic "continuous" furnace? The answer is material handling. By definition, heat treating is a "batch" operation. In virtually all instances, the product must be brought to temperature and held—or "soaked"—for a specific time. Ferritic nitrocarburizing is no different. This ramp heat, hold, and cool is a "batch". Thus, virtually all heat treating is batch and only the material handling is the difference. The basic difference is that in batch we move the product in its cold state and heat it in one place (batch). In continuous furnaces, we move it while it is heating.

Advances in Material Handling

Advanced, fully automated, and reliable material handling has made great advances over the last two decades from more recent industries like Amazon, where millions of packages need to be moved through the shipping process, to older industries like heat treating which moves steel parts through furnaces and other equipment. Automation, such as conveyors with self-driven rollers and photo sensors or proximity switches, or robots and automated self-guided vehicles—all coordinated by a PLC—have made material handling more reliable. Manufacturers have a lot of options.

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A continuous furnace like a roller conveyor—or "roller hearth"—furnace conveys the product while it is heating (Figures 1, 5 & 8). A mesh belt furnace conveys parts while heating, and a rotary retort furnace (Figure 4) moves parts via a heated rotating barrel to the next process step which is typically cooling or quenching. Moving parts while hot is a challenge, but reliable high volume heat treating is why these furnaces have seen such success over the years. Roller furnaces and rotary retort furnaces are still built and used in a wide variety of industries, and they make sense for a number of reasons. Lower energy use is one main factor.

With robots placing the load, both batch and continuous processes can be fully automated. With such options batch processing has increased in use.

Figure 1: Roller hearth conveyor furnace with heating section, cooling tunnel and after cooling. Note the right angle turn via automatic conveyors to meet space requirements.

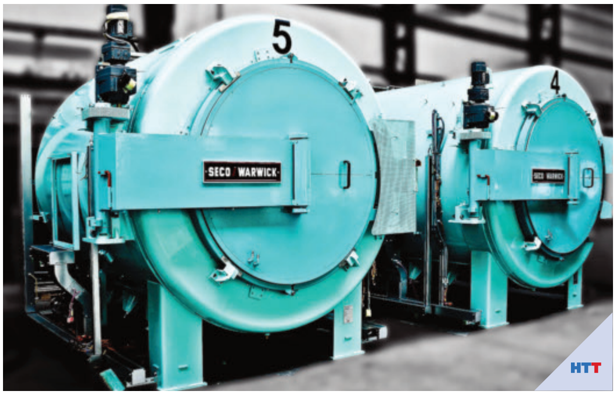

Figure 2: The doors have actuators for automatic opening.

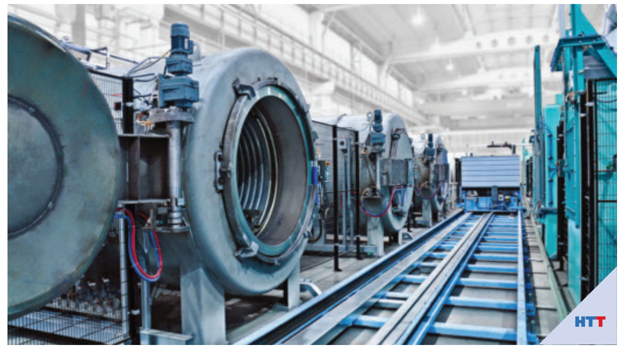

Figure 3: This line consisted of pre-oxidizing ovens on one side to save time in the more expensive FNC furnaces. Cooling stations after heating are also added to reduce time in the batch furnace and make the parts safe for handling.

Automated Batch

A leading manufacturer of heat treating furnaces has implemented the high volume automation approach many times using batch technologies. In 2013, a fully automated batch FNC installation for gears was installed for processing 1 million gears annually[1]. As a result of this success, the customer added more batch furnaces to the line.

The furnaces in Figures 2 and 3 are retort-based nitriding and ferritic nitrocarburizing furnaces. With automatically opening doors, complete PLC control, and automated batch load movement, no humans are needed. A load car operates in both directions for a heavy load of two metric tons or more, allowing furnaces to be placed facing each other.

> "The take-away from this successful project is that in order to increase production even more, automated batch systems need to exhibit two factors to compete with a continuous system..."

Automated, High-Volume System Design

As mentioned, the company supplied nitrocarburizing technology using its ZeroFlow™ method (Figures 2 and 3) for an automated thermal treatment line for the production of a variety of gears. The line consisted of six large, front-loaded retort-style batch furnaces, a four-chamber vacuum washer, two ovens for pre-activation in air, additional post-cooling of the furnace charges, and an automatic robotic loader/unloader, which ensured charge transport within the system (seen in Figure 3). The automated line also included safety monitoring. System workload dimensions were 32" wide x 32" high x 60" long with a gross workload capacity of 4,400 pounds. Production totaled 2,000 pounds of gears per hour. Good equipment design, retort technology, and use of ZeroFlow control technology resulted in a very successful project.

Cooling the Load and Vacuum Purging

There are advantages to continuous furnaces like a conventional roller hearth furnace; however, special options like fast cooling and vacuum purging present challenges to these conventional furnace designs. In batch, this is usually not a problem. Vacuum (and even cooling) is more difficult to attempt in continuous variations due to sealing challenges in the chamber designs. An example of a good solution is the rotary retort furnace shown in Figure 4, which offers single piece quenching where each piece falls into a water or oil quench and is "whirled-away," a continuous furnace design which works well for small parts with a relatively small footprint. In batch, the whole load needs to be quenched together; this can present challenges that understanding the part needs and configurations can lead the process engineer to different solutions.

In a roller furnace, slow cooling means the furnace gets longer (Figure 1).

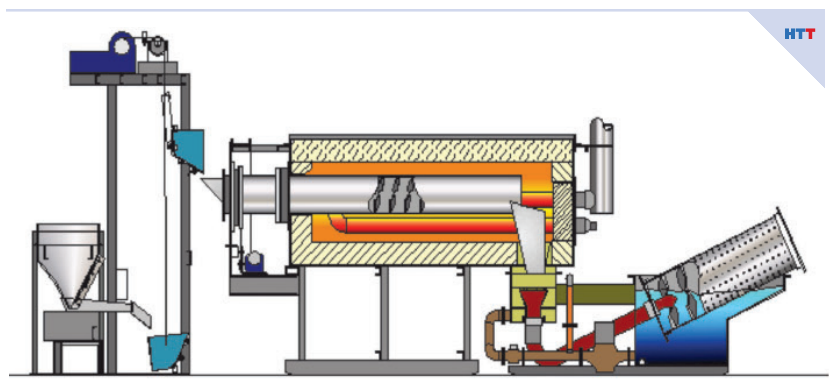

Figure 4: Whirl-Away Quench on a Rotary Retort line for small part efficient quenching/cooling.

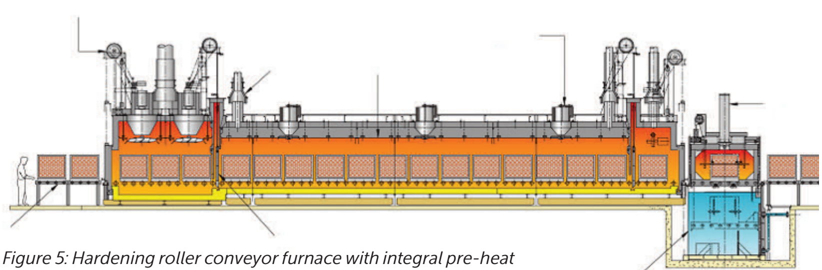

Figure 5: Hardening roller conveyor furnace with integral pre-heat and oil quench system

Figure 6: This automated batch line is for low pressure carburizing and vacuum hardening, with oil quench, automated washer, and batch temper furnace. The smart loader makes the cell fully automated.

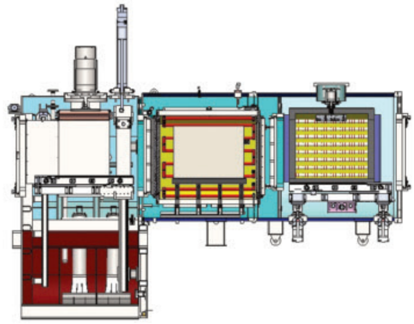

Figure 7: Triple chamber vacuum hardening line with oil quench and pre-heat chamber. Tray flow is right to left.

Figure 8: Cooling tunnel and exit of continuous roller hearth furnace for instrument transformer electrical steels annealing.

Variations in Continuous Batch – Semi-Continuous Processing

In Figure 6, an automated batch hardening line is shown. In Figure 7, the same process is shown, but with an added pre-heat chamber to allow faster processing via the pre-heat and use the single quench in a more productive manner. An oil quench is an expensive piece of equipment. The cycles are also always much shorter for quenching than heating, so we want to maximize the use of the quench. In a pure batch system, you need one quench per furnace. In the semi-continuous approach, the quench is used more frequently and there is higher productivity per capital dollar invested. In a roller hearth or rotary retort installation, the quench can be properly sized to handle all of the heating production. In an installation using pure batch systems, there might be 3 to 6 quench tanks. In a fully continuous roller furnace, there would be one quench (see Figure 5).

Case History and Take-Aways

The automated batch system referred to in Figures 2 and 3 went online in 2014 and is currently operating at full capacity, while meeting the stringent requirements of the automotive industry. It achieved the planned production goal of 1 million gears per year with 99% process reliability and 98% equipment availability. The customer previously had a continuous conventional pusher furnace. The new line achieved an 80% reduction in the consumption of ammonia from that consumed using in the pusher furnace to nitrocarburize. Endothermic gas was also eliminated by the supply of a new methanol CO generator as the carbon source in the process.[1]

The take-away from this successful project is that in order to increase production even more, automated batch systems need to exhibit two factors to compete with a continuous system like a roller hearth furnace. First, the loads need to be optimized and very densely packed. Second, the batch loads need to be larger than the continuous loads. A standard size of 40" x 40" x 60" has since been created which has 50% more volume than the unit in the example above. Making the furnace a bit larger is not that difficult. Additionally, in a recent application, CFC tooling has been utilized to assure more dense loading geometry with much lighter parts, giving reliable rack geometry for a load of 1,000 pieces.

Gas Usage – Benefit Batch

The biggest advantage of batch furnaces is the lower process gas usage. In continuous furnaces, in order to keep the process safe and clean, pressure must be maintained by flowing a significant volume of gases. With the constant opening of doors during the process and the need to keep operating pressures high enough to prevent air infiltration, atmoshpere gas usage is always high. To keep the costs down, gases are typically generated with the use of an endothermic generator (40% Nitrogen, 40% Hydrogen, and 20% CO) or a lean exothermic generator with a low dewpoint. In all instances, the generator is another piece of thermal equipment to maintain and purchase.

Energy Costs – Benefit Continuous

In most instances, batch processing uses more energy—or more expensive energy—such as electricity. Electricity costs can vary tremendously from location to location whereas natural gas prices are more consistent and lower. Batch nitriding furnaces are available in gas-fired heating options at an added capital cost. However, the batch process still uses more energy per pound. If electricity is available at a reasonable rate, then the difference is not as great on a per pound basis. In a recent analysis, it was estimated that an electrically heated batch system came to cost the equivalent of about $0.06 per pound of FNC operating costs, versus $0.03 per pound of FNC operating costs in a continuous gas-fired variation (energy and consumables only).

SUMMARY

Batch or continuous in large volume scenarios is no longer a clear-cut answer. Your heat treating professional and your furnace suppliers should understand this. There are literally dozens of variables that need to be assessed, and only after a careful analysis tailored for each customer can an optimized solution be designed with either batch or continuous furnace solutions. HTT

NOTES

1. Hemsath et al, "Nitrocarburizing Gears using the ZeroFlow Method in Large-Volume Production", *Thermal Processing*, 10/2015

About the Author:

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