FASTENINGTECH

PROCESSING is your last line of defense

by Peter Hushek, President, Phoenix Heat Treating, Inc.

They say if you always do what you've always done, you'll always get what you've always got.

Apply this reasoning to fastener manufacturing, and you'll need to ask yourself these questions: Are my heat treating methods keeping up with the technological advances in processing that will allow our company to hold tighter tolerances? Is my current heat treater providing us with greater ability to achieve repeatable performance, remain cost competitive and have access to all the data that backs up all our heat treating?

For example, if your customers still consider a wide hardness spread of 36-43 HRC on your heat treated fasteners acceptable, maybe you should consider closing that spread to 38-40 HRC to prevent failures from hardness, which may be related to chemistry that is slightly below specs. Two points on Rockwell hardness will result in a heat treatment process that will greatly improve fastener surface strength, which can prevent premature failure due to a lack of quality control over the processing sequence. It won't cost you any more if you're using automated processing. And since processing is your last line of defense against part failure, wouldn't you rather provide your customers with processing certification that guarantees that case hardening, tempering and quenching is spot-on for every lot you deliver?

What process certification means to you

Maybe you're thinking that your heat treating is acceptable, and you have nothing to worry about since automated processing hasn't caught up with your company yet. Maybe you believe that your current processing methods provide a sufficiently controlled sequence of events that will meet end-user specs. But in reality, you can't see case hardening like you can see thread run-out, so how do you know for certain you're receiving uniformity from lot to lot? Your fasteners can meet ASTM and ANSI in part design, wall thickness, head height, thread pitch, fillet radius, etc., and still fail. No longer can you assume that a thorough process of part design, production, quality control and testing will guard you, when processing is the lynchpin of final quality. Many fastener manufacturers are still reluctant to add automated processing to their quality production wares. But we routinely process parts for fastener companies who are now including the type of steel, furnace temperatures and specification for chemistry and/or hardenability in their production criteria before the stock steel is purchased.

Since my family has been in the heat treating and metal processing business for four generations, I am fortunate to have an extensive window of history from which to draw. I see where heat treating has come from and have a clear view of where it's going. For this reason, I can tell you with confidence that in the next few years, fastener manufacturing quality will hinge on automated heat treating, both batch and continuous processing. The fastener industry can no longer afford the labor and risk involved in manual heat treating. Manual processing may have enough leeway in the process procedures to allow different operators on different shifts to add their "experience" to the processing, therefore inducing variation within a single lot of parts. A heat treat assurance program that includes a focus on programmed cycles can produce greater repeatability and real-time monitoring of the heat treating cycles with metallurgical certification. In my observation, that is in the future for the fastener industry.

Process automation and fastener failure

As increasing levels of technology are integrated into fastener manufacturing, many quality control steps that were omitted due to increasing labor costs and manual operation expenses are now being managed through automation. It's the same in the heat treating industry. Complex functions that were unachievable in process control or were too costly to implement just a few years ago are now available, much sought after and less costly. Today, automated control of the entire heat treating process guarantees temperature ramp rates, atmosphere control and soak times for each step in the entire heat treating process. These individual steps can be input into data loggers to meet your customer's parameters and will return precisely the same metallurgical results every time. Digital data is much easier to audit on the fly from a desktop computer instead of walking the floor, which breaks normal workflows and expends time.

In the fastener business, carburizing (which increases the surface carbon to make the surface structure harder than the core) is typically required to produce stronger parts that will greatly reduce fatigue strength of the fastener. And decarburization (which makes the surface softer than the core) will reduce fatigue performance (see Figure 1). With automated heat treating, computerized modeling and programmable control systems, tight target-value specifications can be controlled for every fastener you manufacture. The internal furnace sensors are backed up by analysis of calibration data, again reviewed and audited digitally for accuracy, along with an array of new generation calibration tools. There's no need to take risks when you can provide proof that the process has been performed to meet the required specifications at no additional cost to the customer. In our industry, these standards include ISO, Nadcap, AMS, CQI-9 and AMS-H-6875 (DOD).

Intelligent heat treating

In manufacturing, the conventional quality triangle (Figure 2) includes processes, systems and equipment. The symbiotic relationship of these entities to each other is difficult to manage using manual systems. When equipment is automated, more continuity is achieved in manufacturing, which results in better quality. However, true quality is not achieved as long

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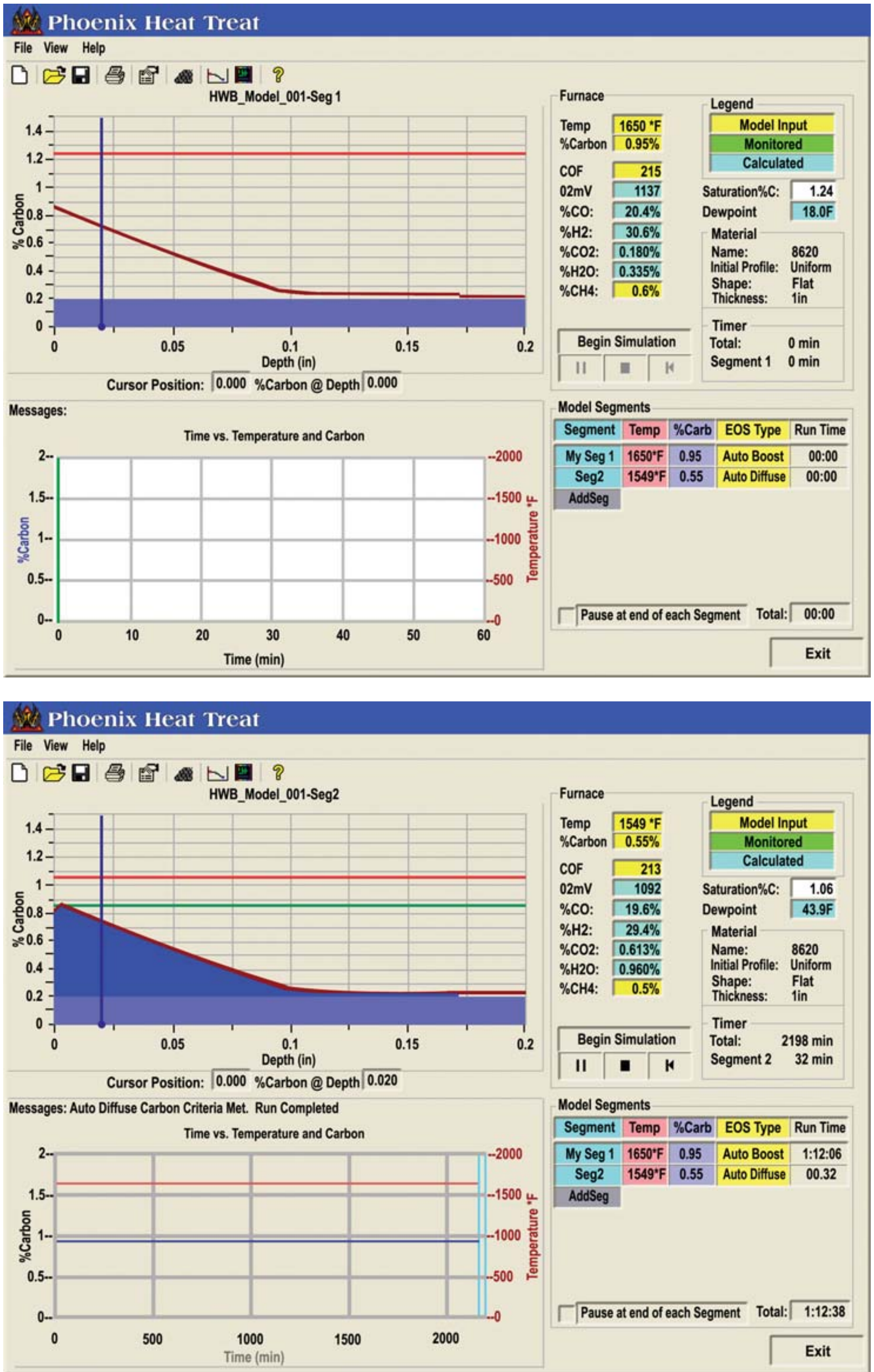

Figure 1. Super Systems, Inc. CarbCALC software used on carburize and carbonitriding cycles. The process cycles can be customized to meet the material chemistry of your parts. Verification of every step in the processing cycle is time-stamped and recorded.

Consider these advanced features compared to manual processing

CarbCALC II automated processing ensures:

- **computer-aided design of heat treatment processes;**
- **optimization of existing cycles;**
- **"what if" analysis when a change in an existing process or material is contemplated;**
- **reconstruction of the effects that an out-of-control process may have had on a load;**
- **education of personnel in the intricacies of atmosphere processing; and**
- **real-time monitoring with an online process.**

as the human element is still involved in controlling some of the processes, equipment or systems. Remove human intervention and you can achieve true quality. That being said, if your current manufacturing processes, equipment and systems are automated, then you can't afford to be without automated processing.

The technically driven triangle (Figure 3) represents achievement of true quality through three separate and distinct performance triangles that are intricately related to each other to achieve uniformity. The quality yield derived from this model grows exponentially in all areas of plant operation. With automated verification, system reporting and robust information to interpret, you get answers and information feedback, not guesswork. In fact, the machines do the thinking and reporting. In the case of the heat treating uniformity triangle, metallurgy sits at the top, where everything is defined and from where process automation flows. The paradox of the quest for uniformity in this model: If you don't know the metallurgy of the metal you are purchasing for manufacturing, processing uniformity and quality can be affected. Predictable uniformity throughout the heat treating process is what I call "intelligent heat treating."

Processing of explosion bolts

PROBLEM: The need for uniformity of mechanical properties in the processing of explosion bolts used in missile defense manufacturing is critical if they are to function properly (see Figure 4). A simple solution would be to machine the bolts from PH stainless steel, precipitation harden, then tensile test and repeat as many times as necessary to fine-tune a process to meet the required ultimate tensile strength properties. But this solution is not suitable in that the process would have to be repeated with every new lot of bolts, resulting in a compromising lack of uniformity. The root cause of the problem is there are always inherent stresses built into stock steel purchased from a mill. Knowing in advance of manufacturing that varying stress in your virgin steel can lead to poor uniformity in processing can prevent disastrous results. These stresses must be eliminated before any processing is attempted.

SOLUTION: Relieving stress in virgin steel can be accomplished through re-solution treating in a uniform manner to achieve a more uniform response to the process and the required mechanical properties. The quality and tightness of the specification range of the mechanical properties can then be identified through processing simulation and control software to turn an out-of-control situation into furnace operation uniformity, repeatability of cycles and quality inspection. With recipes stored in the customer's electronic files, there are no further processing variations from lot to lot of manufactured bolts. The goal was to meet 10 ksi UTS range on PH steels; our final spread

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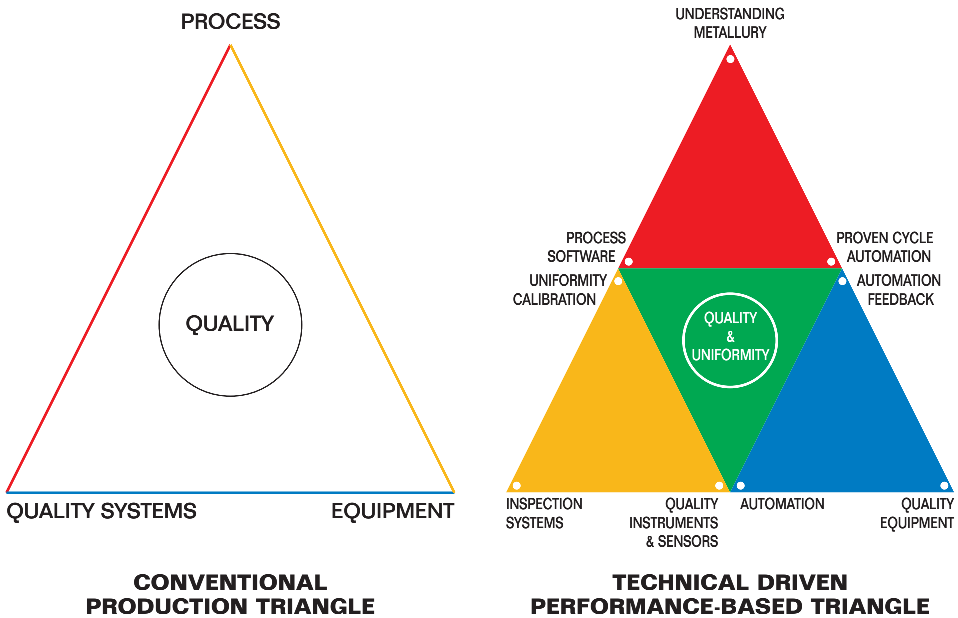

Figure 2 & 3. Performance triangles showing a conventional production system compared to the technically optimized performance production system that includes information throughput to achieve uniformity.

Figure 4. PH steel explosion bolts were stress relieved in +/- F uniformity and re-solution treated in a uniform manner to achieve the required mechanical properties. The spacing of the bolts on the heat treating rack is well-defined.

Figure 5. Example of stacked baskets containing 4037 cold-head cap screws for heat treating. Notice the screws are spread out and stacked in layers to reduce density and improve response to quench.

over three tensile tests was 4 KSI UTS, 60 percent tighter than required.

4037 cold-head cap screws, re-defining a process

PROBLEM: The volumes required by market demands often push processing from continuous belt furnaces to batch furnaces as demand levels change. Certainly, the uniformity of the quench is critical, but thread size differences and the resulting amount of surface area compared to total weight load can cause the heat treat response to the parts to vary outside acceptable ranges. Quality consistency is necessary and can be very problematic, so how should processing be prescribed?

SOLUTION: Load sizes and load density should be based on the total amount of exposed surface area, rather than using weight as the only criteria (Figure 5). Also, it's necessary to determine hardening times based on an extensive examination of uniformity of the loads. Extra hardness inspection in the 'as-quenched' condition will identify flaws in soak times and load density. Standardized hardening cycles, the uniformity of load and density (even to the point of determining the total weight of individual layers in the load specified on the work order), and quench through temperature and agitation will allow for tighten tolerances to be achieved.

Shallow case hardened fasteners

PROBLEM: A customer asked us to fix some screws that required shallow case hardening. The case depth spread from a previous heat treater was way outside the customer's specifications, and the case hardness was totally unacceptable. The customer was in a jam, the heat treater was unable to resolve the problem, and re-ordering material to begin the manufacturing process over was out of the question.

SOLUTION: We asked the customer to send us the bad product and material specifications and then went to work. We discovered there were most likely a combination of issues that resulted in unacceptable case hardening and hardness spread. This includes non-uniformity issues in the load density, varying furnace temperatures, incorrect atmospheres, and quench problems. To determine the extent of non-uniformity, samples were mounted, and process-modeling software was used to reverse the previous heat treating through controlled decarburization. We verified through lab microhardness and metallurgraphic examination that the fasteners were back to their virgin state, and then we used the modeling software again to verify correct carburizing cycles based on meeting the chemistry specified in the certification. The range was easily obtained for case depth and hardness, and the customer was pleased they dodged a bullet of dissatisfaction from their customer.

All heat treaters desire to do the right thing. But if their knowledge, systems and processes are out of sync or outdated, true quality in processing and uniformity will not be achieved consistently. Conversely, the use of information-based automation will vastly improve heat treating and metal processing; that is, as long every step in the heat treating process of your fasteners is clearly defined and perfected to assure the end-user of reliable fastener performance. ■

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Peter Hushek's roots in heat treating span four family generations. His company, Phoenix Heat Treating, Inc. is located in Phoenix, Arizona, and is currently one of the largest and leading heat treating companies in the southwest. The company provides heat treating services for manufacturers of fasteners of all types, including fasteners used in military and aerospace applications. For information, visit www.phoenix-heat-treating.com, or call 602.258.7751.