Heat Treating Fasteners — Part 1: *Tips of the Trade*

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In Part 1 of this latest installment of the Heat Treating Fastener series, the authors provide advice on the full gamut of thermal processing for fasteners.

Tip 1: Know the Steelmaking Process

In selecting the type of steel, attention should be given to the deoxidation practice for the grades used for fastener manufacturing. A number of factors should be considered such as heat treated property requirements, heat treat conditions, fastener size and steel availability, to name a few.

Silicon, for example acts as a ferrite strengthener and therefore in the absence of aluminum, produces steel with somewhat greater hardenability. Silicon killed steel tends to have coarse (large) austenitic grains. For the same carbon grade and heat treatment conditions with and without aluminum, complete transformation of the fastener core during heat treatment can take place in a larger section using a coarse grain steel. Silicon killed, fine grain has both silicon added as the deoxidizer followed by the addition of aluminum for grain size control.

Austenitic grain size is not usually a factor for consideration in cold forming, but has a significant effect in subsequent fastener heat treatment. Aluminum not only deoxidizes the steel, but also refines the grain size (aluminum killed steel). Aluminum also reacts with nitrogen in the steel to form aluminum nitride particles that precipitate both at the grain boundaries and within the austenitic grains thus restricting the size of the grains; even when the steel is reheated for carburizing or neutral hardening, hence the term fine grain.

In the two types where silicon is added, the silicon content can have several ranges with the most common being 0.15% to 0.30%. When aluminum is added to these steels for grain size control, the aluminum content is generally in the 0.015% to 0.030% range. The aluminum content in fully aluminum killed steels is generally 0.015% to 0.055%, somewhat higher on average since the aluminum must both deoxidize and control grain size at the same time.

The disadvantage of silicon killed steels is reduced ductility and tool life during cold heading because of its ferrite strengthening characteristic. Aluminum killed steels are usually more formable and hence provide somewhat improved tool life (e.g., heading operations), but show reduced heat treat response, particularly in larger size fasteners. For this reason, the recommended maximum diameter for oil quenched aluminum killed carbon grades is typically 4.8 mm (0.190").

Tip 2: Pay Attention to Material Chemistry

Certain alloying elements have a strong influence on both the response to heat treatment and the ability of the fastener to perform its intended function. One such element is boron that in a composition range of 0.0005% to 0.003% is a common addition to fastener steels. It is extremely effective as a hardening agent and impacts hardenability. It does not adversely affect the formability or machinability. Boron permits the use of lower carbon content steels with improved formability and machinability.

During the steelmaking process, failure to tie up the free nitrogen results in the formation of boron nitrides that will prevent the boron from being available for hardening. Titanium and/or aluminum are added for this purpose. Therefore, it is important that the mill carefully control the titanium/nitrogen ratio. Both titanium and aluminum tend to reduce machinability of the steel. However, the formability typically improves. Boron content in excess of 0.003% has a detrimental effect on impact strength due to grain boundary precipitation.

In addition, trace element chemistry is an important consideration since these tramp elements (e.g., titanium, niobium and aluminum) may retard carburization.

Tip 3: Control the Annealing Process

Spheroidize annealing is an important step in the cold forming process for fasteners as it ensures that the microstructure of the steel is soft and has maximum formability. Since the fastener manufacturer does not often do this process, be sure to specify and check on a routine basis the level of spheroidiza-

Strict control of the fastener heat treating process is essential.

tion required. In spheroidize annealing, the cementite layers are caused by time and temperature to collapse into spheroids or globules. This globular form of cementite tends to facilitate cold deformation in such processes as cold heading, cold rolling, forming and bending.

Tip 4: Remove Excess Residues and Coatings Present on Parts

Phosphate coatings (e.g., zinc, manganese) present on many fasteners from the thread rolling process have been reported to cause problems in which fasteners clump or fuse together or even melt at austenitizing temperature. In general, unless phosphates are present in large quantities, they do not cause furnace issues although there is a potential to alter the furnace atmosphere. Zinc phosphate, for example will begin to deteriorate staring at 105°C (225°F) a temperature typically found in the entry vestibule of most furnaces.

Residue Tips are as follows:

- Inspect thread areas for residues, fines (metal particles) or the presence of abnormally high levels of lubricants.
- Visually inspect for excessive amounts of sooting or spotty surface appearance on the fasteners, especially in the thread areas.
- Check the operation of the first zone of a continuous furnace (e.g., temperature drop, smoking) to ensure it is handling the residue load without impacting the remainder of the furnace.
- Inspect the entrance end of the furnace for deposits (e.g., zinc vapors leave a whitish residue).
- Monitor carbon dioxide (CO_2) and carbon monoxide (CO) levels in the furnace atmosphere via a three-gas analyzer when phosphate coated parts are run. Watch for spikes in carbon dioxide levels that may indicate that the phosphate coating is decomposing and reacting with carbon monoxide.

Tip 5: Clean and Dry Parts

Many fastener operations heat treat poorly cleaned parts. While most heat treat processes can tolerate wet or oily parts, especially with respect to atmosphere control, this is no excuse for not taking the time to understand how to better clean your parts.

Cleaning is simply moving contaminants from where they are not wanted (on the parts) to where they should be (in the waste disposal system). The process parameters that are important for cleaning are the application of time, temperature, chemistry and energy so as to remove contamination from the surface of a part to a level appropriate for the intended application. If all four aspects of the cleaning process are not working together, the parts will not be properly cleaned. Although heat treating of fasteners demands only a moderate level of cleanliness compared to many industries, contamination left on parts can cause significant problems in our equipment (e.g., atmosphere variability, deterioration of internal components) and on the parts themselves (e.g., shallow or irregular case depths, spotty hardness).

All cleaning systems depend on one or a combination of three basic actions:

- A physical action, that is, a mechanical force such as spray agitation, dunking, ultrasonics or even hand (abrasive) cleaning, to remove the contaminants from the part surface.
- A thermal action to improve the activity of the cleaning solution and increase the kinetic energy of the system.
- A chemical action to allow contaminants to be either desorbed from the part surfaces with the aid of surface active agents or dissolved by an action of absorption and dilution.

Fasteners should be cleaned prior to heat treatment.

Aqueous cleaning is the dominant approach used in our industry. Its simplicity, ease of use and overall flexibility is what makes it an attractive process. Aqueous cleaning uses detergents to lift contaminants from the surface of the parts, heat to make the detergents more compatible with the contaminants and to soften them, fluid force to dislodge the contaminants from the parts and to collect the insoluble contaminants in some removal systems and time to allow the process to take effect.

However, aqueous cleaning is not perfect as it often leaves a surface residue or "film" on the parts that may interfere with the case hardening process. Aqueous cleaners don't dry well especially in continuous systems, which is why wet and/or oily fasteners often wind up entering the furnace. Also, the solutions are difficult to keep clean, oils tend to emulsify and redeposit on the parts. Threaded areas may be susceptible to buildup of residues. Finally, aqueous cleaners evaporate slowly, requiring large amounts of energy to dry them.

Cleaning Tips are as follows:

- Know how clean you need to be so as not to disrupt the heat treating process or damage the heat treating equipment.
- If you currently own cleaning equipment, spend your time (and money) making sure the system is well maintained, operating properly and is performing up to expectation.
- Measure your cleaning effectiveness constantly to ensure the system is not degrading. If you are using an aqueous system, invest in a good oil skimmer. Be sure it is well maintained and operates consistently the same over time.
- Don't re-contaminate clean parts.
- Clean the cleaning equipment thoroughly and often. Replace the bath on a routine basis and don't try to extend its life.
- Do all cleaning, rinsing and drying at as low a temperature as practical. Balance process efficiency and cost of cleaning.

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- If possible, rinse the parts thoroughly. Rinsing is needed to separate the dirty chemistry from the more pure chemistry. The benefits of a good rinse should not be underestimated.
- Dry the parts thoroughly. Drying is separation of parts from pure cleaning agent. Dry only to the extent necessary and consider nonevaporative methods of separating the cleaning agent from the parts.
- Recognize that the average life expectancy of a cleaning system is only three to five years. Replace your equipment regularly to keep the cleaning process working at optimum efficiency.
- If you are considering the purchase of a new cleaning system, narrow the choices to one or two suppliers using published information and referrals, then witness a cleaning trial on your parts by the supplier you most prefer. Understand that your time is best spent making the selection work.

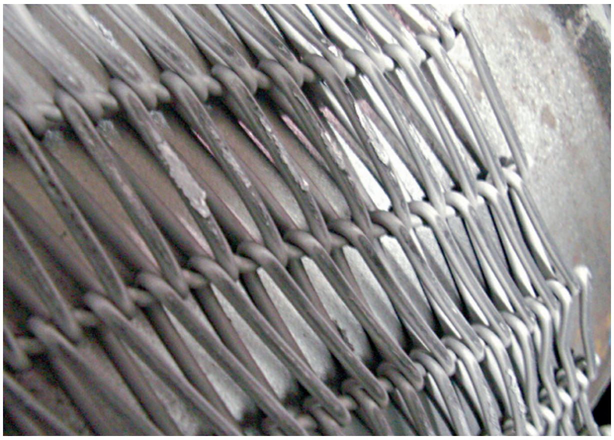
Tip 6: Don't Overload The Belt

When operating a mesh belt conveyor furnace, the goal should be to maintain a consistent temperature profile and uniform belt loading for any given part number over time. Premature or abnormally short belt life is often signs of overloading, misapplication, abuse or neglect. It is not uncommon to find mesh belts used in carburizing or carbonitriding fasteners lasting anywhere from six to 18 months and hardening (only) belts up to 24 months.

Belt Tips are as follows:

- Know your belt speed by actually timing the belt movement. Do not assume it is what is stated in the instruction manual or what is displayed on a digital indicator. Calibrate the speed control (typically a magnetic or inductive pickup device) as often as your temperature instruments.
- Determine your belt loading over time. Improperly adjusted vibratory feed systems and weigh scales that do not read correctly are two of the most common causes for improper loading of furnace belts. Load as uniformly as possibly to evenly distribute wear across the bottom of the belt and help to prevent camber and other belt distortion problems.
- Avoid using skid plates or belt guide rollers to help belt tracking. These items tend to do more harm than good. Where skid plates must be used consider coating them with laminated plastic strips. Observe the motion of the belt, it should be smooth, not jerky and maintain a consistent speed and tracking over time. Remember, a metal mesh belt has flexibility along its length, semi-rigidity across its width and rigidity in its thickness.
- Work with your equipment or belt suppliers to select a belt weave and belt alloy best suited for your process and parts. Be aware that some belts using heavier wire or larger cross rods actually decrease furnace throughput. Avoid upturned edge belts whenever possible.
- Flip and/or reverse the belt at frequent internals as signs of wear or camber become evident. Only flip and reverse the belt when the belt is sufficiently flexible to ensure that reversing of the belt does not create a fatigue problem. Keep the belt clean (free of oxidation and scale) by running it under protective atmosphere above 760°C (1400°F).

Heat treatment system belt conditions should be checked regularly.



- Be sure that the belt is properly supported over its length. Watch for signs of premature belt failure such as abnormal distortion of the cross rods, flat spots, deterioration of belt edges, contamination/buildup of foreign residue and tracking problems.
- Check the tension on the belt frequently or as dictated by production usage. Some systems rely on springs to maintain tension, so check their length. Other systems rely on cylinders so check that plant air pressure does not fluctuate significantly.
- Have your belt drive system analyzed by a furnace manufacturer or belt company at least once a year.
- Keep loading consistent. Fasteners are often loaded on the belt in such a way as to leave space along the edges to prevent parts from moving off the edges.
- Understand that maintenance is different between front end drive systems with pinch and tangential rolls (for tracking) and rear end drive systems with only pinch rolls.

Tip 7: Avoid Mixed Parts/Contaminated Lots

Mixing of fasteners during heat treatment is commonplace. Avoidance and understanding of where fasteners tend to "hang-up" in the system is perhaps the best strategy to combat this problem.

Separation Tips are as follows:

- Leave adequate gaps (10 to 20 minutes) between different sized fasteners and different part/lot numbers.

- Clean out quench tanks after each lot has exited the furnace. Often operators use magnets mounted on poles to retrieve fasteners from quench or rinse tanks.
- During maintenance shutdowns drain all tanks (pre and post washers, quench and dip tanks) and inspect where parts are accumulating. Not only remove these parts from all areas but implement solutions to keep parts from gathering in these areas.
- Use separator screens after the quench and after the temper to segregate fasteners by size.
- Remove stragglers from the system by off line visual or size sort means.

Tip 8: Prevent Thread Damage and Bent Parts

In bulk mass production situations, thread damage can come from a variety of sources, most commonly due to improper handling especially as tubs are dumped into loading/vibratory conveyance machinery and at the pre-wash station when fasteners are still soft. It is not uncommon for an operator to clear jams by using metal rods, to employ shovels or steel rakes to smooth out loading on a mesh belt. Improperly used, thread damage is inevitable.

In some instances fasteners falling or tumbling down a quench chute will strike the sides of the chute or even a refractory ledge or hit a deflector plate at the bottom of the chute causing deformation while they are in a plastic condition. It has also been reported that fasteners striking the flights on the quench tank unload belt in a poorly designed quench system contributed to thread damage.

It is not uncommon to find bent fasteners when the length-to-diameter ratio exceeds 12. In these instances, fasteners must be straightened after processing. Fine threading might best be done after heat treatment.

Tips for Avoiding Thread Damage are as follows:

- Watch the loading operation 24/7 to identify potential sources of damage to the fastener size being run.
- Issue clear instructions to operating personnel on what is and is not allowed when loads jam.
- Understand the quench chute design and look for potential problems with hot parts striking objects in this area.
- Take advantage of maintenance down time on the equipment to look for areas where parts would naturally "hang up" and eliminate these areas.
- Reduce loading as the length-to-diameter ratio becomes greater than 10.

Tip 9: Sample Preparation

Checking the results of the heat treatment operation in a production environment is challenging. Proper preparation of sample mounts is critical in that one often finds the placement of multiple fasteners in a single mount necessary.

Tips for Proper Sample Preparation are as follows:

- Don't let the shear volume of samples or speed at which they need to be prepared catch you unprepared. Do not sacrifice quality for expediency.
- Wet grind fasteners prior to placement into the mount. Extreme care must be taken to avoid burning (tempering back) the surfaces. Often fasteners are held by pliers or other gripping devices so be sure to apply even, steady pressure on a wet grinder. Excessive sparking or discoloration of the surfaces are a clear indication that surfaces have gotten too hot.

Proper sample preparation is vital in checking heat treat results.

- Macroetch with 2% to 3% nital prior to mounting to check for grinding burns and to look for uniformity of case (if case hardening).
- Do not overload the mount. Mounts with too many fasteners tend to bulge or have rounded surfaces making grinding/polishing difficult and producing scratched or poorly prepared surfaces. Some fasteners in crowed mounts invariably are too close to the edge of the mount to be adequately prepared or considered representative parts. Be sure to use the right size mount for the job.
- Use both proper grinding/polishing materials and the proper sequence/number of steps so as to eliminate scratches from all surfaces. Do not compromise quality for speed.
- Microhardness test using proper load. Too often near surface or shallow case depths are measured using 500 gf loads when it is inappropriate to do so (remember the "diving board" effect - as you approach the edge with too heavy a load, deflection occurs and reading is erroneous).
- Etch lightly first to reveal pattern irregularities and to estimate total case depth.
- Look at the microstructure as well as the case depth both at 100X and higher (400X to 1000X) after proper etching.
- Record results on permanent forms or in computer databases.
- Retain sample mounts for the appropriate length of time (typically one to five years).

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Article Series: This article is the fifth in a series on the subject of heat treating fasteners. Future topics will include: Common Fastener Problems; Hydrogen Embrittlement