HOTSEAT

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Each part of the heat treat process requires the parts to be arranged for maximum productivity and quality.

ONE OF THE MANY THINGS I ASK when evaluating a company's heat treating requirements is how they plan on dealing with material handling. As I've said in previous columns, a furnace is an insulated box with a material handling system. What type of handling system they need depends on many considerations such as:

- Is production continuous or intermittent?
- How many gears per week, month, or year are required?
- Is distortion an issue?
- How are gears transported to the heat treat cell?
- Where do the gears go after heat treating?
- If a wash is required, does the pre-wash solution contain potential carburizing stop-off chemicals?
- Is a preheat or pre-oxidation required?
- Will the gears be stored requiring a rust preventative?
- What floor space is planned?
- How much automation is required?
- Is the project going to be installed in stages so critical production can be accommodated?

There are many more questions, but I'm sure you're getting the picture: Each process requires the parts to be arranged for maximum productivity and quality.

Let's say 1,500,000 gears are required annually by the ACME Gear Inc. (no relation to any real company) and the application requires critical distortion control for some gears while other drivetrain parts like pinions and small side gears can be normally quenched. The case hardened strength and core hardness min/max range for all parts can be accommodated any of three ways:

1. LPC-HPGQ (low pressure carburizing - high pressure gas quench) with 20 bar helium—a batch process.
2. Pusher furnace with endo gas atmosphere with traditional quench tank and a multi-head press quench system, a continuous and modified one-at-a-time process.
3. Gas nitriding—a batch process.

The queried items above leave out one important parameter: Material and its cost.

Three different steel grades offer the most suitable outcome for each case hardening process, two require higher alloy: For HPGQ to be effective in achieving the proper [tooth] core hardness, the steel must have adequate hardenability to achieve the appropriate core hardness. Grades such as 20MnCr5 [1.7147/4820] are popular because manganese [1.10% to 1.40%] and chromium [1.00% to 1.30%] are less costly and provide the same hardenability as the more expensive alloys containing Ni, Cr, and Moly. Nitriding, because the parts are held between 535°C and 550°C [995°F and 1022°F] for extended periods, necessitates higher alloy content to preserve its core hardness at these elevated temperatures. Steel such as 4140H [.37% to .44% C, .65% to 1.00% Mn, .75% to 1.20% Cr, 0.15% to .25% Mo] is a common nitriding steel. Conversely, where endo carburizing and oil and press quenching is the process, much lower alloy and more massive gears can be processed due to the very fast quench speeds.

Automotive or passenger car automatic and manual transmissions, generally speaking, do not require deep case hardening, since they're not intended nor designed for high load carrying applications, such as heavy hauling Kenworth tractors. Consequently, an effective case depth [ECD] of 0.014" [.35 mm] is all that's required. However, fatigue, sliding, and pitting wear does enter the gear designer's objectives.

1,500,000 gears are required per year, with equipment operating at 7,466 hours annually [85% of 365 days x 24 hrs.]; this equals 200 gears processed per hour. Now let's consider the cycle required for each of the above examples:

1. LPC-HPGQ, 135 gears, 1.8 Lbs. [.8 Kg] each, per load, 6" [152 mm] dia. X 2" [50 mm] high, requires four [4] treatment chambers, one HPGQ system, electric heated pre-oxidation and temper furnaces; ECD, 0.35mm [0.014"].

Process Cycle for carburizing and HPGQ including 700°F [371°C] continuous pre-oxidation and 350°F [177°C] continuous temper:

- Load, evacuate, convection and vacuum heat [1.8 hrs.]
- Carburize/diffuse at 1700°F [927°C], for 30 minutes
- Transfer load to the HPGQ [20 bar helium]
- Total time in a carburizing chamber = 2.3 hours
- Quench time which takes about 25 minutes and overlaps carburizing is not considered on the critical time path.

Operating cost for the cycle above based on the following utility cost: Helium, $0.1950/SCF; Nitrogen, $0.0025/SCF; Electricity, $0.0550/Kw; Acetylene, $0.12/SCF.

- Cost per part = $0.247. Helium consumption is based on recovering 95% of that used for each quench.

2. Gas Nitrider [gas heat], 1725 4140H gears per load, 19.5 hours per cycle. Per the production and available hours above, 2.26, or three (3) nitriders are required to achieve .25 mm ECD at 40 HRC. Example shown is for case depth for higher speed gears. Gears for low speed requiring higher strength thus deeper case will require longer time thus more nitriders to meet production.

Process cycle consists of the following:

- Pre-oxidize in separate furnace, two (2) hrs.
- Heat nitrider to 545°C [1013°F], 4 hours
- Nitride, at 545°C [1013°F], 11 hrs.
- Cool to 100° [212°F] 3.5 hrs.

Operating cost for the cycle above based on the following utility cost: Ammonia, $0.0299/SCF; Nitrogen, $0.0025/SCF; Natural gas, $0.0045/SCF; Electricity, $0.055/Kw.

- Cost per part = $0.023

3. Pusher furnace [one row, 23 trays, three zones] gas fired, five (5) radiant tubes, gas fired post wash & temper, 18 gears per tray, six (6) per layer, 410 gears total in the furnace. ECD, 0.35mm [0.014"]. Total of 2.04 hrs. in the hot zone, 5.38 minutes between pushes [11.16 pushes/hr.].

Process cycle consists of the following:

- Load & heat zone 1 to 1700°F [927°C], 0.75 hrs.
- Endo carburize zone 2, 1.10 hrs.
- Diffuse zone 3, 0.16 hrs.
- Transfer to sequential three station multi-head press quench system.
- Continuous Wash & temper

Operating cost for the cycle above based on the following utility cost: Natural gas, $0.0045/SCF; Electricity, $0.055/Kw.

- Cost per part = $0.07

Note: Examples for LPC-HPGQ and gas nitriding are based on existing system data; pusher example is based on existing data but hypothetical press quench system.

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