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Process Data Needed for Modeling Heat Treat Processes

The general process scenario should be known. Some basic scenarios are:

- Furnace Heating → Oil Quench → Temper
- Furnace Heating → Carburize → Oil Quench → Temper
- Furnace Heating → Carburize → Cool → ReAustenitize → Oil Quench → Temper
- Furnace Heating → Carburize → Water Quench → Deep Freeze → Temper

Transfer times between steps may or may not be important, but they should be documented.

Furnace Heating - A primary process condition is the heat transfer during heating and cooling/quenching. Important information for heating includes:

- furnace start condition (cold or already hot),
- continuous ramp-up or incremental (stepped or separate furnace zones),
- heating rate,
- austenitizing temperature,
- soak time, and
- furnace atmosphere (oxidizing, neutral, carbon potential).

A high heating rate can result in part distortion, and to a lesser extent in part cracking. These heating issues are typically minor. Furnace atmosphere is linked to more common issues. If the part heats in air, surface oxidation (scaling) occurs, and it can be accompanied by decarburization and formation of oxide fingers on austenite grain boundaries. If the atmosphere has a high carbon potential, carburization will start, and large carbides may form. Soak time is important to ensure that the part has completely transformed, and the time at temperature affects dissolution of carbides in the microstructure, which affects the carbon content of the austenite during the subsequent quench.

Carburizing Process Conditions - Carburizing can be done in conventional gas atmosphere furnaces or in vacuum furnaces. In either process, carburization does not start until the part or batch of parts is at temperature. Soot will form on cold parts.

Gas Carburizing: Most likely, this is the process of most interest as it is the most common carburizing practice. The process variables needed will be:

- gas atmosphere (endogas, methanol-nitrogen, methane, propane, etc.)
- carbon potential of the atmosphere throughout the process
- temperature and time throughout the process

These conditions determine whether the process is a single step or multiple steps. Some furnaces run different conditions as specific steps, and these must be documented. Carbon diffusion and the maximum solubility of carbon in austenite change with temperature.

Low Pressure or Vacuum Carburizing: Low pressure carburizing differs from conventional carburizing in that a carrier gas, such as acetylene, dissociates directly on the hot part surface and the surface carbon level can quickly increase. If the amount of carbon becomes too great, the solubility of austenite is exceeded, surface carbides form, and eventually soot and tar. Therefore, the time for this carrier gas application, termed boost time, is short, typically a minute to a few minutes. The boost step is followed by a diffuse step where the carbon has time to diffuse into the part interior, thus reducing the surface carbon level. The LPC process consists of a series of these boost-diffuse steps. Key parameters are:

- temperature for each process step (usually constant)
- carrier gas type, boost time steps, partial pressure of carrier gas
- diffuse time steps
- number of steps

Liquid Quenching - The type of liquid quenchant used, the temperature of the quenchant and the agitation level in the quench tank all affect the local heat transfer from the part to the quenchant. DANTE has heat transfer coefficient data for commonly used quenchants. Surface heat transfer coefficients that are dependent on the local part surface temperature and the ambient temperature of the quenchant are used in DANTE to simulate liquid quenching. A typical assumption is that the quench tank holds sufficient quenchant and the bulk quenchant temperature does not change more than 10 or 20 °C upon transfer of heat from the part to the quenchant. If so, the ambient temperature is considered to be constant. If this is not true, then the ambient temperature during quenching must be modified accordingly.

The rate of immersion of the part into the quench tank may be critical, especially in terms of distortion. The time for transfer to the quench tank, the ambient temperature, and the time to get the part immersed into the quenchant all affect the temperature magnitude and uniformity in the part. This step can be incorporated into the model and will be included in the model.

Gas Quenching - The type of gas quenchant used, the temperature of the quenchant and the flow pattern all affect the local heat transfer from the part to the quenchant. Surface heat transfer coefficients are considered to be independent of the local part surface temperature for gas quenching and ambient temperatures that are assumed to change with time are used in DANTE to simulate gas quenching. A typical assumption is that the heat transfer coefficient does not change with part surface temperature or time, but the ambient gas temperature around the part does change with time. There is a sharp rise in temperature as the hot part is loaded into the quench chamber and then is reduced to the temperature of the gas leaving the heat exchangers. If this is not true, then the heat transfer coefficients and/or ambient temperature during quenching must be modified accordingly.

Deep Freeze – Cryogenic treatment may be required to transform retained austenite after quenching to martensite. This is mostly for carburized parts or parts with high carbon where the martensite transformation is not completed after quenching and cooling to room temperature. This step requires time and temperature information.

Post-quench cooling practice - Air cooling and/or washing follows oil quenching. The ambient temperature, time for the step, and expected heat transfer coefficient data are needed.

Tempering – Tempering is the last step of the heat treatment process. This may be a one step process, or it could be two or more steps. Process variables include aim temperature, heat-up rate, soak time, and cooling practice.

These data comprise the bulk of what is needed to model a conventional heat treat process where furnace heating is used.