Tailored PM steel materials for heat treatment using a simulation tool to predict the hardenability

Progress and Challenges in Press & Sinter, 28-29 March 2023

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Background

PM steel performance depends on material properties and alloying addition and processes.

Understanding hardenability requirements for specific component size and material is crucial for HT processes.

Sinter-hardening, casehardening, and through-hardening enhance PM steel performance.

Quenching simulations were performed to develop a tool for hardenability calculation based on material, size, and quenching medium.

The tool predicts suitable material and cooling rate to transform microstructure into fully martensitic, minimizing or eliminating the need for HT process optimization trials.
Heat treatment process for PM steels

Processes where material hardenability is required

» Case Hardening
  - Carburising, quenching, and tempering (CQT) – Oil quenching
  - Low pressure carburising (LPC) + High Pressure Gas quenching

» Through Hardening
  - Quench in oil and tempering (QT)

» Sinter Hardening
  - Gas quenching
Hardenability of steel component

**Hardenability**: ability to form martensite upon cooling from austenite

**Influencing factors:**

- **Component**: surface area and mass
- **Quench medium**: oil, gas (N₂, He, Ar)
- **Quench parameters**: flow rate, temperature, pressure etc
- **Alloy composition**: carbon and other alloying elements
Component geometry and quenching medium

» Cooling rates differ between the surface and inside of the component

» Heat conduction in the material
  ○ heat conductivity

» Heat absorption by the cooling medium
  ○ heat transfer coefficient
Modeling

- Gear geometry
- Drawing or CAD model

- FE model
- Geometry
- Thermal properties
- Process conditions

- Calculate how the components cool in different parts

- Evaluate against hardenability data
- Select the right material
Approach

Component

FEM

Cooling curves

Phase transformation calculation

TTT

Experimental Validation

Hardenability

HT process
Example case

» For example, Astaloy 85Mo was chosen for the manufacturing the gear component and the material is supposed to be through hardened (QT) /Sinter hardened (SH) where oil and gas quenching is involved

» The final component mass has a certain mass 1 kg with a density of 7.2 g/cc.

» Using Abaqus, the cooling profiles from the actual component geometry were obtained, one from the surface and one from the core.

» These cooling profiles were then run through the simulated TTT and experimental CCT curves
  » Quench properties module - JMatPro
  » TTT diagram –JMatPro
  » Dilatometry run for verification
Cooling curves for the component
Cooling profile in TTT from JMatPro and experimental validation
TTT from JMatpro

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## Dilatometry validation - Gas cooling surface

<table>
<thead>
<tr>
<th>Surface - gas</th>
<th>JMatPro</th>
<th>Metallography</th>
<th>Hardness HV0.1</th>
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<tr>
<td>0.25C</td>
<td>75 % Bainite</td>
<td>~ 75 % Bainite</td>
<td>221</td>
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<td></td>
<td>25% Ferrite</td>
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<td>40 % Martensite</td>
<td>Martensite with lower bainite</td>
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<td>12 % Bainite</td>
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<td>12 % Bainite</td>
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</tbody>
</table>
Summary

Component

FEM

Cooling curves

Experimental Validation

Phase transformation calculation

TTT

Hardenability

HT process
Höganäs Hardenability Calculator a tool to predict hardenability

Hardenability of a component with specific geometry can be evaluated through simulations and experimental.

Suitable materials can be selected to meet the hardenability requirements.

Minimise the number of experimental trials or eliminate any trials in the long run.