EPMA European Structural Parts Sectoral Group (EuroPress&Sinter)

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Proposal for a new Club Project on Induction Hardening

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From the minute of the Barcelona meeting on March 22nd:  
Group discussion on New Quality insurance and Non-destructive testing

Questions:
1. How to prepare future changes?
2. Joint initiatives to prepare future changes?

There is an ever-increasing demand for quality insurance ....... it means zero-defect.

The main sources for defects in the press-and-sinter process are:
- Segregation during powder handling;
- Dimensional and geometrical defects, missing material, burrs and green cracks occurring in compaction;
- Lack of dimensional and geometrical precision, microstructure defects (bainite in sinterhardening, decarburizing) occurring in sintering;
- Dimensional and microstructure defects in carburizing, defects from machining, cracks in induction hardening, poor cleanness of the parts, all related to post-sintering operations.
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All these defects .......... are not attributable to a scarce knowledge. An exception is the case of **cracks in induction hardening**, since the process is quite complex, the number of variables is very large and the base knowledge is still scarce.

A Club project on induction hardening might be helpful to generate the **base knowledge** and the **simulation procedures** to improve the control of the process.

Induction Hardening of sintered steels is a surface heat treatment aimed at obtaining a controlled case depth where martensitic transformation occurs, without causing the formation of cracks.

Main issues are:
- very fast heating;
- phase transformations on heating and cooling;
- residual stresses generation in a porous structure.

as affected by the Induction Heating parameters and by the physical properties of the steel.
Experience of IWM in the simulation of heat treatment

Coupled fields - Multiphysics

- Temperature
- Constitution
- Deformation
- Electric/magnetic field
- Joule’s heat
- Dissipation due to mechanical work
- Thermal expansion
- Transformation strain
- Stress induced phase transformation
- Heat of reaction
- Diffusion controlled and martensitic phase transformation
- Electro migration
- Electrical conductivity

Developing the Powder Metallurgy Future
Experience of IWM in the simulation of heat treatment

Heat treatment of tool steels

Die-casting mold for a supporting aluminum-structural component

Source: Kind & Co.
Experience of IWM in the simulation of heat treatment

Development of phase fractions and stresses during quenching
Experience of IWM in the simulation of heat treatment

FEM-model of peripheral surface grinding

Experience of IWM in the simulation of heat treatment

FEM-model of peripheral surface grinding
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FEM-model of peripheral surface grinding

Bearing steel
100Cr6 (60±1 HRC)

Grinding wheel
B181V

Grinding parameters
\[ Q'w = 50 \text{ mm}^3/(\text{mm} \cdot \text{s}) \]
\[ v_w = 12 \text{ m/min} \]
\[ v_s = 160 \text{ m/s} \]

Gegenlauf

Cooling medium
Emulsion (5%ig)

Nadeldüse
Experience of Trento University in microstructural analysis and Residual stress measurements of PM steels

Microstructure of a low alloy sintered steel as a function of %C and cooling rate
Experience of Trento University in microstructural analysis and Residual stress measurements of PM steels

Residual stress profile after shot peening of a Cr-Mo low alloy sintered steel
Experience of Trento University in microstructural analysis and Residual stress measurements of PM steels

Effect of density and chemical composition on the residual stress profile after shot peening
Induction Hardening of sintered steels

Two ways to solve the problem:

- **Scientific approach:**
  - Determination of all physical properties of the porous steels that affect heating by induction (electrical resistivity, thermal diffusivity, magnetic properties as a function of porosity), phase transformations (CCT diagrams as affected by porosity), elastic constants as affected by porosity

- **Empirical approach:**
  - Combine published data of PM steels and well known parameters for dense steels to get a first set of parameters for a FEM-simulation of induction hardening of PM steel.
  - carry out experiments on sintered steels with different porosity (density), measure residual stresses and analyzing the microstructure
  - determine the correction factors for the model parameters by fit of the experimental with the numerical results.
Induction Hardening of sintered steels

Project plan

1. Induction hardening of cylindrical specimens;
   1. Variation of density
   2. Variation of induction parameters
   } Industry

2. Investigation of hardened specimens
   1. residual stress fields
   2. microstructure
   } University of Trento

3. Set up of a numerical FEM model
   1. Use of published model data
   2. Adaptation of parameters known from dense steels
   3. Fit to experimental results obtained by cylindrical specimens
   } IWM RWTH

4. Verification of the model
   1. Induction hardening of PM gears
   2. FEM model of PM gears
   } Industry
   } IWM RWTH
Induction Hardening of sintered steels

Expected results

▪ Knowledge about the influence of porosity on the residual stresses after induction heating

▪ Identification of “critical” situations in induction hardening of PM steel in order to avoid cracks during quenching

▪ Proof of concept for a FEM modeling strategy for induction hardening of PM steel
Thank you for your Interest!

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