Institut für Anwendungstechnik
Pulvermetallurgie und Keramik
an der RWTH Aachen e.V.

Proposal for an EPMA club project:

InducSim

Simulation-based assessment of Induction Hardening on Sintered Steel parts

Valérian Iss, Ali Rajaei, Oliver Schenk, Christoph Broeckmann*

*Institute of Applied Powder Metallurgy and Ceramics at RWTH Aachen University, (IAPK)

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Motivation

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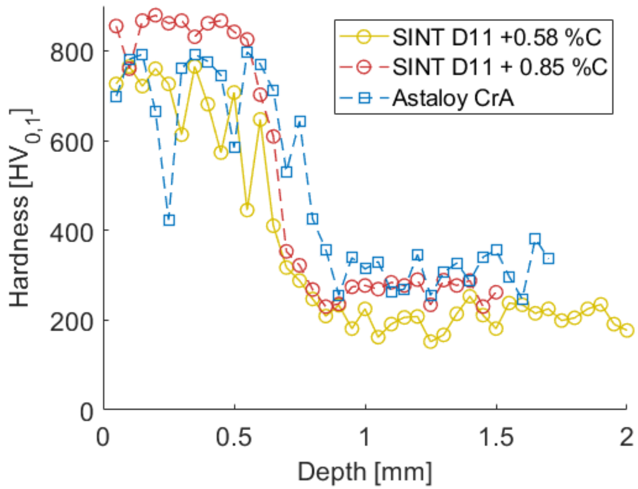
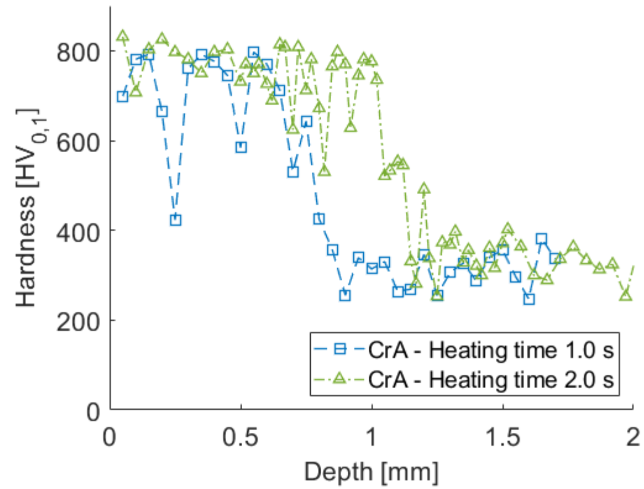
Prediction and optimization of induction-hardened sintered components with regard to:

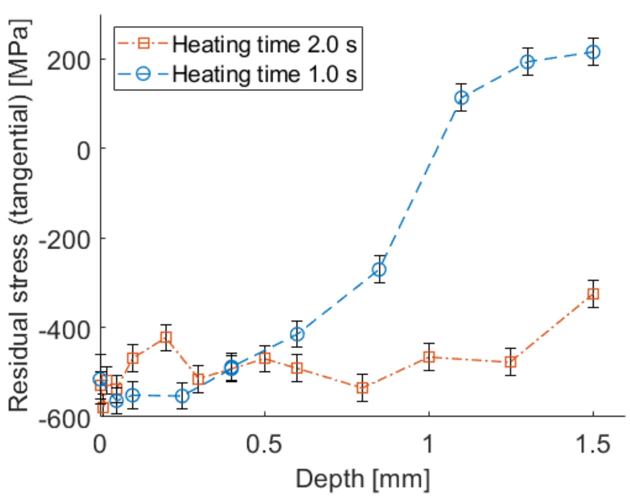
- **Material composition**

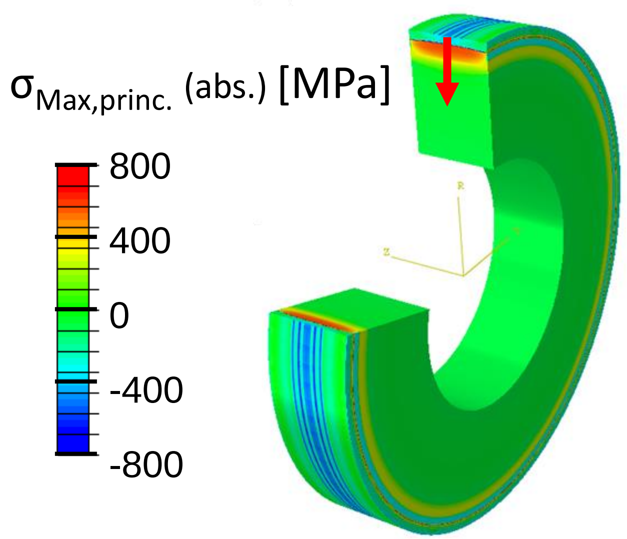


- **Process settings**



- **Residual stresses**





Motivation

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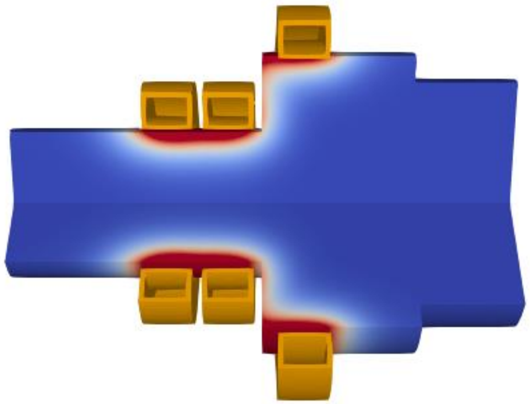
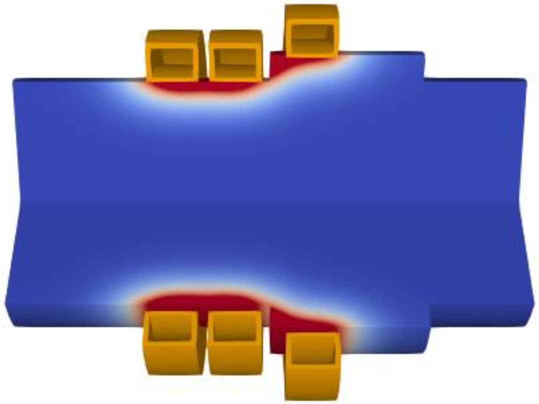
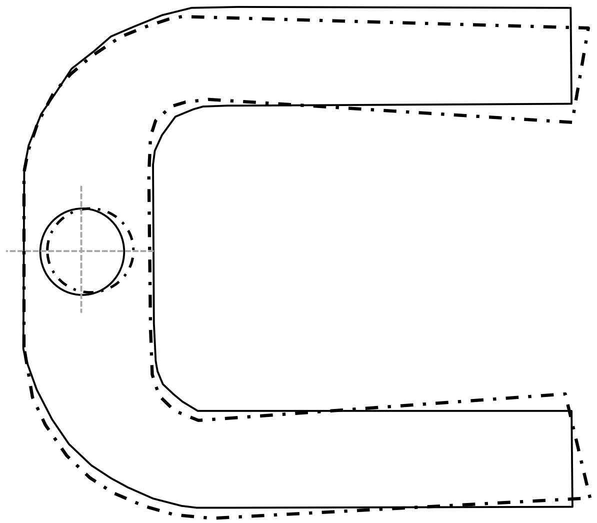
Prediction and optimization of induction-hardened sintered components with regard to:

- **Geometry**

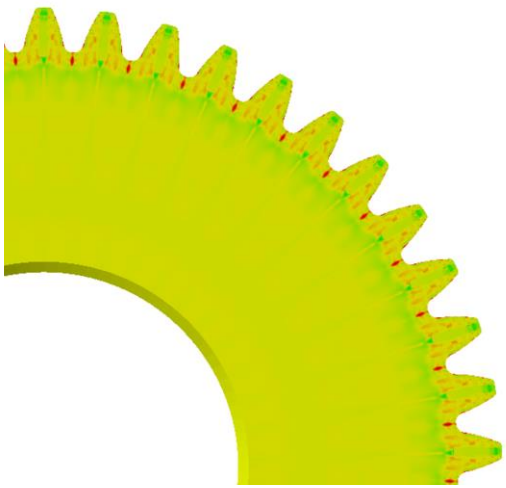




- **Distortion**



- **Cracking risks**



Motivation

The project should provide answers to the following questions:

- Which material parameters have the most influence on the heat-treatment results?
- How accurate is finite-element prediction of hardness and residual stress profiles for both simple and complex induction-hardened sintered parts?
- What correlations can be identified between simulation outputs and cracking risks?

Some insight should furthermore be derived on the following question:

- How accurate is finite-element prediction for distortion of parts with demanding geometrical features (thin cross-sections, asymmetry…) ?

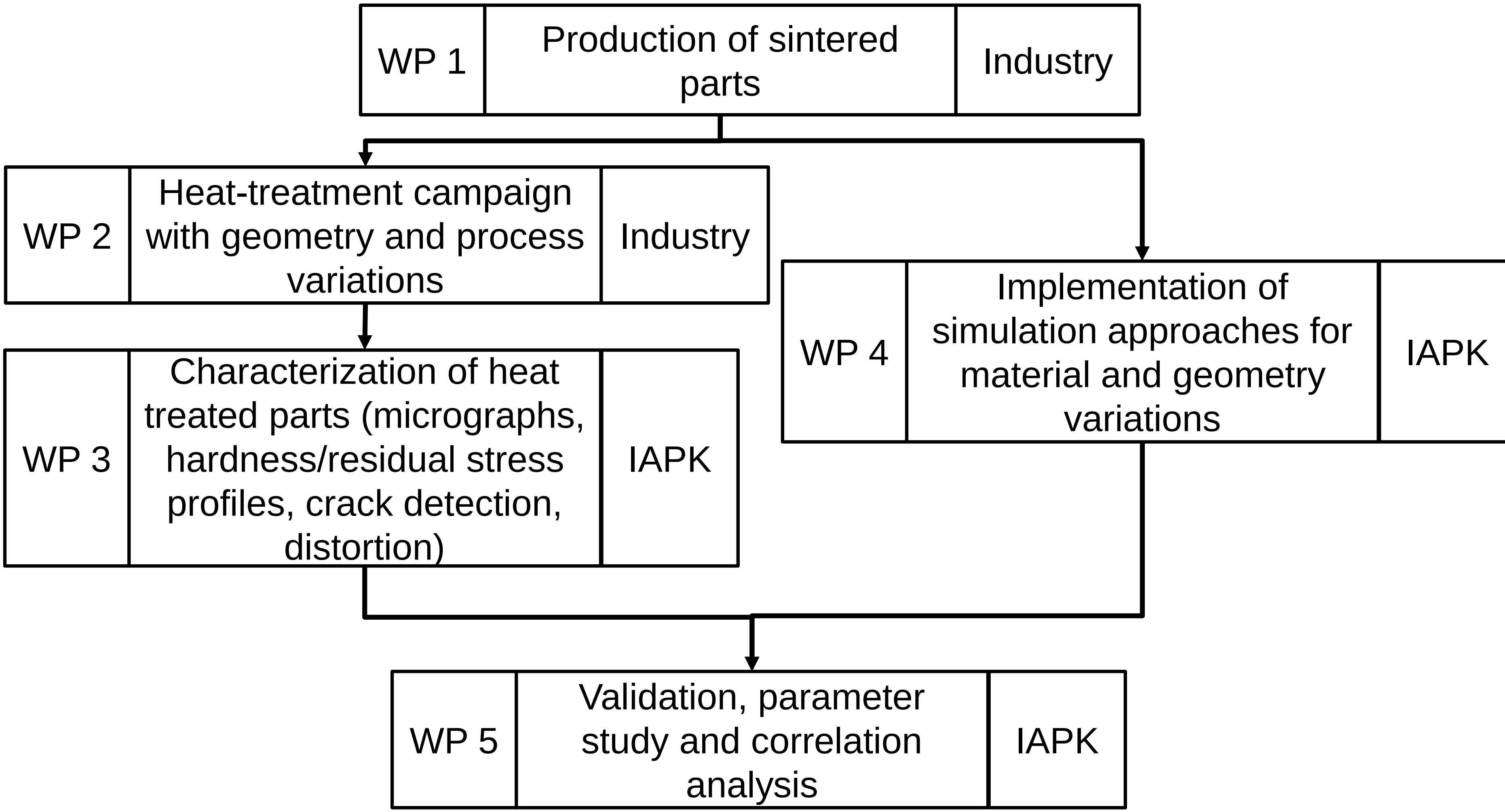
Motivation

Background:

01/2022 – 12/2023: AVIF-Project "Development of a robust and reliable induction hardening process for sintered steel components":

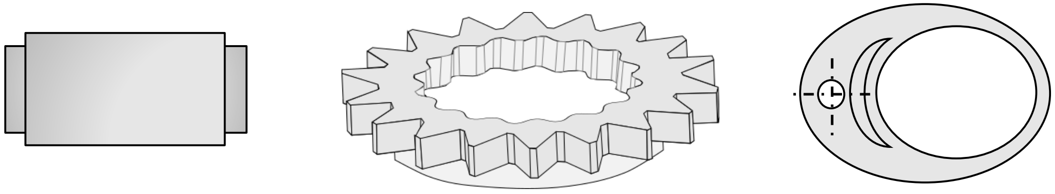
- **Extensive experimental study** of induction hardening on sintered gears with **variations of material** (density, carbon concentration, alloying system) **and process parameters** (process times and intensity, quenching and tempering conditions…).
- **Extensive material characterization** in order to build a Finite-Element model for prediction of phase transformations, hardness development and residual stresses during induction hardening.
- **Simulation models** were built and partially validated on simple cylindrical samples (ongoing validation on sintered gears).
- The problematic of the **cracking risks** during induction hardening process couldn't be fully addressed. For the chosen gear geometry and various process conditions, none of the ~270 investigated parts exhibited cracks after hardening or tempering process.

Work plan


WP 1
Production of sintered parts
Industry
WP 2
Heat-treatment campaign with geometry and process variations
Industry
WP 3
Characterization of heat treated parts (micrographs, hardness/residual stress profiles, crack detection, distortion)
IAPK
WP 4
Implementation of simulation approaches for material and geometry variations
IAPK
WP 5
Validation, parameter study and correlation analysis
IAPK

WP1 + WP2: Production and hardening of sintered parts

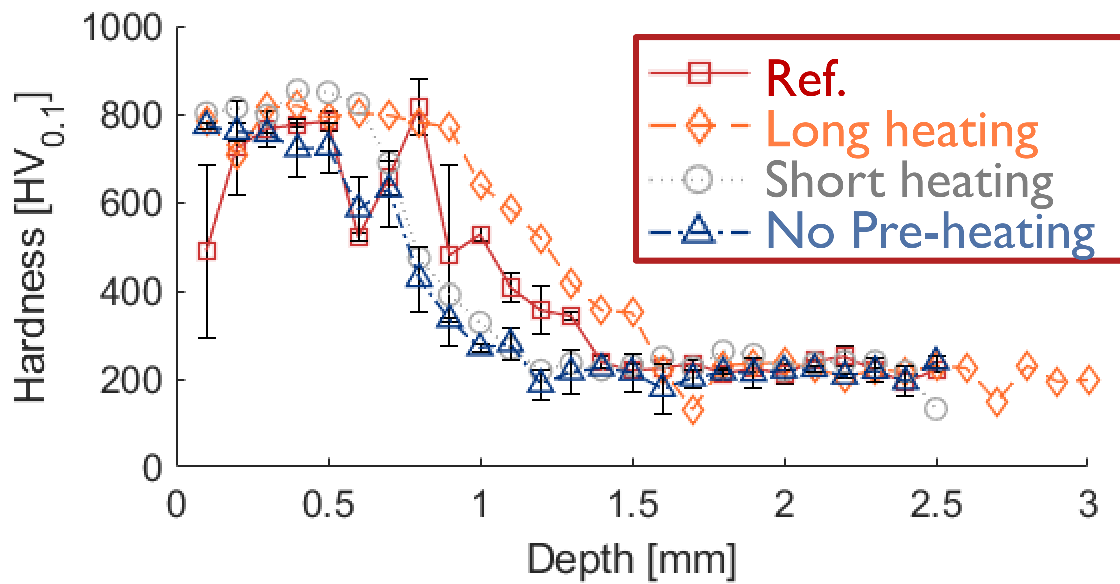
- Production and induction hardening of parts:
- 2 Alloying systems:
  - » D11 Powder + Carbon as in previous research project
  - » One further alloying system relevant for industrial applications
- 3 Geometry variations:
  - → One “simple” geometry with cylindrical symmetry and different section sizes
  - → One more complex geometry, e.g. meshed
  - → One problematic geometry, e.g. asymmetric, with drilled holes or thin cross-sections

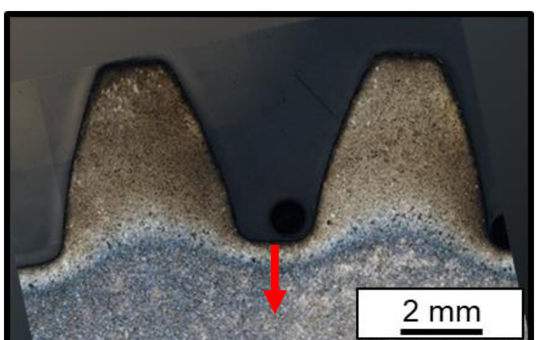


- Process parameter variations: e.g. heating time/intensity, pre-heating step and/or quenching conditions

WP3 Characterization of heat-treated parts

- Systematic analysis of hardness and microstructure profiles
- Exemplary residual stress measurements
- Investigation of cracking behavior and patterns





WP4 Methods for simulative variation studies

- Model adjustments for **complex geometries** (calculation time, meshing…).

- Model adjustments for **additional materials:**
  - → Sensitivity analysis for the most influential material properties
  - → Deriving properties for not-yet investigated material with help of empirical and analytical methods
  - → Quantification of expected uncertainties (e.g. for Surface Hardness Depth SHD or surface residual stresses)

WP5 Validation, parameter study and result analysis

- The **simulation model should be validated** with the produced heat-treatment data from micrographs, hardness and residual stress measurements.

- The simulation model should be used in order to **identify trends in the effects of process and material variations** on the heat-treatment results.

- **Crack tendencies and patterns** of induction-hardened parts should be analyzed to see if **correlations** can be found **with some simple outputs from the simulation** (highest tensile residual stresses, highest plastic strains…). However, since some aspects of cracking mechanisms are not covered by the heat-treatment simulation model yet, this complex topic obviously cannot be fully investigated in this project.

Work package time planning

- Duration of the project: 12 months

		month											
		1	2	3	4	5	6	7	8	9	10	11	12
WP1	Production of sintered parts	■	■	■	■								
WP2	Heat-treatment campaign				■	■	■						
WP3	Characterization of heat treated parts					■	■	■	■				
WP4	Model enhancement for simulative geometry and material variations	■	■	■	■	■	■	■	■				
WP5	Model validation and correlation analysis							■	■	■	■	■	■
Reporting		KM					IM						FM

KM: Kick-off meeting,
IM: Interim Meeting (Webmeeting)
FM: Final Meeting

Cost figure

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IAPK	personnel:	0.3 full engineer for 12 months:	23,940	€
		0.2 technician for 6 months:	5,760	€
		0.6 Student for 12 months	6,500	€
	overheads on personnel (59%):		21,360	€
	Consumables (metallography)		3,000	€
	Software licenses		5,000	€
	External measurements (hardness/residual stress profiles)		5,000	€
	travel costs (2 meetings à 2 persons)		1,600	€
		total funding:	72,160	€
EPMA	administrative costs (15%)		10,825	€
Total costs of project			82,985	€

All costs exclusive VAT if applicable

Input needed from industry

Before project start:

-> Identification of relevant alloys, part/inductor geometries and process settings

-> Coordination and/or adjustments of the project scope (focus more on distortion/cracking/hardness or residual stress profiles).

During project:

-> Supply of powder and pressed and sintered components

-> Provide induction hardening facility and inductor, co-organize and participate to the experimental test study

-> Technical support and participation to project meetings

Thank you for your attention!

M. Sc. Valérian Iss
v.iss@iwm.rwth-aachen.de

IAPK – Institut für Anwendungstechnik Pulvermetallurgie und Keramik
an der RWTH Aachen e.V.
Augustinerbach 4
52062 Aachen

www.iapk.rwth-aachen.de