

Metals Technology

Materials science of metals; *physical metallurgy and engineering properties*

- **Alloy development**

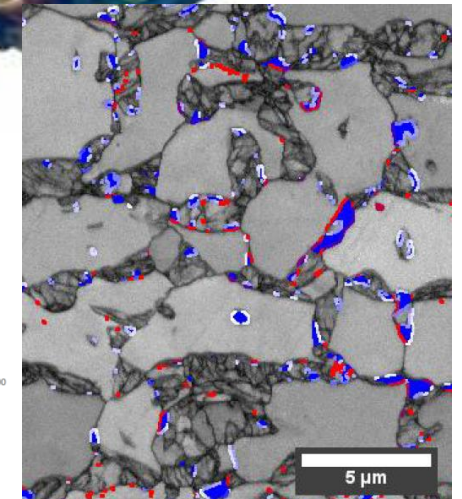
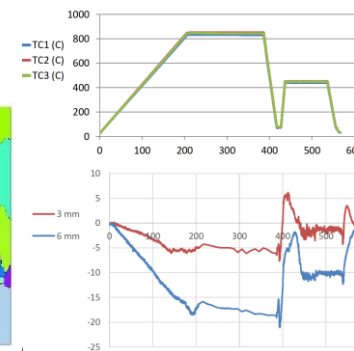
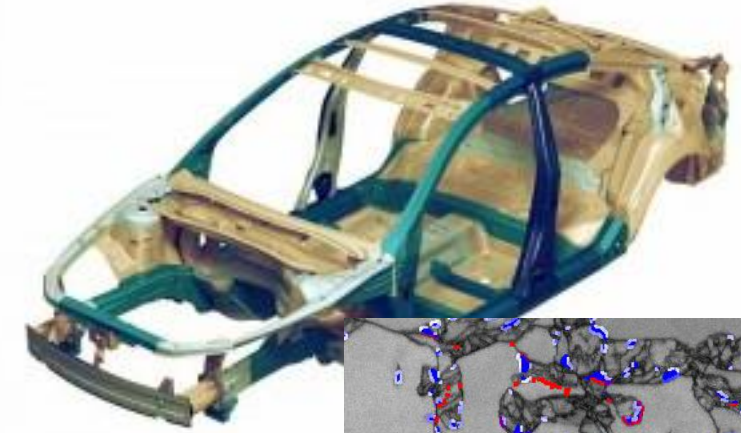
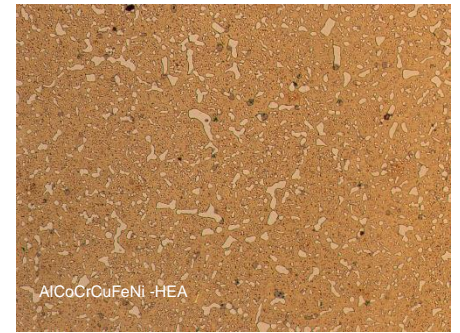
- New metallic materials; for ex. *High entropy alloys*
- Novel materials for engineering; *TRIP-assisted alloys, Quench & Partitioning (Q&P) alloys, Press Hardening Boron Steels (PHS), Complex Phase (CP) Steels, TWIP-steels*
- Property optimization: *Phase transformations, precipitation, hardenability*

- **Heat treatments**

- Novel heat treatment methods
- Heat treatment of printed components
- Case hardening, bake hardening, Q&P treatment
- Tools steels, automotive grades, aluminium
- Phase transformations

- **Fabrication and joining methods**

- Forming of thin sheet; *Deep drawing, Hole expansion of steel*
- Welding metallurgy: Steels, Aluminium, Ni- and Co-base alloys
- 3D printing of metals



Optimization of heat-treatment processes for ultra high strength steel

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Manufacturing of steel materials

Composition

Casting

Forging and
rolling

Heat-
treatments



The diagram illustrates the manufacturing process of steel materials. At the top, four light blue ovals represent the processes: Composition, Casting, Forging and rolling, and Heat-treatments. A large, light blue arrow points downwards from these processes to a central light blue box labeled 'Microstructure'. This box is superimposed on a background of three micrographs: a grayscale image of a fine-grained structure on the left, a color image of a coarse-grained structure in the center, and a grayscale image of a fine-grained structure on the right. Another large, light blue arrow points downwards from the 'Microstructure' box to a row of five light blue ovals at the bottom, which represent the material properties: Strength, Hardness, Toughness, Corrosion resistance, and Weldability.

Microstructure

Strength

Hardness

Toughness

Corrosion
resistance

Weldability

Heat-treatment of steel materials

**Stronger
material**



**More durable
material**



**Longer
service life**



Hardness

Impact toughness

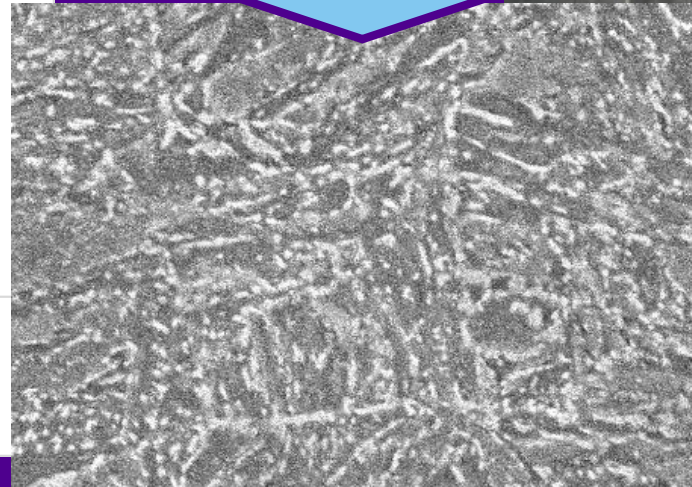
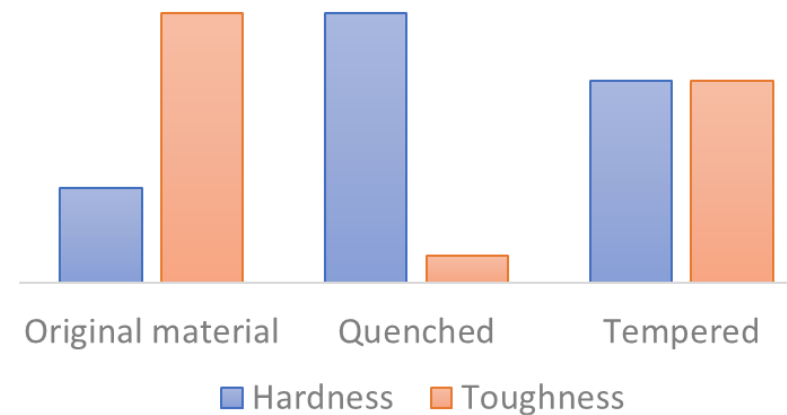
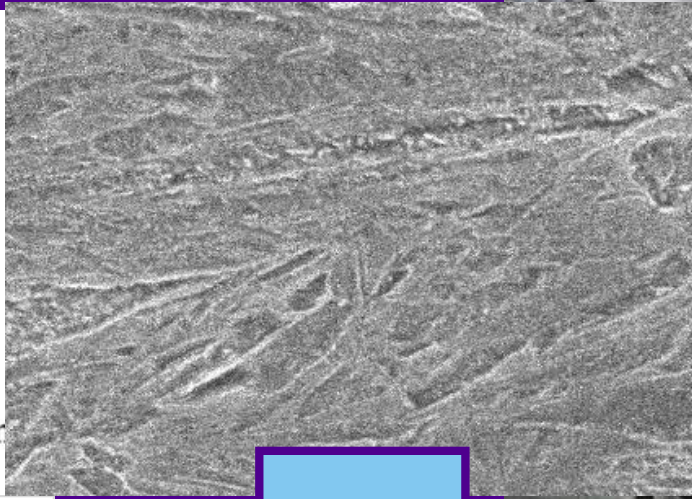
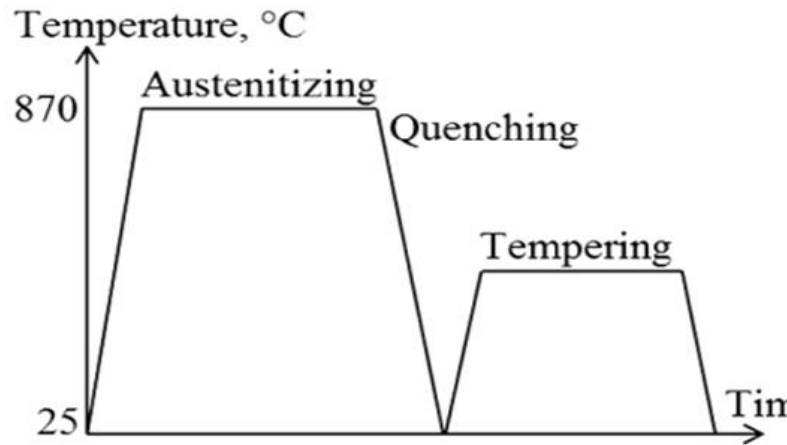
Strength

Fatigue strength

Adjustable properties:

- Mass
- Strength
- Hardness
- Toughness
- Formability
- Machinability
- Etc.

Heat-treatment of steel materials



Changing of the steel
microstructure:

minimizing the amount of suboptimal
structures

minimizing the internal stresses

Quench and tempering process

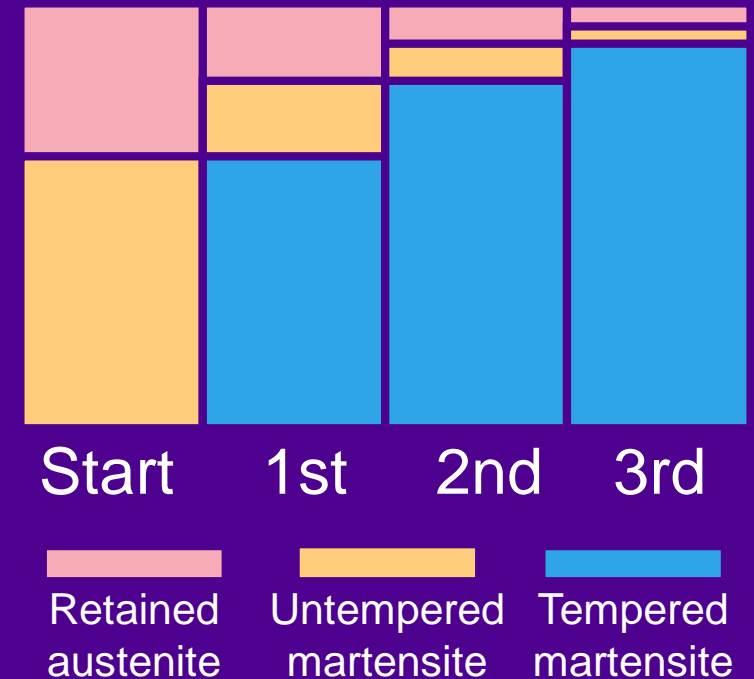
- **Effect of austenizing and quenching:**

- Formation of martensite by quenching austenite
- Minimizing internal stresses by optimal quenching arrangements
- Minimizing the amount of retained austenite by cryo-quenching

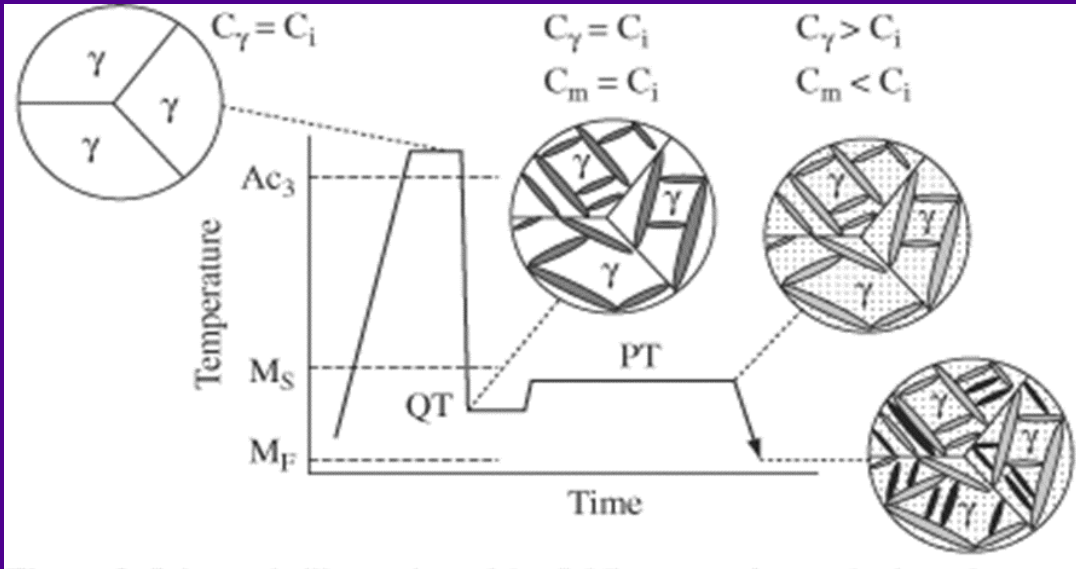
- **Effect of tempering:**

- Partition of carbon from martensite to austenite
 - Elimination of "fresh" martensite
- Choice of conducting tempering multiple times

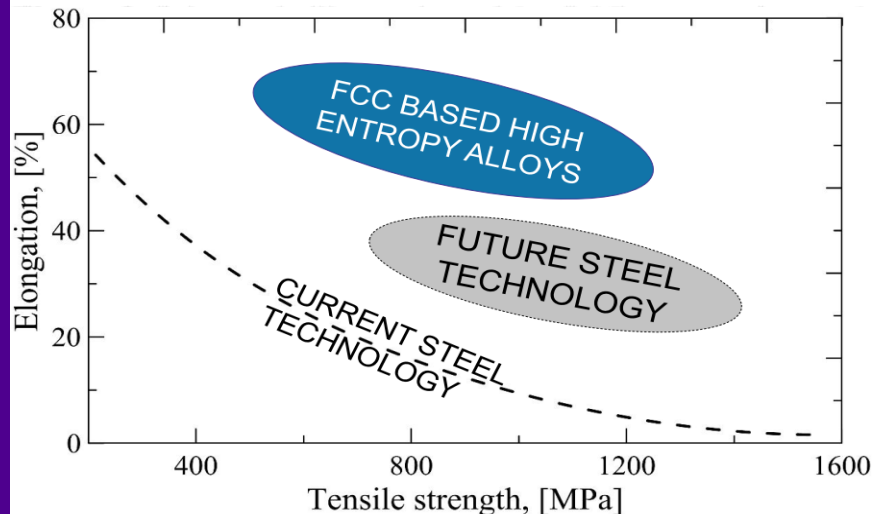
Multiple temperings:



Quench and partition process



Production of multi-phase steel consisting of stabilized austenite and tempered martensite:
Successor to TRIP-steel



Unfinished martensite transformation, followed by stabilization of austenite

- Steel with high strength
- Highly formable steel
- → automotive industry

PROJECT:

Manipulation processes for steel materials

MISSION: Development of expertise in the manufacturing of steel components

METHOD: Investigation on the optimization of heat-treatment processes

Optimization of heat-treatment processes

Requirement-based material selection

Modification of heat-treatment parameters

Fulfilment of property requirements

Hardness

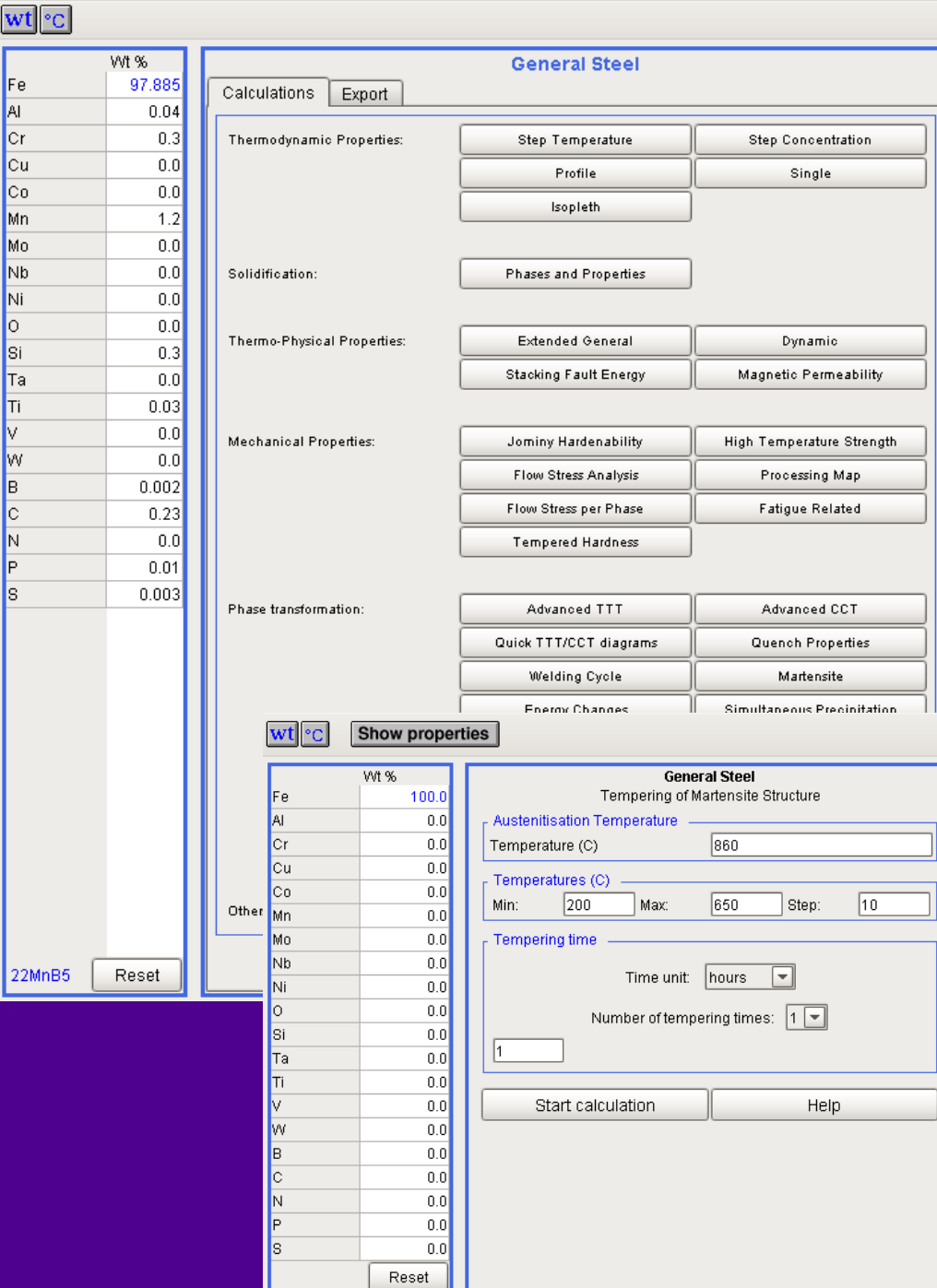
Strength

**Impact
toughness**

**Fatigue
strength**

Research tasks:

- **Simulation of the microstructures and properties with JMatPro® - program**
 - Calphad-simulation
 - Testing of the JMatPro® program
- **Conventional testing of steel grades**
 - Changing of the heat-treatment parameters
 - Austenization temperature
 - Quenching medium and -temperature
 - Tempering temperature and -time
 - Microstructure analyses and testing of the properties



The screenshot displays the JMatPro software interface. On the left, a table lists the chemical composition (WT %) for a steel grade, identified as 22MnB5. The composition includes Fe (97.885%), Al (0.04%), Cr (0.3%), Cu (0.0%), Co (0.0%), Mn (1.2%), Mo (0.0%), Nb (0.0%), Ni (0.0%), O (0.0%), Si (0.3%), Ta (0.0%), Ti (0.03%), V (0.0%), W (0.0%), B (0.002%), C (0.23%), N (0.0%), P (0.01%), and S (0.003%). Below this table is a 'Reset' button.

The main window is titled 'General Steel' and contains several sections of simulation options:

- Calculations** and **Export** tabs.
- Thermodynamic Properties:** Includes buttons for 'Step Temperature', 'Step Concentration', 'Profile', 'Single', and 'Isoleth'.
- Solidification:** Includes a button for 'Phases and Properties'.
- Thermo-Physical Properties:** Includes buttons for 'Extended General', 'Dynamic', 'Stacking Fault Energy', and 'Magnetic Permeability'.
- Mechanical Properties:** Includes buttons for 'Jominy Hardenability', 'High Temperature Strength', 'Flow Stress Analysis', 'Processing Map', 'Flow Stress per Phase', 'Fatigue Related', and 'Tempered Hardness'.
- Phase transformation:** Includes buttons for 'Advanced TTT', 'Advanced CCT', 'Quick TTT/CCT diagrams', 'Quench Properties', 'Welding Cycle', 'Martensite', 'Energy Changes', and 'Simultaneous Precipitation'.

At the bottom of the main window, there is a 'Show properties' button and a smaller table for 'Other' elements (Fe, Al, Cr, Cu, Co, Mn, Mo, Nb, Ni, O, Si, Ta, Ti, V, W, B, C, N, P, S) with their respective WT % values. This table also has a 'Reset' button.

Below the main window, there is a detailed 'General Steel' section for 'Tempering of Martensite Structure'. It includes input fields for 'Austenitisation Temperature' (860), 'Temperatures (C)' (Min: 200, Max: 650, Step: 10), 'Tempering time' (Time unit: hours, Number of tempering times: 1), and buttons for 'Start calculation' and 'Help'.

Results so far...

Conducting austenizing and quenching in different methods:

Component position, loading rate and location greatly affects spreading of the properties

Optimization of heat treatment process for a component:

Tempering temperature should be increased OR steel grade should be changed

Creation of a microstructure library:

Archiving essential information, and to ease the analysis and comparison of process parameters

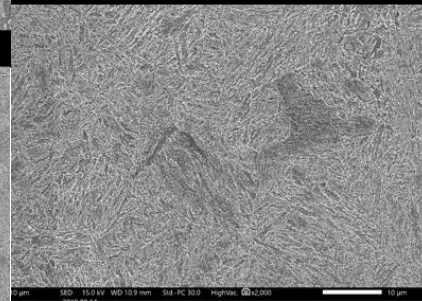
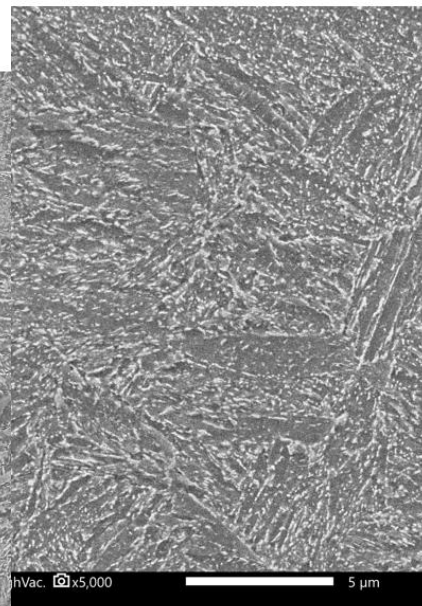
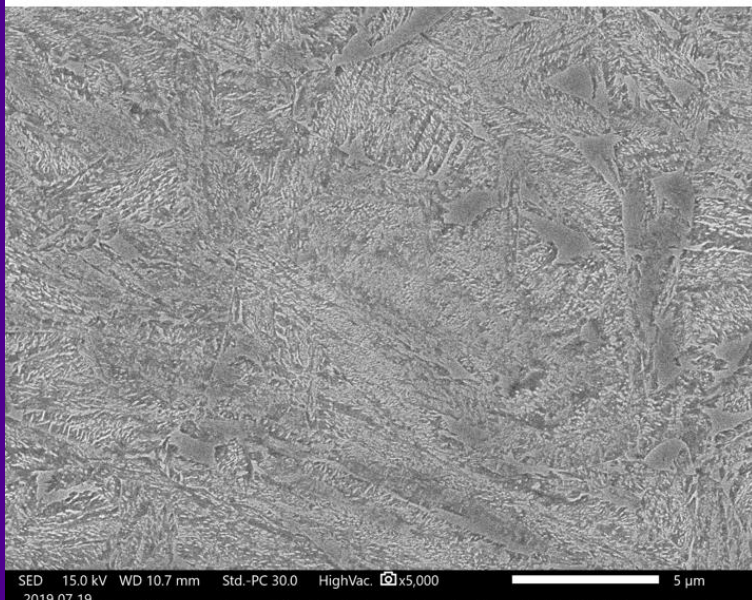
Microstructure library

20. 900C – ö80 – 550 3h

ISO 6. 840C – 310C 10 min - ö hlt

Austenisointi, suola, öljy sammutus

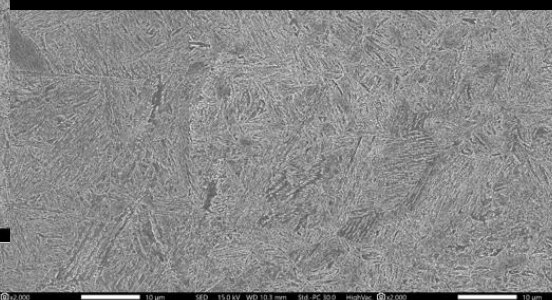
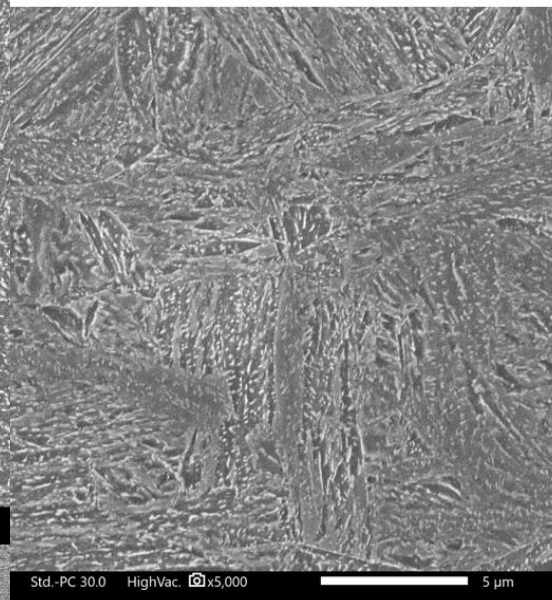
Vickers average: 479



900C – ö80 – 400C 3h

ti, öljy sammutus, päästö

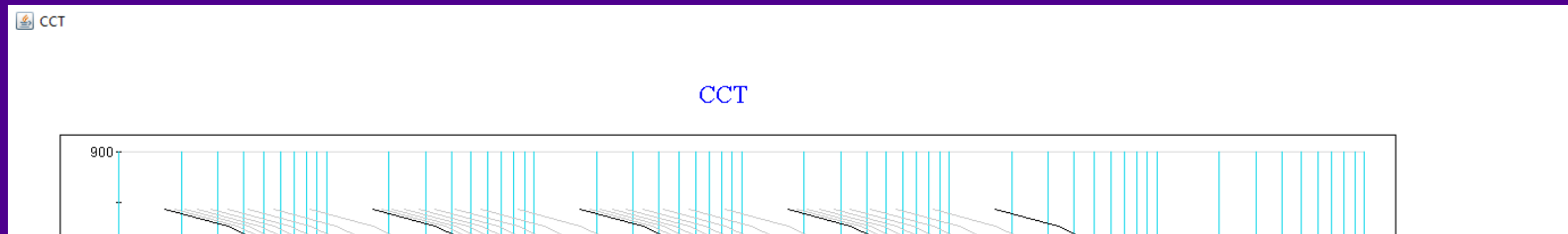
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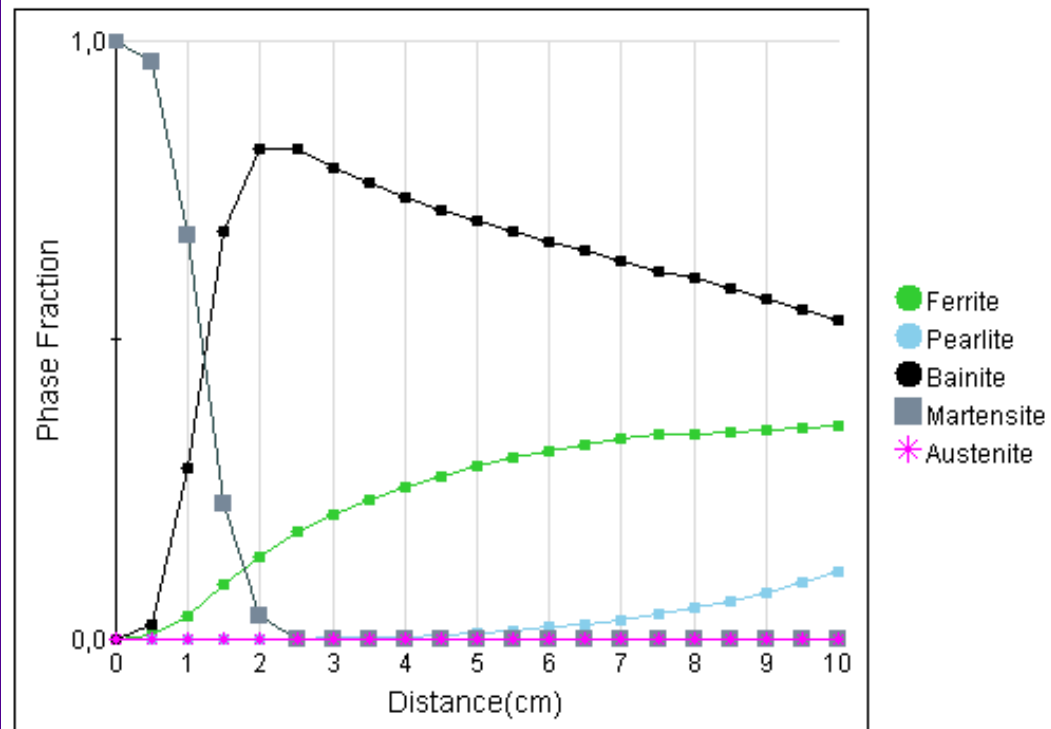
HEAT TREATMENT TESTS

Austenization 45min – oil quench –
tempering 3h – slow cooling

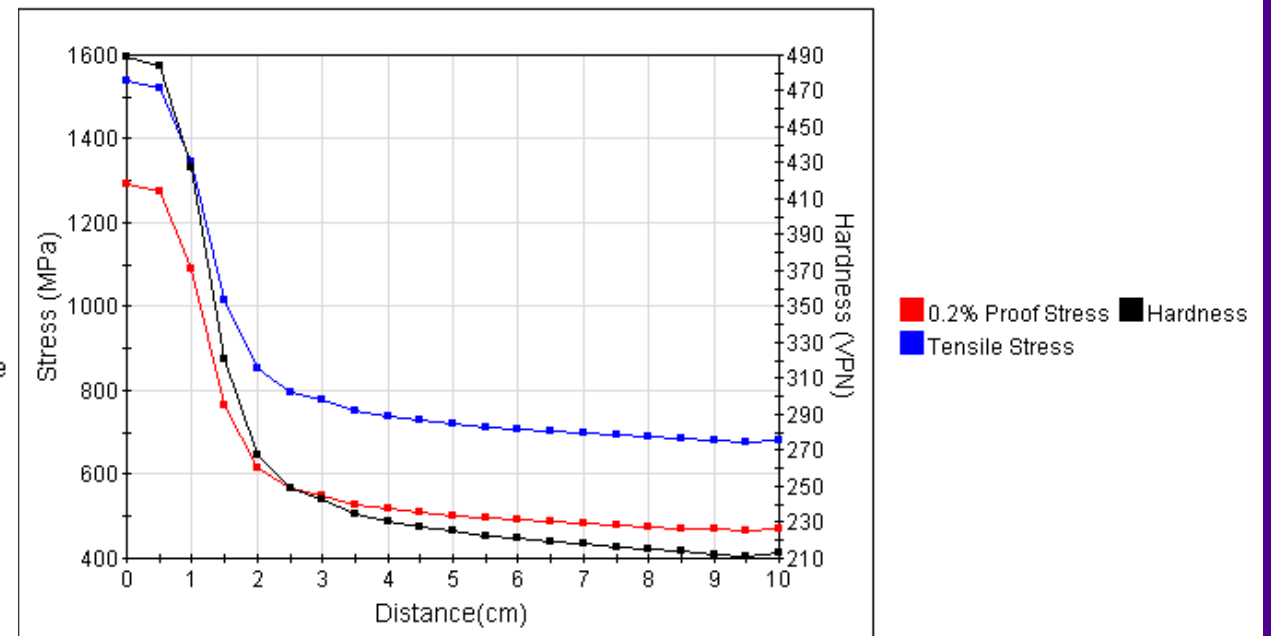
Sample	Aust.	Oil	Temper.
1	840	80	400
2	860	80	400
3	880	80	400
4	900	80	400
5	840	80	450
6	860	80	450
7	880	80	450
8	900	80	450
9	840	80	500
10	860	80	500
11	880	80	500
12	900	80	500
13	840	80	-
14	860	80	-
15	880	80	-
16	900	80	-
17	840	80	550
18	860	80	550
19	880	80	550
20	900	80	550
21	840	80	600
22	860	80	600
23	880	80	600
24	900	80	600



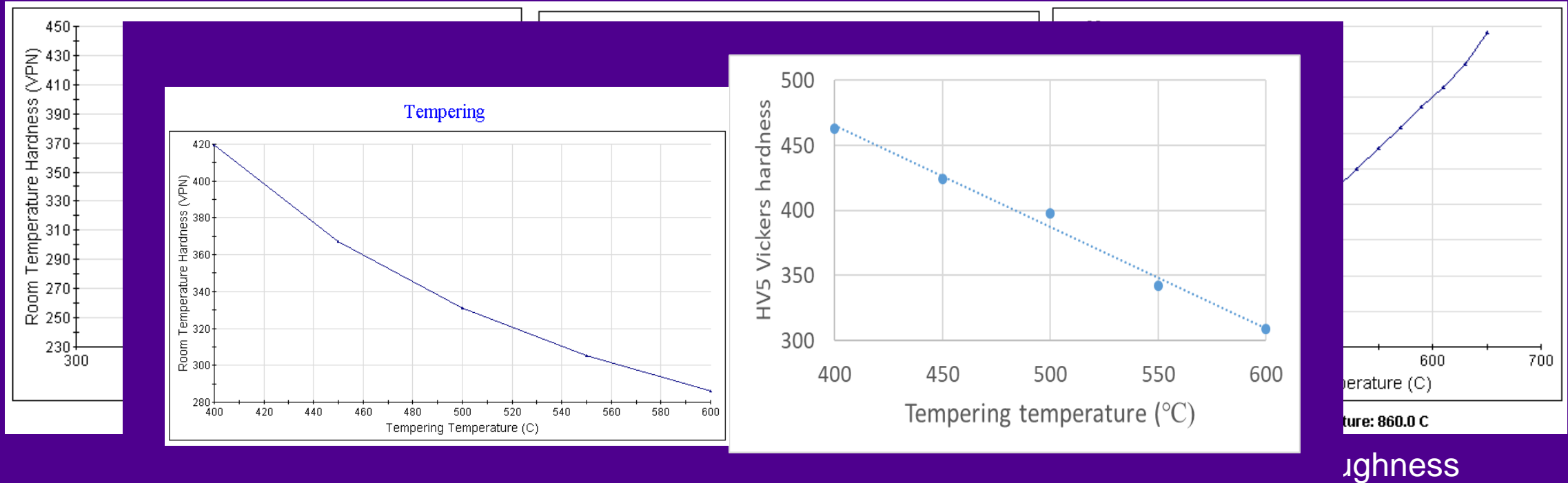
Jominy Hardenability



Jominy Hardenability



JMatPro®: Effect of tempering temperature

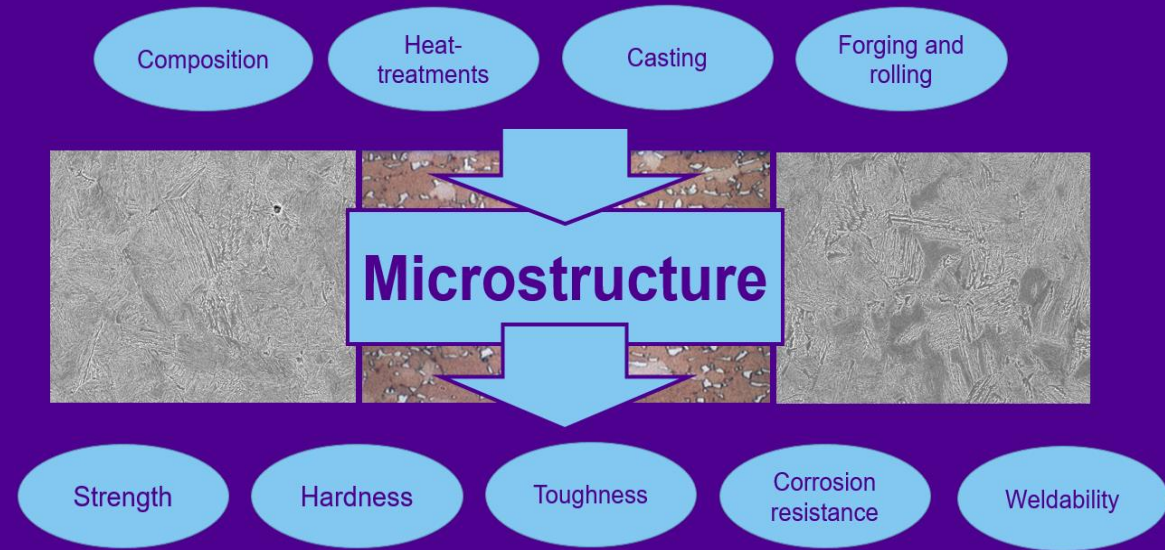


Conducting simulations of heat-treatments
Comparing them to practical tests

Next steps...

- Precise manufacturing of ultra high strength tempering steels
 - Great quality must be guaranteed
 - Scattering of mechanical property values is not allowed
- Investigation on the other possible sources of the scattering

Intelligent manufacturing, intelligent material



**Thank you
for your attention!**