New tool for calculation of heat transfer coefficients, microstructure and hardness from the cooling curve

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- A new software module for cooling curve analysis and interpretation
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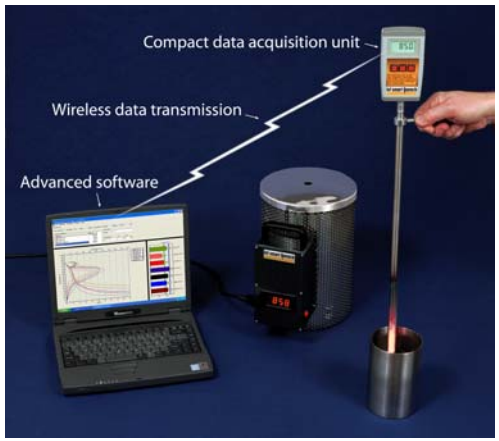
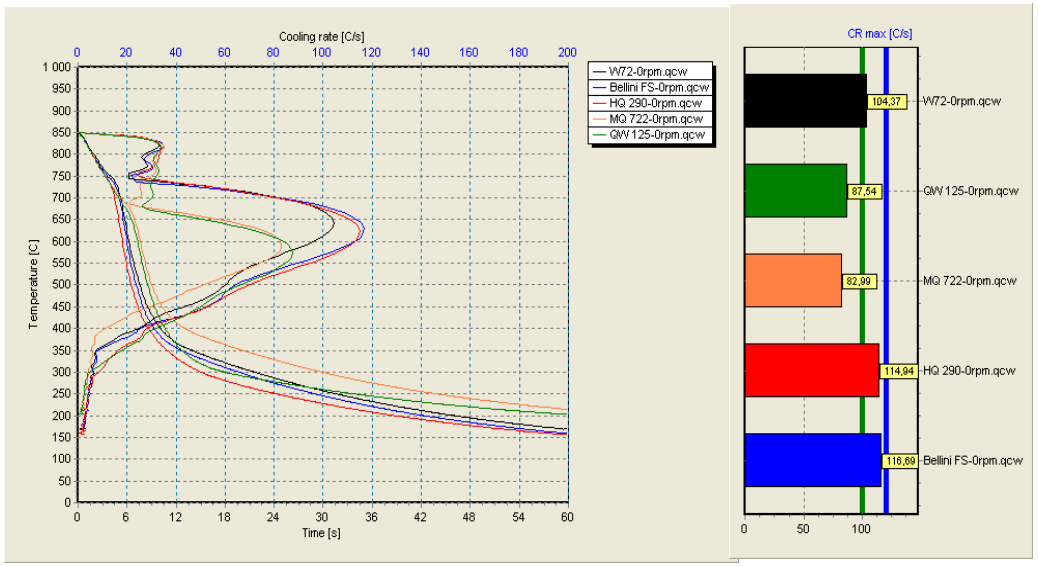
- Verifying tests
- Application examples
- Summary

Original functions ivf SmartQuench

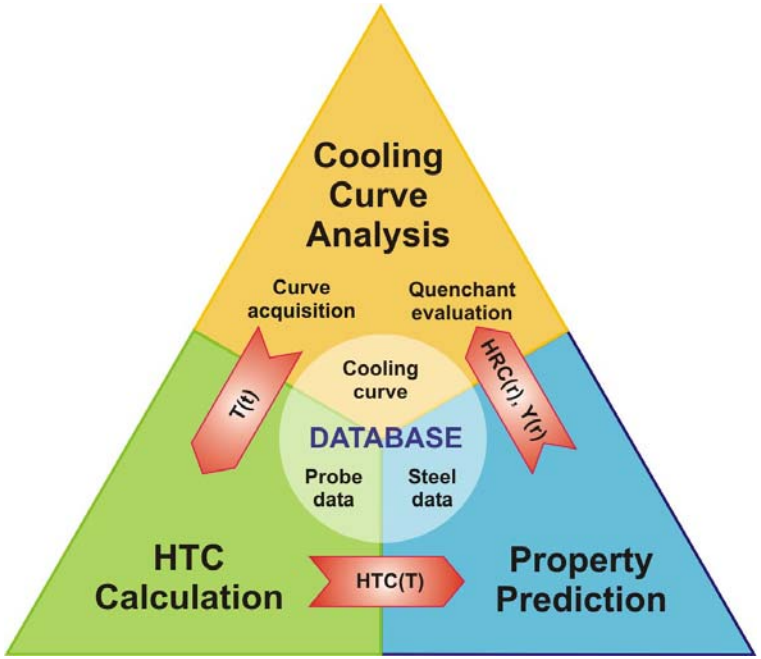
- Testing of quenching media → Cooling curves
- Evaluation of the cooling curve. A large number of characteristics are recorded or calculated:
  - Cooling times to certain temperatures
  - Cooling rates at these temperatures
  - Maximum cooling rate



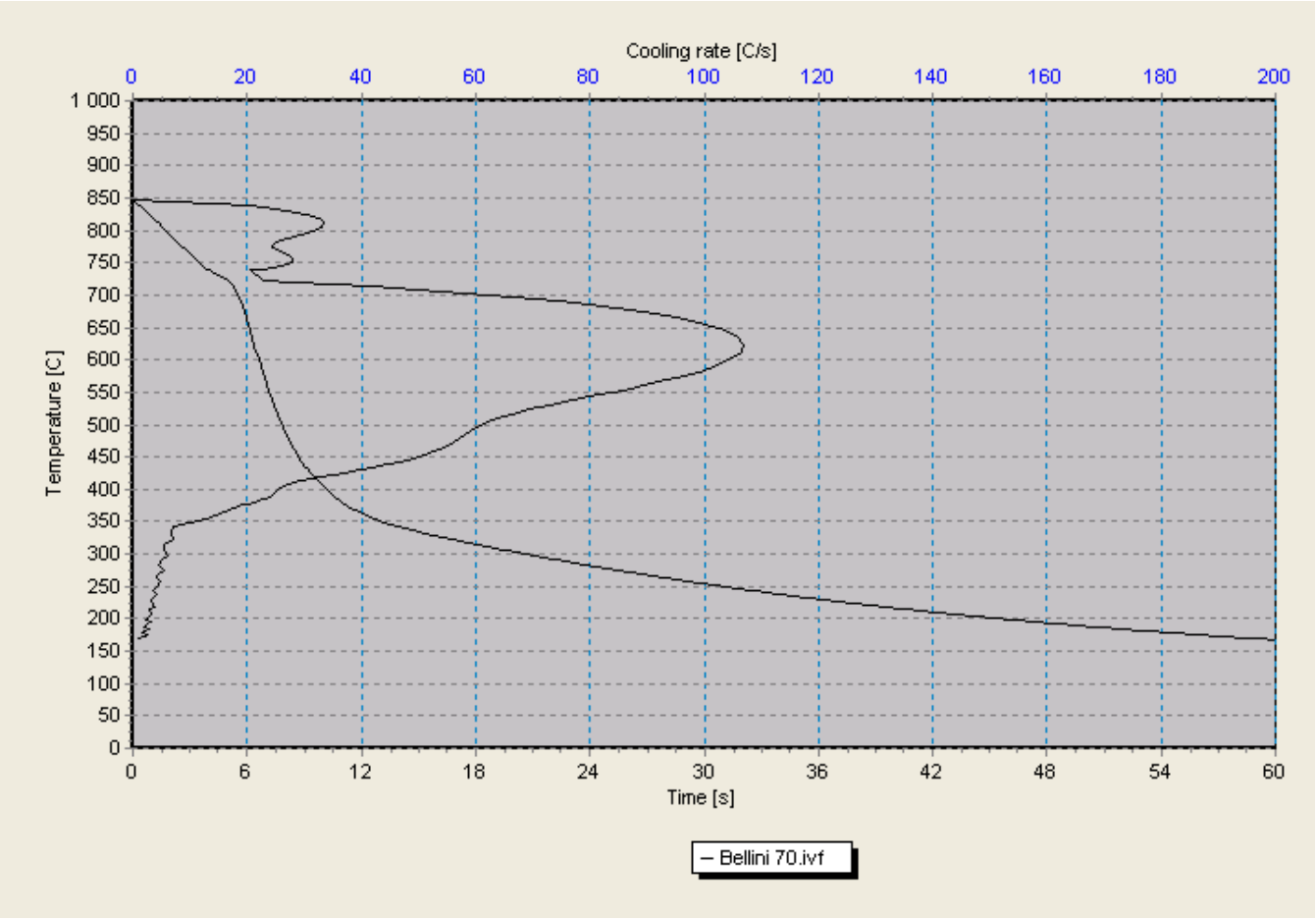


New software – SQintegra
structure and functions of the ivf SQintegra software

- Calculation of heat transfer coefficients (for the ISO 9950 probe)
- Calculation of hardness and microstructure in a cross section

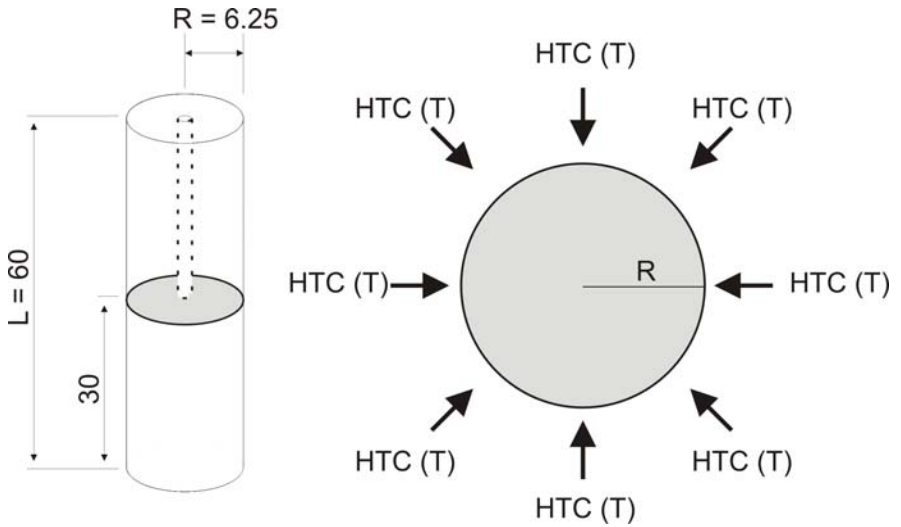


Step 1. Measurement of cooling curve

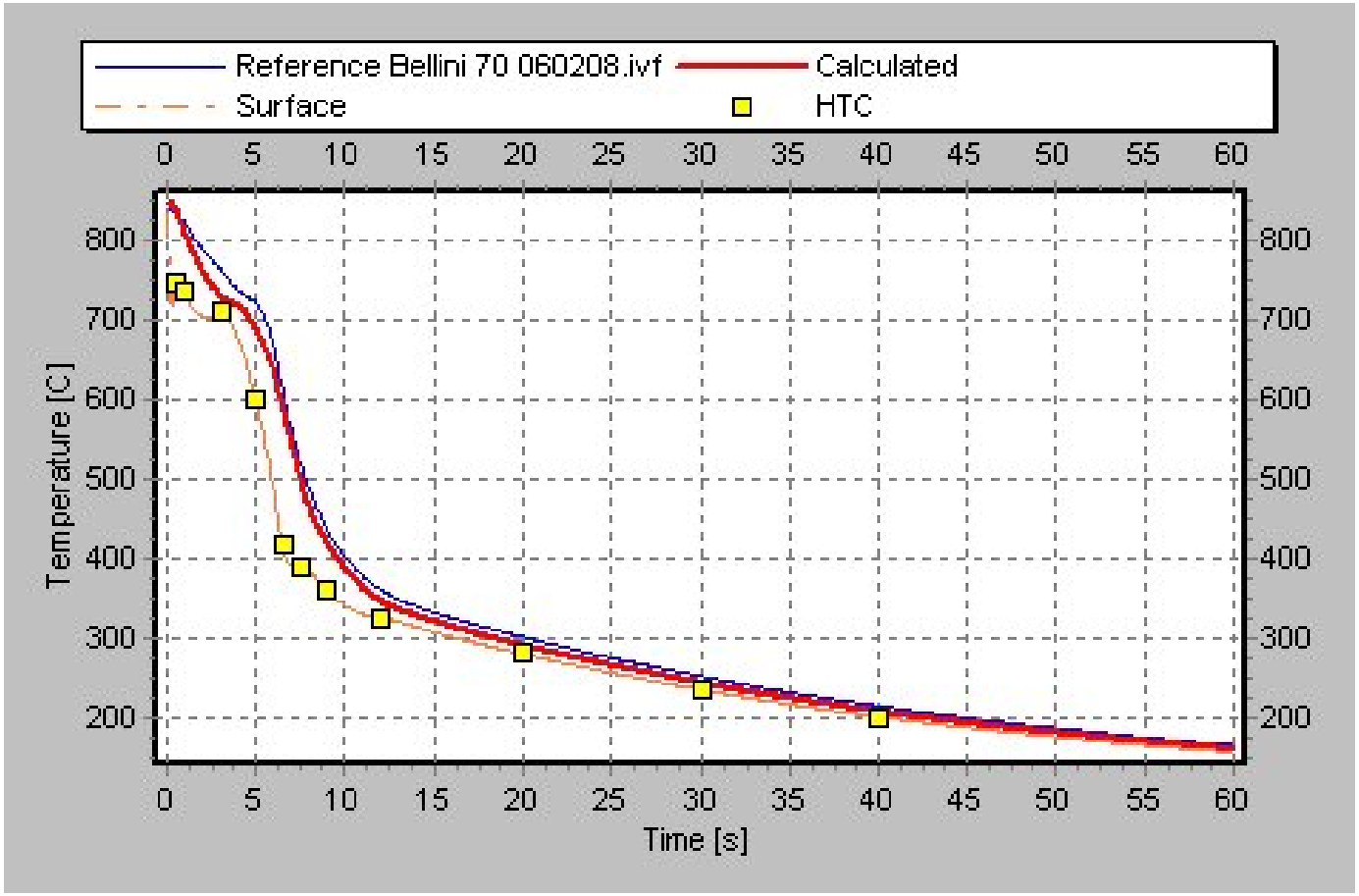


2. Calculation of heat transfer coefficient

- Inverse calculation
- Direct calculation
- The HTC determined is valid at the surface of the probe at the same height as the thermocouple



Step 2. Calculation of heat transfer coefficient – first iteration



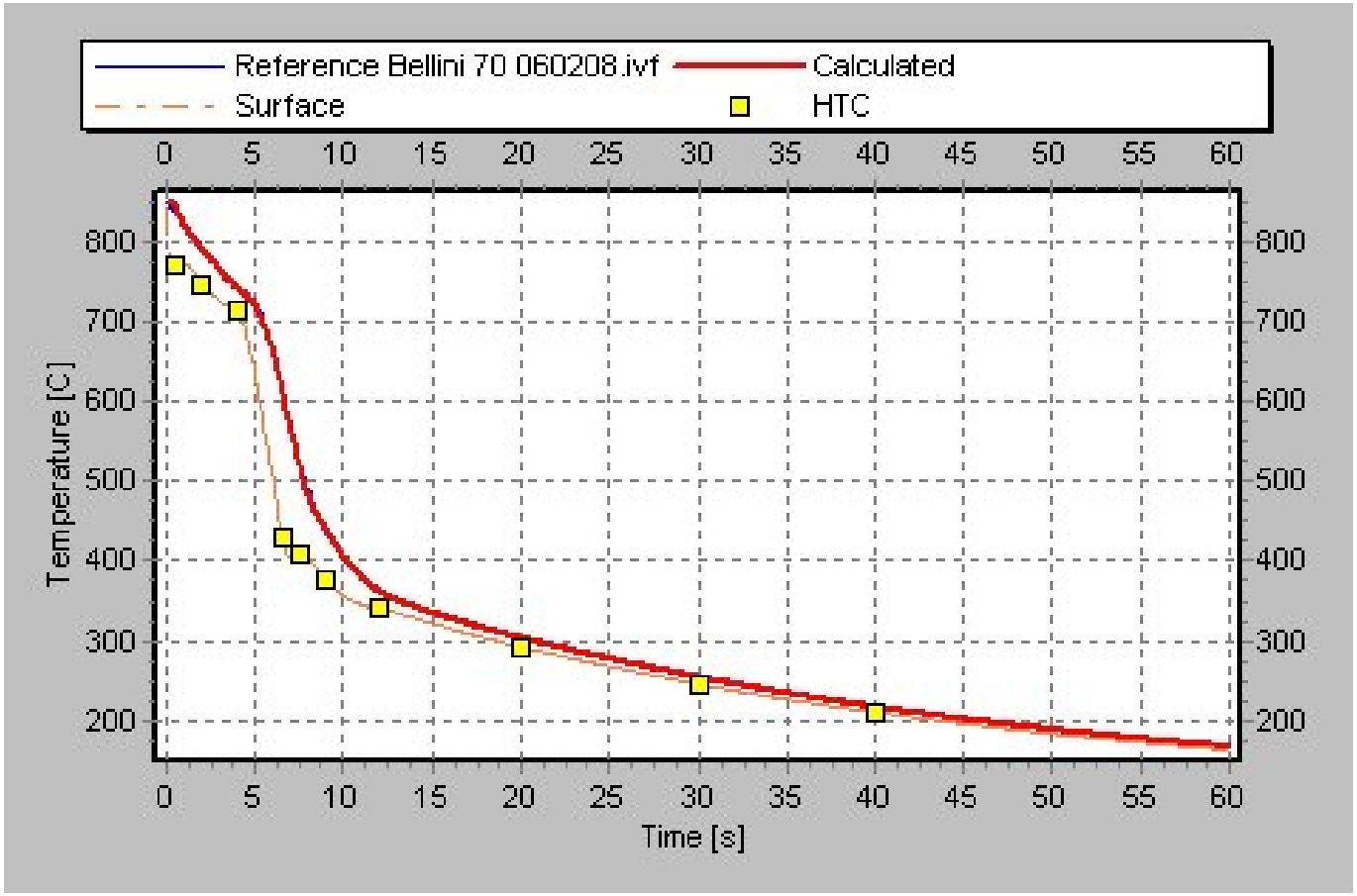
Measured, centre

Calculated, centre

Calculated, surface

Point for HTC

Step 3. Calculation of heat transfer coefficient – completed (addition of time steps)



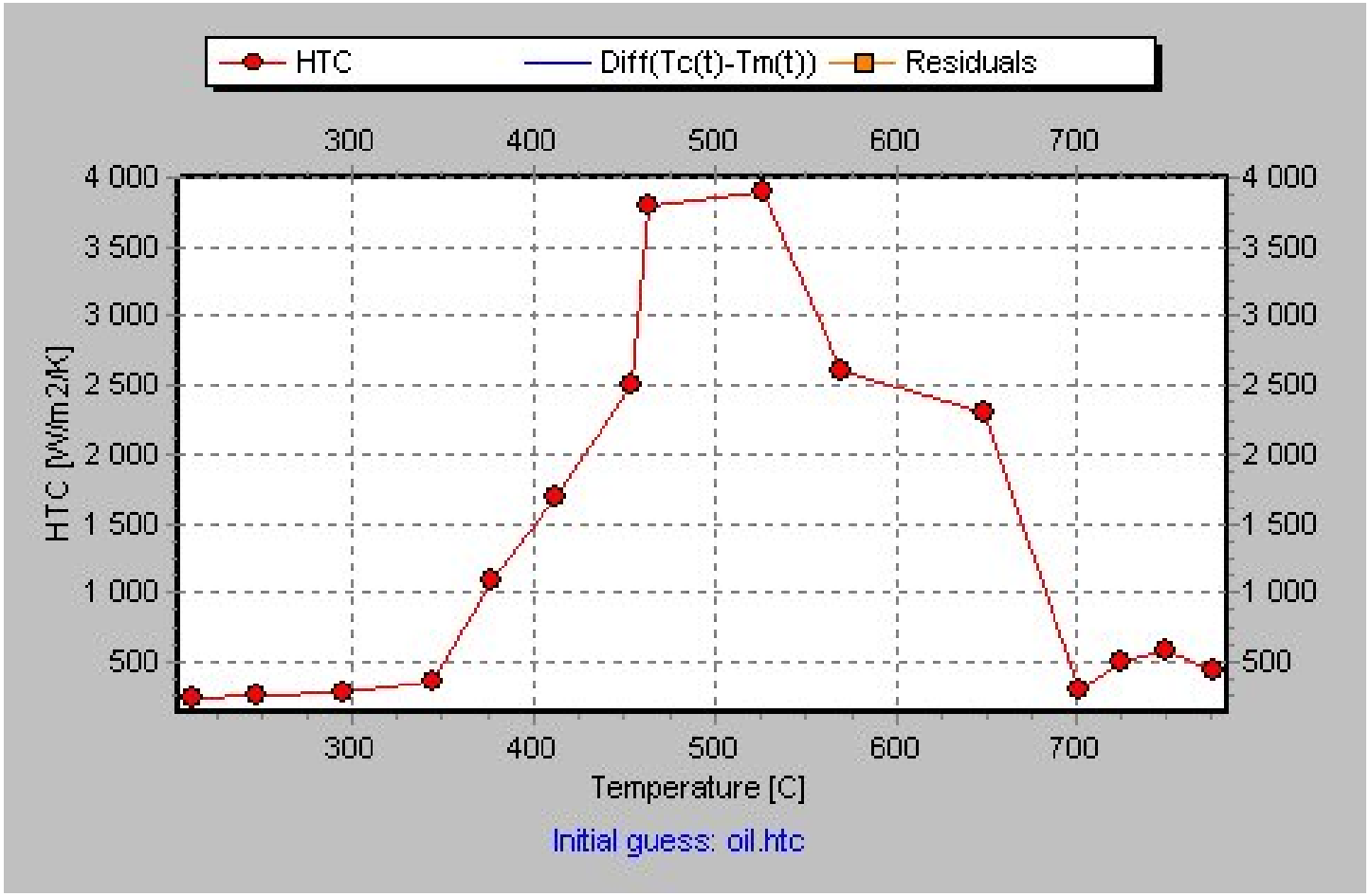
Measured, centre

Calculated, centre

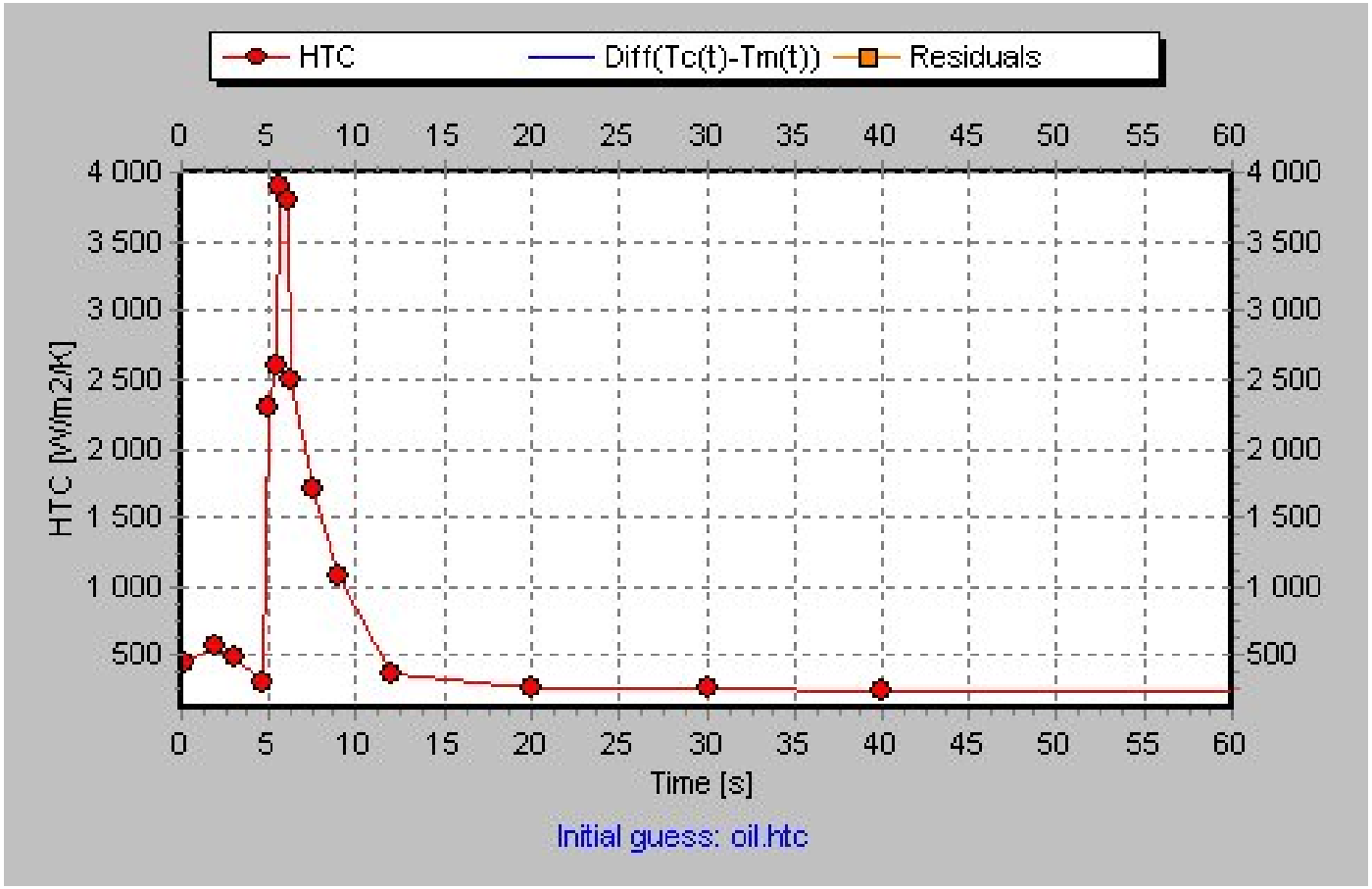
Calculated, surface

Point for HTC

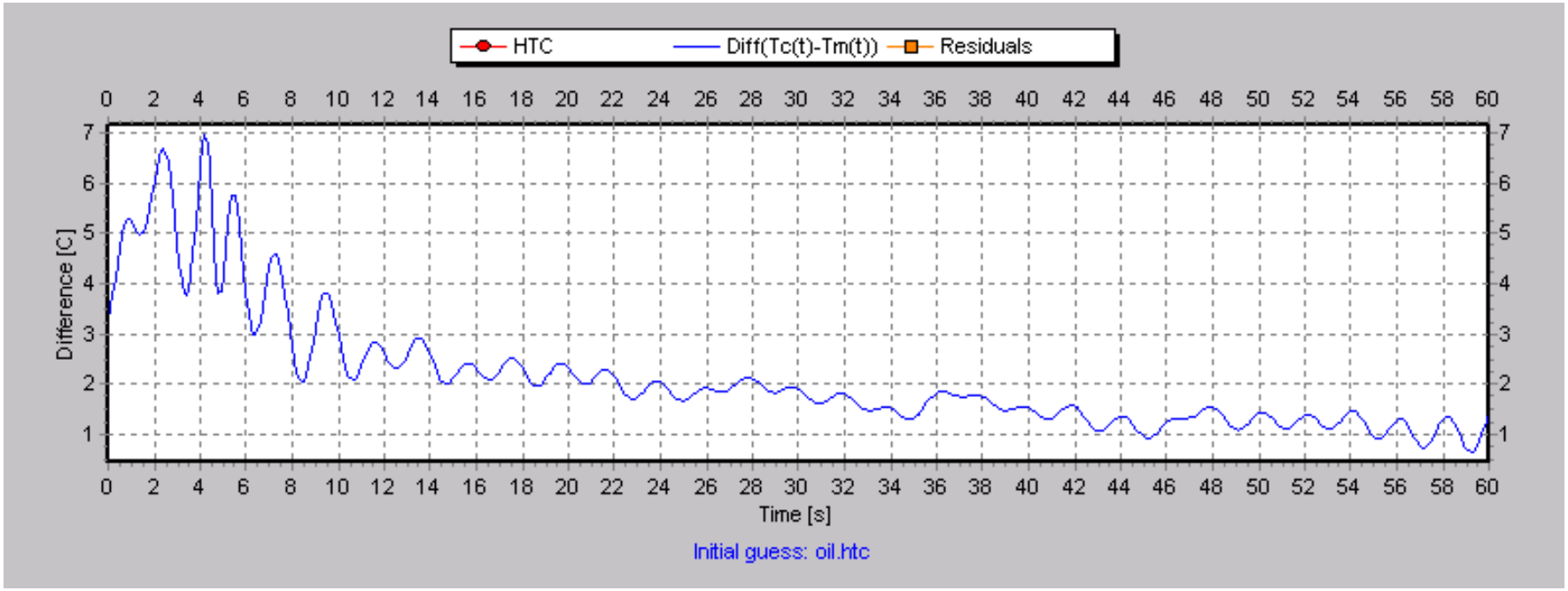
Step 4. Heat transfer coefficient vs Temperature



Step 4. Heat transfer coefficient vs Time

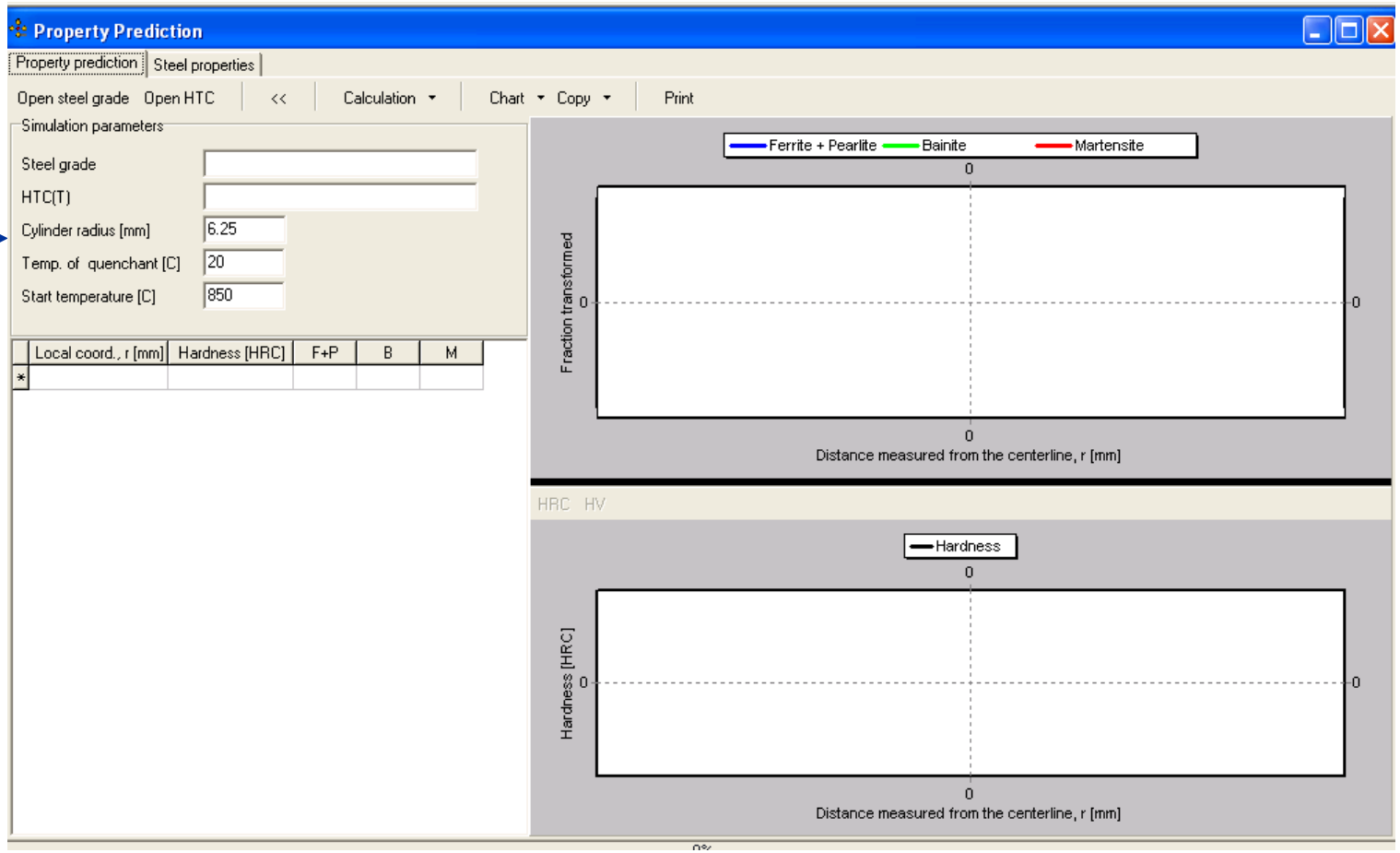


Temperature difference: calculated - measured

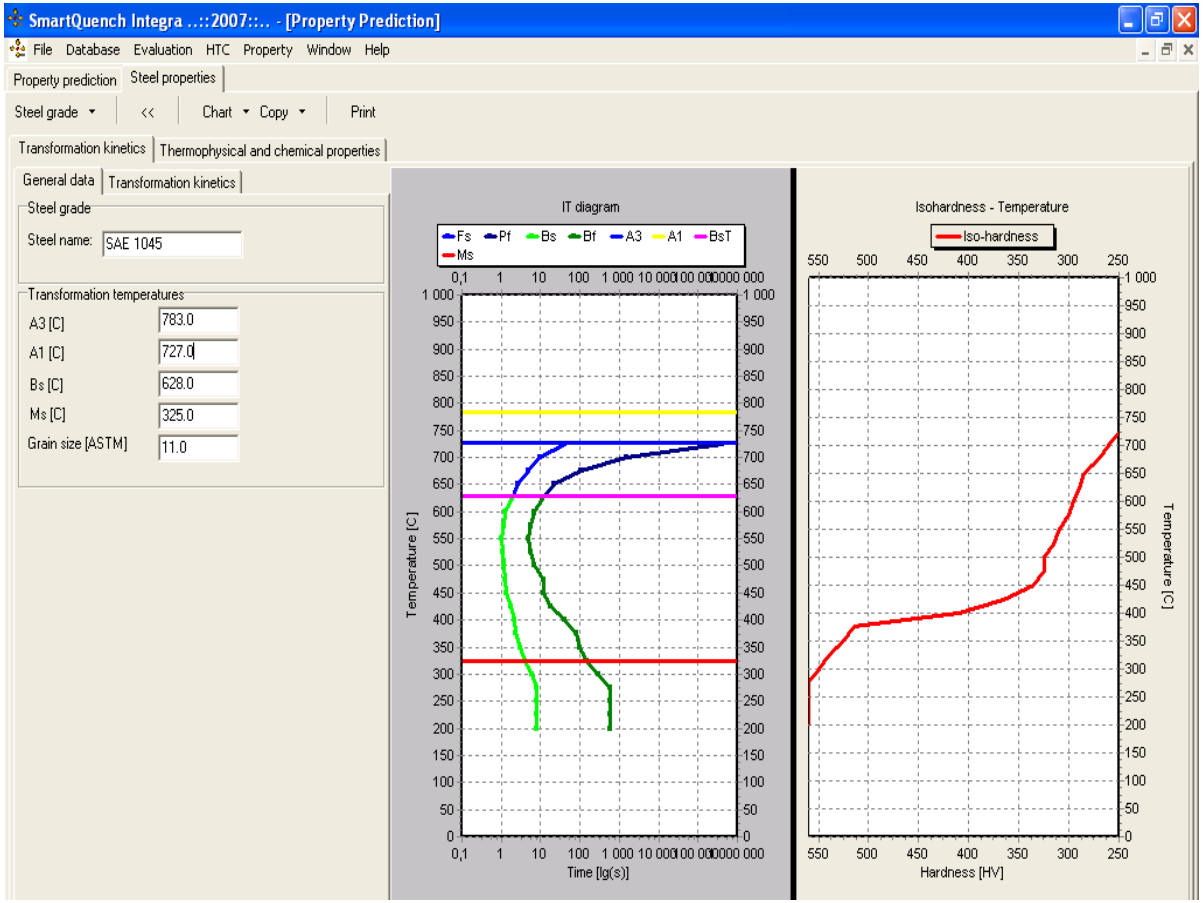


Step 5. Property prediction

- Steel grade
- HTC
- Cylinder radius
- Temp of quenchant
- Start temp

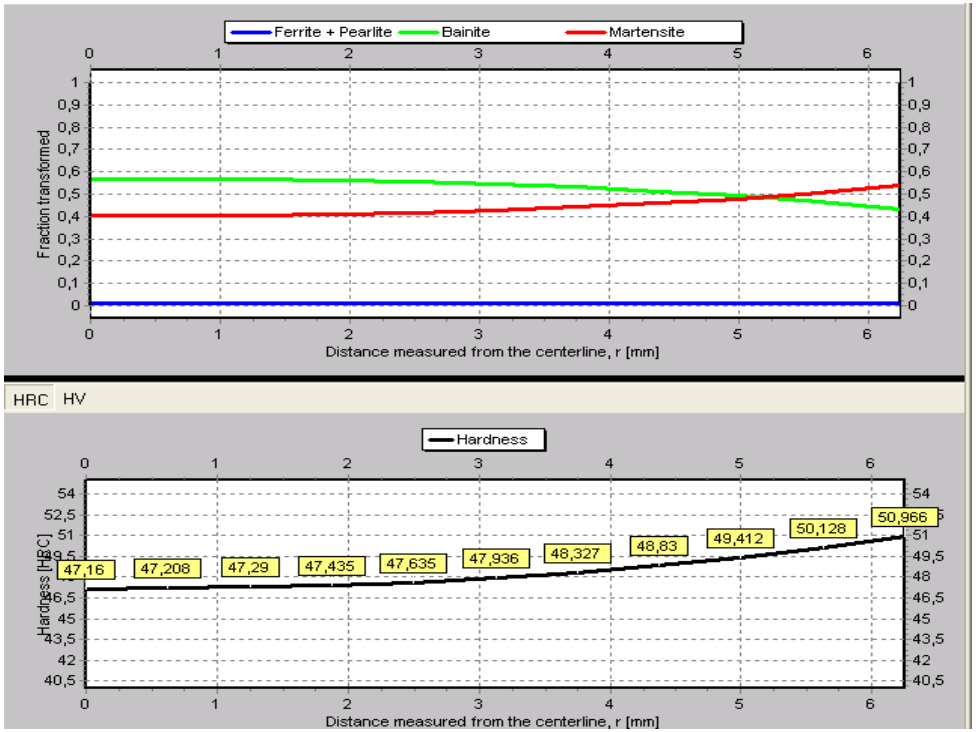


Input Steel data
TTT approach (Réti et al. 1981)

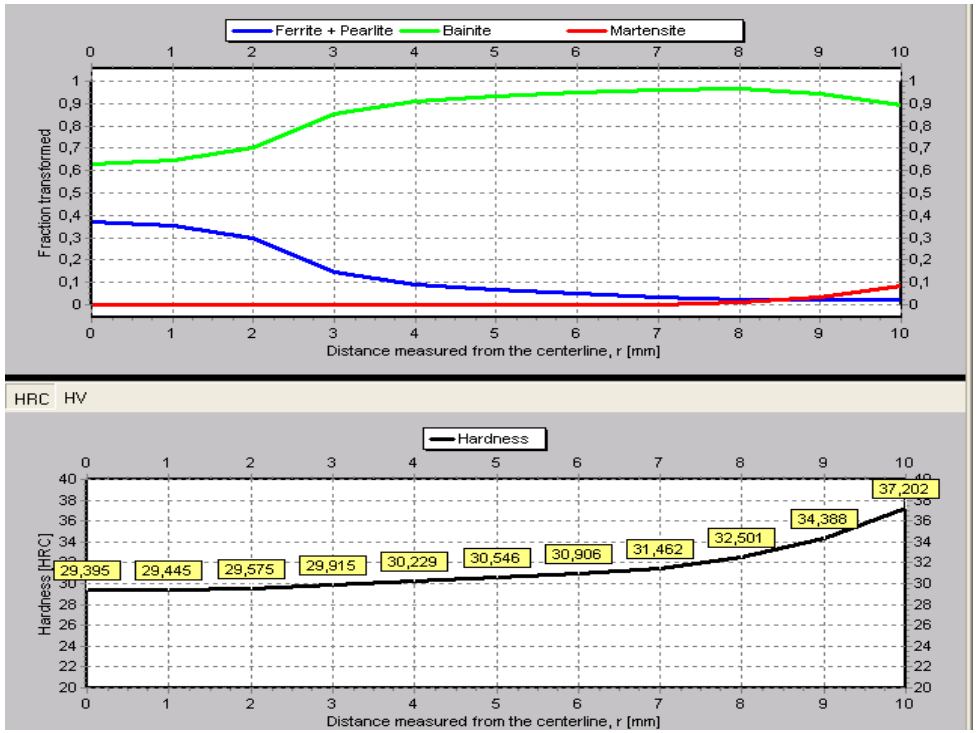


Step 6. Calculation of microstructure and hardness

Steel SAE 1045



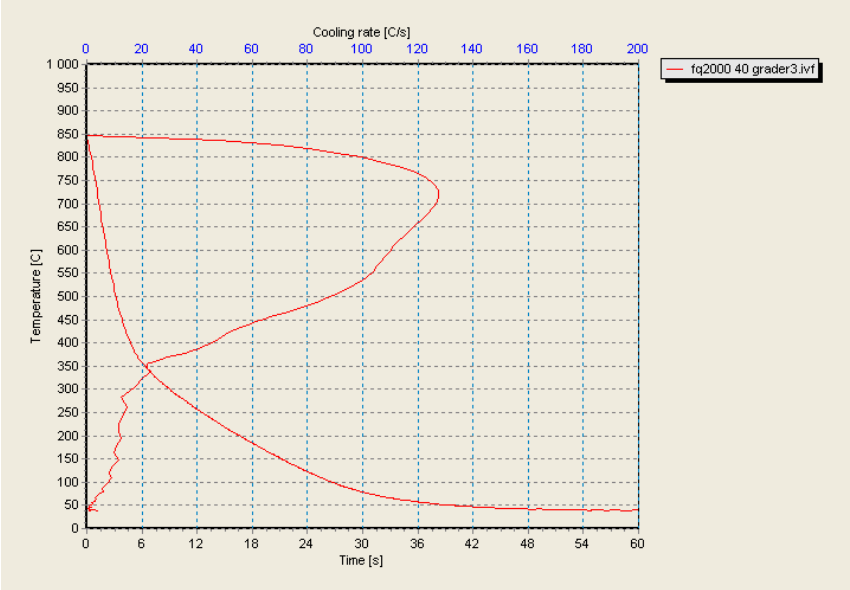
Diameter 12,5 mm

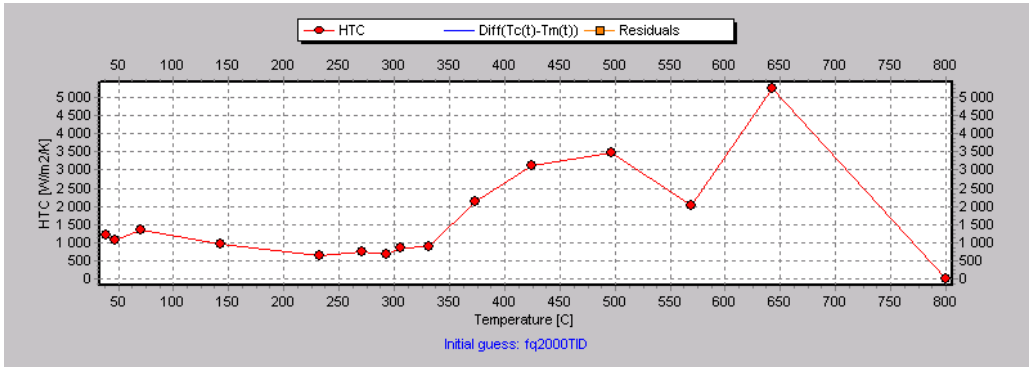


Diameter 20 mm

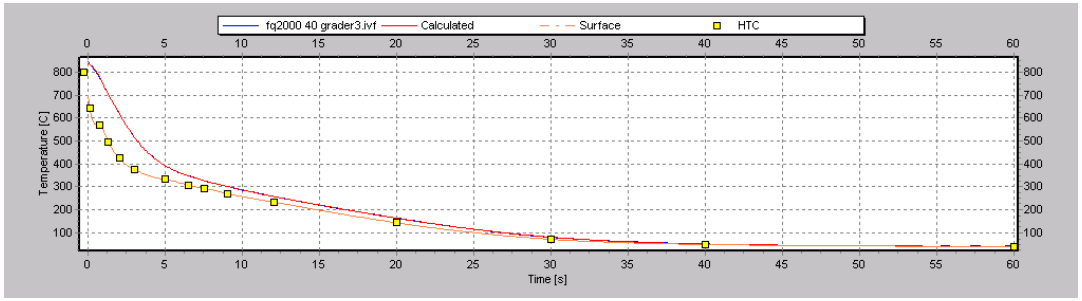
Polymer quenchant - Aquatensid

Cooling curve

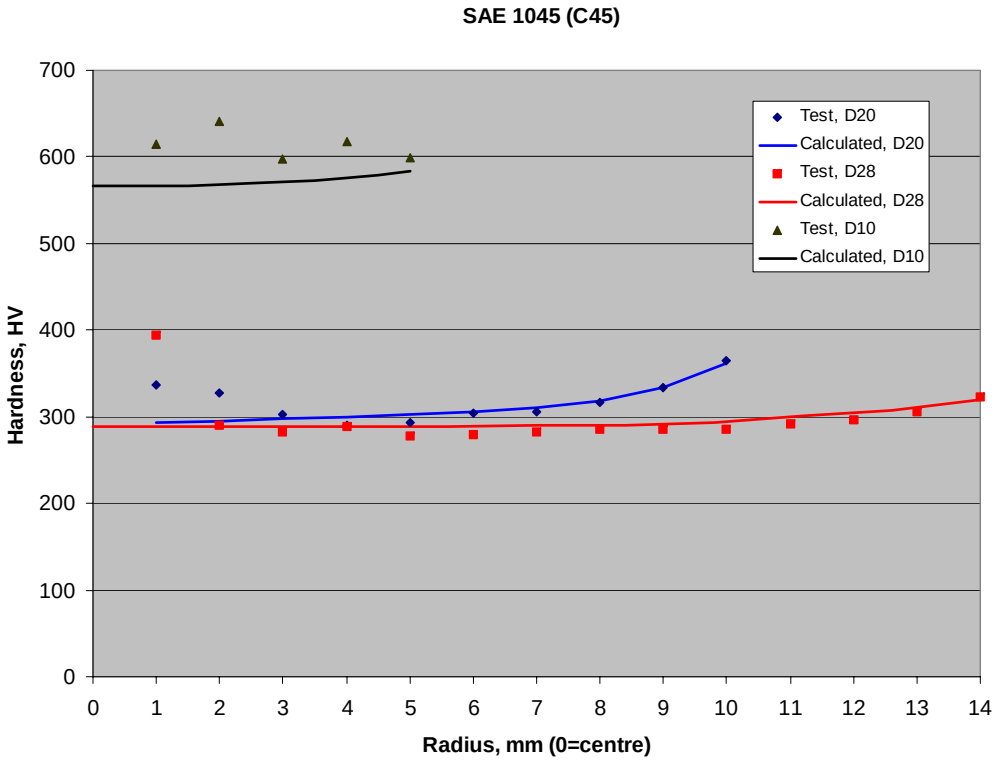


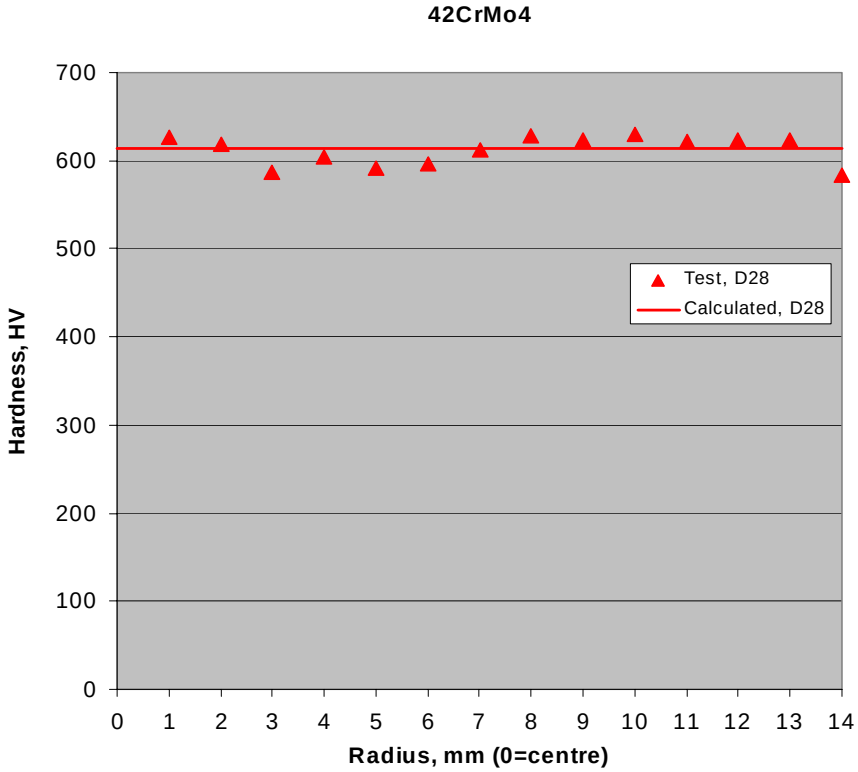


Heat transfer coefficient

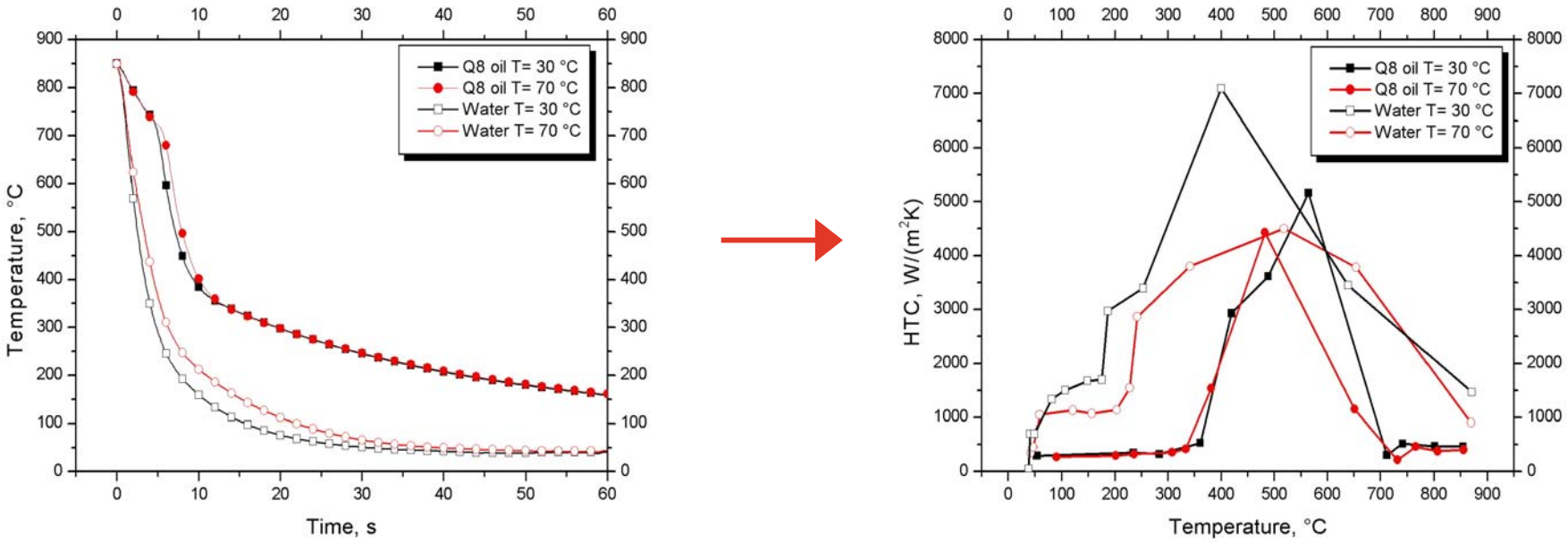


Verifying tests: steels SAE1045 and 42CrMo4

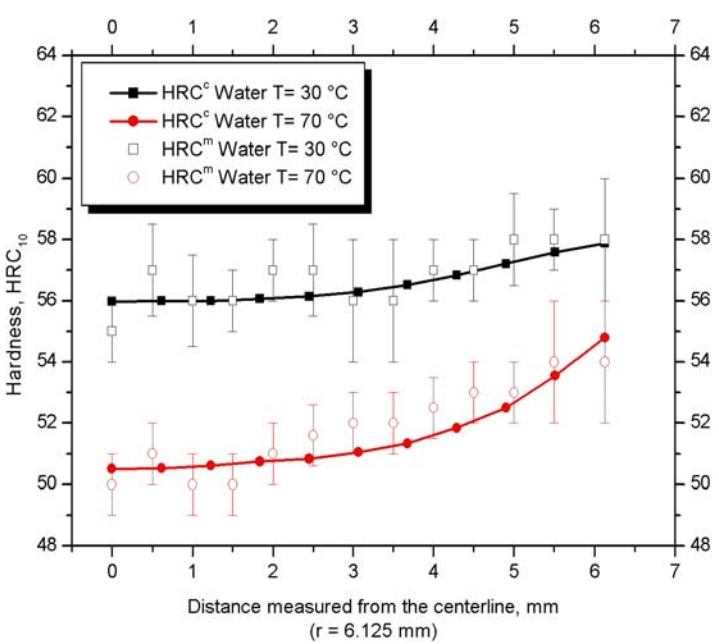




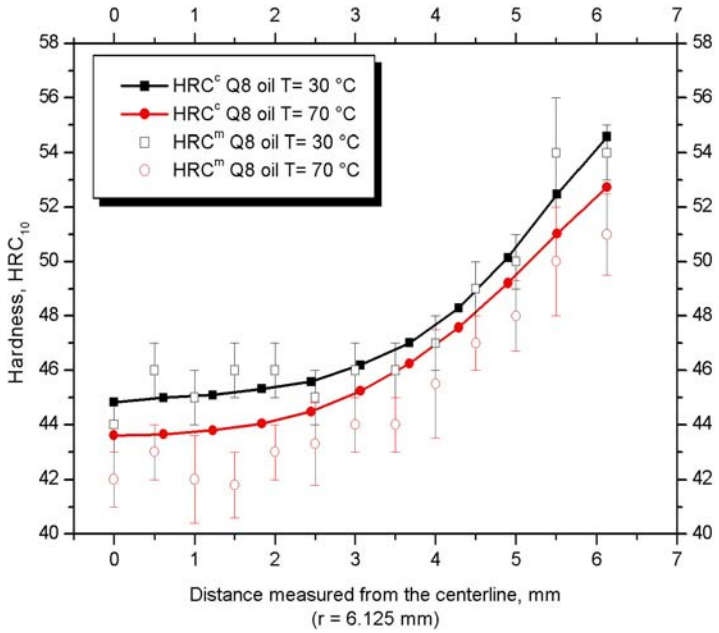
Cooling curves and Heat transfer coefficients
Oil and water; 30 ºC, 70 ºC



Calculated hardness compared to meassured Steel SAE1045 quenched in water 30 and 70 ºC



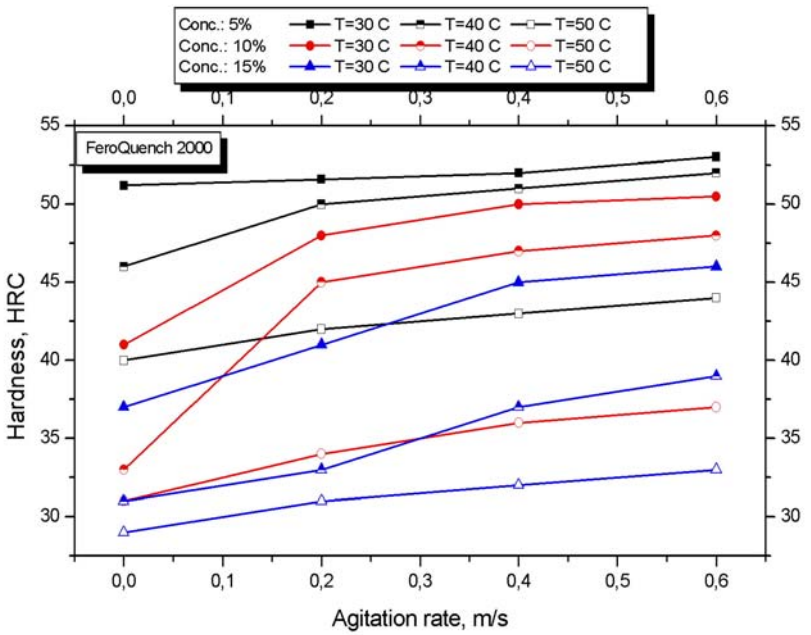
Quenched in water 30 and 70 ºC

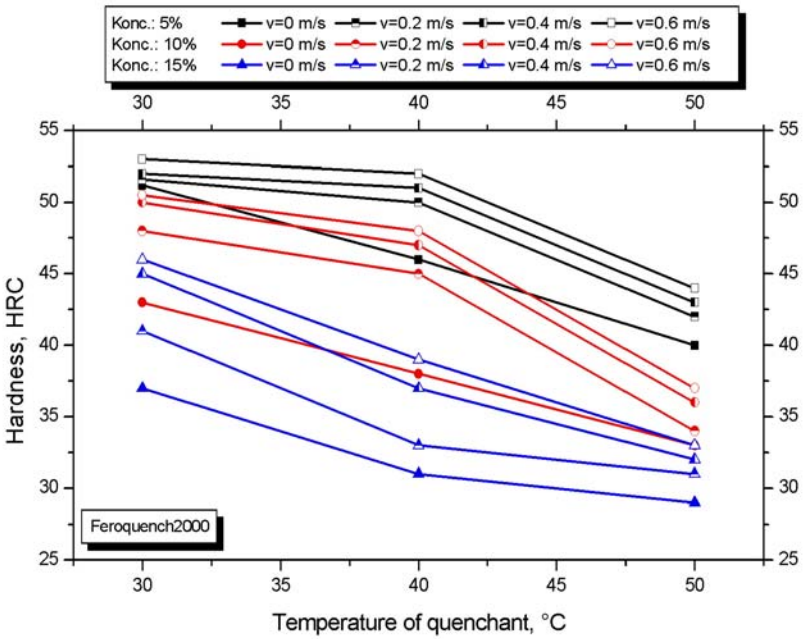


Quenched in oil 30 and 70 ºC

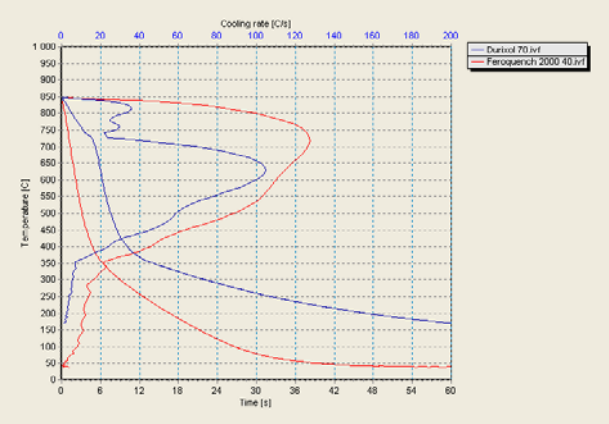
Application examples

- Sensitivity analysis - Parameter prediction

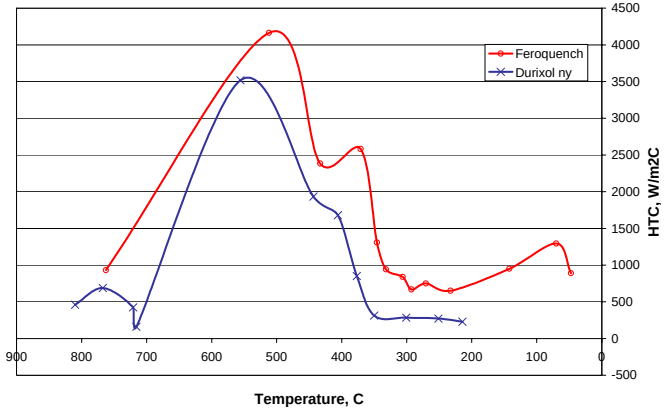




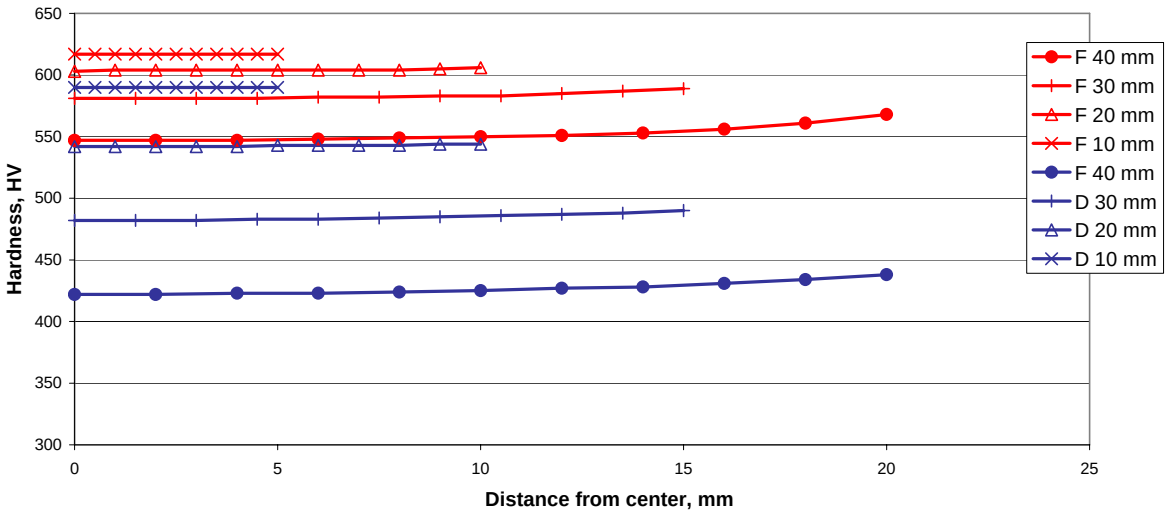
Comparison of cooling curves



HTC



Calculated hardness



Quality of the calculations

- The accuracy of the calculated heat transfer coefficient.
- The correctness of the used steel data

It is important to bear in mind that:

- The HTC calculations are valid for the probe used for recording the cooling curve
- The cooling curve is valid only under the particular measurement circumstances.
- The normal variation in the chemical composition within different steel grades will influence the parameters describing the steel transformation.
- The calculations are one-dimensional.

The quality of the calculations made by SQintegra in predicting the microstructure and hardness is dependent on:

- The accuracy of the calculated heat transfer coefficient. The difference between the measured and the calculated curve can be analysed in the software. If needed, additional time steps can be added to increase the accuracy.
- The correctness of the used steel data, particularly parameters describing the IT phase transformations and iso-hardness.
- It is important to bear in mind that:
  - The HTC calculations are valid for the probe used for recording the cooling curve. When transferring the HTC to much larger dimensions or other geometries, the effects thereof must be taken into consideration.
  - The cooling curve is valid only under the particular measurement circumstances. Flow, temperature and concentration may vary in a quench tank and over a period of time.
  - The normal variation in the chemical composition within different steel grades will influence the parameters describing the steel transformation.
  - The calculations are one-dimensional.

Summary

With the ivf SmartQuench test system and the SQintegra software module it is possible to:

- Continuously perform quality control of the quenching process
- Calculate heat transfer coefficients for simulation purposes
- Predict hardness and microstructure distribution on cylindrical specimens
- Perform sensitivity analysis on quenchants and the quenching system
- Acquire information needed for troubleshooting