

# Design of cooling sections for heat treatment based on laboratory measurements of heat transfer coefficient

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TREATMENT 2022

# Introduction

- **HEATLAB Introduction**
- **Finding the optimal cooling strategy**  
(laboratory approach)
- **Experimental devices for measurement of cooling intensity**
- **Numerical simulations of the cooling process**
- **Comparison of the plant and the laboratory measurement**



# Introduction



**BUT BRNO**



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Faculty of Chemistry  
Faculty of Civil Engineering  
Faculty of Electrical Engineering  
Faculty of Fine Arts  
Faculty of Information Technology  
Faculty of Mechanical Engineering

Total students: 19 240

Founded 1899

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# Introduction



HEATLAB

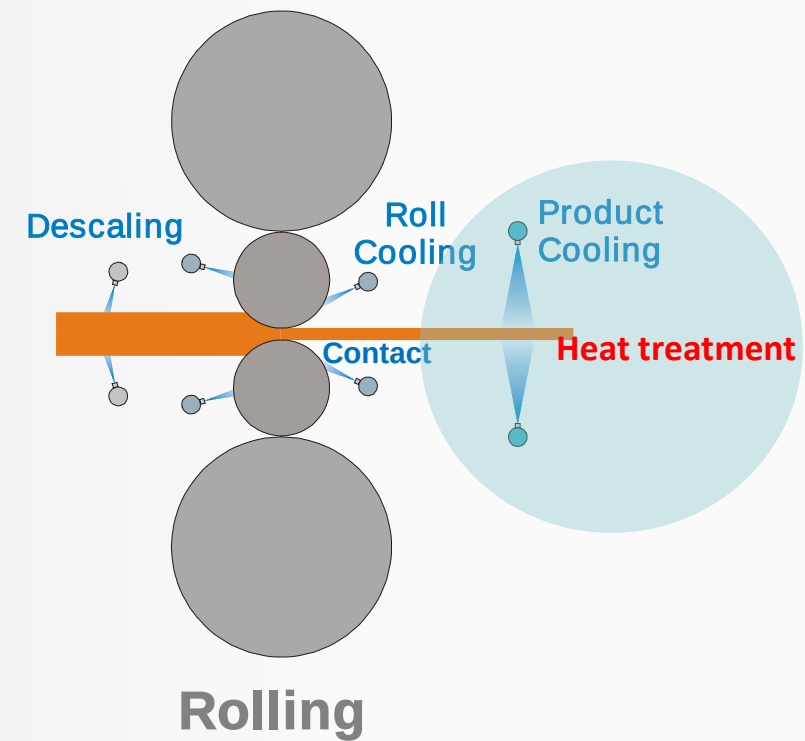
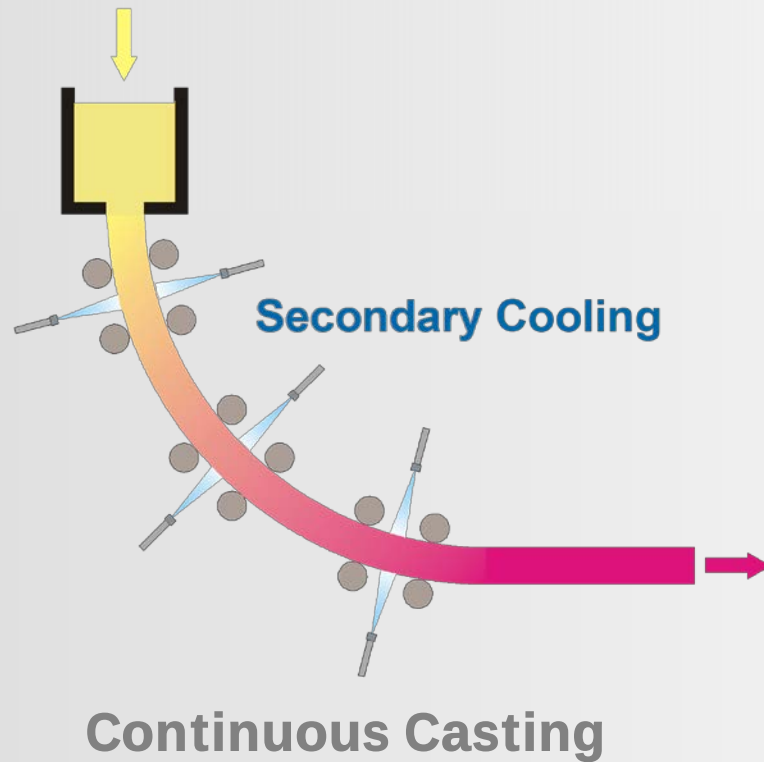


# Introduction

Boundary conditions, HTC, laboratory experiments, inverse task

Experimental research of heat transfer

Numerical models of cooling





# Finding the optimal cooling strategy (conventional approach)

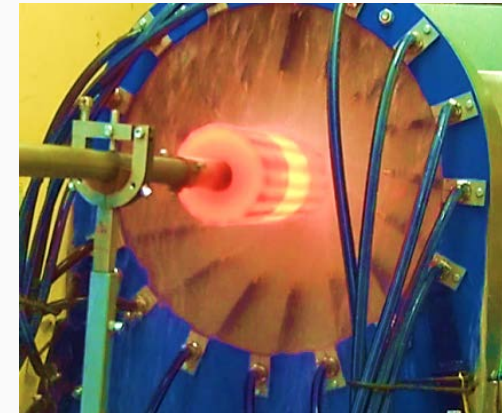
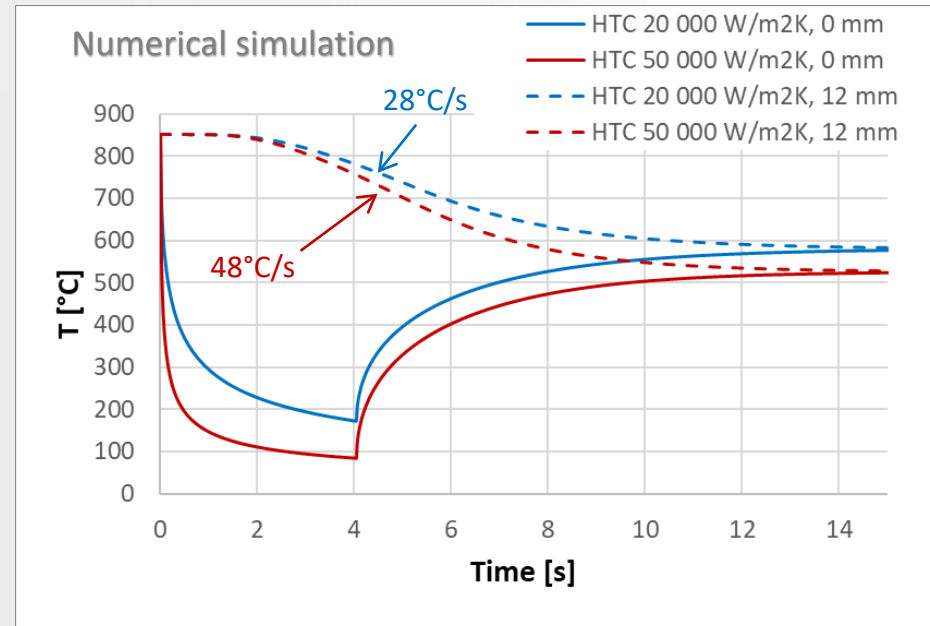
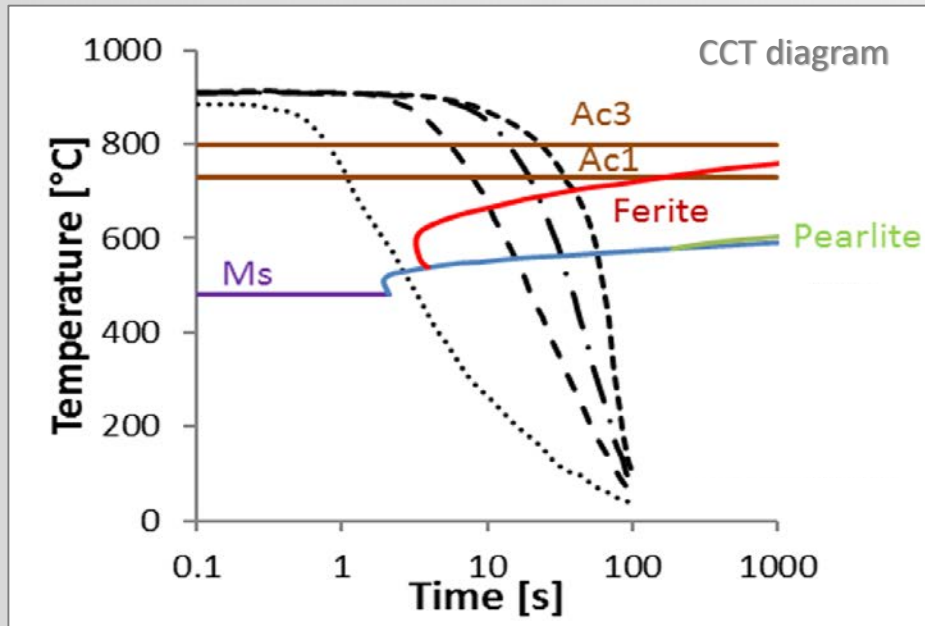
CCT diagram



Numerical simulation of  
the cooling process  
(estimated HTC)



Design of the cooling  
section



# Finding the optimal cooling strategy (laboratory approach)

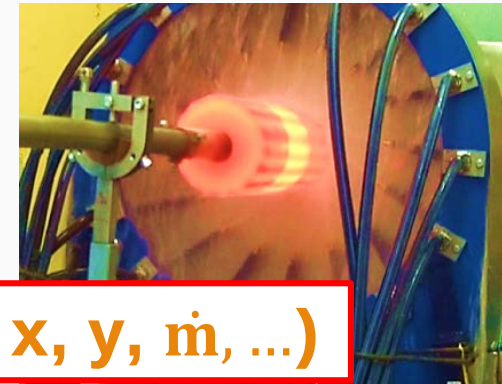
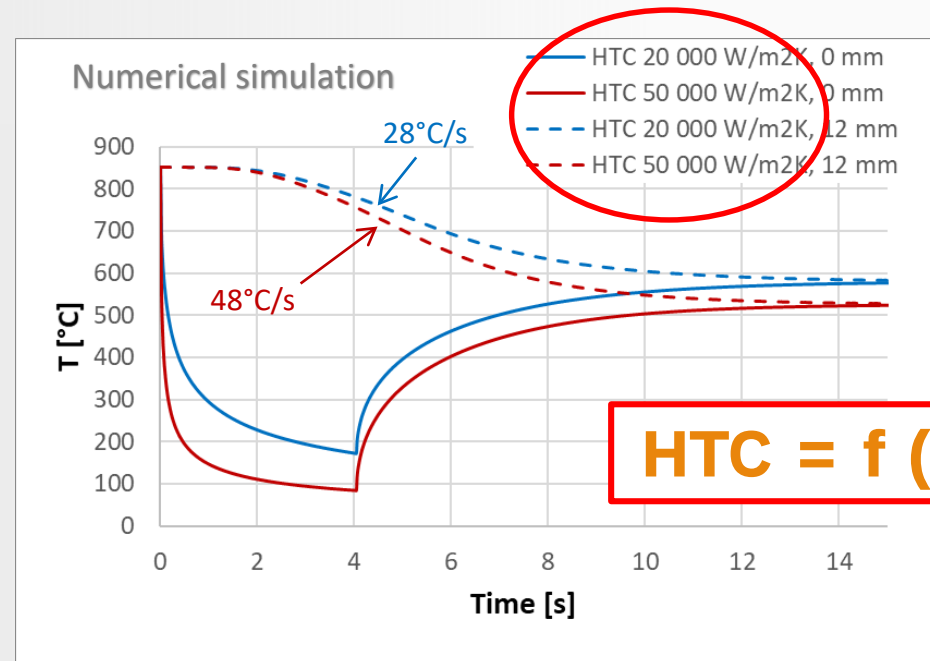
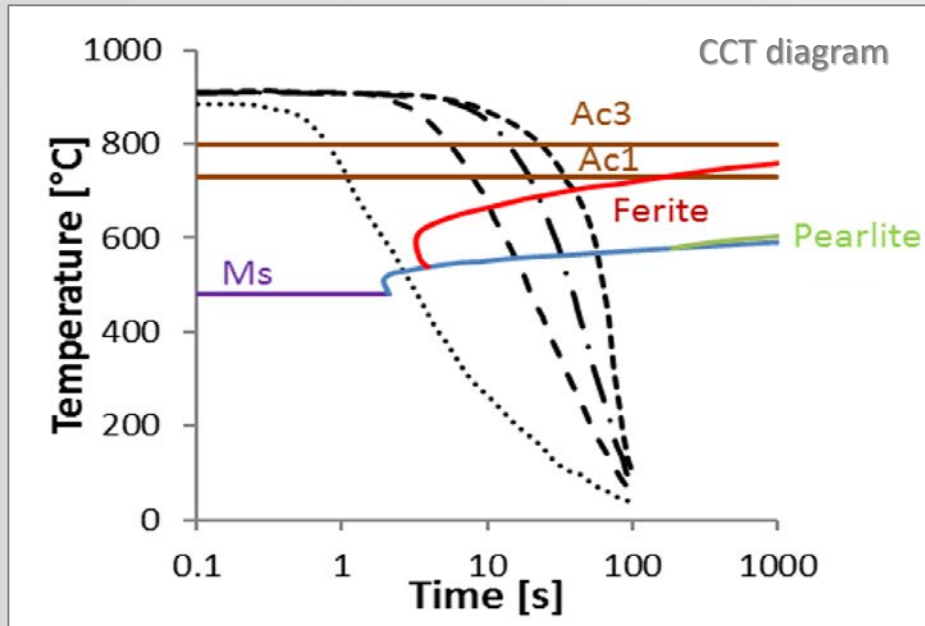
CCT diagram



Numerical simulation of  
the cooling process  
(**estimated HTC**)



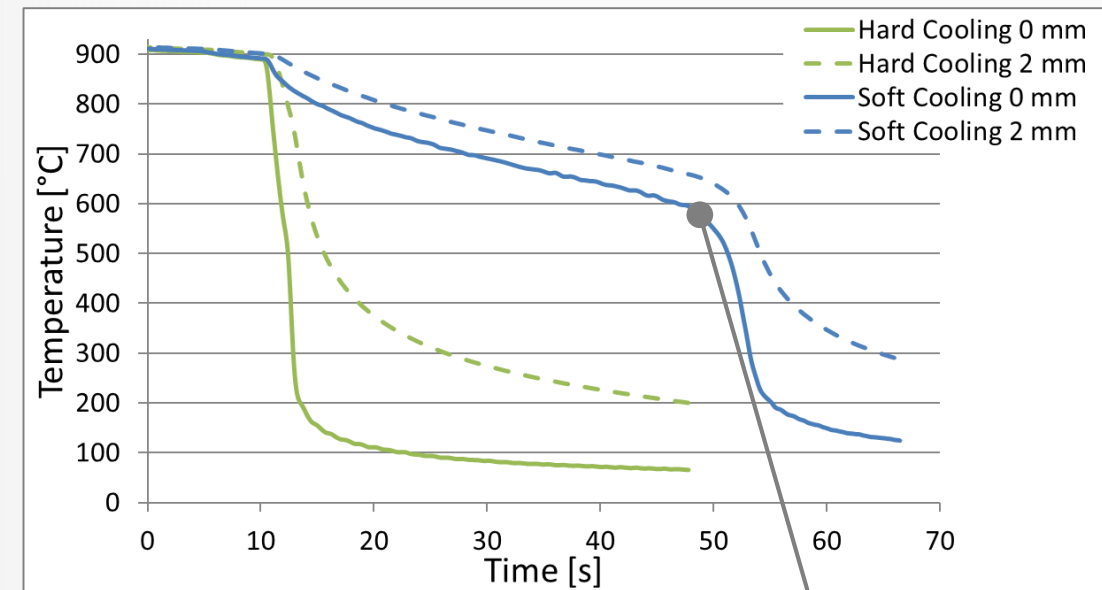
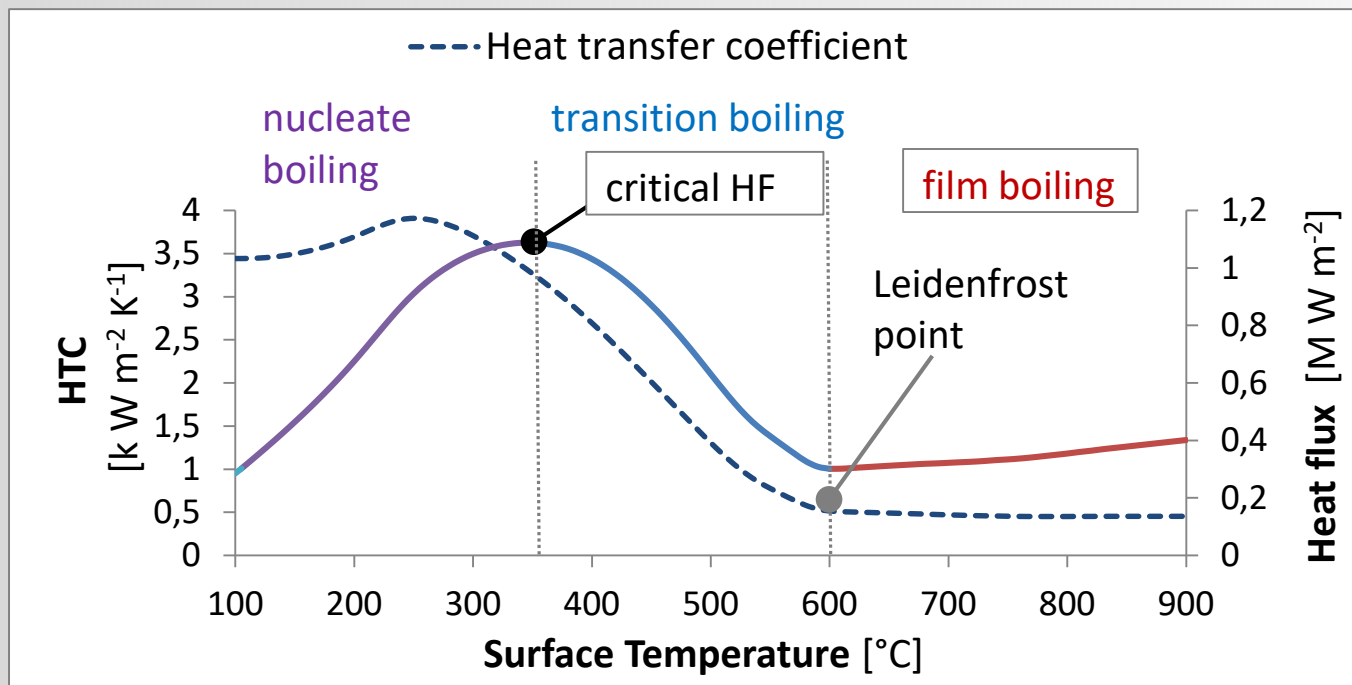
Design of the cooling  
section





# Finding the optimal cooling strategy

- Film boiling - Low cooling intensity
- Nucleate and transition boiling - High cooling intensity



Leidenfrost point

# Finding the optimal cooling strategy (laboratory approach)

- 1) Stationary quenching test
- 2) Test with moving sample
- 3) Numerical simulation of the cooling process
- 4) Laboratory verification of HTC – full scale test



Information about required  
cooling regime

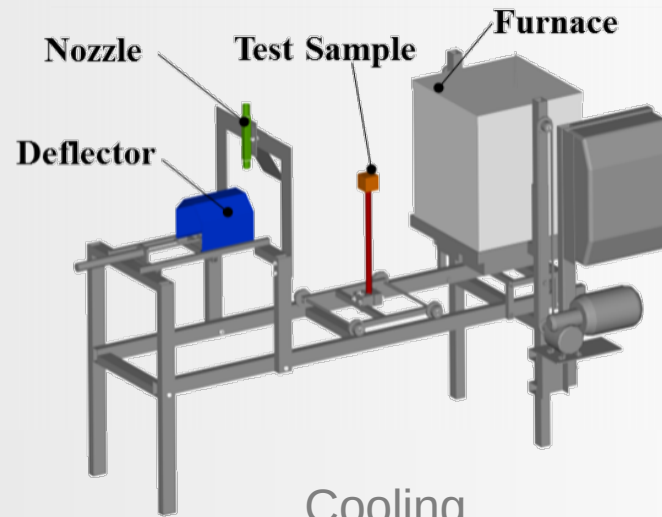
5) FINAL DESIGN OF THE  
COOLING SECTION



6) Plant  
verification

# Finding the optimal cooling strategy (laboratory approach)

## 1) Stationary quenching test



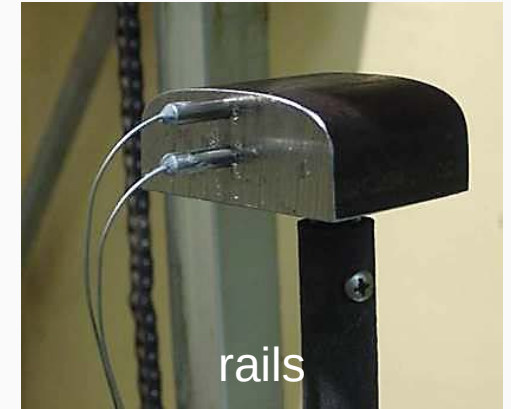
Heating



Cooling



Test Samples

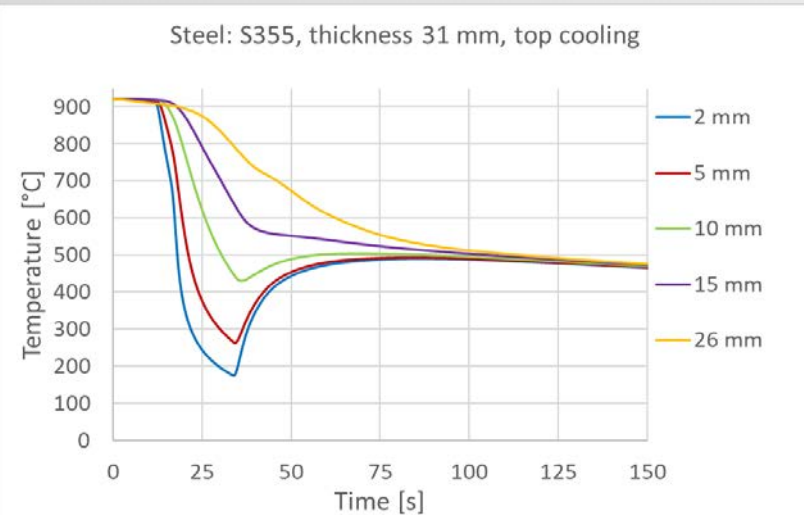




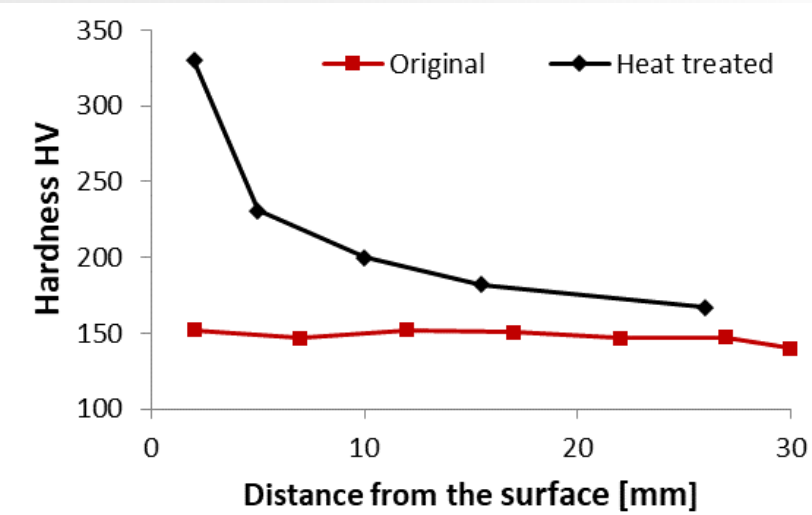
# Finding the optimal cooling strategy (laboratory approach)

## 1) Stationary quenching test - results

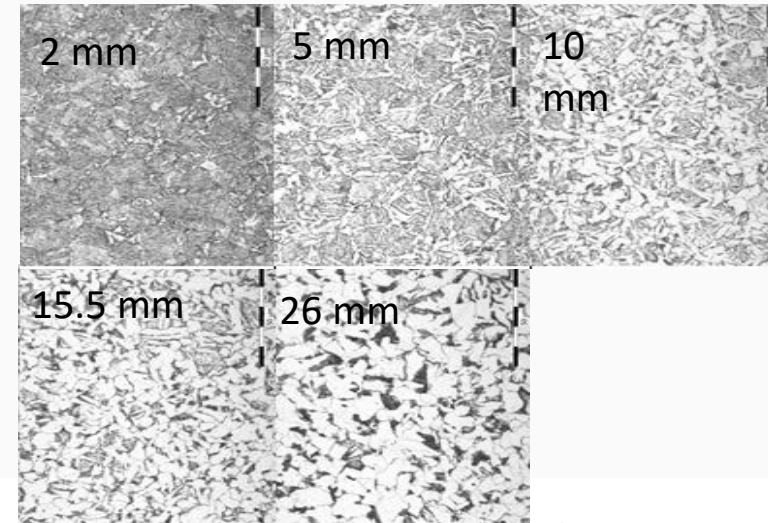
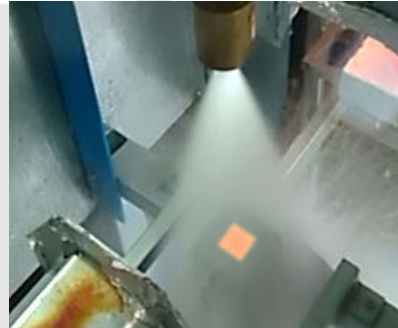
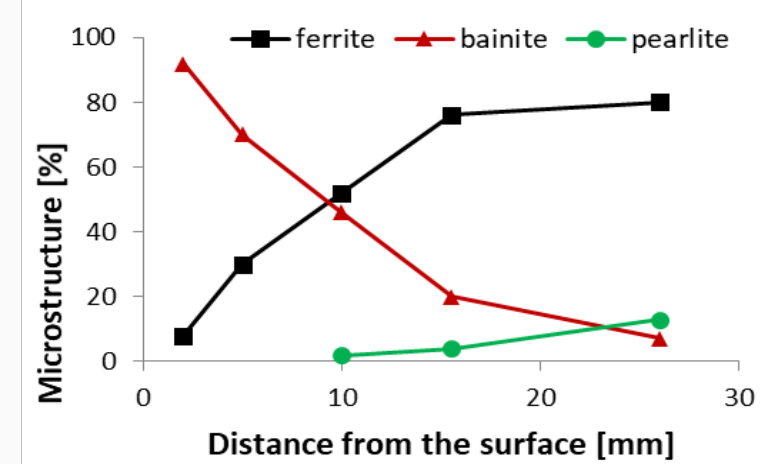
- measured temperatures



- measured hardness

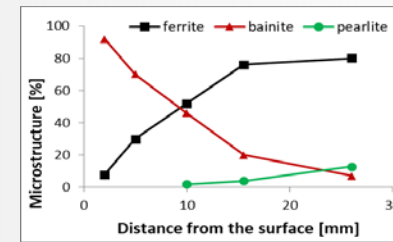
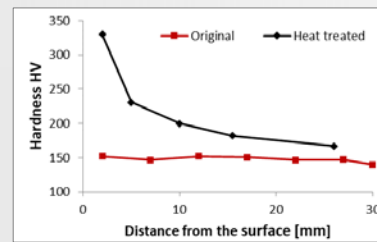
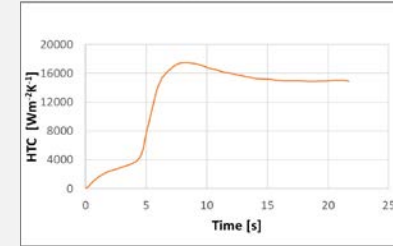
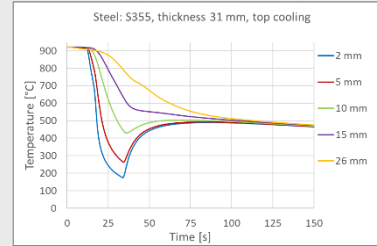
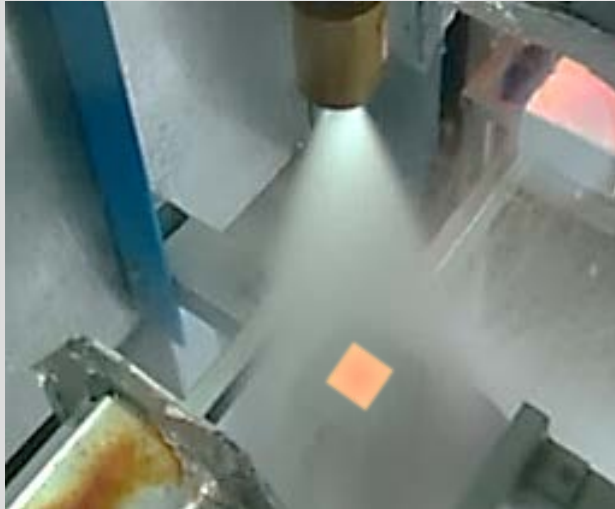


- observed microstructure

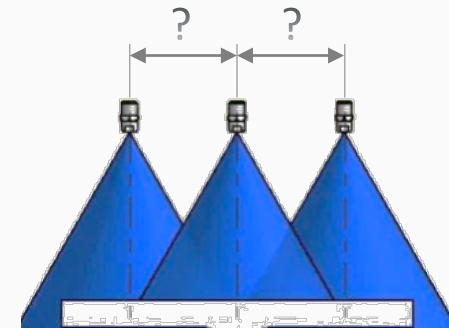
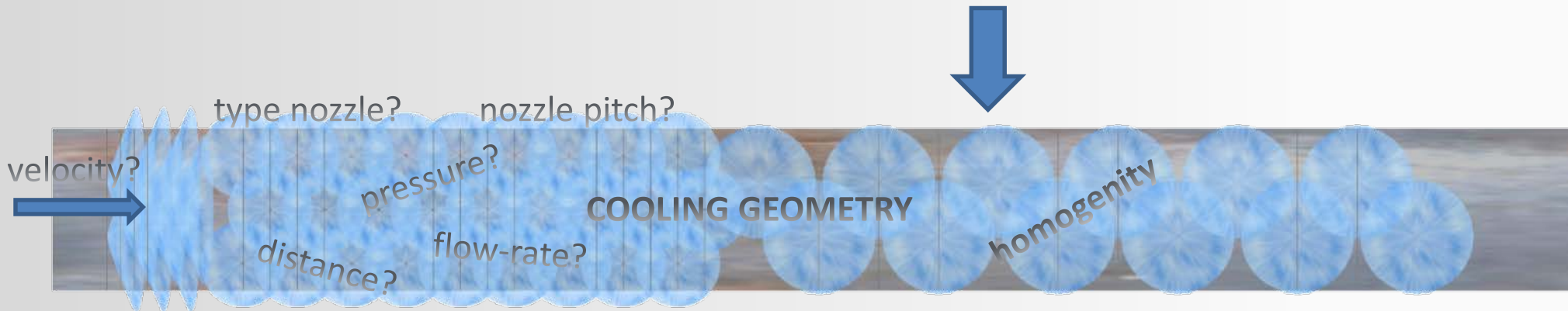


# Finding the optimal cooling strategy (laboratory approach)

## 1) Stationary quenching test



- measured temperatures,
- HTC,
- hardness,
- microstructure,
- mechanical properties, ...



# Finding the optimal cooling strategy (laboratory approach)

## 2) Test with moving sample



Tube diameter 160 mm, velocity 0.75 m/s



Plates



Rails



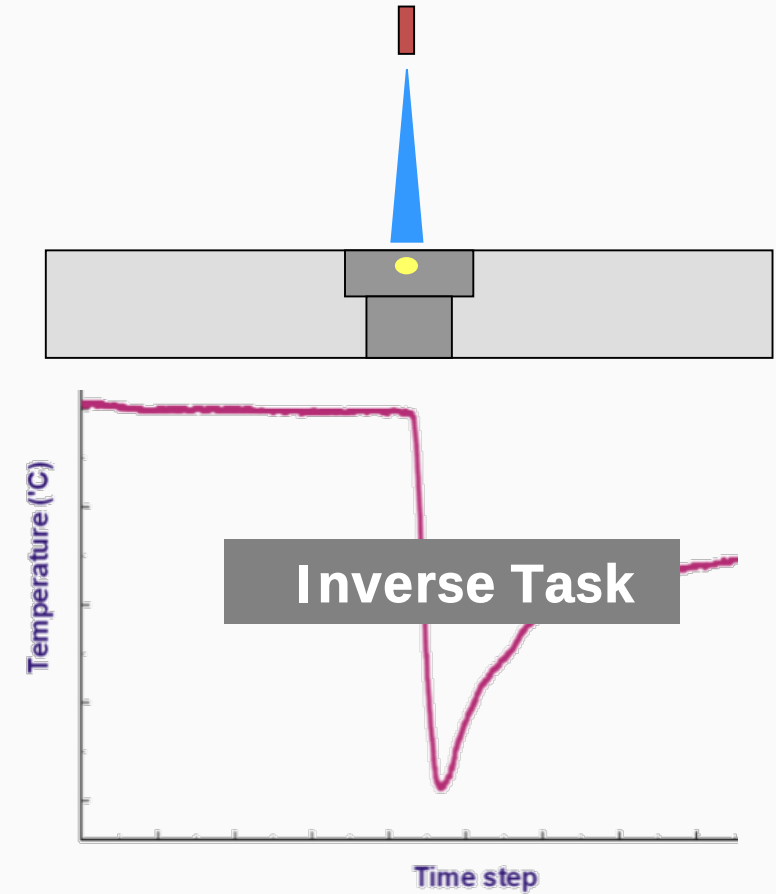
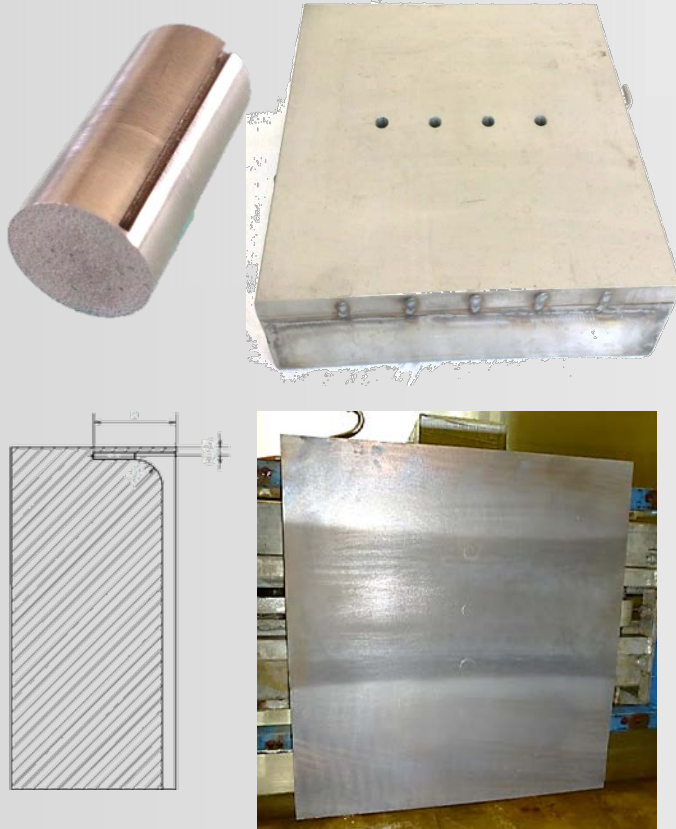
Tubes





# Finding the optimal cooling strategy (laboratory approach)

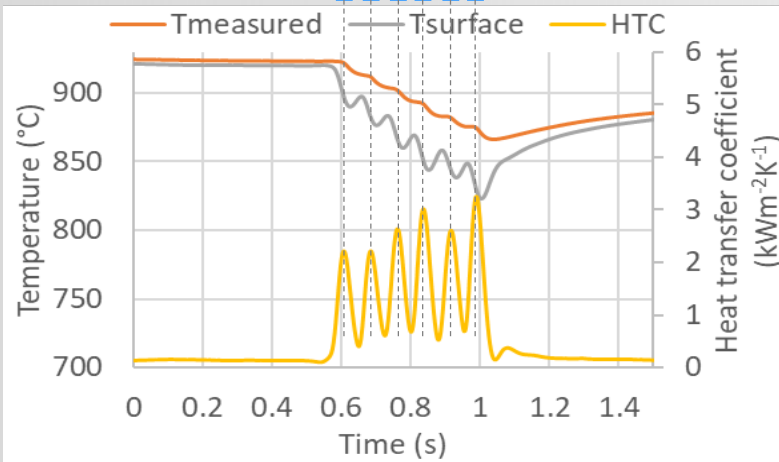
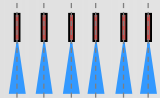
## 2) Test with moving sample



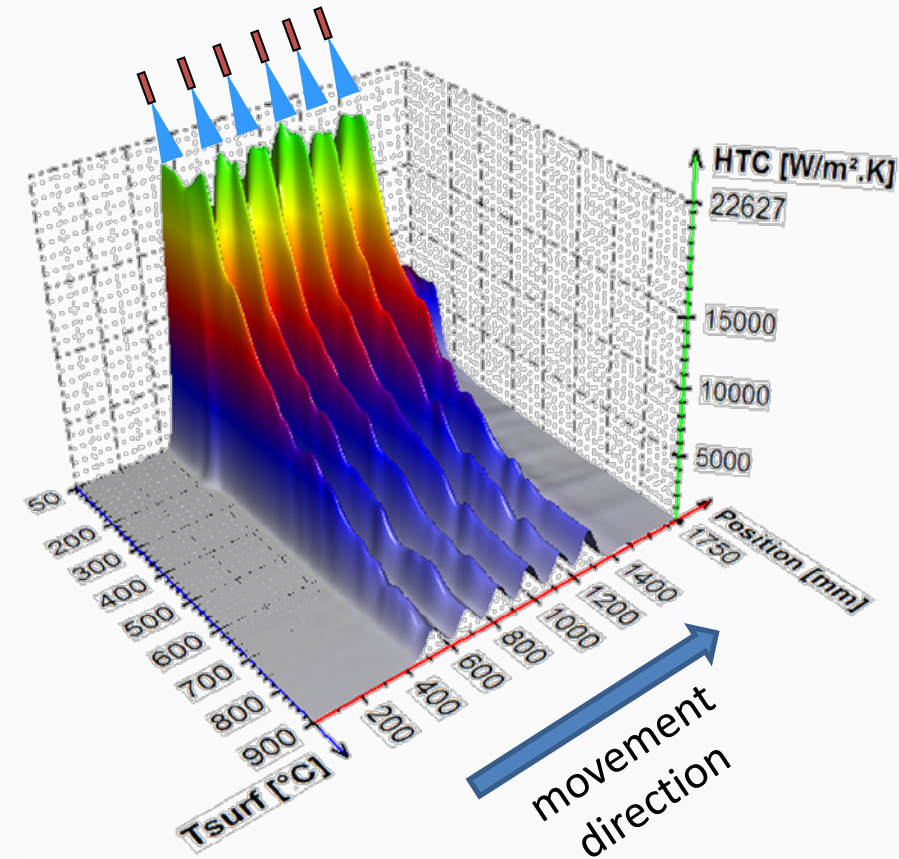
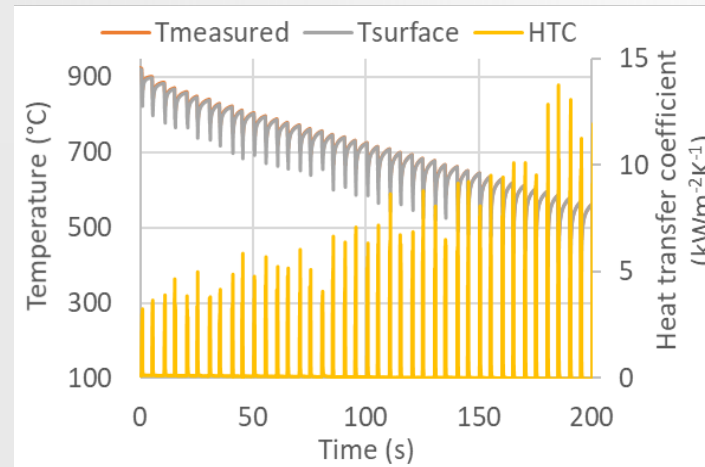
# Finding the optimal cooling strategy (laboratory approach)

## 2) Test with moving sample

1 zone  
6 nozzles  
(1m)



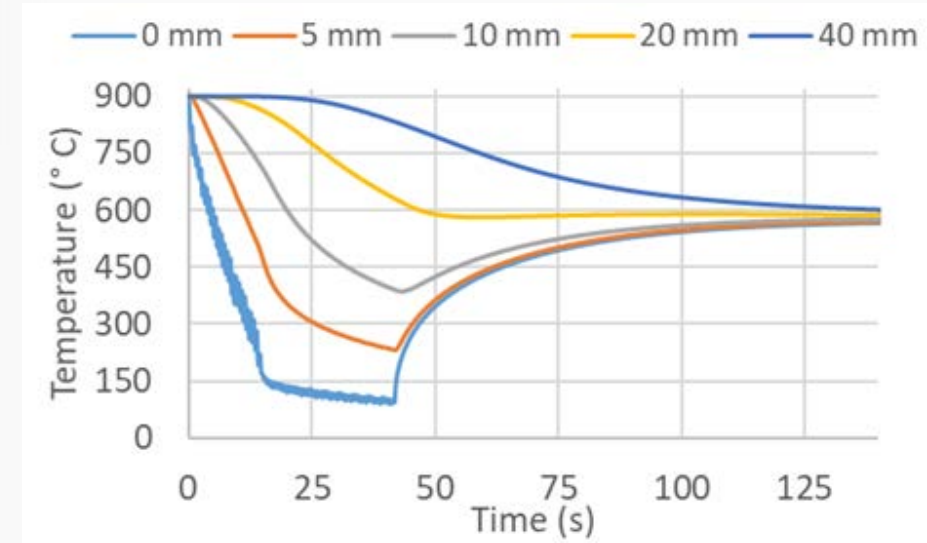
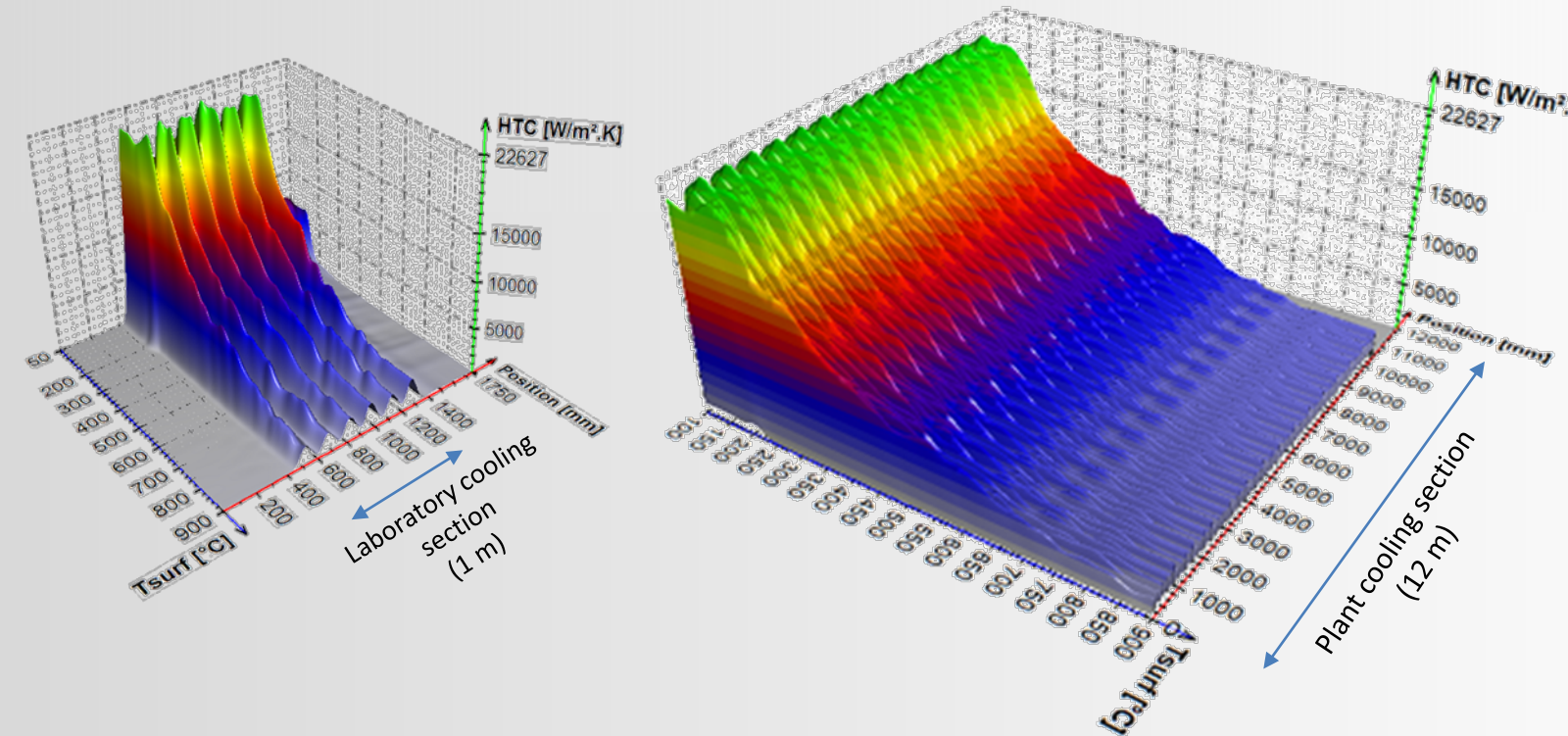
repeated  
cooling  
(38x)





# Finding the optimal cooling strategy (laboratory approach)

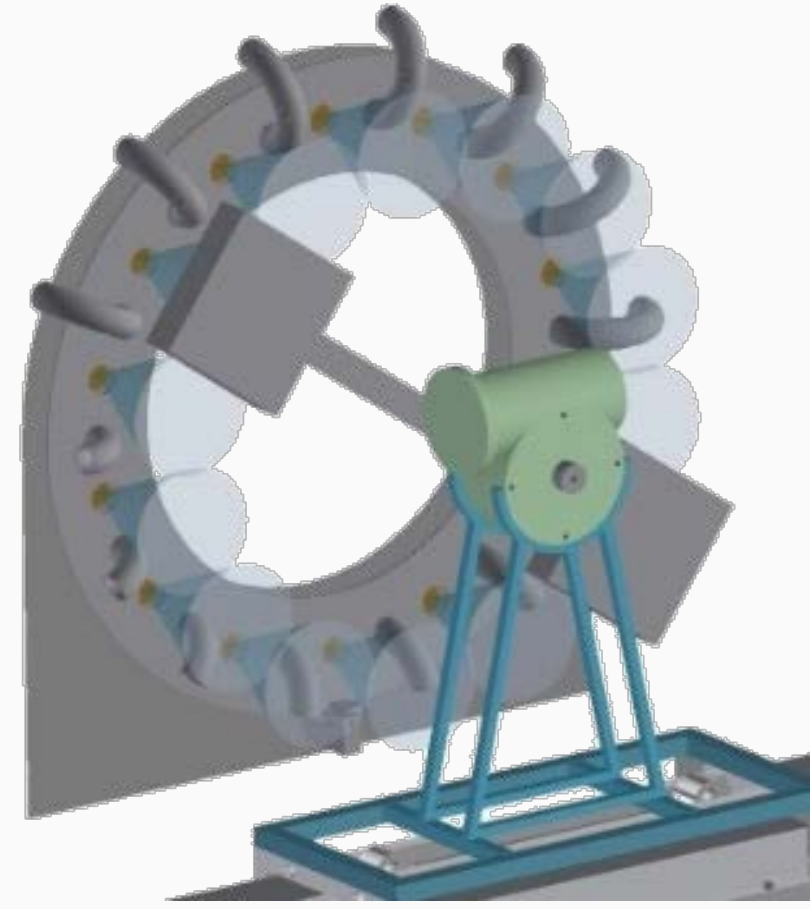
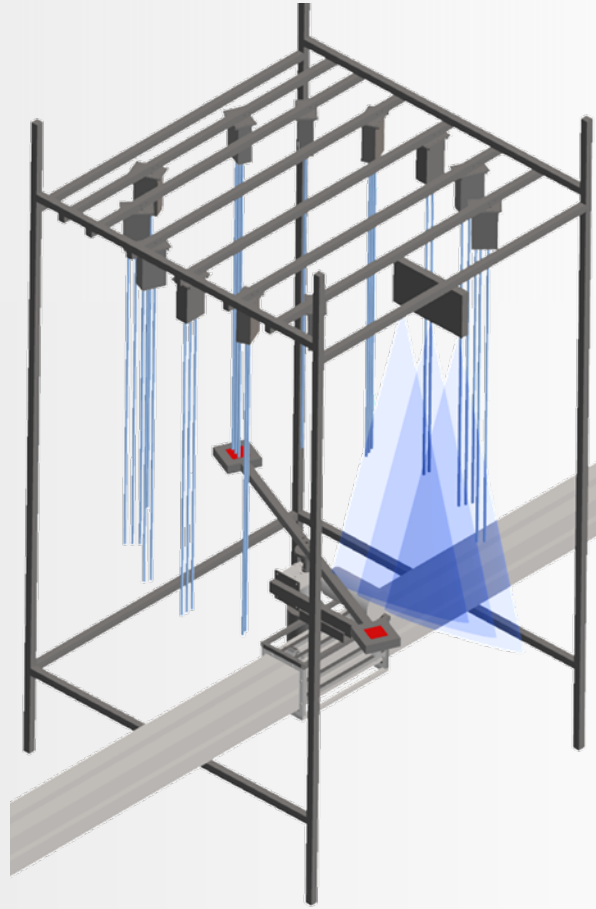
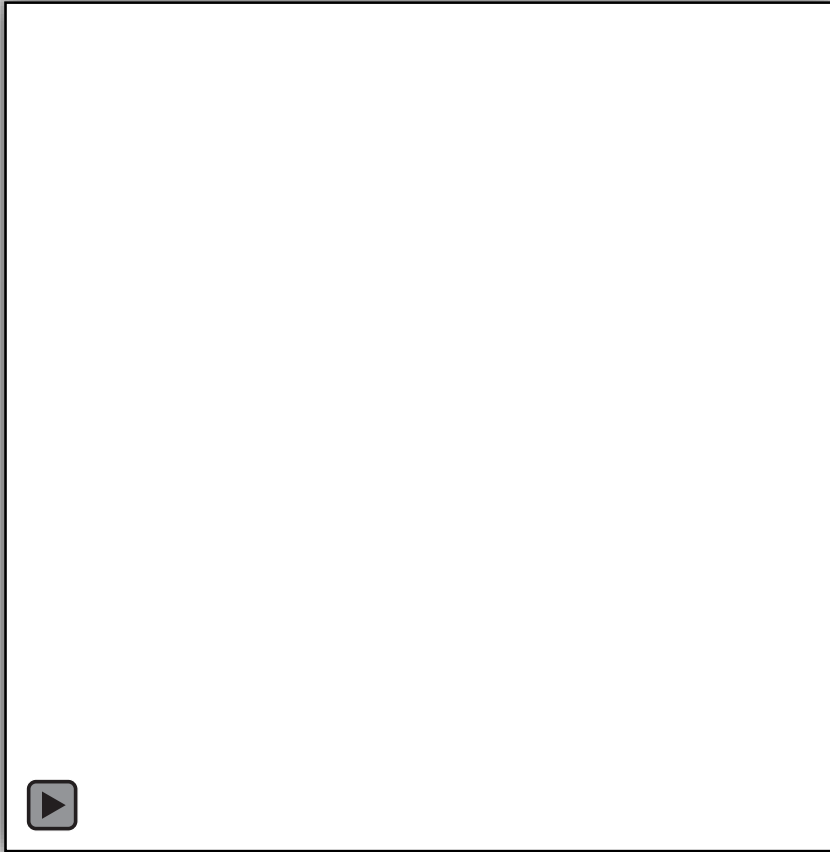
## 3) Simulation of the cooling process





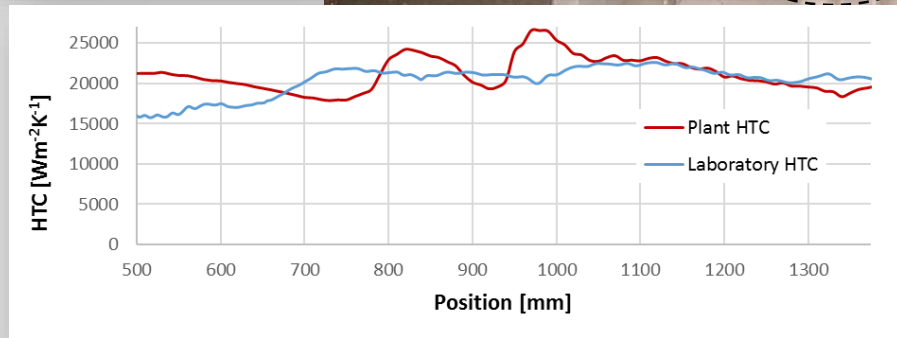
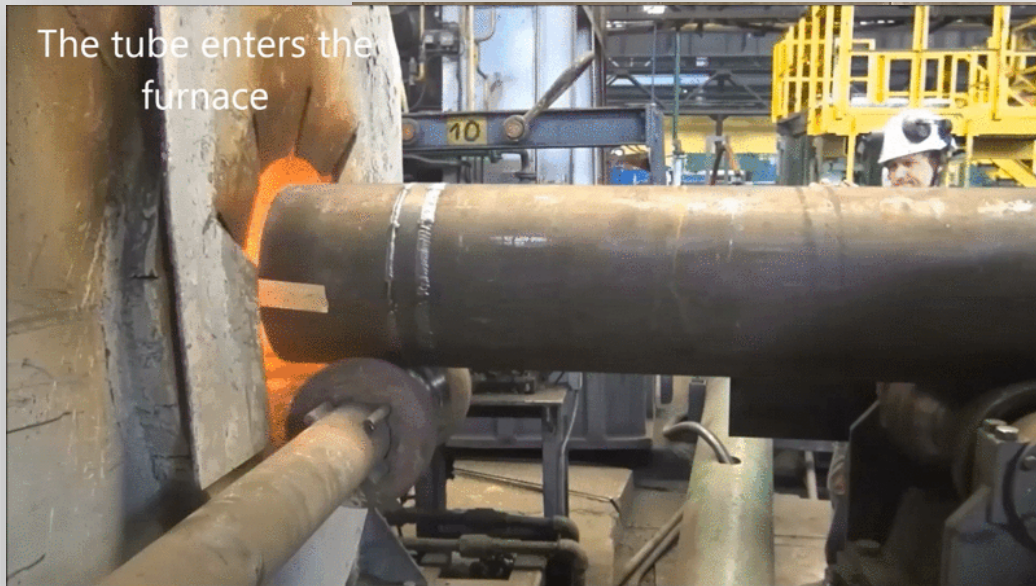
# Finding the optimal cooling strategy (laboratory approach)

4) Laboratory verification - full scale test, continuous cooling, original material, ...



# Finding the optimal cooling strategy (comparison of the plant and the laboratory measurement)

## 5) Final design, 6) Plant verification



**Cooperation with industrial partners:**  
voestalpine Stahl GmbH  
AMAG Austria Metall AG  
Třinecké Železárny – Moravia Steel  
Hyundai Steel



# Cooperation with partners



- ABB, s.r.o., Czech Republic
- ACRONI Jesenice, Slovenia
- **AIT** Austrian Institute Of Technology, Austria
- AL INVEST, a.s., Czech Republic
- Alcoa Inc, United States
- **AMAG**, Ranshofen, Austria
- ANDRITZ Selas S.A.S., France
- ARCELOR MARDYCK, France
- ArcelorMittal Burns Harbor, USA
- ArcelorMittal Dofasco, Canada
- **ArcelorMittal** Global Research Center Chicago, USA
- ArcelorMittal Maizières Research SA, France
- ArcelorMittal Ostrava a.s., Czech Republic
- ArcelorMittal Riverdale Inc., USA
- Cogne Acciai Speciali S.p.a., Italy
- COMALCO, Australia
- Corus Technology BV Netherlands
- CORUS UK Limited, England
- CRM Group, Belgium
- **DANIELI**, Italy
- Davy Distington Ltd. UK
- Delavan Ltd., United Kingdom
- Evertz Hydrotechnik GmbH & Co. KG, Germany
- FEI, Czech Republic
- Fives Stein Ltd., France
- Hyundai NGV, Republic of Korea
- **Hyundai Steel**, Republic of Korea
- IRSID, France
- ISPAT Nová Huť, a.s., Czech Republic
- Kremikovtzi AD, Bulgaria
- Lechler GmbH, Germany
- **Liberty Ostrava a.s.**, Czech Republic
- Mannesmann Demag AG, Germany
- Nová huť, Czech Republic
- **POSCO** E&C, Republic of Korea
- POSCO, Republic of Korea
- **Primetals Technologies** Ltd., Austria
- Primetals Technologies Ltd., Italy
- Severstal Cherepovets, Russia
- Sidenor I + D, Spain
- SIEMENS AG Germany,
- Siemens S.p.A., Marnate VA, Italy
- Siemens VAI Metals Technologies GmbH, Linz, Austria
- SIGMA DIZ, Czech Republic
- SIGMA Group, Czech Republic
- SINTEF, Norway
- Spraying Systems Co., USA
- Swerea Mefos AB, Sweden
- Škoda Auto a.s., Czech Republic
- **TATA Steel** UK, UK
- ThyssenKrupp Steel Europe AG, Germany
- Třinecké železářny a.s., Třinec, Czech Republic
- **U. S. Steel Košice**, Ltd., Slovakia
- United States Steel Corporation, USA
- USIMINAS, Brazil
- Vítkovické slévárny, spol.s r.o., Czech Republic
- **voestalpine Stahl** GmbH, Austria
- VÚHŽ a.s., Czech Republic
- ŽDAS, a.s., Zdar nad Sazavou, Czech Republic
- Železiarne Podbrezová, Slovakia



# European projects (Research Fund for Steel and Coal)

## SmartCool - Smart controlled actuator to homogenize the temperature at the transfer bar

- Duration: 7/2022 -12/2025, Financing: [Research Fund for Coal & Steel](#)
- Code: RFCS - 2021 - PJG 1010057274

## Reduction of Heat Losses During Hot Rolling

- Duration: 7/2020 -12/2023, Financing: [Research Fund for Coal & Steel](#)

## Resource-Efficient Hydromechanical Descaling System for Wire Coils (HIJETROD)

- Code: 709435-HiJetRod Pilot-RFCS, Duration: 07/2016 – 12/2019

## Effective Management of Coolant in Cold Rolling (MANCOOL)

- Code: RFSR-CT-2015-00006, Duration: 07/2015 – 12/2018

## High Performance Hot Rolling Process Through Steel Grade Dependent Influencing of the Scale Formation and Flexible Descaling Control (HIPERSCALE)

- Code: RFSR-CT-2014-00010, Duration: 7/2014-12/2017

## Advanced Roll Gap Sensors for Enhanced Hot and Cold Rolling Processes (ROLLGAP SENSORS)

- Code: HS13045005, Duration: 9/2009 – 9/2013

## Advanced Method to Improve Work Roll Life Time and Surface Quality of Hot Rolled Strip by New Coupled Oil Free Lubrication and Chilling (CHILLUB)

- Code: RFCR-CT-2008-00012, Duration: 7/2008 – 12/2011

## New Cooling Techniques for Enhanced Roll Bite Lubrication during Cold Rolling of High Strength Steels and Thin Packaging Steels (OPTCOOLUB)

- Code: RFSC-CT-2006-00014, Duration: 7/2006 – 6/2009

- Effective Work Roll Cooling (EWRCOOL), Code: RFCR-CR-04015 EWRCOOL, Duration: 7/2004 – 12/2007
- Optimization of forcing characteristics of metal in mushy state, Duration: 2002 – 2004
- Modelling and experimental study of phase changes within binary systems, Code: OC.P3.60, Duration: 1/1998 – 12/2001
- COST, OC.P3.60 - Modelling and experimental study of phase changes within binary systems
- OPTCOOLUB - New cooling techniques for enhanced roll bite lubrication during cold rolling of high strength steels and thin packaging steels, RFSR-CT-2006-00014
- CHILLUB - Advanced method to improve work roll life time and surface quality of hot rolled strip by new coupled oil free lubrication and chilling RFSR-CT-2008-00012
- ROLLGAP SENSORS, Advanced Roll Gap Sensors for Enhanced Hot and Cold Rolling Processes, RFSR-CT-2009-00008, duration
- OPTCOOLUB, New cooling techniques for enhanced roll bite lubrication during cold rolling of high strength steels and thin packaging steels, RFSR-CT-2006-00014
- EWRCOOL - Effective work roll cooling, RFCS-CR-0415
- COPERNICUS CIPA – CT94 0117: Computer Aided Process Simulation of Iron Mushy State Forcing, 1996 - 1998
- COST 512.20, Inverse Problems in Mathematical Modelling, 1994 – 1998



## Thank You ...

[Petr Kotrbacek](#)

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[heatlab.cz](http://heatlab.cz)



cooling sections for heat treatment based on laboratory measurements of HTC

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