

Hot tear segregations as quality decisive factor for advanced steel grades

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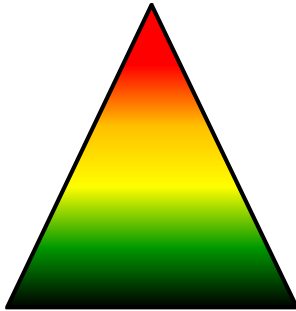
Outline of presentation

- ◆ **Advanced steel grades: A challenge for process metallurgists**
- ◆ **Macro- and mesosegregation in continuous casting**
- ◆ **On the nature of hot tear segregations: Formation and consequence on product quality**
- ◆ **Physical simulation of HTS-formation**
- ◆ **Numerical prediction of HTS-formation in slab casting: Concept and example**
- ◆ **Summary**



◆ Quality pyramid: Increasing quality demands for state-of-the-art advanced steel grades

Advanced steels: low production, lower economic pressure for steel producer but high and mostly complex quality demands



API, GO-Si-steels, SEDDQ, Roller bearing steels, SHSS, ...

Multiphase (DP, CP, TRIP), valve steels, spring steels ...

Deep drawing steels (DDQ), ...

High-strength low-alloy (HSLA), Press hardening, (PH), ...

Reinforcing steels, structural steels, ...

Commodity steel: high production, high economic pressure for steel producer and low quality demands



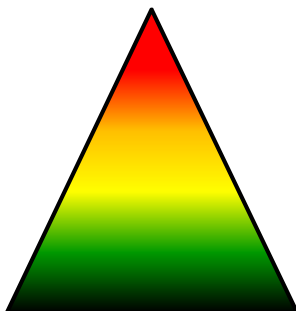
◆ Quality pyramid: Increasing quality demands for state-of-the-art advanced steel grades

Advanced steels

API, GO-Si-steels, SEDDQ, Roller bearing steels, SHSS, ...

Quality demands:

- Strength within small tolerances
- Highest steel cleanness on macro- but also microscopic level
- Homogeneity and internal soundness
- High surface quality (Decarburization, inclusions, ...)
- ...



Reinforcing steels, structural steels, ...

Commodity steel

Quality demand:

- Minimum strength

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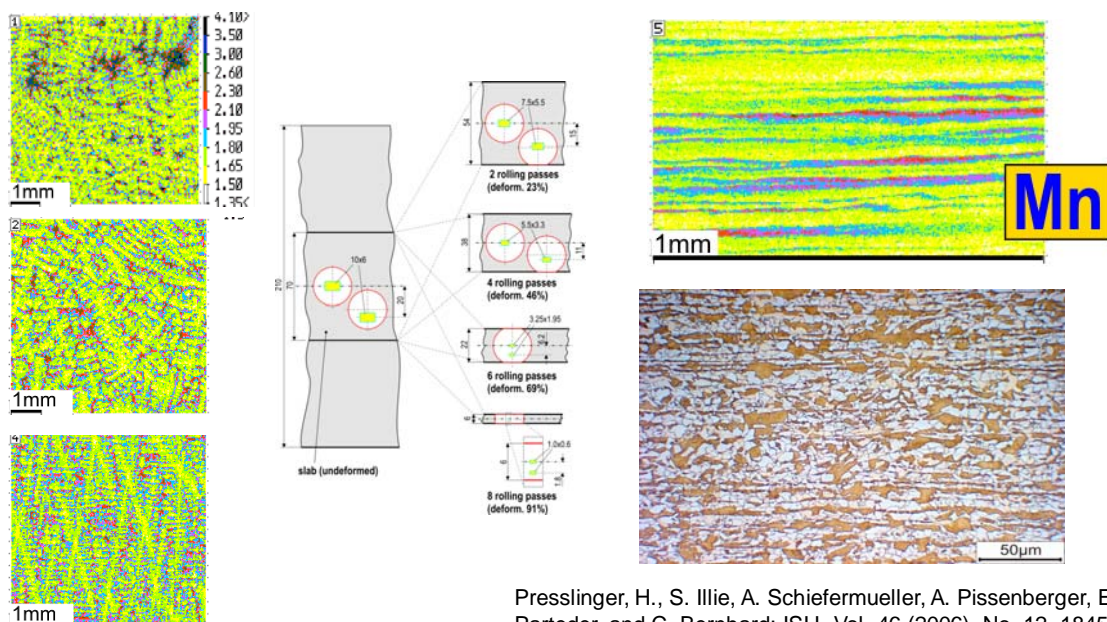


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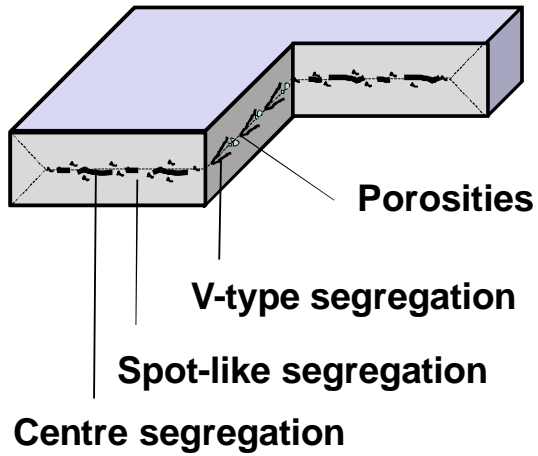
- ◆ Importance of casting process for the homogeneity of the final product, example DP600, 210 mm slab



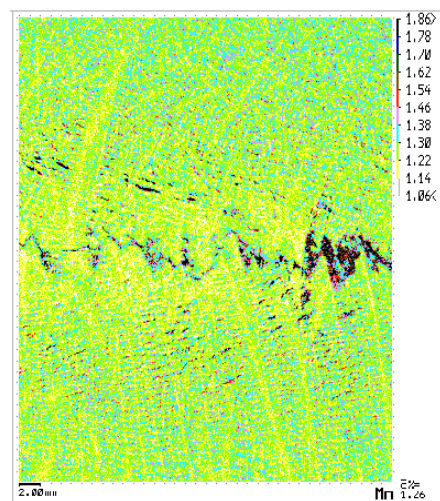
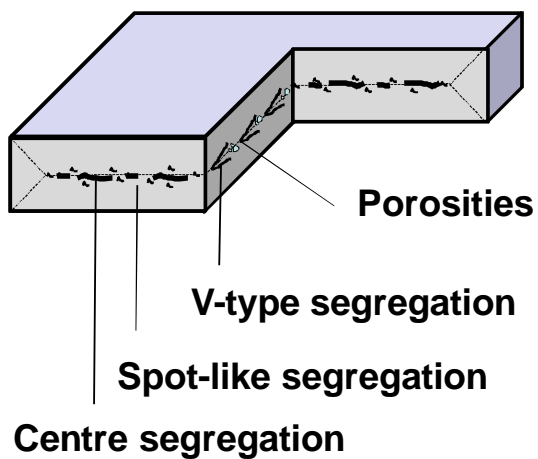
Presslinger, H., S. Illie, A. Schiefermueller, A. Pissenberger, E. Parteder, and C. Bernhard: ISIJ, Vol. 46 (2006), No. 12, 1845-1851



◆ Macro- and Mesosegregations in Continuous Casting of Slabs



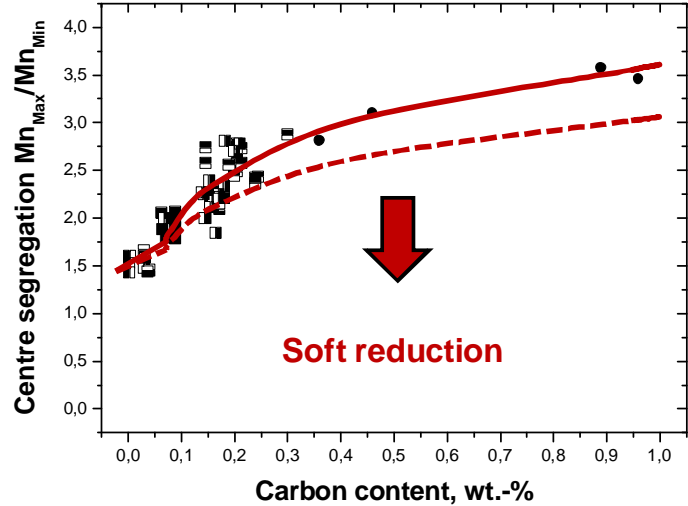
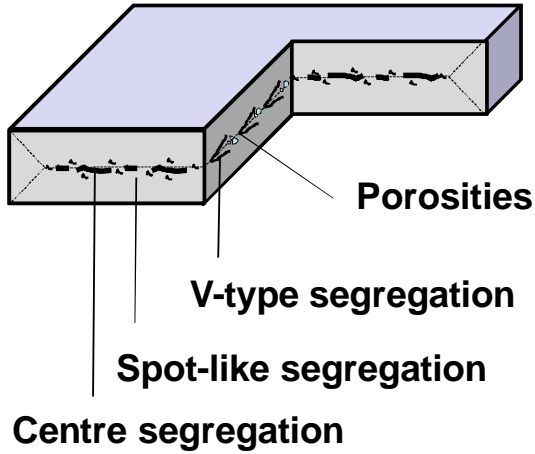
◆ Macro- and Mesosegregations in Continuous Casting of Slabs, Example Mn in DP600



Presslinger, H., S. Illie, A. Schiefermueller, A. Pissenberger, E. Parteder, und C. Bernhard: 12th ISIJ-VDEh-Seminar, November 21-22 2005, Kitakyushu, Japan, 125-134



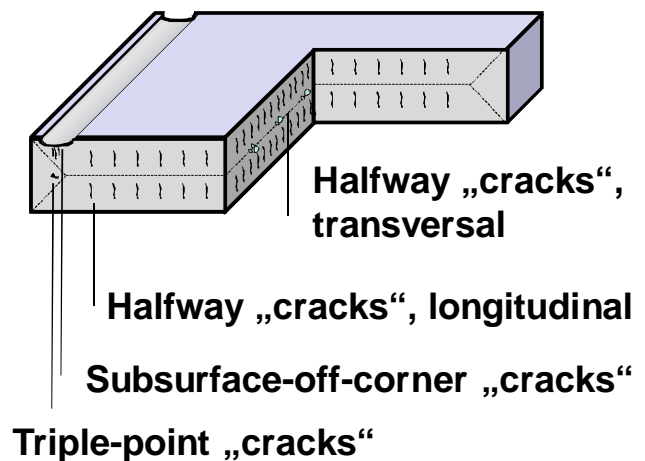
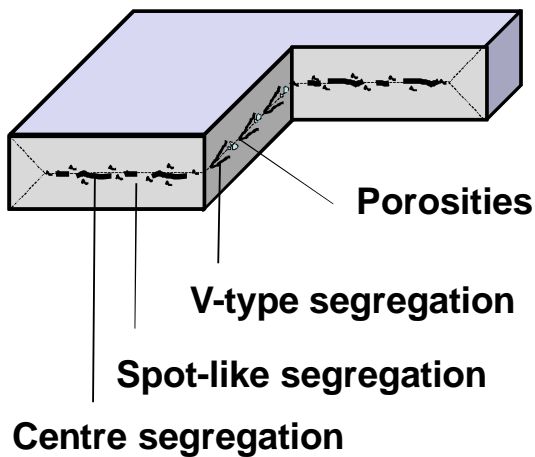
◆ Macro- and Mesosegregations in Continuous Casting of Slabs, Mn in centre segregation of slabs



Illie, S. Et al.: steel research int. 78 (2007), No. 4.

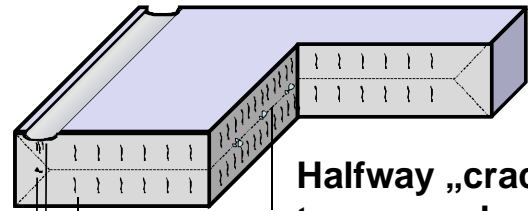
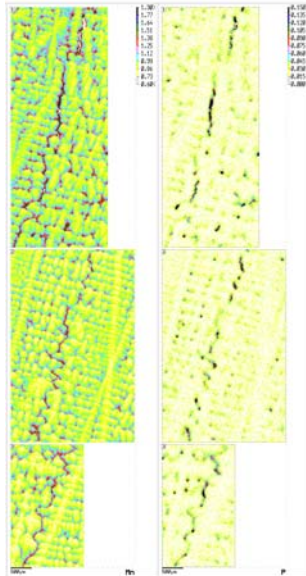


◆ Macro- and Mesosegregations in Continuous Casting of Slabs





◆ Macro- and Mesosegregations in Continuous Casting of Slabs: Hot Tear Segregation



Halfway „cracks“, transversal

Halfway „cracks“, longitudinal

Subsurface-off-corner cracks

Triple-point cracks

Ilie, S.; Reiter, J.; Fluch, W.; Presslinger, H.; and C. Bernhard:
6th European Continuous Casting Conference, June 4-6 2008,
Riccione, Italy, S. Paper – 122

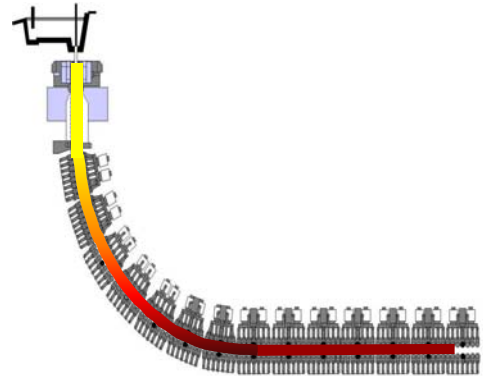
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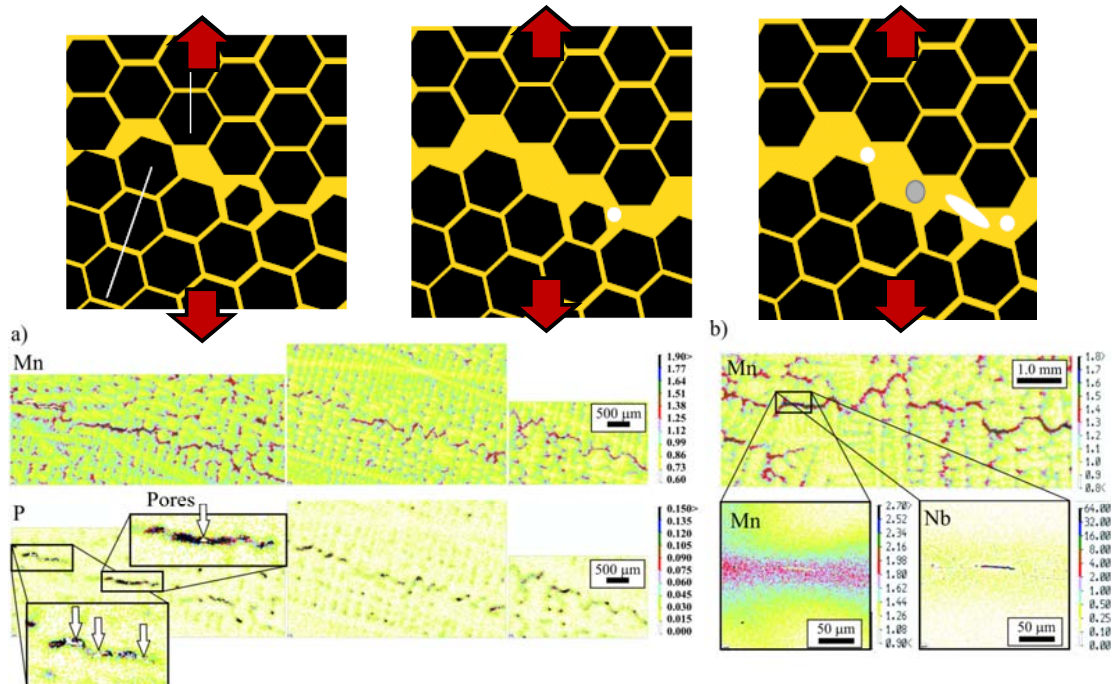


◆ On the nature of hot tear segregations (HTS)

- ◆ HTS form **during solidification** in consequence of an **overcritical straining** of the columnar solidifying shell.
- ◆ HTS do not form between dendrites, as commonly attributed, they form mainly **along primary grain boundaries**.



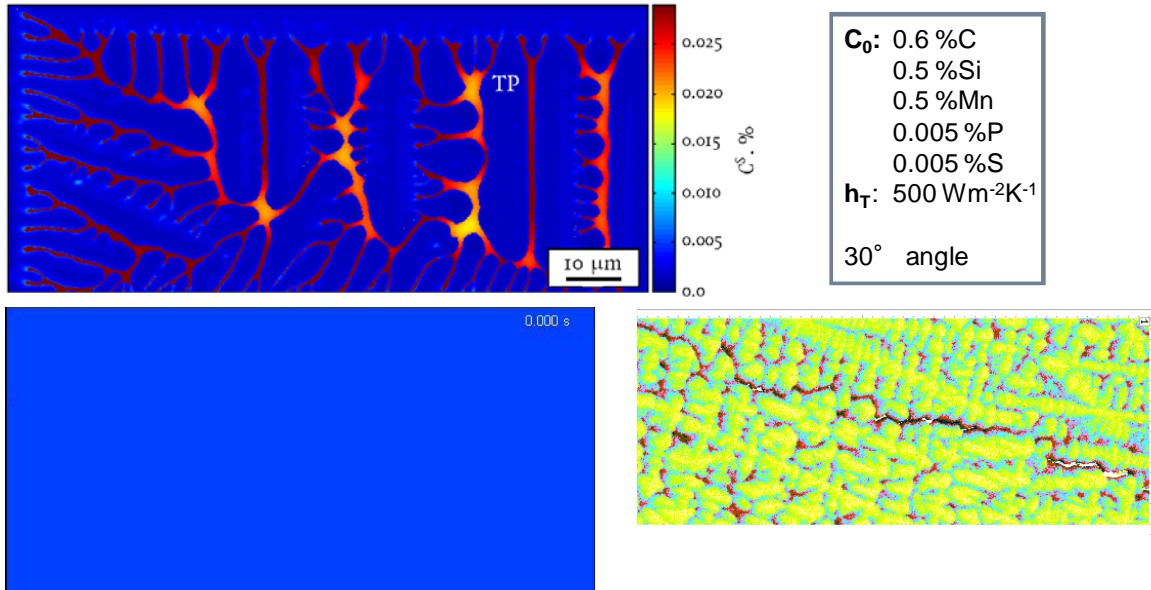
◆ Formation of a hot tear segregation (HTS)



Pierer, R. and C. Bernhard: AISTech 2010, Pittsburg, USA



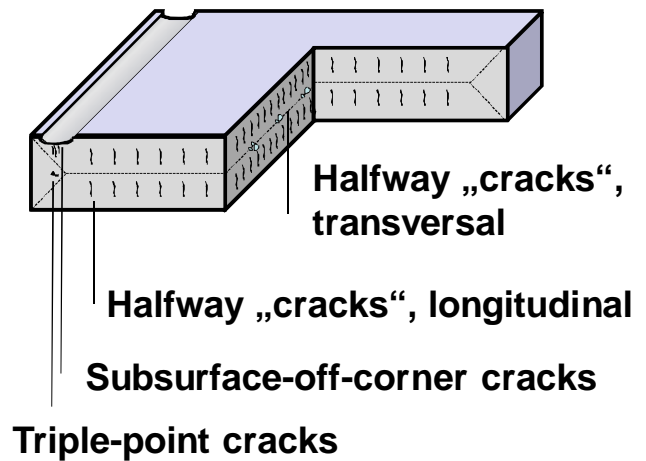
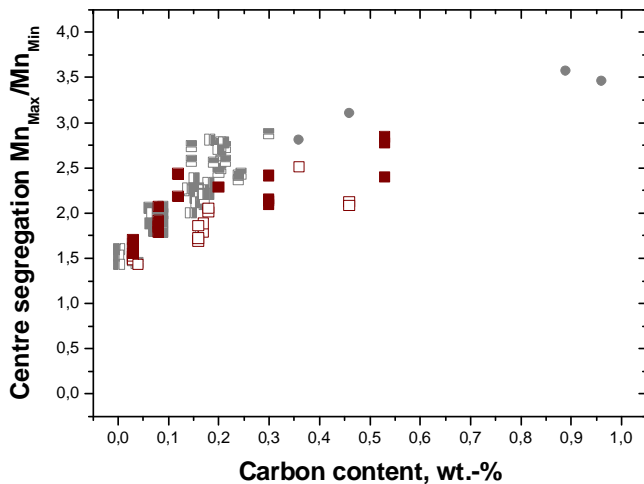
- ◆ Concentration profile of S along a primary grain boundary, Example: 0.6% C, 0.005% S, orientation difference 30°



Michelic, S.C. and C. Bernhard: TMS2013, San Antonio, USA



- ◆ Macro- and Mesosegregations in Continuous Casting of Slabs

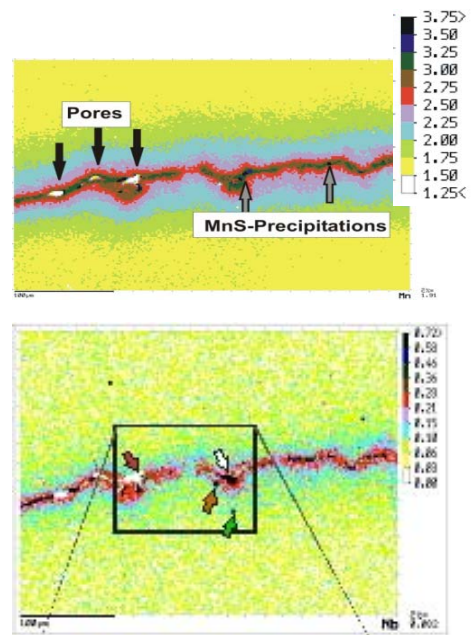


Ilie, S.; Reiter, J.; Fluch, W.; Presslinger, H.; and C. Bernhard: 6th European Continuous Casting Conference, June 4-6 2008, Riccione, Italy, S. Paper – 122



◆ HTS result in

- ◆ ... the formation of undesirable phases (commonly hard and brittle phases like martensite).
- ◆ ... inhomogeneous grain size in the final product.
- ◆ ... the formation of inclusions (Sulphides but also primary carbonytrides).
- ◆ ... may even result in surface defects on cold-rolled band („glossy stripes“).



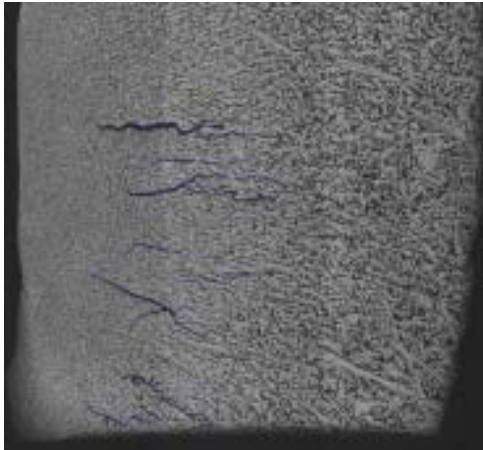
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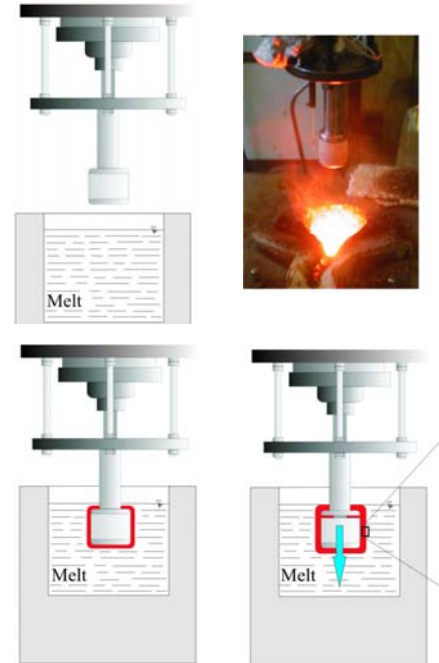


◆ In-situ simulation of HTS - formation

- ◆ Parameters: Steel composition, solidification time, strain, strain rate.

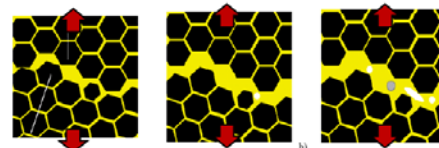
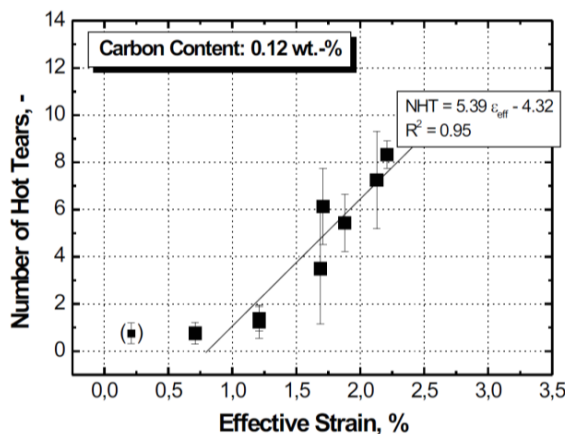


Pierer, R. and C. Bernhard: AISTech 2010, Pittsburg, USA



◆ In-situ simulation of HTS - formation

- ◆ Results confirm proposed mechanism: In contrast to the common opinion no clear boundary between „Cracks“ and „No cracks“ exists. **An increasing strain results in an increasing number of HTS and an more pronounced enrichment.**

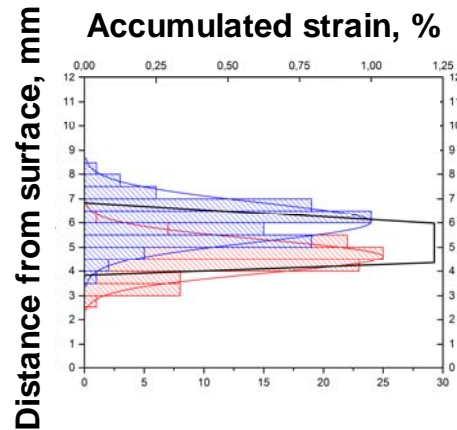
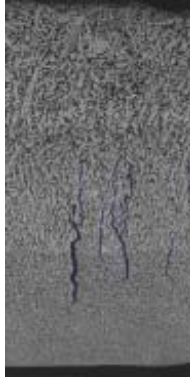


Bernhard, C. and R. Pierer: Solidification 2007, Sheffield, UK



◆ In-situ simulation of HTS - formation

- ◆ The SSCT-experiment allows to assign the HTS-phenomenon to a certain range of solid fractions, commonly in the range of **0,96 – 1,0**.

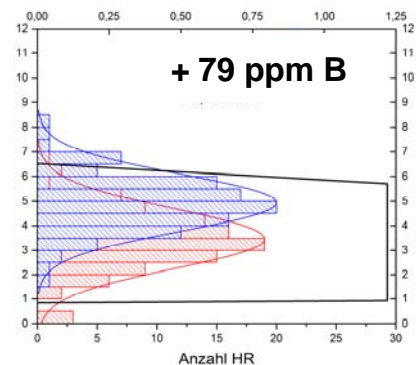
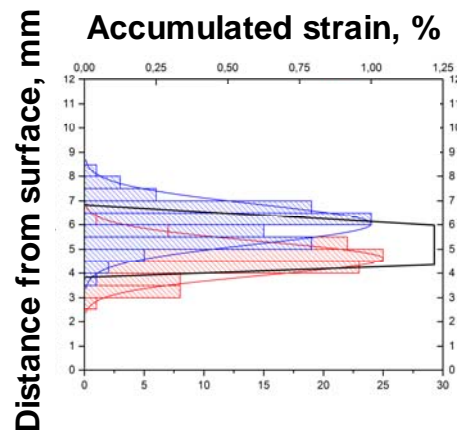
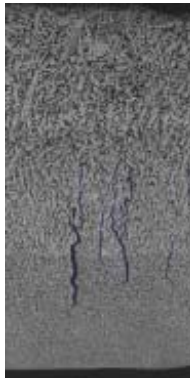


Dierer, F.: Bachelor-thesis, MU-Leoben, 2013



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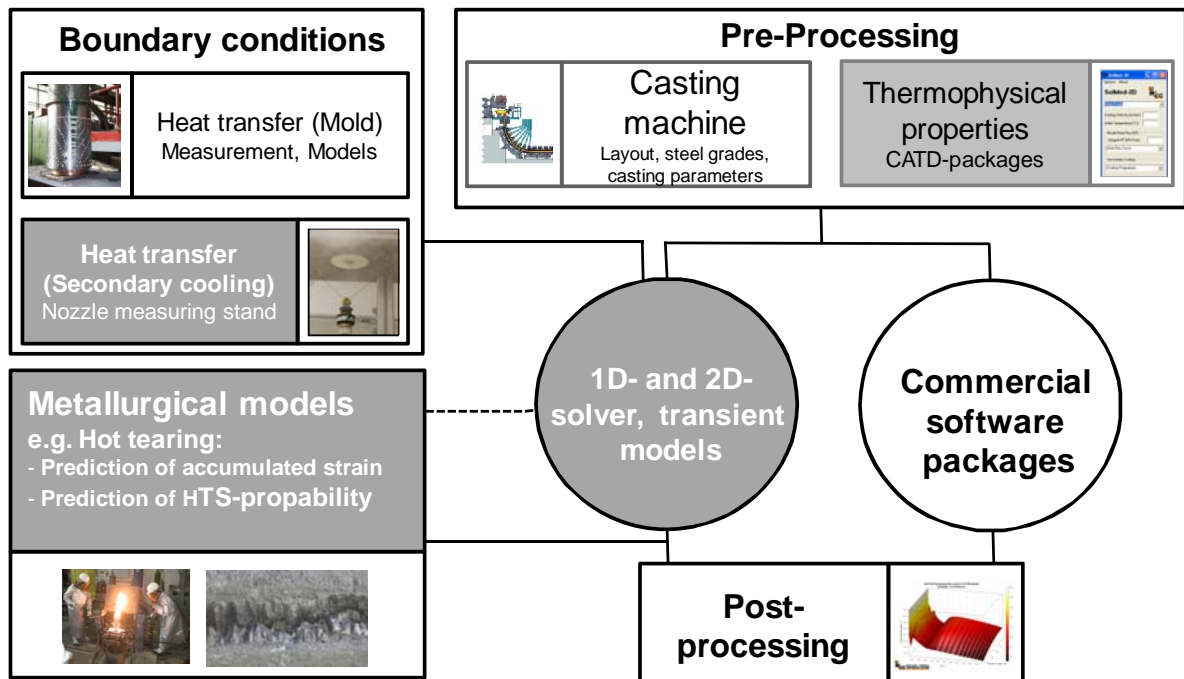


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◆ HTS-Analysis of Casting Processes by Numerical and Physical Simulation



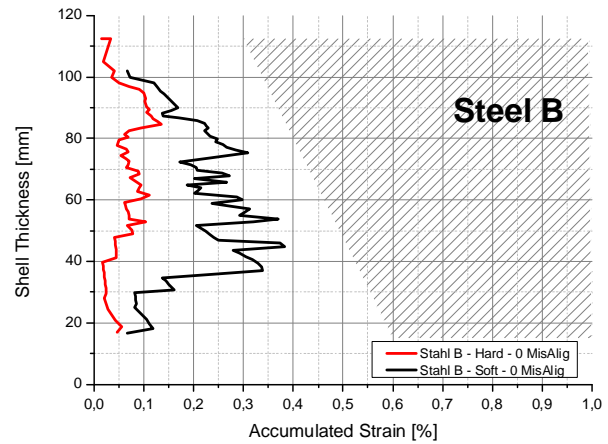
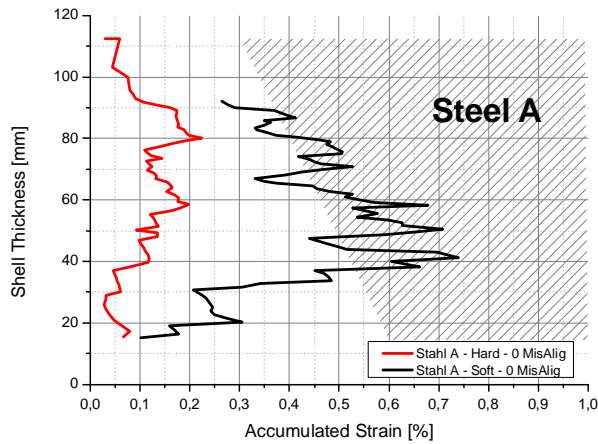
Pierer, R., S.C. Michelic and C. Bernhard: AISTech 2012, Atlanta, USA



- ◆ Case study: slab casting of two steel grades, hard and soft cooling in the first secondary cooling zone

Steel A							
C	Si	Mn	P	S	N	Cr	Ni
0,17	0,43	1,54	0,015	0,007	0,0001	0	0

Steel B							
C	Si	Mn	P	S	N	Cr	Ni
0,15	0,015	1,109	0,008	0,007	0,0001	0	0

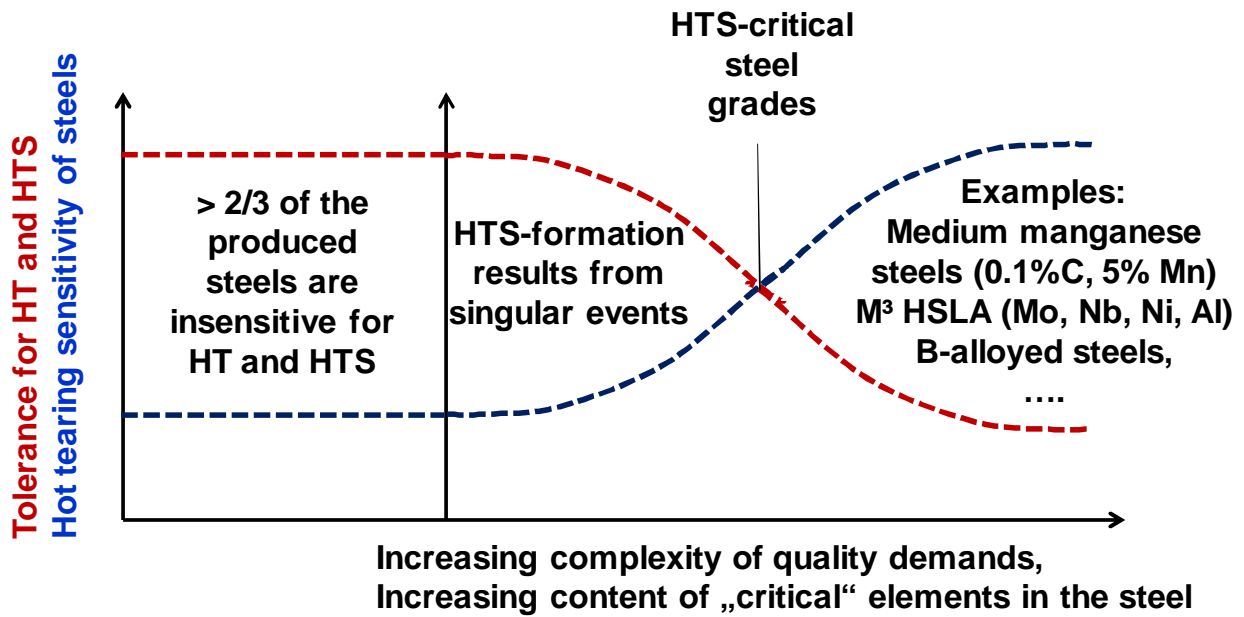


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◆ Conclusions



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