Investigation of the Fe-C-Si-Mn system with special focus on the Fe – 3 w.t.-% Si – high Mn section

P. Presoly[1], **M. Bernhard**[1], **C. Bernhard**[1]
[1] Chair of Ferrous Metallurgy, Montanuniversität Leoben, Leoben, A-8700, Austria
e-mail address of corresponding author: peter.presoly@unileoben.ac.at
Key words: Fe-Si-Mn, DTA, high Mn, TRIP/TWIP

The Fe-C-Si-Mn System is one of the most important systems for nearly all steel grades. In the last decades high strength and ductile steels were developed with increasing quantities of silicon and manganese. Three of these alloying concepts are Dual-Phase (DP), TRansformation Induced Plasticity (TRIP) and even TWinning Induced Plasticity (TWIP) steels. All these steel grades base on the iron-carbon-manganese system with additions of ferrite former such as silicon and/or alumina, followed by micro-alloying elements.

In the last years many authors [1,3,4,5,6] published improvements of the Fe-C-Si-Mn systems and its subsystems (Fe-Si, Si-Mn, Fe-Si-Mn…). In a former study Presoly [1] investigated two sections of the Fe-C-Si-Mn system with 1%Si + 2%Mn and 2%Si + 2%Mn (in wt.-%). A special focus of this work was the investigation of the region of the peritectic phase transformation [LIQUID + BCC → FCC (+ BCC)] whose knowledge is of particular importance for the casting process. Zheng [5] used these results for a new thermodynamic assessment of the Fe-C-Si-Mn system. Due to this extensive work, low and medium alloyed grades can be described quite well.

However, measurements of high alloyed TWIP grades showed, that especially the initial solidification behavior (primary BCC or FCC) cannot be calculated adequately. In order to prove this observation, a typical section of a silicon alloyed high manganese grade was experimentally evaluated. All model alloys (about 450g) were produced from high-purity raw-materials in an alumina crucible with a high-frequency re-melting and spin-casting machine under argon atmosphere. Due to inductive melting and the spin casting process with rapid solidification in the copper mold the chemical analysis shows a very homogeneous distribution of all elements.

Due to the risk of manganese evaporation, DSC measurements could not be performed for samples with Mn-contents >3%. Therefore, a special DTA setup [3], visualized in **Figure 1,** was used to guarantee secured measurements even at highest manganese levels without Mn-contamination of the Pt-thermocouples. In order to determine the equilibrium phase transformation temperatures, a heating rate variation (5-10-15K/min) each with new samples was performed (regression calculation to a heating rate of 0 K/min = equilibrium).

As visualised in **Figure 1**, the measured phase transformations are in clear contrast to the calculated phase diagrams. This simple comparison clearly shows that the stability of delta-ferrite is significantly underestimated in the assessments. A bit higher solidus and liquidus temperature is predicted and the delta-to-gamma phase transformation (BCC→FCC) occurs at much higher manganese contents. This trend is already shown in the latest thermodynamic optimizations of Peak[4] and Zheng[5].

Based on this experimental results, additional measurements up to 6% Si and on the latest assessments of the relevant subsystem, especially the Fe-Si system from Cui [6], an own thermodynamic assessment of the Fe,Mn,Si:*Va,C* system is under development. Due to microsegregation of carbon during solidification, high enrichments can occur. Therefore the influence of higher carbon concentrations (C >2%) on this important system will be investigated in the next step.

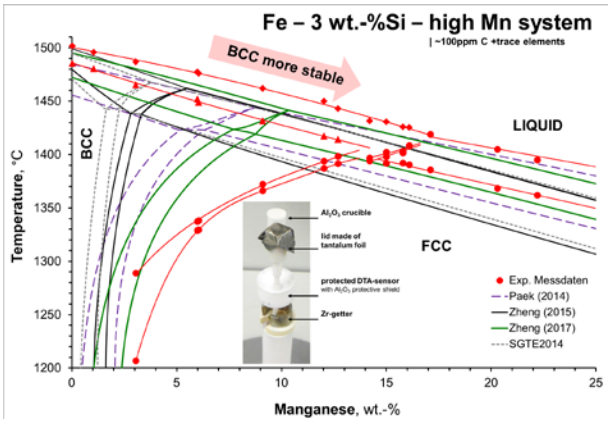

Figure 1. Investigation of the Fe-3wt.-%Si-high Mn system

References

[1] Presoly, P. and C. Bernhard, "Influence of Silicon and Manganese on the Peritectic Range for Steel Alloys", *Iron & steel technology*, Vol. 4, Issue 14, April 2017

[2] Presoly, P., et al. "Identification of Defect Prone Peritectic Steel Grades by Analyzing High-Temperature Phase Transformations", *Metall and Mat Trans A*, Vol. 44, Issue. 12 (2013): page_5377

[3] Zhuang, C.-l., et al. "Analysis of Solidification of High Manganese Steels Using Improved Differential

Thermal Analysis Method", *Journal of Iron and Steel Research, International*, Vol. 22, Issue. 8 (2015): page_ 709
[4] Paek, M.-K., et al. "Phase equilibria and thermodynamics of Mn–C, Mn–Si, Si–C binary systems and Mn–Si–C ternary system by critical evaluation, combined with experiment and thermodynamic modeling", *Calphad* , Vol. 46 (2014): page_92
[5] Zheng, W. S., et al. „Thermodynamic modeling of Fe-C-Mn-Si alloys", *Journal of Iron and Steel Research International*, Vol. 24 (2017): page_190
[6] Cui, S. and I.-H. Jung, Critical reassessment of the Fe-Si system, *Calphad*, Vol. 56 (2017): page_108

Biographical Note

Peter Presoly is postdoctoral researcher at the Chair of Ferrous Metallurgy at the Montanuniversität Leoben. He has been working for 10 years on the experimental determination of high-temperature phase transformations in steels and the evaluation and optimization of thermodynamic databases. His special focus is on the investigation of new steels for the continuous casting process.

Acknowledgments

Financial support by the Austrian Federal Government (in particular from Bundesministerium für Verkehr, Innovation und Technologie and Bundesministerium für Wirtschaft, Familie und Jugend) represented by Österreichische Forschungsförderungsgesellschaft mbH and the Styrian and the Tyrolean Provincial Government, represented by Steirische Wirtschaftsförderungsgesellschaft mbH and Standortagentur Tirol, within the framework of the COMET Funding Programme is gratefully acknowledged. This work is part of the ongoing K2-MPPE project P3.1 "SmartCast".

1.1.1 Call for Abstracts

Contributions to the CALPHAD meeting must be in English and should report original work. By submitting an abstract the submitting author gives permission for the Organizing Committee to reproduce the abstract in all materials associated with the conference. Author preferences will be taken into account but the organizing committee reserves the right to determine the presentation type (oral or poster). For acceptance of an abstract it is required that at least one of the authors is registered to the Conference. Note that the deadline for abstract submission is **March 30, 2018.**

1.1.2 To submit your abstract:

Before you start the process, please have your abstract ready in the standard template. You can download the standard template by clicking on the image below.

1) download the template: DOWNLAD TEMPLATE
1. Use template provided
2. Abstract should be no more than 500 words
3. You must include a figure or graphical abstract
4. Up to four references should be included
5. A biographical note of no more than 50 words for the first author should be included.
6. Allowed file extensions are .doc, or .docx.
7. Maximum file size is 4MB, (4096 KB).