"Experimental simulation of defect formation in the continuous casting process"

C. Bernhard*), R. Pierer*), A. Tubikanec**) and C. Chimani**)
*) Christian Doppler Laboratory for "Metallurgical Fundamentals of Continuous Casting Processes" (CDL-MCC) at Leoben University, Austria
**) Siemens VAI Metals Technologies GmbH & Co, Linz, Austria

Although constantly increasing expert knowledge of the interaction between casting process, material properties, microstructure and crack sensitivity, the increasing potential of numerical simulation and the enormous technological progress, the formation of defects is still an economic problem in continuous casting. To some extent, this is a consequence of insufficiently quantified and general valid material data, both in the first and second ductility minimum.

At the University of Leoben several experimental methods have been adopted or developed in order to simulate the loading of a solidifying strand shell in the continuous casting process. These methods are based on the principle of the so-called Submerged Split-Chill Tensile (SSCT), initially developed for hot tensile tests on aluminium alloys1) and later on adopted for steels. The method bases on the submerging of a coated, cylindrical steel substrate in a steel melt (**Fig. 1**). After a pre-defined period the solidifying shell is subjected to tension perpendicular to the growth direction of the dendrites and grains. Force and elongation are recorded. After tensile testing, the test body and solidified shell are immediately removed from the melt. The cooled specimens are cut and up to 16 metallographic specimens are prepared. The number, length and width of all detected cracks – classified according to characteristic types – are summarized in a crack index, allowing a quantitative indication of the deterioration of the shell dependent on the testing conditions (**Fig. 2**).

The method allows to determine the influence of steel composition, cooling conditions and strain rate on the mechanical properties and the crack susceptibility2-3). The results served as basis for the development of a hot tearing criterion4). Currently, the method has been used to investigate the austenite grain growth under continuous casting conditions3).

During the last years a variety of testing procedures has been developed. In the contraction force test the lower part of the test body remains in its original position, the resulting force, proportional to the contraction force, is recorded, **Fig. 3** 5). The results served as basis for the adjustment of high temperature material laws6). In the contraction test the shell is pre-loaded with a marginal load, the lower part moves upwards under the contraction force of the solidifying shell. The recorded movement of the lower part of the substrate is thus proportional to the contraction of the solidifying shell.

A new testing procedure for the characterization of the material properties at temperatures within the second ductility trough was developed in a co-operation with Siemens-VAI (In-situ material characterization test)7). After a short solidification time inside the melt, the test body is removed from the melt and is allowed to cool in an inert gas atmosphere. During solidification and subsequent cooling the servo-hydraulic control keeps the shell free from contraction forces in the axial direction. At a certain temperature, the lower part of the substrate moves downward and the specimen is subjected to tension (**Fig. 4**). This method allows the determination of a critical strain under conditions close to the continuous casting process within the second ductility trough (**Fig 5**).

Literature: 1) Ackermann, P.; W. Kurz und W. Heinemann: Mat. Science and Eng. Vol. 75 (1985), 79-86; 2) Pierer, R.; C. Bernhard und C. Chimani: BHM, Vol. 150 (2005), Nr. 5, 163-169; 3) Bernhard, C., J. Reiter and H. Preßlinger: AISTech 2007, The Iron&Steel Technology Conference and Exposition, May 7-10 2007, Indianapolis, USA; 4) Bernhard, C. and R. Pierer: A new hot tearing criterion for the continuous casting process, 5th Decennial International Conference on Solification Processing, July 23-25 2007, Sheffield, UK; 5) Bernhard, C. und G. Xia:, Ironmaking and Steelmaking, 33 (2006), No. 1, 52-56; 6) Pierer, R. and C. Bernhard: Materials Science & Technology (MS&T'06), Conference and Exhibition, October 15-19 2006, Cincinnati, USA, 793-803; 7) Bernhard, C., R. Pierer, A. Tubikanec und C. Chimani: Proceedings of the CCR'04 – Continuous Casting and Hot Rolling Conference, June 14-15 2004, Paper No. 6.3

Figures:

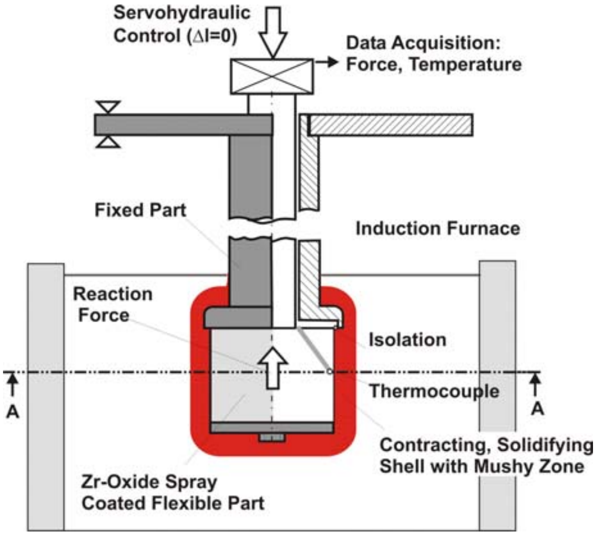


Figure 1: SSCT-test, schematic 6)

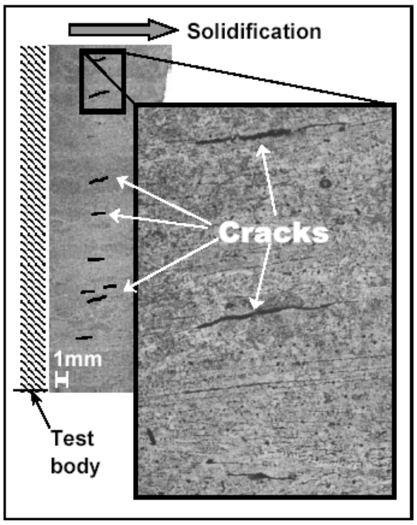


Figure 2: Hot tears in the solidified specimen 7)

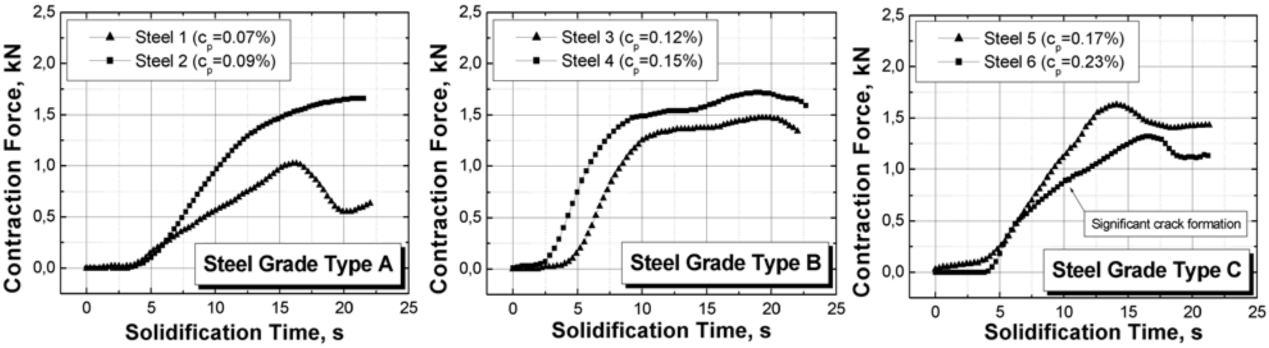
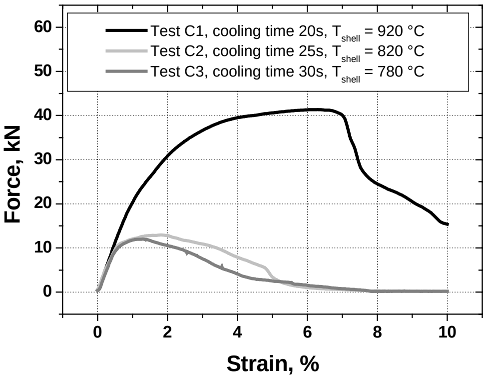


Figure 3: Experimentally determined contraction force as a function of solidification time for the three different steel grades 5)



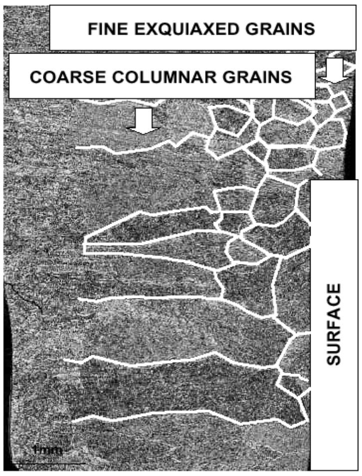


Figure 4: Force-elongation curves for an 0,17 wt.-% C steel, cooling times 20, 25 and 30 s, strain rate 5.10^{-3} s-1, total strain 0.1[7)]

Figure 5: anisotropic grain structure of an IMC-specimen (prior austenite grain boundaries in white)[7)]