

Residual stresses and in-situ measurement of phase transformation in low transformation temperature (LTT) welding materials

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Abstract

For the safety and cost efficiency of welded high-strength steel structures, precise knowledge of the level and distribution of welding- and cooling-specific stresses and residual stresses is essential, since they exert a decisive influence on strength, crack resistance, and finally on the bearable service load. This paper presents innovative filler materials, of which the phase transformation temperature was deliberately adjusted via the chemical composition. The transformation behaviour of these martensitic Low Transformation Temperature (LTT-) filler materials shows direct effects on the local residual stresses in the weld and the HAZ. This can purposefully be exploited to counteract the thermally induced shrinkage of the material and to produce significant compressive residual stresses in the weld. Also the stress build-up in surrounding structure is influenced.

Comparative welding experiments were carried out on 690 MPa base material using various LTT-filler materials. High energy radiation has been used for residual stress measurement and analysis of phase formation during heating and cooling cycles. Even the use of high energy synchrotron radiation makes it possible to detect the residual stress condition fast without destruction of material. Thereby, residual stress depth gradients can be determined simultaneously without removing material. In steel, gradients up to 150 μm can be resolved in such a way. Furthermore, the application of high energy radiation permits determination of residual stresses of any available residual austenite contents. Similarly, formation of phases and respective transformation temperatures can be analysed during thermal cycles to allow a correlation between phase formations and evolving phase specific stress distribution in the weld.

Investigations were carried out to determine the phase transformation behaviour of different LTT-filler materials. Transformation temperatures were identified using Single Sensor Differential Thermal Analyses (SS-DTA). Additionally Synchrotron radiation was used to measure the transformation kinetics of all involved crystalline phases during heating and cooling of a simulated weld thermal cycle. The investigations have demonstrated that targeted microstructure transformation favouring weld metal residual stresses can be observed when appropriate filler material alloy concepts are applied with specifically lowered M_s/M_f -temperatures.