Characterization of Embedded Secondary Phase Carbides in Low-Alloyed Martensitic Steels Using a Combination of High-Resolution Techniques

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In the process development of metal alloys, such as steel, controlling the microstructure is a key factor when optimizing the material properties. Precipitation hardened steels is a class of materials that is alloyed with carbide forming elements in order to form small precipitates that will increase the hardness of the material. Nanometre-sized and well dispersed secondary carbide precipitates will increase strength of the steel by inhibiting dislocation movement. Optimization of this phenomena require exact alloy composition and that heat treatments.

In this work, the formation of small (~2 - 40 nm in diameter) secondary carbides in a low-alloyed martensitic steel during tempering have been investigated. This by using a variety of high-resolution techniques such as (S)TEM together with EDX, 4D Scanning Precession Electron Diffraction (SPED), and Atom Probe Tomography (APT). In addition, to obtain high statistics of volume fraction and size distribution of the precipitates in-situ Small Angle Neutron Scattering (SANS) was performed meanwhile tempering the steel specimens, allowing for investigation of the precipitation process in real time.

Since the small particles are embedded in the steel matrix, (S)TEM samples were prepared using the extraction replica technique. Thus, the only remaining material is the precipitates on ~20 nm thin carbon film.

Using SPED, the different precipitates were clearly identified and the small carbides could be separated from the cementite, like needles in a haystack.

From SANS measurements, both investigated during in situ tempering and for quenched post tempered materials, high statistics of size distribution and volume fraction for the carbides could be obtained.

The combination of different high-resolution techniques such as (S)TEM EDX, APT and SPED, together with neutron scattering experiments, allows for high statistics of the phase distribution and volume fraction of different types of secondary carbides down to the 1-2 nm diameter range. The combination have proven to be an extremely powerful toolbox for extracting both qualitative and quantitative information from small precipitates, and can be very valuable for the metal industry to utilize in their alloy development.