INDUSTRIAL PILOT PROJECT

Characterization of secondary carbides in commercial steel grades using small angle neutron scattering experiments

THE INDUSTRIAL CHALLENGE

The hardness and strength of martensitic steels can be increased by formation of nano-sized carbides, so-called precipitation hardening. Molybdenum and vanadium are both strong carbide forming elements and are often added to the steel composition to increase hardness and strength. In order to form carbides that are ideally homogenously distributed within the steel microstructure, the steel is heat treated, quenched and tempered. It is important for SSAB and Uddeholm to better understand the precipitation sequence during tempering. When designing new steel alloys physically based modelling is often used to predict number densities, size distribution and volume fractions of formed particles, related to alloy content and heat treatment. Thus, extensive data regarding number density and size distribution of formed carbides is of great importance to improve and develop better models.

WHY USING A LARGE SCALE FACILITY

Traditionally, transmission electron microscopy (TEM) and atom probe tomography (APT) have been used to study small precipitates in steel. The micro-to-nano structure of commercial steels can be very complex, with local deviations. Since TEM and APT only analyse a very small and local sample volume, it is difficult to get a complete picture of the resulting nano-structure. On the other hand, small angle scattering (SAS) techniques provide significantly more data over much larger sample volume. The penetration depth of neutrons is very high compared to X-rays. Small angle neutron scattering (SANS) thus provides a more viable path for characterization of nano-particles. SANS provides data from a large sample volume, while retaining a similar detected length scale as TEM/APT (1-100nm). SANS also allows to measure the precipitation sequence in-situ, which is not possible with the laboratory-based techniques. This will help to verify and improve models used to predict particle distribution.

HOW THE WORK WAS DONE

SANS experiments were conducted at the Sans2D beamline of ISIS Neutron and Muon Source in England by representatives from both companies supported by experts from Swerim and Chalmers. The two alloys investigated had been heat treated at 500-650°C for up to 40h. They were of high and low alloy content, respectively, and consequently with different amount of small carbides. A magnetic field (1.5T) was applied perpendicular to the incident beam during measurements to separate the nuclear and magnetic scattering.

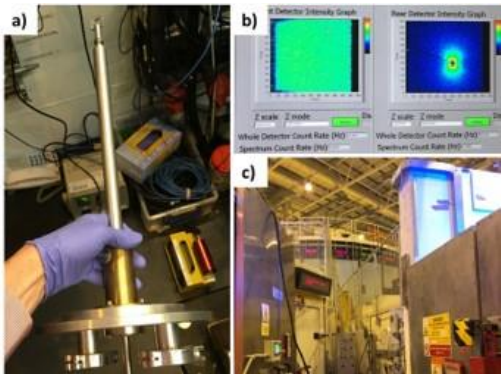

Figure. a) Sample holder, b) live monitoring of detectors, c) the experimental station.

THE RESULTS AND EXPECTED IMPACT

Clear signals could be detected from different particle types in different size ranges. The results regarding precipitation sequence and size and shape of the particles correlate well with the data previously obtained from TEM and APT. The data also allows the size distribution to be determined with very good statistics. More in depth data analysis is planned together with verification of physical based models using the results.

***"The high output of data at this length scale is just amazing"**/Robin Nilsson, SSAB EMEA AB*

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