INDUSTRIAL PILOT PROJECT

Precipitate characterization in electrical steels using a combination of SANS and VSANS

THE INDUSTRIAL CHALLENGE

Surahammars Bruks AB, part of Tata steel, produces electrical steels that are used in magnetically active parts of motors. The use of electric vehicles has been increasing enormously, resulting in great demand for the continuous development of electrical steel. Nano size precipitates (typically 10-400 nm) can strongly influence the magnetic properties of the steels, either directly by interference in domain wall motion, or indirectly by grain growth inhibition.

WHY USING A LARGE SCALE FACILITY

Although electron microscopy techniques are powerful for the analysis of small precipitates, they only give local information from extremely small volumes. Obtaining statistical information on nano-size particles for sample sizes, that also are measurable during magnetic and mechanical tests, requires small-angle scattering (SAS) methods using a photon or neutron beam. Neutrons (SANS) provide two great advantages: good contrast for metallic precipitates within the metallic matrix; and magnetic contrast for non-magnetic precipitates within a ferritic matrix.

HOW THE WORK WAS DONE

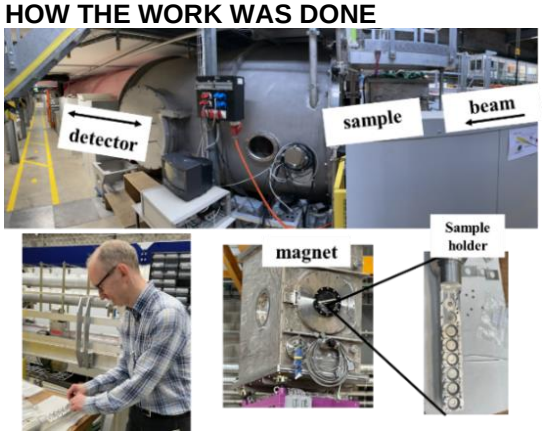

Figure 1. Top: The experimental setup, the detector could move in distances between 3 and 18 m from the sample to cover a wide range of particle size. Bottom: Arvid Broddefalk preparing samples; magnet mounted on the sample stage and the sample holder.

The experiment was performed on SANS-1 instrument at the Swiss Spallation Neutron Source, SINQ, at PSI, Switzerland. In one set of materials, small particles (<15nm) were added deliberately to increase the strength of the material, while another group of materials contained precipitates and particles that were detrimental to the magnetic properties. Each measurement was performed by stacking ten 0.3 mm thick samples and illuminating a 10 mm beam on the stack.

THE RESULTS AND EXPECTED IMPACT

The outcome provided statistical results about precipitates' size and concentration within the bulk. Such results can be directly correlated to the production parameters, as well as to the magnetic and mechanical properties of the final products. As a non-destructive method SANS has great potential for quality control and comparative study of samples. This data analysis resulted in the number density of different types of precipitates. Figure 2 shows the size distribution of precipitates in three samples with different magnetic response.

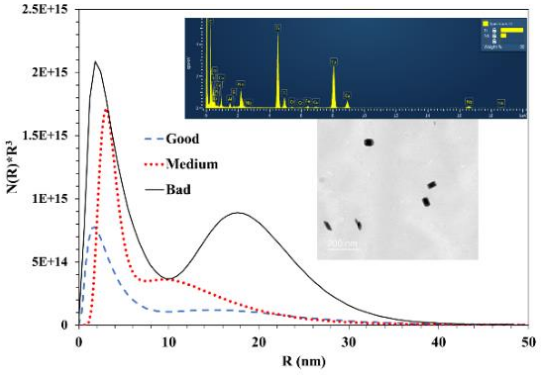

Figure 2. Size distribution of particles for samples that show good, medium, and bad magnetic properties. The inserted TEM results show the type of larger precipitates found with different fractions in all samples.

"To optimize electrical steels for high performance, it is important to understand the parameters that influence the magnetic and mechanical properties. Through excellent collaboration with Swerim, PSI and Anaxam we had interesting results on the size distributions of precipitates in selected samples. The SANS results together with SEM and TEM should enable us to better understand the underlying causes of the physical properties of our materials."
//Arvid Broddefalk, Surahammars Bruks AB

Contacts: Arvid Broddefalk – Surahammars Bruks AB, arvid.broddefalk@sura.se
Shirin Nouhi – Swerim AB, shirin.nouhi@swerim.se

Vinnova's project No: 2020-03786 **Duration:** November 2020 – October 2022

Funded by Sweden's Innovation Agency, Vinnova, in order to build competence and capacity regarding industrial utilisation of large-scale research infrastructures such as MAX IV and ESS.