# INDUSTRIAL DEVLOPMENT PROJECTS

# Towards understanding of high-temperature deformation mechanisms in Cr-doped hard metals by in-situ neutron scattering

## THE INDUSTRIAL CHALLENGE

Hard metal, composed of tungsten carbide (WC) particles bound together by Cobalt (Co)-rich binder, is the material choice for tools for metal cutting and rock drilling. During operation, the tools can reach temperatures exceeding 900°C, and since they are subjected to significant mechanical stress, the residual stresses become an important parameter affecting the performance. These stresses activate several mechanisms which can lead to deformation and finally to failure of the tool. Up to three times longer cutting tool life can be achieved by Chromium (Cr) additions in cemented carbides. The mechanistic understanding of the improved properties by Cr-doping is thus critical for accelerating innovations and reducing the lead-time for product development.

## WHY USING A LARGE SCALE FACILITY

Available lab-scale analyses are constrained to examining very small sample volumes with limited in-situ capabilities, preventing the complete quantitative view of the structural evolution in mimicked production and service conditions. Furthermore, the poor penetration depth of X-rays in materials made of heavy elements, such as W, makes neutron diffraction (ND) and small-angle scattering (SANS) the most suitable characterization techniques to investigate cemented carbides as bulk material. Additionally, the magnetic scattering of the cobalt makes SANS suitable also to separate signal stemming from the binder and secondary carbide phase.

## HOW THE WORK WAS DONE

The in-situ small-angle neutron scattering (SANS) experiments were performed on the LARMOR instrument at ISIS Neutron and Muon Source, UK, using the DELFT furnace to monitor the WC/Co interface structure evolution and precipitation of secondary carbides up to 1000 °C. The figure shows the in-situ setup, where the high temperature furnace positioned inside a magnet. The SANS experiments were complemented by room temperature residual stress measurements using ND on the Engin-X instrument. The sample matrix consisted of five hard metal compositions representing various WC grain size and Cr/Ti additions. Whilst cylindrical samples with 6 mm diameter were used for ND, plate specimens with 12 mm diameter and 0.3 mm thickness were used in SANS experiments. The analysis of reduced ND and SANS data were performed on Scatterin SaaS software. To complement and validate the neutron scattering results, also lab-scale atom probe tomography (APT) and electron backscatter diffraction (EBSD) investigations were performed.

## THE RESULTS AND EXPECTED IMPACT

The in-situ SANS experiments provided previously unattainable information on the evolution of microstructure associated with formation, dissolution, and growth of e.g. interfacial layers and larger carbides in hard metals.
The ND measurements could reveal the influence of dopants on the residual stresses in hard metals. Whilst the addition of Cr was found to increase residual stress in the WC particles, the addition of Ti resulted in reduced residual stress in WC.
This project has not only provided important information on microstructural evolution of Cr-doped hard metals but has also expanded our experience on available sample environments for demanding in-situ SANS experiments.

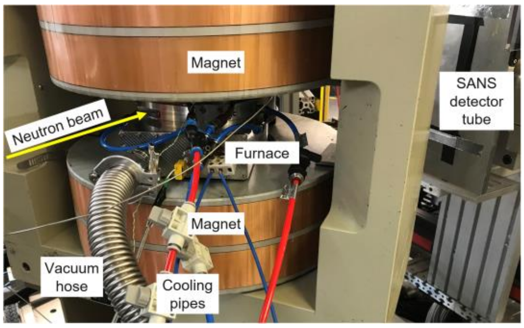


**Figure**. In-situ SANS setup on the LARMOR beamline with DELFT furnace and magnet, allowing 1.5 T external magnetic field.

***"Bulk measurements of material properties in-situ using neutron scattering at simulated operating conditions, will help us to further understand and develop our materials and tools."*** / ***Fredrik Lindberg, Sandvik Coromant***

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