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In-situ study of mechanical properties of 1CrMoV steel using neutron and synchrotron x-ray diffraction

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Abstract – Deformation mechanisms of 1CrMoV steel were studied using in-situ neutron and synchrotron x-ray diffraction. Phases identified by means of diffraction pattern indexation were ferrite and cementite. The study of mechanical properties during deformation showed that 1CrMoV steel exhibits high anisotropy during the elastic and plastic regimes and starts building up internal stresses within less than 0.5% of plastic deformation. When deformation reaches the yield point there is a stress partitioning between ferrite and cementite.

In-situ diffraction experiments during mechanical testing are powerful tools to study mechanical behavior of multi-phase materials. 1CrMoV steel is a low alloy bainitic steel that presents desirable combination of high strength, toughness and creep resistance, and it is widely used in power plants. In order to gain a better understanding of the mechanisms of deformation, load transfer and accumulation of internal stresses with the long term view of improving predictive models for creep and fatigue behaviour in-situ x-ray and neutron diffraction techniques were applied on such material. These techniques allow one to record continuously the diffraction patterns during mechanical testing, providing an in-situ phase and crystal orientation specific stress – strain curve [1-3].

The x-ray analysis was performed at the Materials Science beamline at the Swiss Light Source (SLS), and the neutron diffraction experiments were performed at the time-of-flight neutron diffractometer POLDI (Pulse Overlap Diffractometer) at PSI. A tensile machine was installed on both beam lines and time-resolved measurements were performed on machined dog-bone specimens during elasto-plastic deformation. Single peak analysis of each crystal reflection allowed studying the load transfer between stiff and compliant phases and crystal orientations, and evaluating the built-up of internal stresses.

The phases that were able to be identified by means of indexing the diffraction pattern were ferrite and cementite (Fe_3C) (Fig. 1a). In situ x-ray and neutron diffraction experiments performed during tensile tests (Fig. 1b) have revealed three stages of load transfer during elasto-plastic loading and that significant crystal anisotropy during the elastic and plastic regimes generates internal stresses within 0.5% of plastic deformation. When deformation reaches the yield point there is a stress partitioning between ferrite and cementite, with the cementite taking the load from the ferrite which plastically deforms.

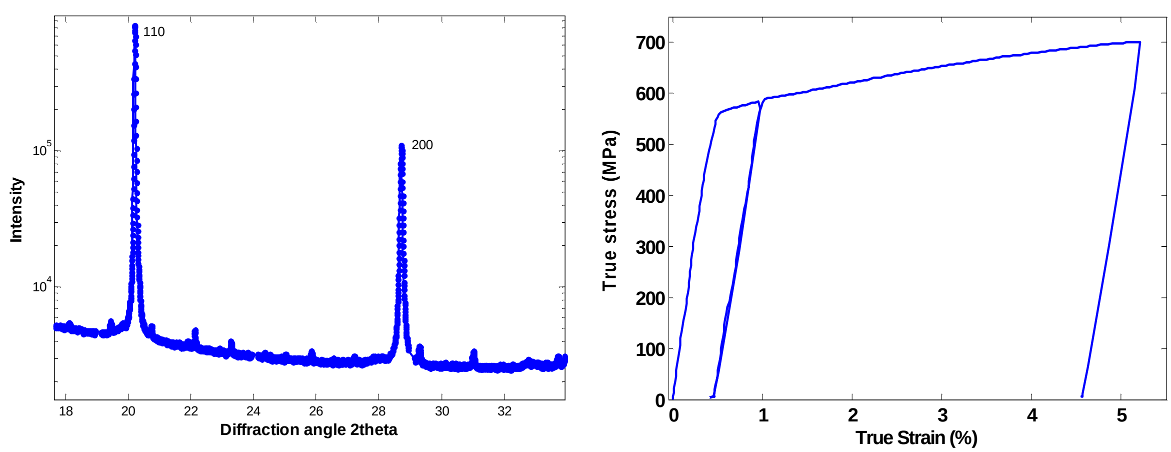

Figure 1(a) Stress strain curve for 1%CrMoV Bainitic steel with a single unload, (b) the synchrotron X-ray diffraction pattern showing the fundamental ferritic BCC reflections and the lower intensity reflections for the cementite.

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[3] Van Swygenhoven, H. (2006). Review of Scientific Instruments, 77.