| | **Experiment title:** In-situ Mechanical Simulation of Twinning Induced Plasticity Steel | **Experiment number**: **MA-991** |
|---|---|---|
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## Report:

Experimental data and results have been published in the Thesis work citing:

**Yan, Kun, *In-situ characterization by high-energy x-ray and neutron diffraction of micro-structural evolution of selected materials during thermo-mechanical processing,* Doctor of Philosophy thesis, School of Mechanical, Materials and Mechatronics Engineering, University of Wollongong, 2012. http://ro.uow.edu.au/theses/3700**

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### Abstract

Despite the limited opportunities in obtaining beam times and difficulties in analysing data, modern techniques of synchrotron high-energy X-ray diffraction and neutron diffraction possess the advantages of fast measuring speed and obtaining microstructural information from a bulk volume rather than surface. These features maintain their advantages and particularities in investigating microstructural evolution of metallic materials during thermal-mechanical processing. Over the past 15 years, considerable improvement has been made in applying these diffraction techniques with other microscopy means.

The present work is concerned with the experimental study of in-situ in real time investigations of materials microstructural change during thermal-mechanical processing by high-energy X-ray diffraction and neutron diffraction. As a benchmark, plastic deformation of single grain and polycrystalline copper was measured by high-energy X-ray diffraction, during unidirectional compression at room temperature. Following this, a systemic study of deformation mechanisms of twinning-induced plasticity (TWIP) steel Fe-18Mn alloy at room temperature was carried out by high-energy X-ray diffraction and self-consistent modelling. The grain statistics and grains orientation distribution of Fe-18Mn have been characterised during various plastic deformation processing, including unidirectional tension, quasi-static compression, shock impact compression and high-pressure torsion. Influence of strain rate and total strain on texture has been specified by the advanced technique of obtaining texture from an individual 2D synchrotron diffraction image. The deformation process

of TWIP steel involved the competition between dislocation sliding, mechanical twinning and even martensitic phase transformation, in some extreme condition of high-pressure torsion and shock loading. The activities of these different mechanisms during various deformation processes were predicted by both statisticity of diffraction pattern and self-consistent modelling.

Following the studies of plastic deformation at room temperature, the author further studied alloys microstructural evolution at high temperature. This started from Zr- 2.5Nb, the segregation of Nb atoms between β-(Zr-Nb) phase and β-Zr phase was recorded by in-situ neutron diffraction experiments. In addition, the hot deformation behaviour of Zircalloy-4 was investigated by high-energy X-ray diffraction. Apart from the lattice relationship between α-phase and β-phase, dynamic recrystallization was also observed.

The final study concerned the use of a high-energy synchrotron X-ray beam to study in-situ and in real time microstructural changes in the bulk of a novel, β-solidifying titanium aluminium alloy. The occupancy and spottiness of the diffraction rings have been evaluated in order to access grain growth/ refinement, orientation relationships, subgrain formation, dynamic recovery and dynamic recrystallization, as well as phase transformations. For the first time, this method has been applied to a Ti-Al alloy system consisting of two co-existing phases at high temperature and it was found that the *bcc* β-phase recrystallizes dynamically much faster than the hcp α- phase, which deforms predominantly through crystallographic slip, that was underpinned by a dynamic recovery process with only a small component of dynamic recrystallization. The two phases deformed to a very large extent independently from each other. The rapid recrystallization dynamics of the β-phase combined with the easy and isotropic slip characteristics of the *bcc* structure, explained the excellent deformation behaviour of the material, while the presence of two phases effectively suppresses grain growth.

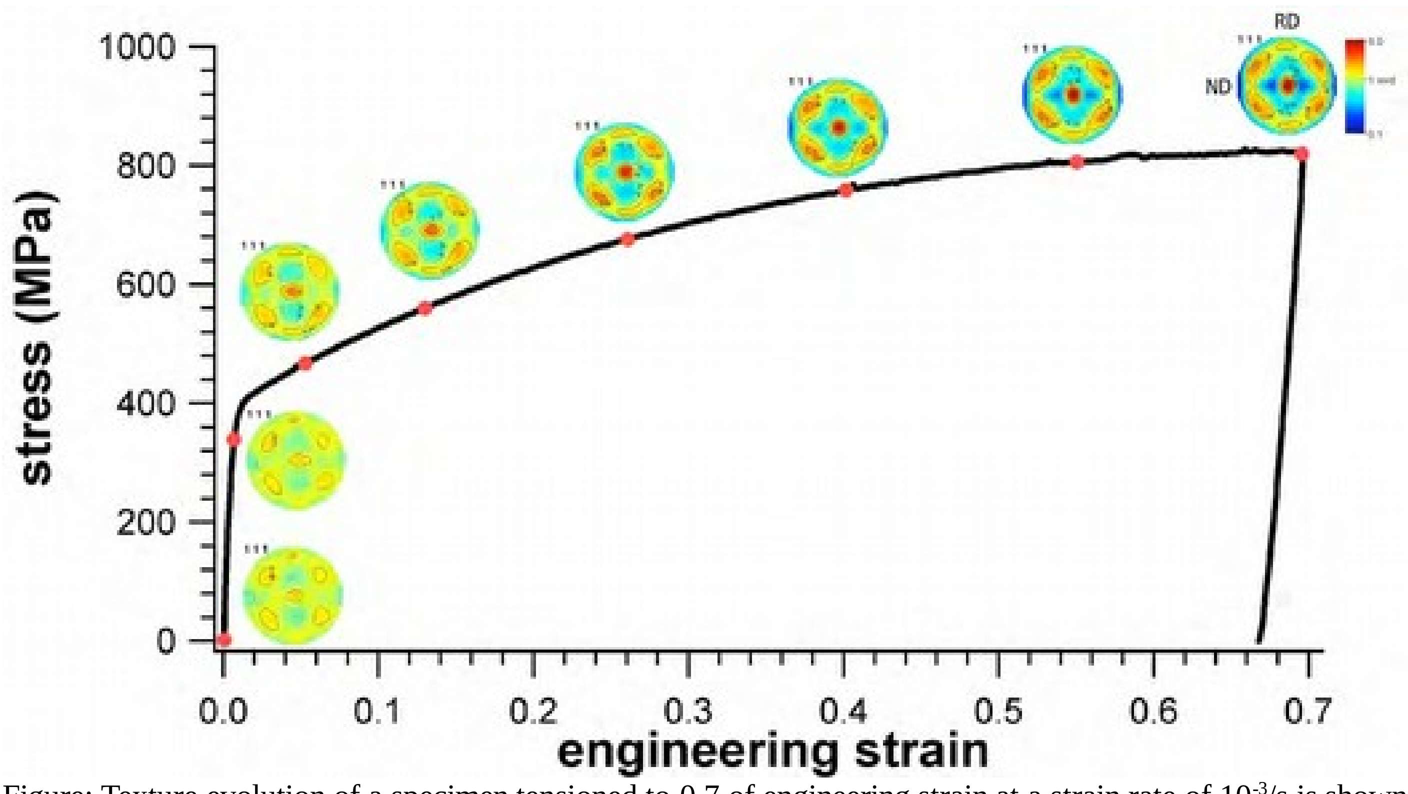

Figure: Texture evolution of a specimen tensioned to 0.7 of engineering strain at a strain rate of $10^{-3}$/s is shown as the 111 pole at $\varepsilon_{eng}$ = 0, 0.01, 0.05, 0.13, 0.26, 0.40, 0.55, 0.67. These pole figures were measured by 2D individual synchrotron images during an in-situ tension test. (Figure 4.7 of Thesis)