Texture Evolution of Zircaloy-2 during Plastic Deformation at 77K

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Zircaloy-2 is used extensively in the nuclear industry as a structural material for the reactor core of both light and heavy water reactors. Intergranular residual stresses and texture greatly affect the mechanical properties of the material during operation.

For this study, a warm-rolled and recrystallized Zircaloy-2 slab was used to examine the texture evolution of Zircaloy-2 at 77 K. The objective was to develop a better fundamental understanding of twinning mechanisms that contribute to plastic deformation in Zircaloy-2. This will provide valuable information to improve models to predict the deformation of Zircaloy-2, and specifically the development of type-2 residual stresses that determine in-reactor behaviour. At room temperature, twinning is not the dominant deformation mechanism. The testing temperature was thus lowered to 77K to suppress the activity of slip systems, and increase the relative activity of twinning mechanisms, making the study of twinning easier.

A sample aligned with its stress axis parallel to the rolling direction of a Zircaloy-2 slab was compressed to -6% plastic strain. The pre-deformed sample texture was measured using material that did not undergo any plastic deformation, while the central portion of the gauge section of the sample was used to measure the deformed sample texture. The texture measurements were performed using the E3 spectrometer. The sample used for texture was then polished and used for Electron Backscattered Diffraction (EBSD) measurements, which provide local texture information, which is complementary to the bulk texture data, obtained by neutron diffraction.

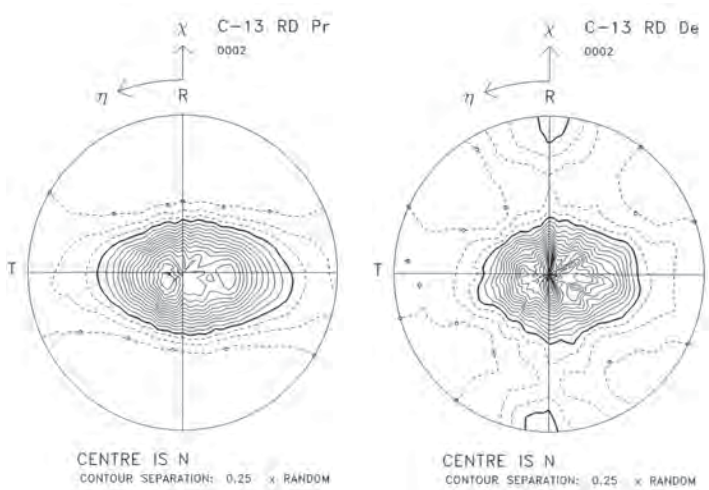

Fig 1. Basal pole figures for (left) as-received and (right) deformed Zircaloy-2

As shown in Figure 1(a), there is a strong concentration of basal poles parallel to the normal (thickness) direction in the as-received Zircaloy-2 slab. This preferred orientation persists after deformation (Figure 1(b)). However, Figure 1(b) also clearly shows that some basal poles have been re-oriented parallel to the compressive axis (rolling direction). This reorientation is evidence of $\{10\bar{1}2\}$ tensile twinning, which reorients the basal poles 85.22° away from the tensile axis (thickness direction) towards the compressive axis (rolling direction).

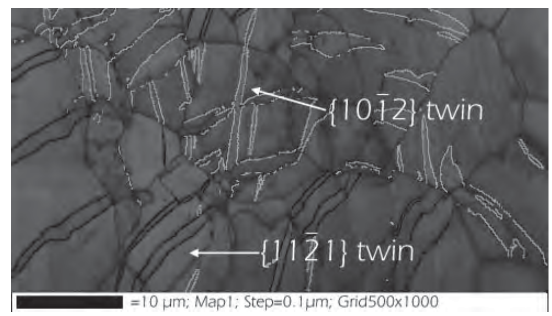

Fig 2. EBSD map for the rolling direction showing $\{10\bar{1}2\}$ and $\{11\bar{2}1\}$ tensile twins

Figure 2 shows an EBSD map for a sample compressed along the rolling direction. Both $\{10\bar{1}2\}$ (85.22°rotation) and $\{11\bar{2}1\}$ (34.84° rotation) tensile twins are visible.

In conclusion, the texture evolution during plastic deformation of Zircaloy-2 at 77K verifies the activation of twinning, and complements work performed on in-situ lattice strain evolution of Zircaloy-2 at 77K. Results will be compared with model predictions of twinning.

References

[1] E. Tennckhoff, Operable Deformation Systems and Mechanical Behavior of Textured Zircaloy Tubing, in Zirconium in Nuclear Applications, ASTM STP 551-EB,180-198 (1974)