Deformation mechanisms of twinning-induced plasticity steels: In situ synchrotron characterization and modeling

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Due to its excellent ductility, high work hardening rate, significantly enhanced ability to absorb energy upon impact, whilst maintaining stability and strength of components, twinning induced plasticity (TWIP) steels are considered as an ideal material for applications in the automotive industry. Previous studies on TWIP steel indicate that the twinning volume fraction increases concurrently with plastic deformation and also a higher critical shear stress level is needed for the nucleation of twins contributing to a high work hardening rate. However, the high ductility of TWIP steel cannot be completely explained if only twinning is considered. Moreover, the contributions of twinning and slip to the texture evolution of the material are unknown. Therefore, more details from the atomic lattice scale are required to ascertain the relation between twinning, slip and texture evolution upon plastic deformation of TWIP steel. In the current study, the plastic deformation behavior of TWIP steels with composition of Fe-25Mn-3Si-3Al is investigated, by means of in-situ synchrotron high-energy X-ray diffraction. The alternating interaction of {111} <110> slip and {111} <112> twinning have been directly observed for the first time in-situ while undergoing uniaxial tensile deformation. Self-consistent models (EPSC and VPSC) were employed to simulate the deformation behavior and orientation evolution for different reflections. Comparisons of the experimental and modeling results revealed that the deformation texture is determined mainly by dislocation gliding, while deformation twinning impedes the reinforcement of texture.