Temperature Dependence of Work Hardening Controlled by Nitrogen-Induced Dislocation Structures in Austenitic Steel

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This study examined the temperature-dependent influence of nitrogen on the tensile behavior of austenitic steel at 293, 201, and 77 K. In both nitrogen-free and nitrogen-bearing steels, the work-hardening rate increased as temperature decreased, but the mechanisms differed markedly. In nitrogen-free steel, dislocation cells formed at 293 and 201 K, while planar dislocation arrays and deformation twins appeared at 77 K due to reduced stacking fault energy (SFE). The temperature dependence of the work-hardening rate became evident only at high strains, reflecting the influence of strain-dependent dynamic recovery and deformation twinning, both affected by SFE. In nitrogen-bearing steel, work hardening showed a clear temperature dependence across all strain regions. Planar dislocation arrays developed consistently, with minimal cell formation. The dislocation density increased at lower temperatures due to suppressed slip system activity and dynamic recovery in nitrogen-bearing steel. A Bailey–Hirsch-like relationship was observed between flow stress and the square root of dislocation density in both steels. The slope was steeper in nitrogen-bearing steel, indicating a stronger contribution of dislocation accumulation to strengthening. Nitrogen also promoted long-range stress fields via dislocation pile-ups on planar slip planes. These effects intensified at lower temperatures, as the thermally reduced activation of Frank–Read sources shortened the mean free path, increased dislocation density, and enhanced work hardening.

References:

[1] T. Ma, T. Masumura, T. Osuki and T. Tsuchiyama: Mater. Sci. Eng. A, 945(2025). https://doi.org/10.1016/j.msea.2025.149025