The Influence of Dynamic Strain Aging Phenomenon on Materials Strength and Ratcheting

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Abstract:

The dynamic strain aging (DSA) phenomenon occurs when solute atoms diffuse to the temporarily trapped mobile dislocations before the dislocations move on to adjacent obstacles. This hindrance to dislocation motion alters the mechanical properties of metallic alloys at certain elevated temperatures, where solute atoms collide with dislocations at high speeds. This phenomenon not only diminishes the rate-dependent characteristics of materials but also enhances cyclic hardening behaviour. In steel alloys within the temperature range of nearly 500-750K, the interaction of diffusing solute atoms, such as carbon or nitrogen, colliding with dislocations induces local hardening and serrated flow. Beyond the DSA temperature regime, at operating temperatures above T>750K, as annihilation and rearrangement of dislocations reduces the rate of strain hardening and steel samples exhibited (i) greater ductility and lower cyclic strength, and (ii) progressive plastic strain accumulation over loading cycles (ratcheting) and damage progression.

In the present study, the influence of the DSA phenomenon on tensile yield strength as well as the ratcheting response of materials as steel samples, that undergo asymmetric loading cycles, has been studied. The outcome of this research promotes a safe and risk-free design of engineering components operating at certain elevated temperatures at which the DSA phenomenon preserves their strength and durability. The implication of DSA in industry is substantial, as it promotes the strength and hardness of machinery parts to withstand higher applied stresses at elevated temperatures. The underestimation of the DSA occurrence at certain temperatures can lead to a reduced safety margin, highlighting the practical importance of considering reliable materials characteristics at elevated operating temperatures and different strain rates. Figure 1 shows the substantial influence of the DSA phenomenon on tensile strength and ratcheting data in steel samples tested at different loading conditions.