Constitutive Relations and Plastic Work Analyses of Work-Hardening in FCC Metals: Evolution of Stored Work

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Work-hardening is due to multiple operation of slip systems imposed by the strain tensor enforcing gliding dislocations to intersect forest dislocations. At constant strain rate and temperature, the strain rate sensitivity, S, has been found to be constant with strain. Hence the activation work is constant implying that the activation distance and obstacle strength coefficient, α, are also constant with strain. It can be deduced that the internal stresses intrinsically maintain the activation work at each activation site constant and equal to that of the mean value of k/S whereby kT is the thermal energy. Recent experiments indicate that the rate controlling mechanism of flow stress is due to repulsive forest intersections only, which imply that the density calculated from the flow stress is about one-half of the total since equal amounts of attractive intersections must exist. The question arises of how to determine the total stored work. The issue is that during deformation, dynamic athermal annihilation occur that has been accounted for in the Saimoto-Van Houtte relation as the A-factor and its cause have been attributed to coplanar mechanisms [1]. In the derivation, A was invoked to balance the energies of the expended work (W_{exp}) to that stored (W_{stor}), as $W_{exp} = A\ W_{stor}$. The new discovery is that A can be assessed by comparing lattice spacing, $h_\gamma = 6\ b/\gamma$ per slip system, as the strain criterion, to that of the limiting height for two parallel screw dislocations of opposite signs on parallel slip planes, $h\tau = \mu b/4\pi\ \tau$, as the stress criterion. Because both criteria must simultaneously apply, it was deduced that $(h\tau\ /\ h_\gamma)^2 = A$ [1]. In this report it will be shown that the constitutive relation analyses (CRA) of the stress-strain locus results in parameters which can replicate the original data from which W_{exp}, W_{disl} and W_{vac} (that for vacancies) can be computed and W_{stor} determined as function of strain.

[1] Shigeo Saimoto, Bradley J. Diak, Anna Kula and Marek Niewczas, Forensic analyses of microstructure evolution of stage II & III: New assimilated model for work-hardening in FCC metals, Acta Mater. 198 (2020) 168-177.