ICSMA19 Metz, France, June 26 - July 1, 2022
International Conference on Strength of Materials

A statistical analysis of the interaction between grain boundary and forest hardening

Rafael Schouwenaars[a]

[a]*Departamento de materiales y manufacutra, DIMEI, Universidad Nacional Autónoma de México, Avenida Universidad 3000, 04510, Coyoacan CDMX, México*

[a]*raf_schouwenaars@yahoo.com*

The grain size effect (GSE) is generally described by a relationship between the yield strength σ_y and grain size d_g as $\sigma_y = \sigma_0 + k_{HP} d_g^{-n}$. For n=1/2, this is the Hall-Petch relationship, generally explained by the formation of dislocation pileups at grain boundaries (GBs) [1]. A large set of experimental data [2] shows n≠1/2 for most metals and a large dispersion of the data with respect to the regression formula.

For a dislocation density ρ_d=10^{12} m^{-2}, the average number of dislocation segments per grain falls below 1 at a value of $d_g \approx 2.5\ 10^{-6}$m, precluding the effect of dislocation pileups [3]. The present work demonstrates this transition trough a mathematical analysis of the probability of storage and annihilation at GB and forest sites, based on the slip length concept proposed in the Kocks-Mecking model [4].

The σ_y-d_g curves are extrapolated from model fits to sets of tensile tests for different d_g. No fitting parameter for d_g is used. For d_g <10^{-7}m, the stress required to activate a GB dislocation source becomes more important than the slip length effect. The combination of the statistical analysis with the mechanistic approach for ultrafine grains [3] provides a consistent explanation for the GSE.

Keywords: Kocks-mecking; Hall-Petch; Dislocation forest; Grain boundary source

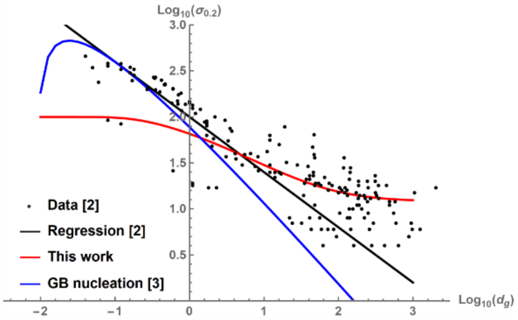

Fig. 1. Predicted σ_y-d_g curve based on tensile tests for aluminium with different grain sizes (red) and nucleation stress for grain boundary dislocations (blue) [3], compared to the dataset and regression curve Eq. (1) provided by Cordero et al. [2].

References:

[1] Eshelby, J.D., Frank, F.C. Nabarro, F.R.N., Phil. Mag. 42 (1951) 351-364.
[2] Cordero, Z.C., Knight, B.E. Schuh, C.A. Int. Mater. Rev., 61 (2016) 495-512.
[3] Schouwenaars, R. Int. J. Plast. 133, (2020) 102802.
[4] Kocks, U. F., and H. Mecking. Prog. mater. sci. 48 (2003) 171-273.