The Influence of Kinks in Edge Dislocations of bcc Fe on the Acoustic Softening Effect

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There is an effect called the ultrasonic vibration-assisted forming effect. It is a phenomenon, in which the flow stress decreases intensely when ultrasonic vibration is superimposed during the plastic deformation. It includes three effects, which are the "Stress superposition effect", "Residual effect" and "Acoustic softening effect". This study focuses on the acoustic softening effect. Asazuma elucidated that the atomic density difference resulting from extra atomic planes affects the interatomic potential, leading to an imbalance in atomic mobility; this promotes slip and gives rise to acoustic softening [1]. However, in that study, the edge dislocations contained kinks, and the effect of these kinks remains unclear. The aim of this study is to elucidate the influence of kinks in edge dislocations on the ultrasonic softening effect by comparing the yield stress, the interatomic potentials, and the kinetic states of atoms, which take account of their orientation.

The molecular dynamics simulations were conducted by LAMMPS [2] using the edge dislocation inserted model shown in Figure 1. Two types of models are created: a tilted model and an orthogonal model. The orthogonal model size is $40.8\text{Å} \times 88.8\text{Å} \times 56.0\text{Å}$ and it contains 17424 atoms. Also, the no-kink model is tilted by 19.2Å in the *xz* direction to satisfy periodic boundary conditions. In this model, slip direction <111> adopted to the x direction, and slip plane (110) to *xz* plane. *xy* shear and ultrasonic vibrations that proportional to the normal yield stress were applied to both models. The stress-time curves are displayed in Figure 2. The yield stress of the orthogonal model decreased from 68 MPa to 40 MPa. Furthermore, the yield stress of the tilted model decreased from 510 MPa to 460 MPa. These results indicate that the kink caused a significant reduction in yield stress. It was also found that acoustic softening effects were increased efficiency by four times due to the kinks.

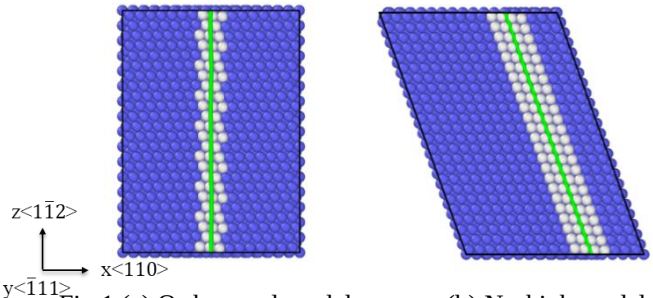

Fig.1 (a) Orthogonal model (b) No-kink model

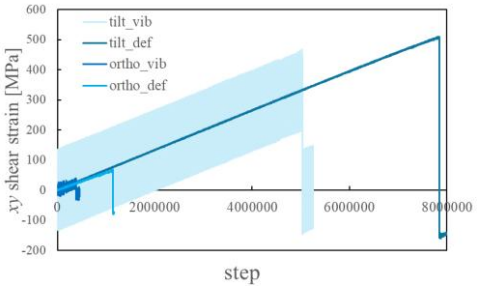

Fig.2 Stress-Time curve

[1] Akari Asazuma and Shuichi Arikawa, Absorption of ultrasonic vibration energy by dislocations in body-centered cubic iron: a mechanistic study using molecular dynamics simulations, 2026. https://link.springer.com/article/10.1007/s10853-026-12331-9

[2] LAMMPS Molecular Dynamics Simulator: https://lammps.sandia.gov