【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Engineering)

Title of Project : Systematization of Academic Foundation on Grain Refinement Strengthening in Steel

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Research Project Number : 15H05768 Researcher Number : 90150490
Research Area : Engineering, Material engineering, Inorganic materials / Physical properties
Keyword : Crystal structure / Microstructure control

【Purpose and Background of the Research】

It has been believed that the appearance of discontinuous yielding is characteristic of steel and it is due to dislocation locking by solute C and N atoms (Cottrell locking). The evidence supporting this idea is the fact that yield strength can be lowered by purifying iron. However, we found recently that the coefficient of grain refinement strengthening k_y is changeable depending on the C content in the range C < 60ppm and, even at same grain size, yield strength is lowered with reducing C content. This is a new finding which disproves an established theory in the academic field of steel. So far, small amount of C and N less than 100ppm has been neglected as impurity on the evaluation of k_y in steel. However, it is likely that small amount of C and N gives some influence on the k_y and we misunderstand it as the effect of alloying elements. For instance, as shown in Figure 1, the k_y of pure iron has been believed to be much higher in comparison with Al or Cu but our research revealed that it shifts to a reasonable value in IF steel, which does not contain free solute C nor N.

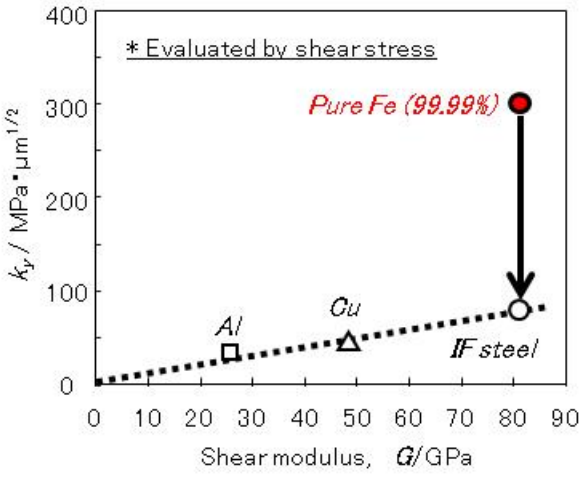

Figure 1 Relation between shear modulus and the coefficient of grain refinement strengthening k_y in several metals.

In this research, the effect of C and N on yielding behavior will be investigated in polycrystalline ferritic steel and the effect of alloying elements will also examined in terms of the k_y. Final goal of this research is to re-construct the data-base related to grain refinement strengthening for the strength design in steel.

【Research Methods】

1)Analysis of yielding mechanism of ferritic steel: Grain boundary segregation of C and N will be examined by 3D-atom prove to evaluate the effect of grain boundary segregation on the k_y. Microstructural change around grain boundary is observed with In-situ SEM which makes dynamic observation possible during tensile deformation in order to clarify the relation between microscopic change and macroscopic yielding. Calculations by molecular dynamics are also performed to inspect the reasonability of results obtained by experiments.

2)Effect of substitutional alloying elements on the k_y value: Seven kinds of interstitial free alloy (IF alloy), which containing Mn, Si, Cr, Ni, S, Cu, Al independently, are prepared to investigate the effect of each alloying element on the k_y.

【Expected Research Achievements and Scientific Significance】

This research will contribute to the development of strength design of steel and the systematization of academic foundation on grain refinement strengthening through the construction of data-base related to Hall-Petch relation in steel.

【Publications Relevant to the Project】

K. Takeda, N. Nakada, T. Tsuchiyama, S. Takaki: ISIJ Inter., 48 (2008), 1122-1125.
D. Akama, N. Nakada, T. Tsuchiyama, S. Takaki, A. Hironaka; *Scripta Mater.*, 82(2014), 13-16.

【Term of Project】 FY2015-2019
【Budget Allocation】 121,600 Thousand Yen

【Homepage Address and Other Contact Information】

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