Study on Micromechanics in Duplex Stainless Steels for Long term Operation of Nuclear Power Plants

*Viet Quoc Ha[1], Kenta Murakami[1], Masahide Suzuki[1]

[1]Nagaoka University of Technology

Abstract

Keywords: Duplex Stainless Steels, Thermal Ageing , Irradiation , Nanoindentation.

Duplex stainless steels (DSSs) are composed of both austenite and ferrite phases and used for various structures and components in light water reactor, such as primary coolant pipes and claddings of reactor pressure vessel. It is known that the Spinodal decomposition of ferrite phase is a main cause of mechanical properties changes at its long term operation, but G phase and dislocation formation in both phases may also contribute. Therefore, relationship between microscopic material changes and large scale mechanical properties is important topics in DSSs. In this study, relationship between micro and macro hardness is investigated using nanoindentation technique following thermal ageing or ion irradiation.

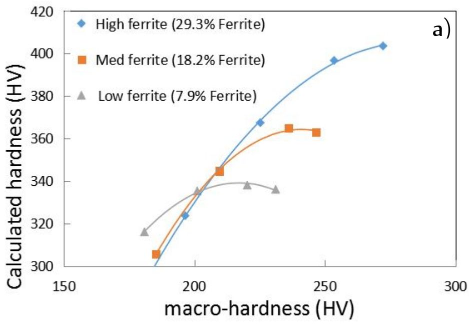
Specimens are SCS16A DSSs with different ferrite fractions (29.3%, 18.2%, and 7.9%). Some of these specimens were thermally aged at 400℃ up to 2400 hours, corresponding to 30000 hours at 300℃[1]. The other specimens were irradiated by 2 MeV He^{++} with ion fluence up to 5 x 10^{16} ion/cm^2 in room temperature using the Tandem accelerator of Nagaoka University of Technology.

Microscopic material changes in each phase were assessed by nanoindentation, selecting the indentation position carefully for at least 15 times. The load of microscopic indentation is 5 mN and the indentation depth is about 0.2 µm. Macroscopic mechanical properties changes were assessed by the larger scale indentation with the load of 1961 mN, in which several ferrite and austenite grains exist under an indentation mark.

Under thermal ageing, microscopic hardness in ferrite phase changes with the similarly regardless the difference of ferrite fraction, and the microscopic hardness in austenite phase is almost unchanged in all specimen. The macroscopic hardening is more evident in the specimen with higher ferrite contents, as it is well known. In Fig. 1(a), relationship between macroscopic hardness and calculated harness based on microscopic hardness is shown. The calculation was a simple weighted mean of microscopic hardness in both phases considering the phase fractions. The relationship of three specimens shows similar trend at lower hardness, but is deviated at higher hardness.

Under irradiation, hardening in ferrite is approximately four times smaller than austenite, though there are large scattering in the results. Though the microscopic hardening in austenite was more evident, macroscopic hardening in higher austenite specimen was less evident than higher ferrite specimens. In Fig. 1(b), relationship between macroscopic hardness and calculated hardness based on microscopic hardness under irradiation was also shown. Comparing with the Fig. 1(a), the trend is largely deviated between specimens.

To understand the relationship, indentation size effect as well as the hardening at the grain boundary are under the examination. These results would also introduced in the presentation.



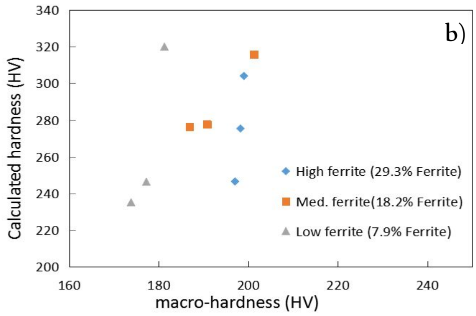


Fig. 1 The relationship between macroscopic hardness and calculated hardness using microscopic hardness in both phases. a) Thermal ageing, b) Irradiation

References

[1] Takuya Yamada, Katsuhiko Fujii, Masanori Aoki, Koji Arika, *Thermal-aging evaluation of on site aged cast duplex stainless steel,* INSS JOURNAL Vol. 19 2012 NT-7, p.115.