Atom Probe Study of Microstructural Features Affecting Mechanical Properties and Delamination Cracking of Annealed Hyper-eutectoid Steel Wires

Jafari Bahramabadi, M.[1], Bang, C.[1], Seol, J.[2] and Park, C.[3]

[1] Pohang University of Science and Technology (POSTECH), Pohang 790-784, South Korea, Republic of Korea, [2] National Institute for Nanomaterials Technology (NINT), POSTECH, Pohang 790-784, South Korea, Republic of Korea, [3] Pohang University of Science and Technology (POSTECH) & National Institute for Nanomaterials Technology (NINT), POSTECH, Pohang 790-784, South Korea, Republic of Korea

In practical applications of heavily cold drawn hyper-eutectoid steel wires like cable wires for suspension bridges, the manufacturing process includes wire drawing and a subsequent annealing treatment. Therefore, microstructure evolution during post-deformation annealing of the wires is a major concern for their manufacturing process. Here, the evolution of microstructure, tensile properties and delamination behavior through annealing treatments of as-drawn lamellar structured wires in the temperature range of 150-450 °C was investigated from micrometer-scale down to atomic-scale regime. The wires annealed at 150 °C showed a tensile strength increment from 3452 MPa for as-drawn state to 3765 MPa without significant loss of tensile and torsional ductility due to the age-hardening associated with dislocation pinning by carbon atoms. Annealing at 300 °C yielded partial removal of lamellar structure and formation of nanosized carbide particles with a size of < 20 nm. This resulted in a severe reduction in tensile strength as well as tensile and torsional ductility due to age-softening, leading to a catastrophic delamination failure. Annealing at 450 °C was accompanied by complete removal of the lamellar structure and spheroidization of lamellar cementite. Also, upon annealing at 450 °C, the driving force for growth of the nanosized carbides was sufficient to trigger their drastic coarsening and subsequent integration to the spheroidized cementite. This phenomenon, together with reduced carbon content in ferrite and decreased dislocation density through recovery and recrystallization, yielded a more pronounced age-softening at 450 °C, but no delamination fracture was detected for 450 °C-annealed wire. This study offers a comprehensive understanding of annealing induced age-hardening or -softening phenomena and its correlation with undesirable delamination of hyper-eutectoid steel wires.