Type of presentation: Poster

IT-7-P-1969 Observation of Strain Aging Behavior in Strain Based Line Pipe Steels using in-situ Heating and Straining TEM stage

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One of the new concepts for American Petroleum Institute (API) X100 grade line pipe steels was the strain-based design (SBD) approach. As demands increased for the harsh environmental applications such as the artic and seismic area, SBD line pipe steels were considered as a key solution. Even though the strength could be diminished by the processing or design, uniform elongation is the top-most property to attain in the line pipe steel. Many researchers have focused on the alloy design, combined with microstructure analysis and mechanical properties, to fabricate line pipe steel delivering both the transport efficiency and the performance. Full size X100 steel plate and pipe with 32mm thickness were selected and investigated in this study. The pipe shaping was achieved through UOE (U-ing, O-ing, and Expansion) piping process. The mechanical properties such as yield stress (YS), tensile stress (TS), and uniform elongation (uEl) were measured from the tensile test. Furthermore, microstructures were observed by scanning electron microscope (SEM) and transmission electron microscope (TEM). The dislocation structures of the plate and pipe were analyzed by selecting several layers through the thickness. Because the plastic deformation history of the surface is different from that of the center during the UOE piping process, it is expected that the dislocation density and structures were formed differently through the thickness. UOE process is typically followed by the anti-corrosion coating process, which requires heating the pipe up to 200 ~ 250°C. During the heating process for the anti-corrosion coating, the pipe reveals the strain aging phenomena giving yield drop in the stress-strain curves. To investigate both the strain and the thermal effect on the strain aging behavior of SBD X100 steels, in-situ heating and straining TEM stage was designed and applied to test the alloy. Each step of process conditions, such as applying stress and heat/cooling, was simulated in the TEM while observing the microstructural change. The analysis of strain aging behaviors was conducted.

Acknowledgement: This work was supported by the Development program(No.10040025) of the Korea Evaluation Institute of Industrial Technology grant funded by the Korea government the Ministry of Trade, Industry and Energy.

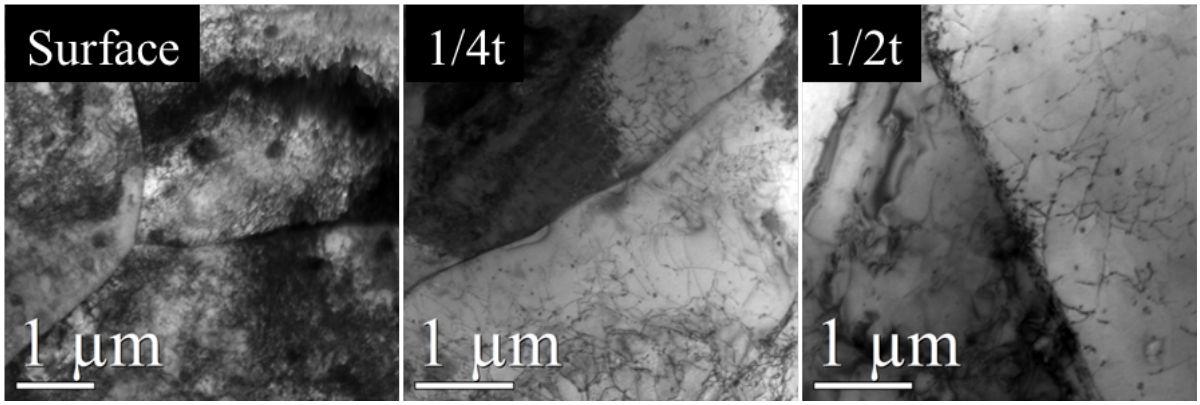

Fig. 1: TEM images of dislocation structures of the line pipe: (a) surface, (b) 1/4t, and (c) 1/2t

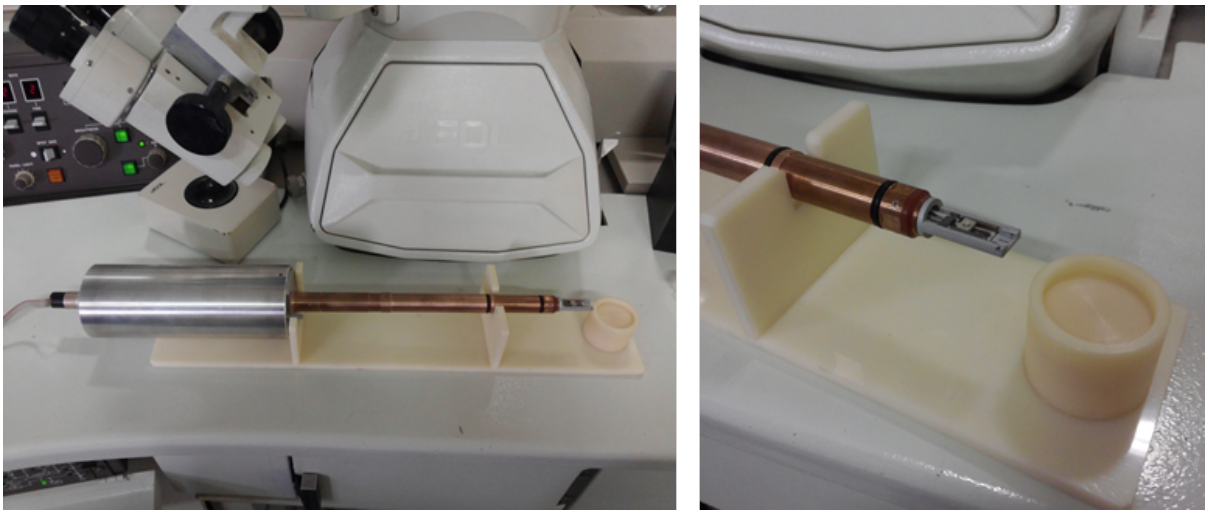

Fig. 2: in-situ heating and straining TEM stage: whole view (left), detail view (right)