The Effects of Microscopic Metallurgical Factors on Macroscopic Deformation Properties in Dual Phase Steels

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ABSTRACT

Linepipes for high strain applications, such as in seismic or permafrost regions, are required to have sufficient deformability, in order to prevent buckling or weld fracture caused by compressive and/or tensile deformation induced by large ground movement. Extensive efforts have been made in developing linepipes, which have lower yield strength to tensile strength (Y/T) ratio, and higher strain hardening coefficient (n-value) and uniform elongation. Dual phase (DP) microstructure control is one of the key technologies for obtaining these desired properties. These high strain linepipes, with a ferrite-bainite microstructure, are produced by applying an accelerated-cooling process from the α+γ region. It is well known that the volume fraction of the hard phase, the hardness difference between soft and hard phases (hardness ratio), and microscopic inhomogeneities, such as local strain distribution, affect macroscopic deformation properties in DP steels. However, the effects of microscopic metallurgical factors such as the second-phase (bainite or pearlite), dislocation structure and the micro hardness of each phase on macroscopic deformation properties (Y/T ratio, n-value, uniform elongation, etc.) in DP steels with polygonal ferrite are not as well understood.

In this paper, the effects of microscopic metallurgical factors on macroscopic deformation properties are discussed. In both of ferrite-bainite and ferrite-pearlite DP steels, as the volume fraction of second-phase increased, Y/T ratio decreased. Then, in the case of ferrite-bainite steels, Y/T ratio increased in the samples with more than 60% bainite. Ferrite-bainite steels showed lower Y/T ratios and higher n-values, compared with ferrite-pearlite steels. And they also showed stress-strain curve with round-house type without yield phenomenon. It is well known that the volume fraction of the hard phase, the hardness difference between soft and hard phases (hardness ratio), and microscopic inhomogeneities, such as local strain distribution, affect macroscopic deformation properties in DP steels. However, the effects of microscopic metallurgical factors such as the second-phase (bainite or pearlite), dislocation structure and the micro hardness of each phase on macroscopic deformation properties (Y/T ratio, n-value, uniform elongation, etc.) in DP steels with polygonal ferrite are not as well understood.

INTRODUCTION

Linepipes installed in seismic or permafrost regions must have sufficient resistance against buckling or weld fracture caused by large ground deformation of buried pipeline. In order to design the pipelines installed in seismic or permafrost regions, new design methodology, so called “strain-based design”, has been developed (Denys et al., 2000; Wang et al., 2002, 2007; Ishikawa et al., 2004; Suzuki et al., 2002, 2004). Limit state of the pipeline under displacement-controlled loads is given as the point where “strain demand”, which is defined by the strain imposed to the pipe body by ground movement or other load, exceeds “strain capacity” of the pipeline. Strain capacity for both compressive and tensile deformation need to be determined for the strain-based design. Many studies on both compressive and tensile strain limits revealed that deformability of the pipe materials, which is parameterized by, Y/T ratio, n-value, or uniform elongation is important to improve strain capacity of pipeline. Therefore, using the linepipe with higher deformability is the essential process in the strain-based design.

High deformability linepipe was first developed for the application of the gas pipeline installed in seismic area (Endo et al., 2000, 2002). Stress-strain behavior of the linepipe steel was controlled by dual phase microstructure. Higher strain hardenability and lower Y/T ratio was achieved by ferrite-bainite microstructure, and higher resistance against buckling was demonstrated by compression and bending test of the pipe. Ferrite-bainite microstructure can be obtained by applying controlled rolling and accelerated cooling process in plate manufacturing process. High strength linepipes with various strength grades from X65 to X120 for high strain application were developed by ferrite-bainite dual phase microstructural control (Ishikawa et al., 2006, 2006). In order to improve the resistance to strain aging by coating heat, another type of multi-phase steel, that is bainitic microstructure with dispersed MA constituents, was developed. Advanced plate manufacturing technology with the combination of accelerated cooling and heat treatment on-line process enables to obtain bainite-MA microstructure. Grade X70 to X100 linepipes with bainite-MA microstructure were developed by the heat treatment on-line process and resistance to buckling was demonstrated by full scale pipe compression and bending tests (Okatsu et al., 2005; Shinmiya et al., 2007; Suzuki et al., 2007).