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Material Design for Line Pipe Steel to Minimize HAZ Softening and Obtain Good HAZ Toughness

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In order to develop a material design concept for strain-based design, the effect of HAZ (Heat Affected Zone) softening on deformation behavior was studied by finite element (FE) analysis. To control the HAZ softening and hardening, the effect of chemistry on hardness in HAZ was evaluated by the taper hardness test. A UOE pipe of X80 with low carbon content of 0.05 mass %, adequate Pcm value of 0.20 mass % and high Ceq(IIW) of 0.50 mass % was produced, and its properties were evaluated.

INTRODUCTION

In general, steel ductility decreases by increasing strength. Thus, the necessity of strain-based design in pipelines is discussed more seriously with the growing application of pipes of higher strength than X80. Strain-based design indicates 2 strain limits of deformation in the longitudinal direction: tensile rupture (Wang, 2006) and compressive buckling (Suzuki, 2006). As regards tensile rupture in the longitudinal direction, the control of strain concentration at the toe portion of the girth welding bead is important. Mohr (2006) discussed strain-based design for materials with HAZ (Heat Affected Zone) softening.

From the point of view of material design, the application of rich chemistry steel must be a way to control HAZ softening. The softest region in HAZ is fine-grain HAZ. In this region, steel is reheated just above transformation temperature and normalized. Thus, increasing hardenability by increasing alloying elements must be effective to decrease HAZ softening. However, the relation between the minimum hardness in HAZ and steel chemistry is not studied enough. On the other hand, significant hardening and poor toughness at coarse-grain HAZ is a concern in rich chemistry steel. From these points of view, in this paper, a fundamental study about the effects of steel chemistry on hardness in HAZ was conducted by the taper hardness test. The effect of HAZ softening on deformation behavior during pipe bending was also estimated by finite element analysis.

SIMULATION OF DEFORMATION BEHAVIOR OF GIRTH WELDED PIPES DURING BENDING

Finite Element (FE) Analysis Model

Fig. 1 shows an FE analysis model to simulate deformation behavior during pipe bending. This model includes a welded portion.

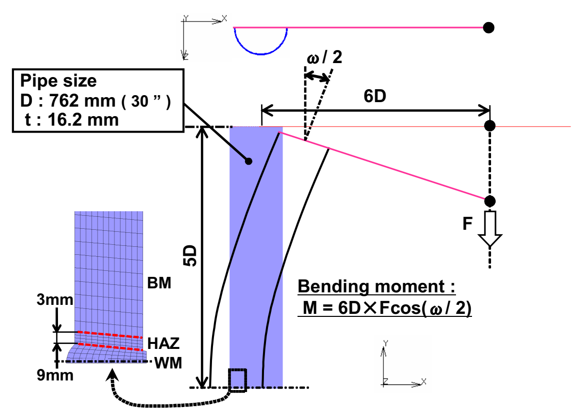

Fig. 1 FE analysis model to simulate deformation behavior of pipe during bending

True stress-strain curves used as input data for FE analysis were calculated by engineering stress-strain curves shown in Fig. 2. The stress-strain curve of base metal in this figure was measured by using a round bar tensile specimen 12.7 mm in diameter taken from X80 pipeline steel in the direction of the pipe axis. Tensile

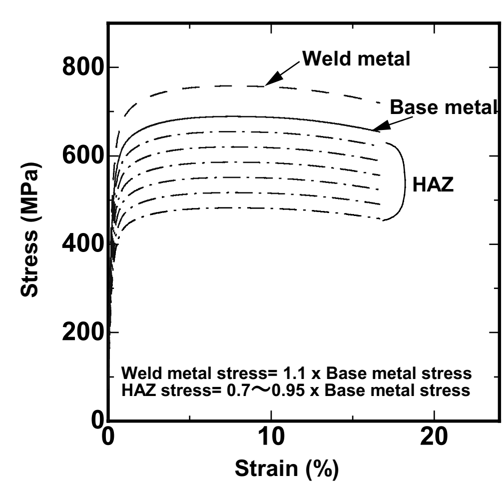

Fig. 2 Stress-strain curves for FE analysis

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KEY WORDS: Strain-based design, X80, UOE, Ceq(IIW), Pcm, HAZ softening, HAZ toughness.