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Correlative Hardening Parameters to Strain Capacity of High Strength Linepipes

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ABSTRACT

Hardening parameters showing good correlation with the critical compressive strain of X80 linepipes are presented, which linepipes are pressurized and subjected to bending moment. A series of finite element analysis was conducted taking into account the geometric imperfections of the linepipes to estimate the critical compressive strain precisely. Whereas the stress ratio $\sigma_{2.0}/\sigma_{1.0}$ (stresses at 2.0% and 1.0% strains) presents good correlation with the critical compressive strain, other stress ratios and the Y/T ratio do not present good correlation with the critical compressive strain.

KEY WORDS: Linepipe; X80, bending deformation; local buckling; strain-hardening; stress ratio.

INTRODUCTION

High-strength linepipes tend to have less strain capacity compared to conventional linepipes. Therefore there have been strong demands from pipeline projects to improve the strain capacity of the high-strength linepipes, which pipeline projects plan to construct long distance and high-pressure gas pipelines in arctic or seismic regions (Glover et. al., 2003). In order to satisfy the strong demands, some practical studies on stress-strain curve control have been progressing (Suzuki et. al., 2001, 2002, 2003, 2004; Zimmerman, 2004). Recently high-strength linepipes endowed with high-strain capacity have been supplied to such pipeline projects.

Hardening parameters presenting good correlation with the critical compressive strain of X80 linepipes are discussed in this paper, which are pressurized and subjected to bending moment. A series of FEA was conducted defining the tensile properties, the Y/T ratio and the uniform elongation. The hoop stress and the D/t ratio of the FE models were assumed based on the information from some pipeline projects. The geometric initial imperfections of the linepipes were also taken into account in the FE models in order to predict critical compressive strain precisely (Suzuki, et. al., 2006, 2007, 2007). In addition to the Y/T ratio, the stress ratios were defined to investigate the correlation with the critical compressive strain.

Correlations between the critical compressive strain and the hardening parameters, Y/T ratios and stress ratios, were investigated. Finally the Y/T ratio does not present good correlation with the critical compressive strain, whereas some stress ratios are effective to yield preferable correlation. The stress ratio $\sigma_{2.0}/\sigma_{1.0}$ is the most effective to obtain good correlation with the critical compressive strain, where $\sigma_{1.0}$ and $\sigma_{2.0}$ are stresses at 1.0% and 2.0% strains, respectively.

ANALYSIS OF BENDING DEFORMATION

Dimensions and Internal Pressure of X80 Linepipes

Table 1 presents the pipe diameter, the wall thickness, the D/t ratio, the hoop stress and the internal pressure of the X80 linepipes. The pipe diameters are 48", 42" and 36" and the D/t ratios are 46.9, 55.4 and 66.4. The hoop stress of 50, 60 and 72 %SMYS are defined.

Tensile Properties of X80 Linepipes

Table 2 captures the tensile properties of the X80 linepipes with the yield stress through the tensile strength and the uniform elongation. The ten materials are classified into three groups, Groups A, B and C, depending on the Y/T ratios. Whereas the materials belong to Group A have a low Y/T ratio less than 0.82, those of Group C tend to have a high value of Y/T ratio such as 0.89 and 0.90. And the Y/T ratios of Group B are 0.86 and 0.87 which are the intermediate properties between Groups A and C.

Figure 1 compares six stress-strain curves, where a couple of stress-strain curves were chosen from each material group in order that one has the maximum YS and the other the minimum. Observing the figure, it is obvious that the hardening rate of Group A is very high up to 3% strain. The hardening rate of Group B is also high up to 1% strain and gradually decreases with increasing strain and becomes small until 2% strain. On the other hand, the hardening rate of Group C quickly decreases between 0.5 and 1.0% strain and becomes very small with increasing strain.