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Evaluation of Influence Factors of Compressive Buckling by FE Analysis

Hidenori Shitamoto, Hiroyuki Makino, Shuji Okaguchi and Masahiko Hamada
Corporate Research and Development Laboratories, Sumitomo Metal Industries Ltd.
Amagasaki City, Hyogo, Japan
Nobuaki Takahashi and Akio Yamamoto
Pipe Dept. Kashima steel works, Sumitomo Metal Industries Ltd.
Kashima City, Ibaraki, Japan
Izumi Takeuchi
Sumitomo Metal Industries Ltd.
Chuo-ku, Tokyo, Japan
Shusuke Fujita
Technology department, Sumitomo Metal Pipeline and Piping Ltd.
Warabi City, Saitama, Japan

ABSTRACT

It is important to assess the strain capacity of line pipe in SBD (Strain Based Design). In case of compressive buckling, the Japan Gas Association guideline gives the allowable strain limit by the function of D/T regardless of pipe grade up to API X65 (Japan Gas Association, 2000). Application of API X80 grade line pipe has been promoted to increase operating pressure. The assessment of strain capacity of X80 SAW pipe is required for SBD. In addition to the pipe tensile property, pipe dimensions have to be taken into consideration for precise analysis of strain capacity. FEA (Finite Element Analysis) was employed to evaluate strain capacity of 610mm OD (Outside Diameter) X80 line pipe produced by UOE process. The essential factors, which influence strain capacity of X80 SAW pipe, are identified. The effect of internal pressure and thermal aging on compressive buckling is clarified.

KEY WORDS: Strain based design; line pipe; X80; UOE; FE analysis; buckling.

INTRODUCTION

Strain capacity of line pipe has been focused in respect to the ground movement, which pipeline might encounter (Glover et al, 1999; Zhou et al, 2006). There are various types of ground movement mentioned in literature. Seismic wave propagation is one of the most common events (Barbas and Weir, 2007). Lateral spread caused by soil liquefaction might induce large-scale soil displacement. Frost heave and thaw settlement are the common events in the arctic region (Zhou et al, 2006). In order to apply SBD for the safety of high-pressure pipelines, it is necessary to know the strain imposed to pipelines in each kind of ground movement. The interaction between soil and pipeline is also an important factor. The strain capacity of pipeline is not defined by line pipe only, but also bends and girth weld joints. However to apply X80 line pipe for cost reduction of gas transportation, the strain capacity of X80 line pipe must be evaluated to ensure the safe operation of high pressure gas pipelines under axial strain.
Thermal aging, which changes stress-strain behavior of steel pipe from round house type to Luders elongation type, has been pointed out that it might change the strain capacity of X80. Luders elongation type of S-S (stress-strain) curve is not preferable to strain capacity of line pipes (Shitamoto et al., 2007; Tsuru et al., 2005, Tsuru et al., 2006). The effect of thermal aging must be evaluated as aging by coating is applied to line pipes for corrosion protection. In order to establish FEA model, the following three factors were taken into account for quantitative evaluation of strain capacity of X80 line pipe: (1) Distribution of material property, (2) Irregularity of cross section shape, (3) Variation of wall thickness.

EVALUATION OF X80 UOE PIPE

The precise evaluation of X80 SAW pipe having nominal OD of 610 mm and nominal WT (wall thickness) of 15.5 mm was conducted for FEA in this study. In terms of pipe dimension cross section shape was measured by the contact type coordinate measuring instrument. Table 1 shows the result of measurement of maximum, minimum and average value of each item. The difference between maximum and minimum is 4.2 mm in OD, which corresponds to 0.69 % of nominal OD, and 0.3 mm in WT, which corresponds to 1.83 % of nominal WT, respectively.

Table 1. Measured OD and WT of X80 SAW pipe.

	Ave.	Max.	Min.	Max.-Min.
OD (mm)	611.0	613.4	609.2	4.2
WT (mm)	15.5	15.7	15.4	0.3

Round bar specimens with diameter of 8.9 mm and length of 60 mm were cut out from the pipe in longitudinal direction with interval of 15 degree in circumference as shown in Fig. 1. Table 2 summarizes the tensile test results of before and after thermal aging. Thermal aging was performed in the furnace at 250 degree C for 5 minutes. The YS, which corresponds to 0.2 % offset strain, is 608 MPa in average before aging and 690 MPa after aging. The increase of YS by thermal aging is fairly large and as the consequence the Y/T ratio is increased by the thermal aging. The distribution of YS and TS are reasonable range in X80 SAW line pipe. The typical S-S curves of X80 before and after aging are shown in Fig. 2. It is clear that round house type curve changed to Luders type by the thermal aging.