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Yield Strength Prediction of UOE Pipes: From Forming to Flattening

Jiwoon Yi
Department of Technical Research, Korean Institute of Bridge and Structural Engineers
Seoul, Korea

Soo-Chang Kang
Department of Steel Solution Marketing, POSCO
Incheon, Korea

Hyun-Moo Koh
Department of Civil and Environmental Engineering, Seoul National University
Seoul, Korea

Jinkyo F. Choo
Department of Energy Engineering, Konkuk University
Seoul, Korea

With the advent of higher steel grades for offshore pipelines and the reliance of the UOE forming process on trial and error, knowing the final yield strength of the pipe beforehand would be beneficial in terms of time and cost. However, predicting the yield strength of the UOE pipe constitutes a difficult task because of the alteration of the material properties throughout the forming process. Moreover, the yield strength is measured by tensile test executed on specimens obtained by flattening samples cut from the formed pipe, but this flattening process also alters the properties of the material. Accordingly, this study presents a 2-D finite element method (FEM) program considering both forming and flattening processes to predict the yield strength of the UOE pipe measured by tensile test. The results show that the simulation predicts the yield strength with good accuracy.

INTRODUCTION

UOE forming is a popular method used for the production of longitudinally welded thick-wall pipes. The longitudinal edges of the steel plate are first crimped, and the beveled plates are then formed into a U shape using a U-press followed by O-ing using an O-press. After welding of the edges, the formed pipe is expanded by applying internal pressure to improve the cross-sectional ovality and to relieve the residual stress on the pipe wall (Yi et al., 2017).

Throughout these forming stages, the steel plate undergoes a series of plastic deformations that alter its material properties and endow each fiber located along the circumferential direction with a unique strain hysteresis (Kyriakides et al., 1991; Kyriakides and Corona, 2007). Among the material properties, the yield strength is a key design parameter that can be measured by tensile test on flattened samples cut from the formed pipe. This yield strength is also an indicator of the pipe quality specification in the API Standard (American Petroleum Institute, 2012).

With the growing demand for higher steel grades for offshore pipelines with improved performance, steel manufacturers have continuously developed products of which the properties are controlled and can be guaranteed. Additionally, the UOE pipe manufacturer has to design the UOE forming process by relying on trial and error or experience to determine various parameters like the die shape, the upper die and lower die stroke distance, and the level of press. However, even if the pipe manufacturer has successfully designed the forming process, the so-produced pipe may fail to pass the quality test since the possibilities of controlling the steel properties of the pipe are nonetheless limited. Therefore, tracking the change of the material properties throughout the forming process would help steel mills to specify target strength to ensure the final pipe strength (Zhang et al., 2012; Cooreman et al., 2016). Predicting the yield strength of the UOE pipe beforehand would thus be beneficial in terms of time and cost.

Therefore, numerous works have been conducted to numerically track the changes in the material properties induced by UOE forming (Kyriakides et al., 1991; Herynk et al., 2007; Zou et al., 2015; Chatzopoulou et al., 2016). These works succeeded in accurately tracking the development of the yield strength throughout the UOE process but did not consider the flattening process in the simulation. However, this flattening, which is large reverse bending, significantly alters the material properties, and its consideration in the simulation will save huge amounts of time in the design stage (Crone et al., 2010; Walsh and Preston, 2010). Zou et al. (2016) mentioned the necessity of considering the flattening process in expansion ratio design, especially for high-strength steels, since this process reduces the measured yield stress.

Accordingly, this paper proposes a 2-D finite element (FE)-based simulation that accounts for both UOE and flattening processes to predict the yield strength measured on flattened straps sampled transversally from the formed pipe. Focus is on the simulation of the flattening process and tensile test. The predicted results are compared to those obtained experimentally.

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