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Low-Cycle Tearing in a Deep-Water Buckle-Arrestor Assembly Girth Weld During S-Lay Installation

Ruud Selker* and Ping Liu
INTECSEA
Delft, The Netherlands

Erich Jurdik and Jay Chaudhuri
South Stream Transport BV
Amsterdam, The Netherlands

Andrea Fonzo and Massimo di Biagio
RINA Consulting–Centro Sviluppo Materiali
Rome, Italy

S-Lay installation of inline buckle arrestors in deep water can introduce plastic strain to girth welds. The welds are repeatedly loaded by large-strain cycles when traversing the stinger. A material-testing program was launched to assess the impact of this load sequence on the welds' integrity. It is essential to establish the correct mechanism of crack growth caused by a limited number of sequential large-strain cycles. Segment specimens with increased specimen "daylight" length were tested. Fracture morphologies of ductile tearing and fatigue growth were distinguished; ductile tearing was identified only for the first load cycle, whereas subsequent cycles were dominated by fatigue crack growth.

NOMENCLATURE

Δa Crack growth (m)
a Crack depth (m)
a_0 Initial crack depth (m)
B Specimen width (m)
c_0 Initial half-length of crack (m)
D Outside diameter (m)
E Young's modulus (Pa)
f_y Material yield stress (Pa)
K_I Elastic stress-intensity factor (Pa$\sqrt{\text{m}}$)
L_{BA} Buckle-arrestor length (m)
P_e External pressure (Pa)
P_{pr} Buckle-propagation pressure (Pa)
P_X Buckle-crossover pressure (Pa)
R Stress ratio
t Pipe wall thickness (m)
W Specimen thickness (m)
α_{fab} Fabrication factor
γ_m Material resistance factor
γ_{SC} Safety-class resistance factor
ν Poisson ratio
$\sigma_{\text{p0.2}}$ Proof stress at 0.2% strain (Pa)

INTRODUCTION

The TurkStream Offshore Pipeline was developed by South Stream Transport BV (SSTTBV). It is a major gas-transmission system that currently comprises two pipeline strings installed in up to 2,200 m water depth, connecting large gas reservoirs in Russia to the Turkish gas-transportation network through the Black Sea. The system currently has a capacity to transport 31.5 bcm of natural gas annually over a distance of more than 900 km. The pipeline's outer diameter (D) is 32 inches, and its wall thickness (t) is 39 mm. Material grade is DNV SAWL (submerged arc-welded longitudinal) 450 with supplementary requirement F, D, U, and (light) S according to offshore standard DNV-OS-F101 (Det Norske Veritas, 2010) plus project-specific modifications. Pipe joints are produced by UOE (U-ing, O-ing and expansion) and JCOE (J-ing, C-ing, O-ing and expansion) pipe-forming methods. Ultra-deep water in combination with the large pipeline diameter makes this project one of the most challenging pipeline projects ever, pushing the boundaries of the industry. The first portion of the pipeline was installed in 2017–2018.

For more background on this ultra-deep-water-pipeline project, reference is made to a set of papers that materialized during the project. Meijer and Ethembabaoglu (2014) and Timmermans et al. (2014) discuss waiving the hydrotest requirement for intermediate water depths. Kerstens et al. (2014) describe the applied procedure of controlled heat treatment to reduce the material fabrication factor. Selker et al. (2015) present the application of ring collapse testing within the project. Selker et al. (2016) discuss anisotropy of elastic properties observed in the project line-pipe material, and Selker et al. (2018) show that the compressive material strength has a lower bound.

To prevent catastrophic propagation of a buckle in the unlikely event of collapse of the empty pipeline, inline buckle arrestors (BAs) are deployed at certain spatial intervals where the water depth exceeds a depth equivalent to the pipeline buckle-propagation pressure. The BAs were designed and sized according to design standard DNV-OS-F101 (Det Norske Veritas, 2010). Figure 1 schematically presents the design of the inline buckle-arrestor assembly (BAA) that is used for the project.

*ISOPE Member.

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KEY WORDS: Fracture, SENT testing, segment testing, pipelines, ductile tearing, low-cycle fatigue, installation.