International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 25, No. 1, March 2015, pp. 63–70

http://www.isope.org/publications

Interpretation of the South Stream Ring Collapse Test Program Results

Ruud Selker, Pedro M.C. Ramos and Ping Liu
INTECSEA
Delft, The Netherlands

A study was conducted on the collapse mechanism of rings cut off from line pipe specimens. It was theoretically established that a ring without end restraints should have a lower collapse pressure value than an equivalent full-scale joint. However, similar collapse pressure test results were obtained for both rings and joints. Ring tests differ from joint tests in end restraint, but both capture collapse resistance integrally, while coupon tests (production tests) only capture the influence of material properties. The "length effect" and the "end cap effect" increase the collapse resistance of a joint, while radial end restraints increase the collapse resistance of a ring. These effects are found to be of the same order of magnitude for the investigated combination of parameters (thermally aged SAWL 450 and D/t of approximately 20). Furthermore, the influence of the out-of-roundness shape and material properties on the collapse behaviour of rings was assessed.

NOMENCLATURE

Symbols

D	Outside diameter (m)
D_{max}	Maximum measured outside diameter (m)
D_{min}	Minimum measured outside diameter (m)
D_{nom}	Nominal specified outside diameter (m)
E	Young's modulus (Pa)
N	Number of data points (-)
f_0	Ovality (%)
f_y	Specific minimum (uniaxial) yield stress (Pa)
k_R	Radial foundation stiffness (Pa/m)
n	Circumferential wave number (-)
p	Contact pressure (Pa)
p_c	Collapse pressure (Pa)
p_e	Elastic collapse pressure (Pa)
p_p	Plastic collapse pressure (Pa)
t	Wall thickness (m)
Δ_n	Fourier ovality with respect to wave number n (%)
α_{fab}	Fabrication factor (-)
β	End cap pressure toggle factor (-)
δ	Push distance (m)
ε	Strain (m/m)
μ	Friction factor (-)
ν	Poisson's ratio (-)
ξ	Ramberg-Osgood shape factor (-)
σ	Stress (Pa)
$\sigma_{0.23}$	Material strength corresponding to 0.23% strain (Pa)
$\sigma_{0.5}$	Material strength corresponding to 0.5% strain (Pa)
σ_a	Axial (longitudinal) stress (Pa)
σ_c	Compressive stress (Pa)
σ_h	Hoop (circumferential) stress (Pa)
σ_t	Tensile stress (Pa)
τ	Shear stress (Pa)

Abbreviations and Acronyms

CoV	Coefficient of variation
FEA	Finite element analysis
FEED	Front end engineering design
FEM	Finite element model
FFT	Fast Fourier transform
JCOE	J-ing, C-ing, O-ing, and expansion (production method)
Linopot	Linear potentiometer
OOR	Out-of-roundness
RO	Ramberg-Osgood
SAWL	Longitudinally submerged arc-welded pipes
SMYS	Specific minimum (uniaxial) yield stress
UOE	U-ing, O-ing, and expansion (production method)

INTRODUCTION

For the South Stream Offshore Pipeline project, four 32-inch (outside diameter D) subsea pipeline strings, having 39 mm nominal wall thickness (t) and approximately 930 km length each, will be installed in the Black Sea from the Russian shore, through Turkish waters, to the Bulgarian shore, in water depths ranging up to 2200 m.

To confirm the collapse resistance of offshore pipelines, full-scale tests are usually conducted. As it is inconvenient to transport large pipe joints around the world, it was decided to conduct ring collapse tests as a part of the South Stream Offshore Pipeline Materials Development Program. Because of the relatively short length of the rings, transport by airfreight was possible. This resulted in great savings of time and costs.

Ring specimens of 50 mm width were cut from pipeline joints, as shown in Fig. 1, and inserted into a test apparatus (Roberts and Walker, 2010). Pressure was increased progressively until the ring collapsed. The results were then compared to those obtained from full-scale collapse tests carried out during the South Stream Offshore Pipeline Pre-FEED and were found to be similar. However, some ring tests showed lower, seemingly inconsistent, collapse pressure values.

In this paper, the interpretation of the results of the performed ring collapse tests is presented. The explanation of certain lower-bound ring test results is addressed. The influence of key parameters on the collapse behaviour of rings and pipelines is evaluated.

Received August 4, 2014; updated and further revised manuscript received by the editors November 3, 2014. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-fourth International Ocean and Polar Engineering Conference (ISOPE-2014), Busan, Korea, June 15–20, 2014.

KEY WORDS: South Stream, collapse, pipelines, length effect, end cap effect, seal friction, out-of-roundness.