

Behavior of Mechanical-Bonding Double-Wall Pipe Under Various Loading Conditions

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ABSTRACT

A new type of mechanical bonding double-wall pipe produced by shrink-fitting and hydraulic expanding has developed for sour gas service. The behavior of this pipe was experimentally and analytically examined under the following loading conditions: (1) interfacial gas pressure between the inner and outer pipes; (2) bending load; (3) tensile load; and (4) internal pressure. The results revealed no practical problems of using this double-wall pipe. Simple formulas were established for evaluating the critical fracture strength of this pipe under the loading conditions tested, which make it easier to select the double-wall pipe sizes and materials.

NOMENCLATURE

C	: plastic coefficient, N/mm^2
D	: outside diameter, mm
D_m	: average diameter, mm
E	: Young's modulus, N/mm^2
F	: tensile fracture load, N
h	: height of inner pipe wrinkles in axial direction, mm
K	: constant
L	: length of implosion specimen, mm
m	: constant
n	: work hardening coefficient
P_b	: burst pressure, MPa
P_c	: collapse pressure of single-wall pipe, MPa
P_{con}	: contact pressure, MPa
P_I	: implosion pressure, MPa
$P_{L/D}$: implosion pressure for specimen with length-diameter ratio of L/D , MPa
P_0	: implosion pressure for specimen with infinite length, MPa
S	: cross-sectional area, mm^2
t	: wall thickness, mm
u	: ovality
w	: radial displacement of wrinkles, mm
X	: radial displacement on cross-section flattened in bending test, mm
δ	: initial interference between inner and outer pipes, mm
ϵ_t	: circumferential strain
ϵ_u	: uniform elongation
Θ	: angle of bend with unit length
θ	: angle of bend
λ	: wave length of wrinkles, mm
ν	: Poisson's ratio
ρ	: radius of curvature, mm
σ_B	: tensile strength, N/mm^2
σ_{GS}	: gripping stress, N/mm^2
σ_L	: axial stress, N/mm^2
σ_t	: circumferential stress, N/mm^2

σ_y : yield stress, N/mm^2

Subscripts

C	: compression side of bend
i	: inner pipe
N	: neutral axis of bend
o	: outer pipe
T	: tension side of bend

INTRODUCTION

In recent years, higher corrosion resistance is being demanded of line pipe between the wells and processing plants, with the oil and gas production environments becoming more severe. The number of chemical processing plants that used to be installed for each well is being reduced as far as possible for the purpose of cost reduction. As a result, the length of corrosion-resistant line pipe required between wells and processing plant has increased.

High-alloy line pipe with excellent corrosion resistance is too costly. Double-wall pipe composed of an outer pipe of high-strength carbon steel and an inner pipe of corrosion-resistant stainless steel or high-alloy is more economical.

Nippon Steel has developed a new type of double-wall pipe with the inner and outer pipes bonded mechanically, not metallurgically. This double-wall pipe is manufactured by a new process, a combination of shrink-fitting and expanding. By this new process, higher gripping stress is obtained than through other conventional processes such as the shrink-fit method. This double-wall pipe has the following advantages:

- (a) It permits any desired combination of inner and outer pipes suitable for the intended application environment.
- (b) It requires no heat treatment after bonding.
- (c) It is less expensive than clad steel pipe.

The double-wall pipe behaves under various loading conditions in a more complex manner than single-wall pipe or clad pipe, because the inner and outer pipes are bonded only mechanically. Therefore some customers may be anxious about accidents such as implosion of the inner pipe by interfacial pressure and buckling of the thinner inner pipe during bending for submarine line pipe. Reported here are the behavior and fracture load of the double-wall pipe under the following loading conditions:

- (1) interfacial pressure between the inner and outer pipes
- (2) bending load
- (3) axial tensile stress
- (4) internal pressure

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KEY WORDS: Double-wall pipe, line pipe, implosion, bending, finite element method, burst pressure, mechanical properties.