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Collapse Capacity of Corroded Pipes Under Combined Pressure, Longitudinal Force and Bending

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ABSTRACT

The buckling/collapse strength of corroded pipes has been investigated for cost-effective and safe design of pipelines and risers. An analytical solution for calculating the collapse and bending moment capacity of corroded pipes is proposed. The solution is an extension of existing analytical equations for noncorroded pipes: (1) Elastic-plastic collapse of pipes under external pressure (Timoshenko's equation); (2) collapse of pipes under internal pressure, bending and axial force (Mohareb's analytical equations). The analytical equations agree well with results obtained by the finite element method, and may be used in strength assessment and risk-based corrosion allowance design.

INTRODUCTION

The buckling and collapse strength of metallic pipes has been an important subject for the design of pipelines, risers and TLP tendons, as well as piping, pressure vessels and tubular structures in offshore and civil engineering.

The elastic-plastic collapse of pipes under external pressure was solved by Timoshenko as described in his book *Theory of Elastic Stability* (Timoshenko and Gere, 1961). Today, nonlinear finite element programs can be used as an accurate tool to predict the buckling/collapse capacity of pipes under external pressure, bending and axial force. The finite element model developed in this study has been validated against laboratory tests and used to verify the presented capacity equations.

A review of the historic work and the latest research results on this topic may be found in Murphey and Langner (1985), Ellinas et al. (1986), Gresnigt (1986) and Bai et al. (1993, 1997). Analytical equations for the collapse capacity of pipes under internal pressure, bending and axial force were derived by Mohareb et al. (1994), and their equations agreed well with their finite element analyses and laboratory tests.

The purpose of this study is to derive analytical equations for the capacity of corroded pipes under combined loads. The derived capacity equations are compared with the results from finite element analysis. The derived analytical capacity equations may be used to extend the applicability of the existing pipeline rules/guidelines.

MOMENT CAPACITY OF PIPE UNDER INTERNAL PRESSURE, BENDING AND AXIAL FORCE

Here, an analytical solution is given for the calculation of the moment capacity for corroded pipes subjected to internal pressure, bending and axial force. The corrosion defect is assumed to be symmetrical to the plane of bending, which represents the worst scenario. For simplicity, cross-sectional out-of-roundness is not included in the solution as the influence on the capacity will be small for thick-walled pipes with practical out-of-roundness. In the analytical solution the moment capacity is defined as the moment at which the entire pipe cross-section yields.

The solution presented here takes the following configurations into account: Case 1 corroded area in compression, Case 2 in compression and some in tension, Case 3 in tension, Case 4 in tension and some in compression. The 4 cases are shown in Fig. 1. Only Case 1 is fully discussed here, but the solution for Cases 2~4 is given in the guideline at the end.

CASE 1- CORROSION IN COMPRESSION

To reduce the complexity of the capacity equations, the following assumptions have been made for the pipe at maximum loading:

- Diameter/wall-thickness (D/t) ratio limited to 15-45
- Cross-section remains circular
- Entire cross-section is yielding
- Material model is elastic-perfectly-plastic
- Defect region is symmetric around plane of bending

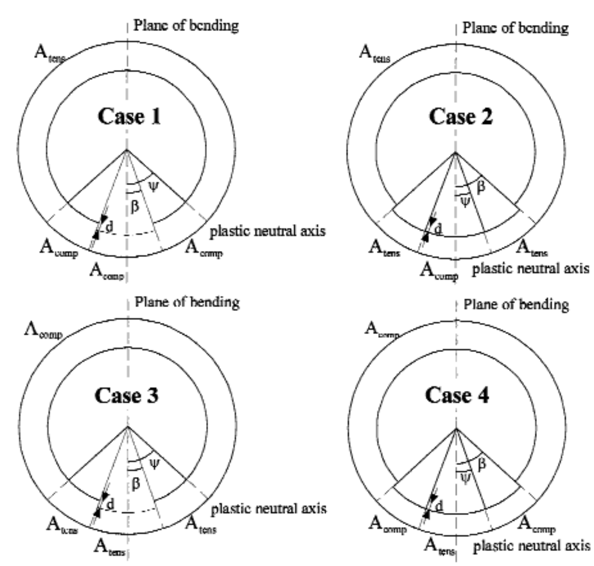

Fig. 1 The 4 combinations of defect and bending

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KEY WORDS: Local buckling, collapse, corrosion, metallic pipes, combined loading.