Analytical Collapse Capacity of Corroded Pipes

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ABSTRACT

Buckling and collapse strength of corroded pipes has been investigated, for cost-effective and safe design of pipelines and risers. Two sets of analytical equations are newly proposed for collapse capacity of corroded pipes, by extending the existing analytical equations for non-corroded pipes: (1) Elastic-plastic buckling 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 of finite element analysis and laboratory tests, and may be used in strength assessment and risk-based corrosion allowance design.

Keywords: Collapse, Capacity, Bending, Axial Force, External Pressure, Corrosion, Pipelines

INTRODUCTION

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

Elastic-plastic buckling of pipes under external pressure was solved by Timoshenko as described in his book "Theory of Elastic Stability" (Timoshenko and Gere, 1961). Recent years, non-linear finite element analysis can be used as an accurate tool to predict buckling/collapse capacity of pipes under external pressure, bending and axial force, see Bai et al (1993). The finite element model has been validated against laboratory tests and applied to derive design equations. The review of the historic work and the latest research results on this topic may be found from Murphey and Langner (1985), Ellinas et al. (1986), Gresnigt (1986) and a series of journal papers by Bai et al (1993, 1994, 1995, and 1997).

Mohareb et al. (1994) derived analytical equations for collapse capacity of pipes under internal pressure, bending and axial force. Their equations agreed well with their finite element analysis and laboratory tests.

The above mentioned literatures were used in the development of local buckling and collapse criteria in DNV’96. However, due to lack of research on corroded pipes, it was proposed by pipeline rules that any corrosion allowance, which may be designed in a pipe, should be deducted in the buckling/collapse calculations.

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

BUCKLING/COLLAPSE OF PIPES UNDER INTERNAL PRESSURE, BENDING AND AXIAL FORCE

In this section an analytical solution is given for the calculation of the moment capacity for a pipe under internal pressure bending and axial force, with a corrosion defect symmetrical to the bending plan. Initial ellipticity is for simplicity not included in the solution. The rationality of this is that an initial ellipticity more or less will disappear when the pipe is subjected to high internal pressure such as mostly will be the case under operational and pressure test conditions. The moment capacity of the pipe is here defined as the moment at which the entire cross section yields. The solution presented in this section takes the following configurations into account: Corroded area in compression (case 1), in compression and some in tension (case 2), in tension (case 3), in tension and some in compression (case 4). The four cases are shown in Figure 1.