

Ultimate Strength of Damaged Tubular Members

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ABSTRACT

A moment-thrust-curvature-based procedure for calculating the behavior and ultimate strength of damaged tubular members is presented. The new set of moment-thrust-curvature expressions for damaged or undamaged tubular members developed by the authors is used. A computer program, BCDENT, was developed, whose capability includes analysis of single or multident tubular members subjected to axial compression, end moments, and distributed or concentrated lateral loads. In this paper, the validity and accuracy of the moment-thrust-curvature approach for determining the ultimate strength of damaged tubular members are verified by comparing analytical predictions with the available 151 test results.

INTRODUCTION

Owing to their low drag coefficient in comparison to other structural shapes, tubular members are used extensively in offshore structures. These members are generally subjected to gravity, wind, wave and current loads. For members in the wave zone, they often experience localized damage caused mainly by supply workboat collisions or dropped heavy object impacts. In the last two decades, experimental and analytical research on structural tubes has made significant progress in establishing refined criteria for the design of undamaged cylindrical tubular members in offshore platforms (Marshall, 1970; Sherman, 1976; Chen and Ross, 1977; Toma and Chen, 1979; Sherman, 1982; Chen and Han, 1985; Loh, 1990). However, available design specifications (API-RP-2A, 1989; API-RP-2A-LRFD, 1989; AISC-LRFD, 1986; AISC-LRFD, 1989) give no specific information on how localized damage affects the behavior and strength of dented tubular members under field service conditions. To assess the fitness of these offshore structures in service, technical information is needed for these dented members in terms of both their behavior and ultimate strength.

Damaged tubular members were first studied experimentally by Smith, Kirkwood and Swan (1979). During the '80s, a considerable amount of experimental and theoretical research about the effects of damage on the strength and behavior of tubular members has been conducted (Smith and Dow, 1981; Smith, Somerville and Swan, 1981; Ellinas, 1984; Ueda and Rashed, 1985; Richards and Andronieous, 1985; Yao, Taby and Moan, 1986; Taby and Moan, 1985 and 1987). Recently, MacIntyre and Birkemoe (1989) used a nonlinear finite element shell analysis (ABAQUS) to investigate the denting and subsequent axial compression of dented tubular members. This is the most rigorous

procedure among all existing analyses, but it requires a considerable computing effort.

Research reported in the open literature has, in the past, focused particular attention on dented members subjected to axial compression combined with negative bending (compression at the dent). In actual offshore structures, however, local damages may occur in any orientations relative to applied end moments. Dent locations vary along the member, and lateral loading can often accompany axial compression. Little attention has been paid to dented members subjected to loads of different directions with respect to the dents. It is the purpose of this study to develop a computer model for the analysis of a dented tubular beam-column subjected to biaxial bending with respect to the dents.

Based on the M-P- Φ relationships developed previously by Duan, Loh and Chen (1993), an analytical procedure and the computer program BCDENT were developed to calculate the general behavior of a dented (single or multiple dents) tubular beam-column subjected to loads of different directions and combinations. A brief comparison of BCDENT predictions to test results for 151 dented member tests is also presented. In general, good agreement was obtained, confirming the validity of the M-P- Φ approach in dented member analysis. The program listing of the BCDENT and typical input/output details are given in a recent book by Chen and Toma (1995).

GENERAL DESCRIPTION

The tubular beam-column under BCDENT consideration is treated as an individual member. The initial geometrical imperfections, w_i (out-of-straightness), is considered, and its boundary conditions are pinned. The dents can be multiple in arbitrary orientations and can be located anywhere along the member length. The loading cases include:

1. Constant end axial loads, increasing end bending moments.
2. Constant end axial loads, increasing lateral loads (either linearly distributed or two concentrated loads).
3. Constant end bending moments and/or lateral loads, increasing end axial loads.

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KEY WORDS: Beam-column, column, damaged tubular member, dent, moment-thrust-curvature, stability, strength.