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# Ultimate Strength Formulation for Axially Loaded CHS Uniplanar T-joints

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**As presented by van der Vegte in 1995, the strength of axially loaded uniplanar T-joints is governed by a combination of (local) joint failure and failure due to (global) chord in-plane bending moments. The current study, which is more rigorous than the 1995 research, presents the effect of chord length, boundary conditions and chord end conditions on the strength of uniplanar T-joints. Comparisons are made with the new T-joint strength formulations developed by API (2003) and ISO (2004). Finally, a simple ultimate-strength equation is proposed for uniplanar T-joints with compensating chord end moments. An interaction contour is established to describe the effect of chord in-plane bending moments on the strength of uniplanar T-joints.**

## INTRODUCTION

In recent years, a number of references was published regarding the effect of chord stress on the strength of tubular circular hollow section (CHS) joints. Numerical studies carried out by Pecknold et al. (2000), van der Vegte et al. (2001) and Choo et al. (2003) identified the influence of tensile or compressive chord pre-stress on the strength of either thin- or thick-walled X-joints for various types of brace load. Other research presented by Pecknold et al. (2001) and van der Vegte et al. (2002) focused on the chord stress effect of uniplanar gap K-joints. For the third type of the basic uniplanar joint configurations, the T-joint, the evaluation of the chord stress effect is not as straightforward as for X- and K-joints. Unlike the X-joint configuration, where axial brace loads do not cause equilibrium-induced chord loads, for uniplanar T-joints, axial brace loads will lead to chord in-plane bending moments, which will affect the joint strength.

For uniplanar T-joints under axial brace load, several failure modes can be identified. Depending on the chord length, failure may occur by chord face plastification (local failure) or by a combination of overall chord in-plane bending and shear (chord member failure). In most cases, these 2 failure modes are strongly related. Experiments alone may not provide the data necessary to quantify the effect of in-plane bending moments (i.e. chord stress) on the overall strength of the T-joints. As a result, for T-joints, the most governing parameters (chord stress and chord length) are not included satisfactorily in the current design codes.

In 1995, van der Vegte proposed the following approach, using finite element (FE) analyses, to separate and evaluate the 2 aforementioned failure modes. A T-joint under brace axial load is numerically analyzed twice: once excluding and once including the effect of chord in-plane bending moments. In the first analysis, without the effect of chord in-plane bending moments, compensating in-plane bending moments are applied to the chord ends. By forcing the chord end moments to be equal to those caused by the brace load, the bending moments at the cross-sections at the crown points remain zero throughout the loading history. The second analysis simply considers an ordinary T-joint without chord end moments.

In this study, further FE analyses have been conducted on uniplanar T-joints under brace compression. Sixteen combinations of the brace-to-chord diameter ratio $\beta$ and chord diameter-to-thickness ratio $2\gamma$ have been numerically analyzed for 5 values of the chord length parameter $\alpha$. In comparison to the research programme in 1995, the current study considers a much wider array of geometric parameters $\alpha, \beta$ and $2\gamma$. Material and geometric nonlinear FE analyses have been conducted with the general purpose package ABAQUS/Standard (2003).

The database derived from the FE analyses enables answers to the following important questions. Is it indeed possible to exclude the effect of the chord length parameter $\alpha$ for uniplanar T-joints under brace load by applying compensating chord end moments? In other words, will the strength of a T-joint become independent of $\alpha$? A second issue addressed in this study involves chord end plate effects. Unlike X-joints, for which the interaction between chord length and end plate effects can be determined rather straightforwardly, such an assessment is complicated for axially loaded T-joints, because of the strong, yet at the same time unknown, relation between local joint failure and failure due to chord bending.

Because of the increasing number of data available, especially numerical data, improved strength formulations for tubular joints were proposed recently.

- In the framework of the project to update the API RP2A (1993), Pecknold et al. conducted an extensive series of FE analyses (2001, 2002) as mentioned above. A relatively small part of this programme was devoted to axially loaded uniplanar T-joints. The strength formulations developed for T-joints, adopting the moment-free baseline approach described above (API, 2003), will be included in the 22nd edition of API RP2A.
- Based on a strictly screened experimental database, Dier and Lalani (1998) presented a new set of ultimate strength equations

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