

Effect of Chord Load on Ultimate Strength of CHS X-Joints

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Due to inconsistencies between the approaches for circular hollow section (CHS) and rectangular hollow section (RHS) joints, extensive numerical research has been conducted into the chord stress effect of CHS uniplanar K-, T- and X-joints. The objective of these studies is to establish chord stress functions using the maximum chord stress as the major parameter in line with the approach for RHS joints. The current study presents the results of finite element (FE) analyses on CHS uniplanar X-joints under axial brace load with the chord subjected to (i) axial load, (ii) in-plane bending moment, or (iii) combinations of axial load and in-plane bending moment. The chord stress effect is evaluated for 16 combinations of the geometric parameters β (brace width to chord width ratio) and 2γ (chord width to chord wall thickness ratio). Based on the available FE data, first, a new strength formulation is established for X-joints under axial brace load solely. In addition, a chord stress function is derived, describing the combined effect of axial chord load and in-plane bending chord moment on the ultimate strength of uniplanar X-joints. These formulae will be included in the updated IIW recommendations (2008).

INTRODUCTION

In current design rules, different approaches are used for circular hollow section (CHS) and rectangular hollow section (RHS) joints to account for the influence of chord stress on the ultimate strength. For CHS K-joints, the chord stress function is based on the chord pre-stress, i.e., the additional load in the chord which is not necessary to resist the components of the brace forces, while for RHS joints the maximum chord stress is used. As it is widely accepted that the maximum chord stress is the most appropriate parameter, in the framework of CIDECT (Comité International pour le Développement et l'Étude de la Construction Tubulaire) programme 5BK, multiple numerical studies were conducted to establish chord stress functions for CHS joints consistent with the approach adopted for RHS joints. In order to generate more evidence on the strength of CHS joints under chord load, extensive numerical analyses were carried out on various types of uniplanar configurations (K-, T- and X-joints). For example, finite element (FE) research presented by Pecknold et al. (2001) focused on the chord stress effect of uniplanar gap K-joints with the chord subjected to either axial load or in-plane bending moments. Van der Vegte et al. (2005) evaluated the interaction between boundary conditions and chord load for uniplanar K-joints under axial brace load.

For uniplanar T-joints, the evaluation of the chord stress effect is not as straightforward as for X-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 unavoidably lead to chord in-plane bending moments affecting the joint strength. Van der Vegte and Makino (2006) derived 2 equations describing the strength of axially loaded uniplanar T-joints: one defines the so-called local strength of a T-joint, i.e., excluding the in-plane bending chord moments caused by the axial brace load; a second function accounts for the chord stress effect.

Recently, the chord stress effect has been investigated not only for CHS joints, but also for RHS joints, as part of CIDECT programme 5BU. After a re-analysis of the chord stress functions for RHS X- and T-joints, new equations were developed by Wardenier et al. (2007a). Further, after additional numerical analyses on RHS K gap joints were carried out (Liu and Wardenier, 2006), new chord stress functions were also derived for this configuration (Wardenier et al., 2007b). These new formulae will be incorporated in the updated design recommendations of IIW Subcommittee XV-E, which in the past has served as basis for the CIDECT Design Guides and most international standards, e.g. Eurocode 3.

For X-joints, the evaluation of the chord stress effect is rather straightforward since the brace load and chord load are independent. The current study considers the numerical analyses of 16 axially loaded CHS X-joint configurations (4 brace width to chord width ratios β and 4 chord width to chord wall thickness ratios 2γ) under axial brace load. Prior to the brace load, the chord of each of the 16 configurations is subjected to (i) axial load, (ii) in-plane bending moment, or (iii) multiple combinations of axial load and in-plane bending moment. Material and geometric nonlinear FE analyses are conducted with the general-purpose package ABAQUS/Standard (2003).

Based on the generated FE data, a new strength formulation is established for CHS X-joints under axial brace load. In addition, a chord stress function is presented, describing the combined effect of in-plane bending chord moment and axial chord load on the ultimate strength of the X-joints considered. The formulae presented for CHS joints are in line with the aforementioned chord stress equations established for RHS joints (Wardenier et al., 2007a, b).

RESEARCH PROGRAMME

Fig. 1 illustrates the configuration of uniplanar X-joints and the definition of the geometric parameters. Table 1 summarizes the geometric parameters of the X-joints considered. For all joints, the chord diameter d_0 is 406.4 mm. The chord length parameter α is taken as 20, which can be considered sufficiently long to exclude possible effects of the boundary conditions.

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Received July 10, 2007; revised manuscript received by the editors October 15, 2007. The original version (prior to the final revised manuscript) was presented at the 17th International Offshore and Polar Engineering Conference (ISOPE-2007), Lisbon, July 1–6, 2007.

KEY WORDS: Tubular joints, circular hollow section, chord stress function, X-joints.