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Comparison of fatigue performances of gapped and partially overlapped CHS *K*-joints

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ABSTRACT

In this paper, a parametric numerical study is conducted to compare the fatigue performances of gapped and partially overlapped circular hollow section (CHS) *K*-joints under different loading conditions. In order to obtain a more complete understanding of the fatigue performances of these two joint types, the maximum stress concentrated factor (SCF), the hot spot stress (HSS) and the predicted fatigue life for a set of selected gapped and partially overlapped CHS *K*-joints which cover a wide range of geometrical parameters are determined and compared. For the gapped CHS *K*-joints, their SCF, HSS and fatigue life are obtained by using parametric equations from standard design guidelines. For partially overlapped joints, since no reliable parametric equation is available, their SCF, HSS and fatigue life are obtained from a validated finite element modelling procedure. The comparison results showed that the partially overlapped CHS *K*-joints are able to outperform their gapped counterparts under pure or dominating axial loadings while the reverse is true when the joints are subjected to pure or dominating in-plane bending loadings.

1. Introduction

Due to the ease of fabrication and the availability of many assessment methods for ultimate strength and fatigue performance, gapped *K*-joints are widely used for the construction of many tubular structures. However, when the brace-to-chord diameters ratio, β, is higher than 0.7, gapped *K*-joints may not be easily designed due to the limited range of validity of many design codes [1–3] and a partially overlapped joint (joints with overlapping ratio between 25% and 75%) may be needed instead. In general, a partially overlapped CHS *K*-joint has a higher fabrication cost than a gapped joint due to the more complex intersection profile and construction procedure. However, in terms of ultimate strength capacity, a partially overlapped CHS *K*-joint is generally higher than its gapped counterpart due to the more compact connection and optimized load transfer pattern [4]. In fact, in a study comparing the costs of three *K*-joints design options [5], it was found that for the same ultimate strength requirement, the partially overlapped joint is the cheapest option, with the fabrication cost lower than that of the gapped joint which needs a larger and thicker CHS section. While it is clear that partially overlapped joints could outperform their gapped counterparts in terms of ultimate static strength, only a few small scale studies were carried out to compare the fatigue performances between these two types of joints. Bouwkamp [4] reported that the stress concentration factors (SCF) of overlapped CHS *K*-joints could be 30% lower than those of gapped CHS *K*-joints having the same parameters and properties. In addition, Fessler et al. [6] reported that the hot spot stress (HSS) could be reduced as much as 40%–45% by switching from a gapped joint design to an overlapped joint design. In terms of fatigue strength, Gibstein [7] reported that improvements could be obtained by using a partially overlapped joint with same chord and brace diameters. For the development of SCF and HSS equations for partially overlapped joints, Efthymiou and Durkin [8] published their equations based on a small scale finite element study involving 100 joint configurations and loading cases. Their equations were verified experimentally by Dharmavasan and Seneviratne [9] using scaled down acrylic models and it was found that overlapping may help to reduce the chord SCF. However, a recent study by Sopha et al. [10] during full scale testing found that Ethymiou's formulae [8] are conservative only when the joints were subjected to in-plane bending loading, but not for the case of axial loading. In addition, it was also found that the HSS may be located on the brace side of the joint and this agreed with the observations by Moe [11]. This implies that the fatigue failure mode of a partially overlapped CHS *K*-joint could be different from a gapped joint in which the chord fatigue failure almost always determines the fatigue life. Research on fatigue behavior of overlapped tubular *K*-joints with an overlapping ratio larger than 50% can be found in the works done by Gho et al. [12,13], Gao et al. [14] and Pang et al. [15]. In addition, Mashiri et al. [16] studied the SCF and fatigue behavior of thin-walled CHS and square hollow section *T*-joints under in-plane bending loading.

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