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Geometrically parametric study of central brace SCFs in offshore three-planar tubular KT-joints

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ABSTRACT

In the present paper, a set of geometrically parametric FE stress analyses is carried out for right-angle three-planar tubular KT-joints under three different axial loading conditions. Three-planar KT-joints are one of the most important joint types in the six-legged offshore jacket-type structures since they connect the bracing members to the main legs of the jacket template. The analysis results are used to present general remarks on the effect of geometrical characteristics on the stress concentration factors (SCFs) at different saddle positions on the central braces. Based on the results of FE analyses which are verified against the experimental data, a complete set of SCF databases is developed. Afterwards, through nonlinear regression analysis, a new set of SCF design equations is established for the fatigue design of three-planar KT-joints under three different axial load cases. An assessment study of these equations is conducted against the experimental data and the acceptance criteria proposed by the UK Department of Energy (DoE).

1. Introduction

Steel circular hollow section (CHS) members are widely utilized for the construction of offshore jacket-type structures. The main reason is their excellent structural and mechanical properties such as high strength-to-weight ratio, non-directional buckling and bending strength, and low wave resistance. In a tubular joint, circular hollow members (tubulars) are connected by welding the prepared end of the brace members onto the surface of the chord member. The fatigue design of such joints constitutes a critical factor towards safeguarding the integrity of tubular structures. The complex joint geometry causes significant stress concentrations at the vicinity of the welds. Under repeated loadings, they result in the formation of cracks which can grow to a size sufficient to cause the joint failure. The location of maximum stress concentration is called “hot-spot” and the corresponding local stress is referred to as “hot-spot stress” (hss). For fatigue design purposes, the “hot-spot stress method” has been quite efficient and popular. According to this method, the nominal stress range $\Delta\sigma_{nom}$ at the joint members is multiplied by an appropriate stress concentration factor (SCF) to provide the so-called “geometric stress” S' at a certain location. Hence, this design method relies on the accurate prediction of SCFs for tubular joints. When the members of a joint are subjected to a combination of axial and bending loads on all members, the geometric stress at a specific location around the weld is calculated by superimposing the contributions of the nominal stresses from each loading type (k) considering the corresponding SCF values:

$$S' = \sum_k (SCF)_k \Delta\sigma^k_{nom} \tag{1}$$

The SCF is the ratio of the local surface stress to the nominal direct stress in the brace. The SCF value depends on joint geometry, loading type, weld size and type, and the location around the weld under consideration. Geometric stresses S' are calculated at various locations around the welds and the maximum geometric stress is the hot-spot stress S. The fatigue life of the joint is estimated through an appropriate S–N fatigue curve, N being the number of load cycles.

Over the past three decades, significant effort has been devoted to the study of SCFs in various uni-planar tubular joints (i.e. joints where the axes of the chord and the braces lay in the same plane). As a result, many parametric design equations (formulae) in terms of the joint geometrical parameters have been proposed, providing SCF values at certain locations adjacent to the weld for several loading conditions.

Multi-planar joints (Fig. 1) are an intrinsic feature of offshore tubular structures. The multi-planar effect plays an important role in the stress distribution at the brace-to-chord intersection areas of the spatial tubular joints. For such multi-planar connections, the parametric stress formulae of simple uni-planar tubular joints are not applicable in SCF prediction. Nevertheless, for multi-planar joints which cover the majority of practical applications, very few

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