International Journal of Offshore and Polar Engineering
Vol. 12, No. 4, December 2002 (ISSN 1053-5381)

SCFs and Fatigue Design of Multiplanar Tubular DT Joints

Spyros A. Karamanos
Department of Mechanical and Industrial Engineering
University of Thessaly, Volos, Greece

Arie Romeijn and Jaap Wardenier*
Faculty of Civil Engineering and Geosciences
Delft University of Technology, Delft, The Netherlands

ABSTRACT

This paper concerns the fatigue design of multiplanar welded tubular DT (double T) steel connections. Stress Concentration Factors (SCFs) are used for the calculation of the geometric or hot-spot stress of a DT joint and for the subsequent assessment of joint structural integrity against fatigue. Following extensive finite element analyses, a simple and efficient methodology has been developed to predict stress concentrations and calculate fatigue design capacity in DT joints with equal-size braces subjected to axial loads and bending moments. The proposed design methodology is based on simple SCF parametric equations and graphs and is illustrated in 2 design examples. The results of the present investigation aim towards an improved DT-joint design in tubular structures subjected to repeated loading.

INTRODUCTION

Multiplanar welded joints of tubular members are widely used not only in offshore platforms, but also in several onshore applications (cranes, masts, towers and bridges) where they are subjected to repeated loads and may fail because of fatigue. The fatigue design of welded tubular multiplanar joints constitutes a challenging issue, and this paper focuses on the fatigue design of a particular multiplanar configuration, the DT connection (Fig. 1).

The fatigue design of tubular joints is based on the hot-spot stress method, which has proven to be quite efficient and popular. The hot-spot stress is the maximum geometric (local) stress at the weld toe of the joint. According to this method, the nominal stress range $\Delta\sigma$ at the joint members is multiplied by an appropriate Stress Concentration Factor (SCF) to provide the so-called geometric stress at a certain location. When the members of a joint are subjected to a combination of axial loads and bending moments at all members, the geometric stress $S^{(k)}$ at a specific location (k) around the weld is calculated by superimposing the contributions of the nominal stress amplitudes $\Delta\sigma_i$ from each loading type (i):

$$S^{(k)} = \sum_i SCF_i^{(k)} \cdot \Delta\sigma_i \qquad (1)$$

The SCF value depends on joint type and geometry, loading type, the location around the weld under consideration and, to a lesser extent, on the weld size and type. Geometric stresses $S^{(k)}$ are calculated at various locations around the welds, and the maximum geometric stress is the hot-spot stress S of the joint. The fatigue life of the joint is estimated through an appropriate S–N fatigue curve, N being the number of load cycles.

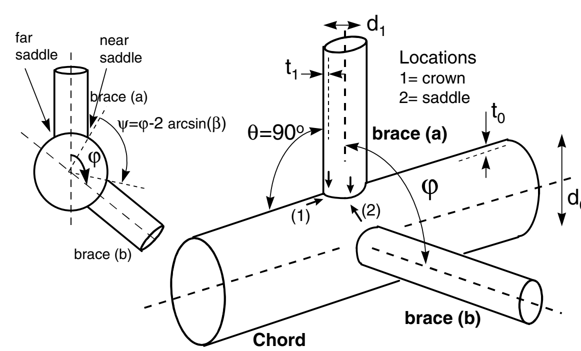

Fig. 1 DT-joint configuration and joint parameters

There exists considerable information regarding the fatigue behavior and design of uniplanar joints (e.g. see Appendix I for T joints), where all members lie in a single plane. However, many joints used in practical applications are multiplanar, and little information has been reported concerning their fatigue capacity. In particular, the calculation of the SCF value constitutes an important issue. In DT joints, the SCF value depends mainly on the joint geometry, and particularly on the following dimensionless parameters:

- brace-to-chord diameter ratio—beta ($\beta = d_1/d_0$)
- chord radius-to-thickness ratio—gamma ($\gamma = d_0/2t_0$)
- brace-to-chord thickness ratio—tau ($\tau = t_1/t_0$)
- out-of-plane angle—phi (φ)

The in-plane angle (θ) for all DT joints considered in this paper is equal to 90°, i.e. braces perpendicular to the chord. Further, overlap joints are not considered in the present study. The gap angle ψ is a parameter related to the gap as shown in Fig. 1.

SCFs are measured around the joint welds, mainly at crown and saddle locations. In multiplanar joints the carry-over phenomenon is of particular importance. Referring to Fig. 1, it is defined as the

*ISOPE Member.

Received March 6, 2002; revised manuscript received by the editors June 7, 2002. The original version (prior to the final revised manuscript) was presented at the Eleventh International Offshore and Polar Engineering Conference (ISOPE-2001), Stavanger, Norway, June 17–22, 2001.

KEY WORDS: Fatigue design, hot-spot stress, tubular joint, welded connection, multiplanar effects.