Marine Structures 33 (2013) 56–70

Contents lists available at SciVerse ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Local joint flexibility element for offshore plateforms structures

A. Akbar Golafshani [a], Mehdi Kia [b,*], Pejman Alanjari [c]

[a] Sharif University of Technology, Department of Civil and Environmental Engineering, Tehran, Iran
[b] Structural Engineering, Sharif University of Technology, Tehran, Iran
[c] Structural Engineering, K.N. Toosi University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 27 December 2011
Received in revised form 13 April 2013
Accepted 13 April 2013

Keywords:
Joint flexibility
Chord
Brace
Tubular framed structure
Flexibility matrix

ABSTRACT

A large number of offshore platforms of various types have been installed in deep or shallow waters throughout the world. These structures are mainly made of tubular members which are interconnected by using tubular joints. In tubular frames, joints may exhibit considerable flexibility in both elastic and plastic range of response. The resulting flexibility may have marked effects on the overall behavior of offshore platforms.

This paper investigates the effects of joint flexibility on local and global behavior of tubular framed structures in linear range of response. A new joint flexibility element is developed on the basis of flexibility matrix and implemented in a finite-element program to account for local joint flexibility effects in analytical models of tubular framed structures. The element formulation is considerably easy and straightforward in comparison with other existing tubular joint elements. It was concluded that developed flexible joint model produces accurate results comparing to sophisticated multi-axial finite element joint models.

1. Introduction

In the past years, considerable investigative efforts have focused on understanding the real behavior of offshore structures subjected to severe seismic loadings. Moreover, there is an increasing demand for reappraisal of existing installations of steel jacket structures. This perhaps could be due to the revised

* Corresponding author. Tel.: +98 9111186949.
E-mail addresses: golafshani@sharif.ir (A.A. Golafshani), mehdikia2519@gmail.com, M_kia@mehr.sharif.ir (M. Kia), Pejman_alanjari@sina.kntu.ac.ir (P. Alanjari).

0951-8339/$ – see front matter
http://dx.doi.org/10.1016/j.marstruc.2013.04.003

design recommendations based on a better knowledge of structural performance. As a consequence, variety of analytical models have been developed to simulate the response of offshore platforms. Welded steel tubular joints are the kind of connection used extensively in the construction of fixed, offshore steel structures. The behavior of these welded joints must be predicted to ensure safe and reliable analytical simulations of such structures. The use of tubular connections in circular hollow sections is not confined to offshore platforms and many structures employ these types of joints for interconnecting their members such as large-span space frames and towers.

One of the earliest investigations on effects of local joint flexibility (LJF) on the response of offshore installations dates back to 1980 when Boukamp et al. [1] conducted a research on analytical techniques used to develop the joint flexibility (JF) model and to find some procedures to incorporate these effects into overall structural response. They provided joint analysis models which were assembled from component branch and chord substructures using a consistent multilevel substructure technique. Later, Ueda et al. [2] provided an improved joint model and equations for flexibility of tubular joints. The accuracy of their models was confirmed through comparisons with results of finite element analysis. They concluded that their models are capable of accurately representing the nonlinear behavior of actual joints. Fessler and Spooner [3] and Fessler et al. [4] presented improved equations for flexibility coefficients in terms of joint parameters, in Y, X and gap-K joints. Buitrago et al. [5] also obtained new equations for flexibility coefficients and gave explicit formulas to determine the local joint flexibilities for various joint types and geometries. Karamanos et al. [6] investigated the fatigue design of K-joint tubular girders. Skallerud et al. [7] performed experimental investigations on cyclic in elastic behavior of tubular joints and provided the researchers with valuable test data. Dier [8] described the recent developments that have taken place in offshore tubular joint technology. Mirtaheri et al. [9] investigated the comparative response of two analytical platform models and concluded that LJF is of great significance in both elastic and plastic range of response. Static loading performance of tubular joint in multi-column composite bridge piers was studied by Lee et al. [10]. Lee and Parry [11] conducted a research on strength prediction for ring-stiffened DT-joints in offshore jacket structures. Holmås [12] describes a fully coupled finite element for local joint flexibility of tubular joints based on solving the equations for elastic shell. Hellan [13] presents (among many topics) the different models for joint flexibility and how the flexibility impacts the ultimate strength. Alanjari et al. [14] performed an experimental research on a small-scaled 2D platform and developed an analytical model which made use of uniaxial fiber elements to model a fracturing tubular joint. However, their model lacked joint local biaxial and triaxial effects as they did not take LJF into account.

In this study a JF element based on flexibility matrix is developed and formulated with the aid of empirical Fessler [4] equations. Stiffness matrix derivation is discussed in detail through the use of equilibrium of the uni-axial element without rigid body modes in the vicinity of chord and brace intersection. The proposed element is subsequently implemented in nonlinear finite element (FE) program OpenSees [15] and verified using more general multi-purpose FE programs which make use of multi-axial elements such as shell or solid elements. Finally, improved tubular framed structure models are made and compared against conventional rigid-joint models which are widely employed in engineering practice.

2. Tubular joint element

In general, a tubular joint comprises a number of independent chord/brace intersections and the ultimate strength limit state of each intersection is to be checked against the design requirements. However, as mentioned earlier, JF has marked effects on overall deformation pattern of the structure, nominal stress distribution within the joints, buckling load of members as well as natural frequencies and mode shapes of platform.

2.1. Analytical treatment of tubular joints

Conventionally, in structural analysis of offshore platforms, jacket structure is modeled by a plane or space frame having tubular members rigidly interconnected to each other at nodal points. There exist some other techniques which can take into account LJF in a reasonable fashion such as the so-called effective length model. The model utilizes an effective length which is adopted to replace the real