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Probability density functions of SCFs in internally ring-stiffened tubular KT-joints of offshore structures subjected to axial loading

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ABSTRACT

The stress concentration factor (SCF) which is one of the critical parameters in the fatigue reliability analysis of tubular joints exhibits considerable scatter calling for greater emphasis in the accurate derivation of the probability functions governing the SCFs. As far as the authors can tell, no comprehensive research has been carried out on the probability distribution of SCFs especially in stiffened tubular joints commonly found in offshore structures. What has been used so far as the probability distribution of SCFs in the reliability analysis of this type of joints is mainly based on assumptions and limited observations, especially in terms of distribution parameters. In the present research, data extracted from the finite element analysis of 108 models, verified against test results obtained from the experimental investigation, were used to propose probability distribution models for SCFs in internally ring-stiffened tubular KT-joints subjected to axial loads. Based on a parametric study, a set of sample databases was prepared for the maximum central- and outer-brace SCFs; and density histograms were generated for these samples. Nine different probability density functions (PDFs) were fitted to these histograms. The maximum likelihood method was used to determine the parameters of fitted distributions. In each case, using a developed computer code, the chi-squared and Kolmogorov–Smirnov tests were applied to evaluate the goodness of fit. Finally, the best-fitted distributions were selected and after substituting the values of estimated parameters for each distribution, three fully defined PDFs were proposed for the maximum weld-toe SCFs of central brace, compressive outer brace, and tensile outer brace in internally ring-stiffened tubular KT-joints subjected to axial loads.

1. Introduction

Offshore jacket-type platforms are mainly fabricated with circular hollow section (CHS) members. The intersection between CHS members is called a tubular joint. Fig. 1 shows a tubular KT-joint along with the commonly named positions along the brace/chord intersection: saddle, crown, toe, and heel. Tubular joints are subjected to wave induced cyclic loads and thus are susceptible to fatigue damage. The stress-life (S–N) approach, based on the hot-spot stress (HSS), is widely used to estimate the fatigue life of the joint. The HSS can be calculated through the multiplication of nominal stress by the stress concentration factor (SCF).

The SCF is defined as the ratio of the local surface stress, at the brace/chord intersection, to the nominal stress in the brace. The SCF depends on the joint geometry, loading type, weld size and type, and the considered position for the SCF calculation around the weld profile. Under any specific loading condition, the SCF value along the weld toe of a tubular joint is mainly determined by the joint geometry. Dimensionless geometrical parameters including α, α_B, β, γ, τ, ζ, and η which are used to feasibly relate the behavior of a tubular joint to its geometrical characteristics are defined in Fig. 1.

Deterministic fatigue analyses typically produce conservative results; since limiting assumptions are to be made on input parameters. Some of the key parameters of the problem can exhibit stochastic behavior. This highlights the necessity of conducting a reliability analysis in which these key parameters can be modeled as random quantities. The fundamentals of reliability assessment, if properly applied, can provide immense insight into the performance and safety of the structural system.

Regardless of the method which is used for fatigue reliability analysis of steel offshore structures (i.e. based on either S–N approach or fracture mechanics approach), the probabilistic and statistical measures of the SCF are among the most important input parameters. The SCF exhibits considerable scatter calling for greater emphasis in the accurate derivation of the probability functions governing the SCFs. As far as the authors can tell, no

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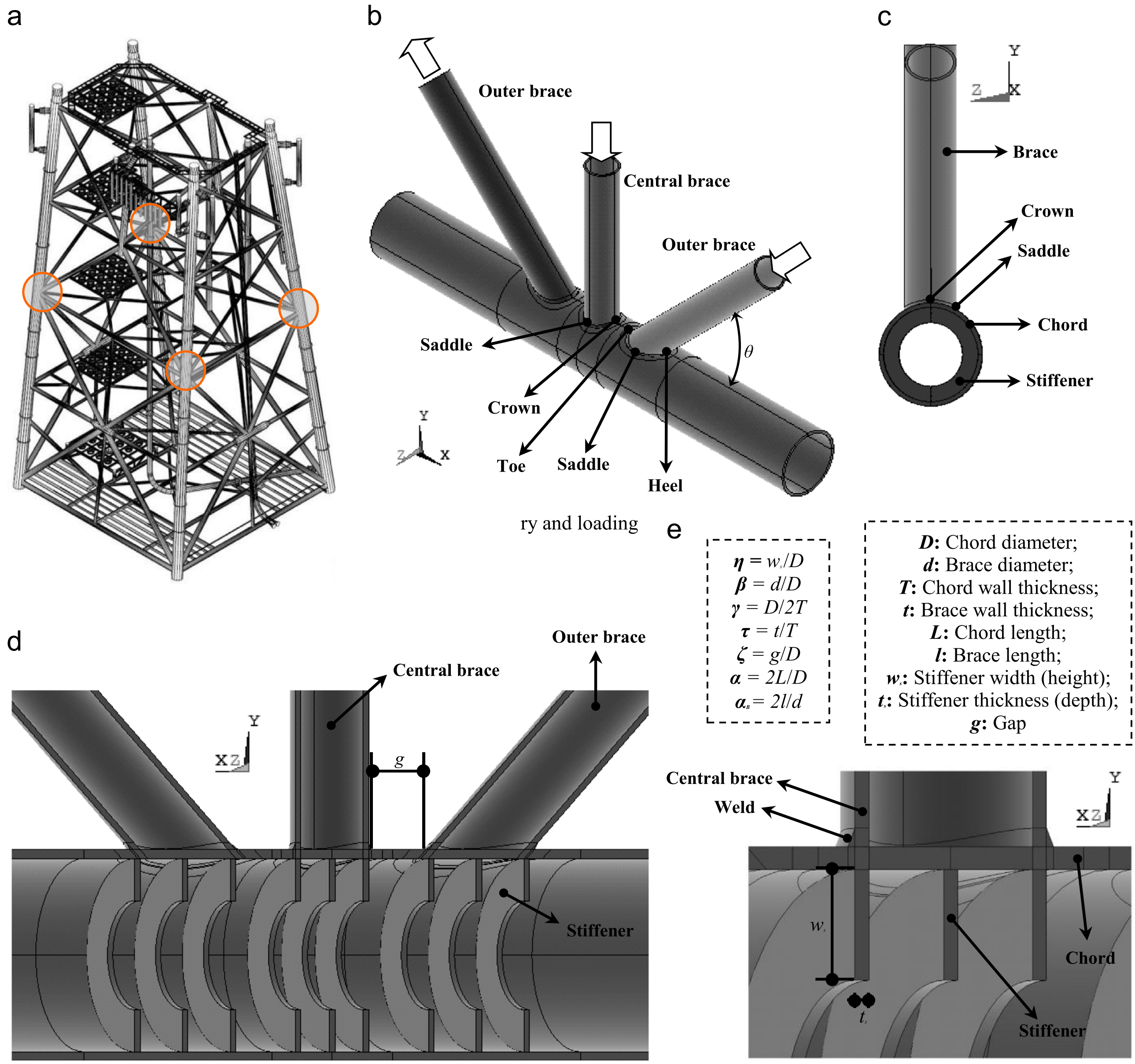

Fig. 1. Geometrical notation for an internally ring-stiffened KT-joint subjected to axial loading.

comprehensive research has been carried out on the probability distribution of SCFs especially in stiffened tubular joints commonly found in offshore structures. What has been used so far as the probability distribution of SCFs in the reliability analysis of this type of joints is mainly based on assumptions and limited observations, especially in terms of distribution parameters.

In the present research, firstly, the previous deterministic and probabilistic studies on SCFs were reviewed (Section 2). Afterwards, data extracted from the finite element (FE) analysis of 108 models, verified against test results obtained from the experimental investigation, were used to propose probability distribution models for SCFs in internally ring-stiffened tubular KT-joints subjected to axial loads. Based on a parametric study, a set of sample databases was prepared for the central- and outer-brace SCFs (Section 3); and density histograms were generated for these samples (Section 4). Nine different probability density functions (PDFs) were fitted to these histograms. The maximum likelihood (ML) method was used to determine the parameters of fitted distributions (Section 5). In each case, using a developed computer code, the chi-squared and Kolmogorov–Smirnov tests were applied to evaluate the goodness of fit (Section 6). Finally, the best-fitted distributions were selected and after substituting the values of estimated parameters for each distribution, three fully defined PDFs were proposed for the weld-toe SCFs of central brace, compressive outer brace, and tensile outer brace in internally ring-stiffened tubular KT-joints subjected to axial loads (Section 7).

2. Literature review

2.1. Assumed distributions for the SCFs in the reliability analysis

Kirkemo [1], in his comprehensive paper on the applications of probabilistic fracture mechanics to offshore structures, assumed that the SCFs follow a log-normal distribution with the CoV of 0.15 and the mean of 2.75 and 2.50 for axial and in-plane bending (IPB) loads, respectively. Aghakuchak and Mosayyebi [2] assumed a normal distribution for the SCFs with the mean of 2.56, 2.50, and 1.90 and the standard deviation of 0.26, 0.25, and 0.19 for axial, in-plane bending, and out-of-plane bending (OPB) loads, respectively.