Probabilistic residual ultimate strength assessment of cracked plates subjected to uniaxial compression

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ABSTRACT

Initial defect and crack damage pose a significant risk to the safety of the whole structure. To ensure the reliability level, the probabilistic residual ultimate strength of cracked plates under uniaxial compression is evaluated based on a Kriging-based Monte Carlo simulation method. Results demonstrate that the length and orientation of crack have a significant influence on the residual compressive strength, whereas they have a negligible effect on the initial stiffness. The initial deflection and transverse center-offset distance of crack have a remarkable effect on both the residual compressive strength and initial stiffness.

KEY WORDS: Residual ultimate strength; Probabilistic assessment; Compressive residual stress

INTRODUCTION

Usually the ultimate strength of a structure under high waves or extreme loading conditions is evaluated using the deterministic method. However, different kinds of initial defects are usually inevitable for the ships and offshore structures since the manufacturing and working conditions are complicated (Saad-Eldeen et al., 2018; Cui et al., 2016; Xu et al., 2014). Crack is one of the most common damage that can usually be found at the structural discontinuities, welded joints and stress concentration regions (Saad-Eldeen et al., 2018; Cui et al., 2016). It is commonly acknowledged that not only the buckling performance but also the load bearing capacity of structures is significantly affected due to the existence of the cracks. The size, location and direction of the cracks are often different for different structures because of the uncertainty in the initiation and propagation of the crack. Therefore, it is significantly important to carry out the probabilistic assessment of ultimate strength under compressive load thoroughly during the damage-tolerant design and service life (Xu et al., 2019; Cui et al., 2017; Amlashi et al., 2008; Benson et al., 2013).

With the introduction of damage tolerance approach, the reliability evaluation of the structure with initial defect has attracted more and more attention in ship and marine engineering. Risk-based inspection (RBI) has already been proposed to evaluate the optimal inspection and maintenance strategies of aged structures due to its advantages in identifying the primary factors among the basic random variables. Recently, within reliability-based approaches increasing attention has also been paid to quantifying the uncertainties of design variables via probabilistic models. Probabilistic modelling of ultimate strength mainly involves two aspects: the assessment of ultimate strength and the analysis of structural reliability. The ultimate strength assessment of cracked plates is usually associated with nonlinear structural behavior, which should rely on numerical approaches such as the nonlinear finite element analysis. Reliability analysis is a complex process that requires a huge number of numerical models (such as nonlinear finite element analysis (FEA) structural models), therefore, it is usually not suitable for local design of engineering structures because it is time-consuming and computationally intensive. To effectively solve this problem, alternative model-based methods are established as an effective technique to provide accurate reliability analysis with lower computational costs, such as polynomial response surface (Faravelli, 1989), artificial neural network (ANN) (Papadrakakis et al., 1996), support vector machine (SVM) (Vapnik, 2006) and kriging model (Matheron, 1973). Cui et al. (2019) predicted the probabilistic characteristics of the ultimate strength of typical box girder plates under local pitting accurately and efficiently based on gaussian process (GP), which is inserted with a new design point and integrated with a surrogate model. Gaspar et al. (2012) evaluated the failure probability and reliability of stiffened hull box girder plates under uniaxial compression and lateral pressure loads considering the effect of corrosion based on Monte Carlo simulation combined with response surface method. From the literature above, it is found that the reliability assessment of ultimate strength under compression load mainly focuses on the basic uncertainties, such as initial deformation and corrosion damage of the plate, the probabilistic ultimate strength investigation of the cracked plates are seldom reported.

In this paper, a reliability method for evaluating probabilistic residual limit strength of cracked plates is proposed by combining nonlinear finite element analysis with Kriging-based reliability method. Firstly, the influence of uncertainty of initial defect and crack damage on ultimate strength reduction of cracked plate under longitudinal compression are discussed using the deterministic analysis. In addition, the failure probability and the reliability index evolution with each uncertain parameter are also studied, based on the proposed probability reliability analysis for residual ultimate strength of cracked plate.

FINITE ELEMENT MODELING

The ultimate strength calculation of structural models is essentially a nonlinear problem, which mainly includes material nonlinearity and