Experimental and analytical investigations on behavior of clamped offshore tubular members subjected to lateral indentation

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ABSTRACT

Experimental and theoretical research on behavior of clamped offshore tubular members subjected to lateral indentation are conducted in the present research. Experimental investigations of fully clamped tubular specimens under quasi-static indentation of wedge indenter and flat indenter are conducted, force-displacement relationship, energy dissipation, deformation mode and failure mode are presented out. A simplified analytical method with consideration of both the local denting and global bending has been proposed. The local denting performance of the tubular member is proposed by discretion of the tube. The global deformation performance is proposed based on rigid-plastic beam assumption. Force-displacement relationship is obtained by superimposing the local denting depth and the global beam deformation resultantly. The simplified analytical method is expressed with a concise expression, and good agreements have been achieved between the theoretical results and test results. The proposed simplified analytical method provide a thorough insight into the structural performance of the tubular member structures subjected to lateral impact, and could be used for rapid prediction.

KEY WORDS: Offshore tubular structure; lateral indentation; energy dissipation; quasi-static experiment; simplified analytical method.

INTRODUCTION

Thin-walled tubes are widely used in the offshore structures. Tubular structures are exposed to risks of collision with supply vessels and impact of dropped heavy objects (Yu & Amdahl, 2018a). In extreme conditions, failure of several tubular members in collision accident may cause collapsing of the whole offshore platform, which will lead to catastrophic consequences, including great economic loss, environmental pollution and human lives loss. Therefore, it is of great importance to consider the dynamic performances of the tubular members subjected to lateral impact during offshore structural design.

There are normally four typical analyzing methods on estimating the dynamic performance of tubular member during lateral impact scenario, including empirical method, experimental method, numerical simulation and analytical method. Currently, empirical method is seldom proposed. Experimental research are the research benchmark. Jones & Birch (1992) conducted an experimental study on impact responses of clamped steel pipes; Hu et al. (2016) and Lu et al. (2020) proposed impact responses of clamped offshore joint structure. Meng et al. (2022) proposed impact tests of aluminum tubes. Besides, numerical simulation method has shown powerful capability to acquire structural responses. Travanca & Hao (2014) proposed numerical simulation of of a tubular member; Sourne et al. (2015), Travanca & Hao (2015) and Fan & Yuan (2014) conducted structure responses of tubular platforms. Mechanical responses of mono-pile foundations (Yu & Amdahl, 2018b) and spar wind turbine tube (Amdahl & Yu, 2021; Zhang et al. 2021) under collision of supply vessels has been becoming research hotspot. Nevertheless, numerical simulation method has its disadvantages, for instance, large computing CPU time, substantial efforts for modelling and the challenges on mesh-size sensitivity, failure criteria definition and strain-rate effect, et al.

Meanwhile, simplified analytical method has its advantage on low calculating resource consumption with accuracy. There are large amount of existing analytical method on dynamic analysis of tubular structures. Furnes & Amdahl (1980) made the first attempt to establish a local deformation model; Amdahl (1983) proposed an analytical method for tube local denting under impact; Wierzbicki & Suh (1988) established an analytical method for predicting responses of tubes under concentrated lateral load. Furthermore, Yu & Amdahl (2018b) proposed a modified formula by taking account of the width of the indenter. Jones & Shen (1992) discretized the lateral deformation into local denting and global deformation, and solved the lateral force-displacement relationships, thereby an empirical formula for predicting fracture had been established (Shen & Shu, 2002). Buldgen et al. (2014), Sourne et al. (2016) proposed an analytical solution under arbitrary impact.

However, among the expressions above, theoretical methods with consideration of both local denting and global bending have good accuracy, but rely on complicated calculation. The present research is to propose a simplified analytical method with a concise expression. The first step is to conduct experimental investigations of fully clamped tubes under quasi-static indentation. By then a simplified analytical method with a concise expression with consideration of both local denting and global bending has been carried out. Gradually, the