Experimental and Numerical Investigations on the Impact Response of Ring-Stiffened Cylindrical Shells

Burak Can Cerik, Hyun-Kyoung Shin and Sang-Rai Cho
School of Naval Architecture and Ocean Engineering, University of Ulsan
Ulsan, Korea

ABSTRACT

In this paper, an experimental and numerical evaluation of the impact response of ring-stiffened cylinders struck at mid-bay with a mass having a rigid knife-edge indenter is presented. The experiments aimed at reproducing a collision scenario involving offshore installations with supply vessels. Dynamic force-displacement curves and strain measurements are presented. The results are compared with the nonlinear finite element simulations performed using Abaqus/Explicit software. The numerical simulations accurately predicted the force-displacement response of the test models. Detailed information on the response and the deformation behavior of ring-stiffened cylinders are presented based on the experimental and numerical results.

KEY WORDS: Ring-stiffened cylinder; impact test; collision; numerical simulation; energy absorption.

INTRODUCTION

The purpose of this study is to provide insights on impact response of ring-stiffened cylinders based on experiment and numerical simulations. The ring-stiffened cylinders are mainly used as structural components of floating offshore installations. Abnormal loads arising from collision is a potential threat to these structures. Collision is a dynamic event involving large deflections and material nonlinearity. Simple rigid-plastic analysis approach may not cover all the aspects of the problem due to simplifications and may lead to unrealistic results. Therefore, it is important to address this problem with experiments conducted in realistic physical conditions and compares the numerical simulations with the experimental results.

Several researchers carried out experimental and analytical studies on this topic. Harding and Onoufriou (1995) and Karroum et al. (2007) conducted quasi-static denting tests on small-scale specimens. Quasi-static tests provide continuous recording of damage process; however, dynamic effects such as inertial forces, stress wave propagation and especially strain-rate effect are not taken into account. There are analytical studies on unstiffened cylinders subjected to concentrated load causing local denting, for instance, Walker and Kwok (1986), Wierzbicki and Suh (1987), Hoo Fatt and Wierzbicki (1992), Wierzbicki and Hoo Fatt (1993), Moussouros and Hoo Fatt (1995), Hoo Fatt and Wierzbicki (1991) extended the work of Wierzbicki and Suh (1987) to ring-stiffened cylinders by treating ring-stiffeners discretely and assuming that the main effect of them is an increase in bending strength of cylinder in circumferential direction. Consequently, at the vicinity of stiffeners concentrated strain is expected. This approach is straightforward, but the validity should be checked with actual deformation behavior and strain distributions.

Considering the limited data and the shortcomings of earlier studies, the experimental and numerical results presented in this study have considerable importance. The impact tests not only give a realistic view of the response but also are used for validation of the numerical modeling proposed. Numerical simulations provide understanding of deformation process and give stress and strain fields in cylindrical shell and stiffeners. The finite element modeling strategy in this paper can find application in the analyses of other marine structures subjected to impact. Also, the presented experimental data can be useful for future benchmark studies.

DETAILS OF EXPERIMENTS

Description of models

The experimental models are two internally ring-stiffened steel cylinders denoted as RS-C-1 and RS-C-2. The material of the models is SS41 general purpose structural steel. The manufacturing of the models follows the standard methods and the techniques of full-scale structures of this kind. The cylinder shell is cut from 4 mm thick sheets, cold-bent by rollers and welded to form a cylinder with an outer diameter 800 mm. The ring-stiffeners are 4 mm thick flat-bars cut from flat sheets and welded internally to cylinder shell. The depth of ring-stiffeners is 35 mm. The spacing of the stiffeners reduces towards the ends of the cylinder. In the middle three bays, the stiffener spacing is 200 mm whereas in the next bay it is 150 mm and in the outmost bay 80 mm. The cylinder is welded at one end to a circular plate with 20 mm thickness. At the other end it is welded to a ring with 20 mm thickness. The end plate and the ring have extensions at the bottom which are