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Deflection and Fracture of Clamped Stiffened Plate Under Lateral Indentation by a Sphere

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Stiffened plate is a fundamental element of ship and other engineering structures. Deflection and fracture of a clamped stiffened plate under lateral indentation by a spherical indenter was investigated by a semi-analytical approach and experiments. To investigate the influence of the indented position, two quasi-static experiments with different numbers of stiffeners were conducted. To predict the initial failure of the stiffened-plate maximum-resistance force up to this point, a semi-analytical approach was established. The results of the proposed semi-analytical approach were compared with the experimental results.

INTRODUCTION

Stiffened plate is a fundamental element of ship and other engineering structures. The crashworthiness and failure mechanism of stiffened plates subjected to lateral indentation by a sphere have been studied extensively by researchers with experimental and theoretical methods.

To investigate the indentation resistance of hull panel during ship grounding, Alsos and Amdahl (2009) conducted a series of scale stiffened plate experiments with quasi-static loading. Meanwhile, Karlsson et al. (2009) conducted two scale quasi-static experiments of ship double-side structure subjected to lateral indentation by a sphere. To investigate the crashworthiness of stiffened plate, Cho and Lee (2009) conducted a series of pendulum impact experiments. Also, extensive analytical or semi-analytical research was conducted to predict the maximum resistance. For theoretical analysis of the clamped plate subjected to lateral indentation by a sphere, much research has been done. For example, Shen et al. (2002) and Shen (2002) presented a theoretical method to predict the onset of failure for thin circular plates struck by a conical indenter. Jones and Birch (2008), Jones et al. (2008), and Jones and Paik (2013) discussed the perforation energy for plates struck by a cylindrical indenter with different impact faces. However, for an analytical or semi-analytical study of clamped stiffener, there is not as much research as on clamped plate. Ohtsubo et al. (1995) proposed a simplified analysis method to discuss the crashworthiness of ship double-side structure subjected to collision by a bulbous bow. In their analysis, the shape of the bulbous bow is simplified as a truncated pyramid. Suzuki et al. (1999) proposed a simplified analysis method to discuss the crashworthiness of ship double-side structure subjected to collision by a wedge bow.

The objective of this study is to develop a quasi-static semi-analytical method of predicting the resistance force of clamped stiffened plates under lateral indentation by a sphere. Based on the deflection model of clamped plate under lateral indentation by a sphere proposed by Gong et al. (2015), this study further proposes the deflection model of a clamped beam. The resistance force of stiffened plate is assumed to consist of two parts: the resistance force of the plate and the resistance force of the stiffener. Hence, the resistance force of clamped stiffened plates is obtained by the superposition principle. Meanwhile, to investigate the influence of the indented position, two quasi-static experiments with different numbers of stiffeners are conducted. The results of the proposed semi-analytical approach are compared with the experimental results.

TEST

Test Setup

Two stiffened plate specimens (A1 and A2) were used in the experiments. The main difference between specimens A1 and A2 is the number of stiffeners. There are four stiffeners in specimen A1 and five stiffeners in specimen A2. The dimensions of the specimens and the indenters are summarized in Table 1 and Fig. 1. These specimens were made of mild steel. The mechanical properties determined by tensile tests are shown in Table 2.

The experiments on specimens A1 and A2 were conducted in the rig illustrated in Fig. 2. The specimens A1 and A2 were welded at the box structure, as shown in Fig. 3. The thickness of the box structure was 20 mm. By these fixation methods,

Test ID	A1	A2
Length of plate (mm)	1,200	1,200
Width of plate (mm)	1,000	1,000
Thickness of plate (mm)	3.6	3.6
Number of stiffeners	4	5
Height of stiffener (mm)	70	70
Thickness of stiffener (mm)	4.6	4.6
Radius of indenter (mm)	250	250

Table 1 The dimensions of stiffened plate specimens

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