Ocean Engineering 130 (2017) 103–114

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Ultimate strength experiment of hull structural plate with pitting corrosion damage under unaxial compression

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ARTICLE INFO

Keywords:
Ultimate strength
Corroded volume loss
Pitting corrosion
Hull structural plate

ABSTRACT

The ultimate strength assessment method of corroded plates based on corroded volume loss had been proposed by the theoretical derivation and Finite Element Analysis in the previous researches. The method still needs to be validated by experiments before it is applied in engineering. Firstly, the jigs were designed and made for being suitable for the present testing machine system and simulating the simply-supported boundary. Secondly, ultimate strength experiments of plates with no corrosion were carried out in order to validate the assumptions about the plates in Finite Element Analysis. Thirdly, the corrosion parameters of the corroded plates were measured and the corroded volume loss was calculated in order to validate the proposed calculation method of the corroded volume loss. Lastly, ultimate strength experiments of plates with corrosion were carried out in order to validate the assumptions about corrosion damage in Finite Element Analysis and the ultimate strength assessment method of corroded plates based on corroded volume loss.

1. Introduction

The corrosion is one of the important damage of hull structure. Pitting corrosion is common and complicated corrosion in the hull structure. The research on the ultimate strength assessment of hull structural plates with pitting corrosion is always the hot issue. An ultimate strength assessment method based on corroded volume loss had been proposed by theoretical derivation and Finite Element Analysis (Zhang et al., 2016), but the relative experiments are still needed in order to validated the feasibility of the method application in engineering. The researchers had carried out many ultimate strength experiments of stiffened plates and box girders.

Ghavami and Khedmati (2006) carried out two series of experiments on longitudinally stiffened steel plates with and without transversal stiffeners subjected to uniform axial in-plane load and studied the buckling and post-buckling up to final failure. But the unloaded edges of models were free. Nakai et al. (2006) conducted a series of tests on structural models which consist of web, shell and face plates to investigate the effect of pitting corrosion on strength of web plates subjected to patch loading. In these tests, artificial pitting was made on the web plates and two equal concentrated loads were applied vertically at the one third points of simply supported models. Paik (2008) examined the residual ultimate strength characteristics of steel plates with cracking damages under axial compressive actions through experimental investigations. The test structures were composed of four identical sheets of steel plates. Further, Paik et al. (2012) examined the buckling collapse characteristics of fusion welded aluminum-stiffened plate structures under axial compression until and after the ultimate limit state reached. Both the loaded and unloaded edges of the test structures were kept straight and in a simply supported condition during testing. Kim et al. (2009) undertaken a series of experimental on buckling and ultimate strength of plates and stiffened panels with an opening subjected to axial compression. The simply supported and rotationally restrained unloaded edges were kept by two flat-bar. Xu and Soares (2011, 2012, 2013a, 2013b) made a series of the ultimate strength tests, including five narrow stiffened panels tested with two stiffeners, five wide stiffened panels tested with four stiffeners and long stiffened panels under axial compression until collapse. The ultimate strength of tested models was compared with the result in the finite element analysis. The effects of the initial imperfections and the width on the strength were analyzed. The unloading edges of specimens were free and the specimens were not corroded. Zhao et al. (2015) investigated the failure behavior of plate girders with perforated web under axial compression and bending moment and proposed an influence curve to account for the effects of hole location. All specimens were tested with two ends simply supported on the reaction frame.

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http://dx.doi.org/10.1016/j.oceaneng.2016.11.065
Received 14 December 2015; Received in revised form 14 October 2016; Accepted 29 November 2016

Moreover, there was not corrosion and was only a hole on the web.

Shi and Wang (2012) carried out a four-point bending experiment of hull structure and measured the ultimate hogging strength of the test model. The test model was a section of hull structure and was not corroded. Saad-Eldeen et al. (2011, 2012, 2013) analyzed the initial and post-collapse plate deflections based on the measurement records of the experiments of three corroded box girders subjected to pure vertical bending loading inducing a compressive stress on deck and a uniform bending moment. Only the thicknesses of plate at the selected points were measured and analyzed. Xu et al. (2012) performed the ultimate strength experiment of scaled models subjected to extreme wave-induced loads and investigated the collapse behavior. The scaled model design was developed. Jelovica et al. (2013) carried out ultimate strength experiments in three-point bending for beams with different corrosion exposure times. But for corrosion damage, only the thicknesses of plate were measured. Cui et al. (2015) carried out a series of experimental tests of ultimate strength to square column models under cyclic axial compression, which were conducted to simulate the ship plates. Each model consisted of four rectangular plates welded into a column and two thick plates shrouding at column ends. Tanaka et al. (2015) made the progressive collapse tests of three 1/13-scale models of a container ship to evaluate the effect of the torsional moment on the ultimate strength of the container ship. The torsional moment was applied on the models. Yamada and Takami (2015) carried out a large-scale bending collapse test with a box girder with a hole at one side shell. The model is quasi-statically loaded by 4 points bending moment and the unloaded edges were free. The hole was assumed to be damage due to ship-ship collision.

In the above experiments, most boundaries on the unloading edges were free and the corrosion damage was not surveyed. In engineering, the hull structural plates are generally considered as the simply-supported plates at all four edges. Furthermore, corrosion parameters are the important parameters in the ultimate strength assessment of hull structural plates with pitting corrosion. The paper focuses on the ultimate strength experiments of plates with four simply-supported edges and the measurement of corrosion parameters in order to validate the feasibility of the previous proposed ultimate strength assessment method (Zhang et al., 2016) applied in engineering.

2. Jigs design

2.1. Design purpose

'Shimadzu electro-hydraulic servocontrolled fatigue testing machine system' was used in the ultimate strength experiments and its host machine is shown in Fig. 1. The jigs of testing machine system are only suitable for the small size samples. The suitable plates are limited in the range of 0–50 mm breadth and 0–28 mm thickness. Moreover, the top and bottom ends of plates are fixed by the jigs of the system and the unaxial compression loading is carried out at the top end of plates.

For hull structural plates, the breadth of plates is usually greater than 600 mm and the thickness of plates is in the range of 5–30 mm. Even if the scaled model is applied, the supplied jigs of the system are not still suitable for hull structural plates. In addition, the boundary condition of hull structural plates is elastic constraint which is between fixed constraint and simply-supported constraint. Generally, it is considered as simply-supported constraint at all four edges. Thus, the supplied jigs can not be satisfied with the ultimate strength experiments of hull structural plates.

According to the above analyses, the new jigs are needed in order to be suitable for the ultimate strength experiments of hull structural plates.

2.2. Design principle

The jigs are designed based on the capacity of the testing machine

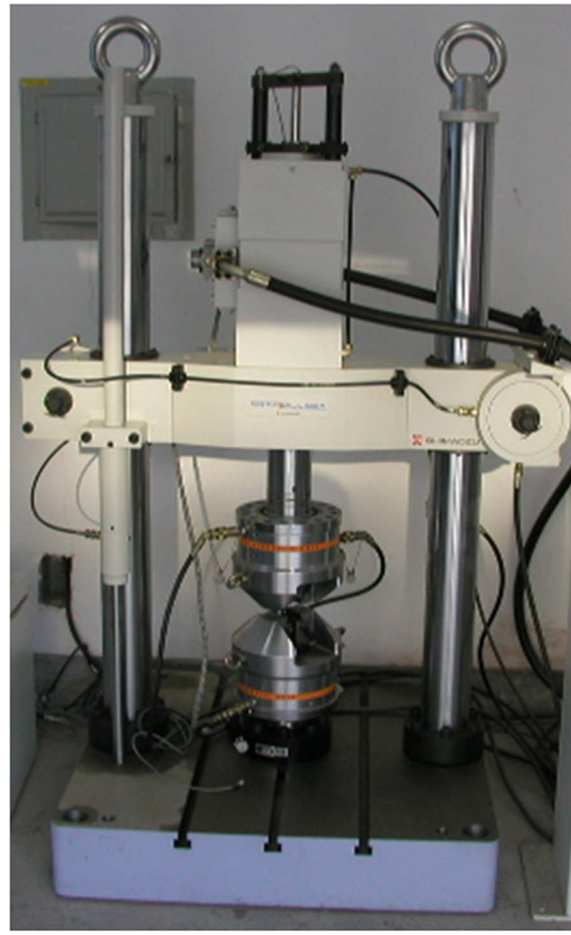

Fig. 1. Host machine of Shimadzu electro-hydraulic servocontrolled fatigue testing machine system.

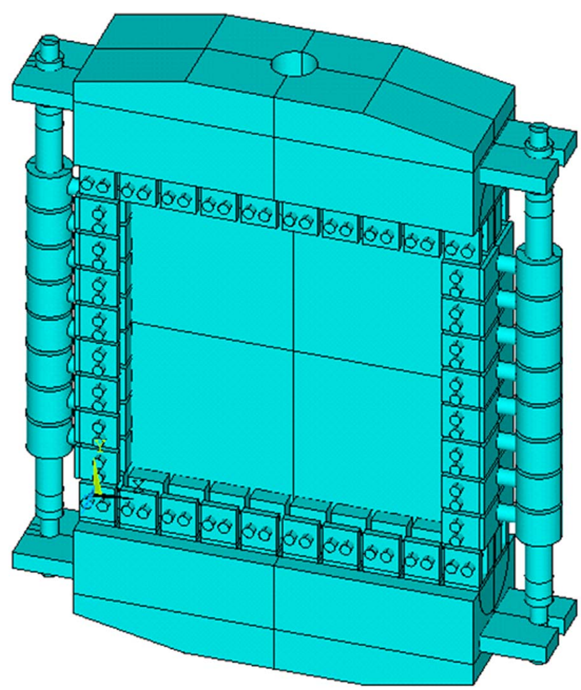

Fig. 2. Design sketch of the clamped sample.