Practical Evaluation of the Structural Integrity of Welded Joint Structures Towards the Improvement of the Hull Construction Quality Standards

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https://doi.org/10.15017/1470564

出版情報：九州大学, 2014, 博士（工学）, 課程博士
バージョン：

（様式 2）

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論文題名　：Practical evaluation of the structural integrity of welded joint structures towards the improvement of the hull construction quality standards
（船殻工作精度標準の改善に向けた溶接継手の実用的な構造健全性評価）

区　　分　：甲

論 文 内 容 の 要 旨

The structure is designed to serve for the purpose of its function with adequate in economy, safety and capability to provide optimum service life. In the ship building and offshore construction industries, it is common practice to refer to the international standards and codes to construct sound engineering structure with high reliability, integrity and safety. Besides, the standards and codes guide designers, engineers and constructors in performing their job. In large built up welding structures like ship hull and offshore platform, defects such as undercut, porosity and lack of fusion cannot be avoided completely. Even though there are many techniques suggested by international standards and codes, such defects have been occurring. Hobbacher stated that most of the reports concluded 75% of welding failure was related to the fatigue problem especially during the design stage. In order to allow the occurrence, most of the requirements with regard to welding joints give certain parameters as a guide.

The thesis consists of 5 chapters. In the chapter 1, the background of overall studies was explained. The suggestions for improvement of hull construction quality standard e.g.; Japan Shipbuilding and Quality Standard (JSQS) and International Association of Classification Societies (IACS) Recommendation No.47 become the overall focus of the study. Welded joint with defects such as undercut and large gap size is highlighted. Numerical study and experimental work are conducted in order to confirm such geometrical parameter to investigate the structural integrity in terms of mechanical and fatigue performance. At the end of the chapter, limitation of the studies is concisely discussed.

In the chapter 2, the objective of the study is explained. The continuity between numerical study and experimental work are briefly explained. Literature reviews from another researcher related to the geometrical parameter of welded joint, such as flank angle, plate thickness and weld toe radius are entirely described. Besides, current standards, and classification codes related to the allowable limit, fatigue design S-N curves and testing methodology are highlighted in this chapter.

In the chapter 3, the numerical studies on butt welded joint with undercut defects and various geometrical parameters are performed. Geometrical parameters which affected the structural integrity of the welded joint in this study are plate thickness, weld bead height, weld bead width, flank angle and weld toe radius. In addition, the effect of different geometrical shape of undercut like U and V-shape is discussed. Furthermore, the importance of stress concentration factor (SCF) and stress gradient (ϕ) in the evaluation of fatigue strength is highlighted with various geometrical parameters. Re-tensile plastic generation (RPG) stress criterion established by Toyosada is applied in order to estimate the fatigue performance of the welded

joints. At the end of the numerical study, practical formula with suggested allowable limit is established for engineer or inspector procedure. The numerical work found such shape factor can be ignored by considering undercut breadth and depth. This formula will be beneficial for the extension of the allowable limit in the standards and codes.

Recently, the semi-automatic CO_2 gas shielded arc welding is mainly used in large welded built up structures such as ships and offshore structures instead of manual arc welding because of its high performance and cost benefit. In general, CO_2 gas shielded welding enables to fabricate welded joints with large gaps. Even though excess of filler metal for large gap welded joint might contribute to increase production cost, but in industrial practise total cost not only depends to the amount of the filler metal used. Most of the production time is consumed during the structural arrangement and the preparation for the fabrication process. Due to the allowable limitation of gap size of the hull construction quality standards such as IACS Rec. 47 and JSQS, more time consuming is needed if any welding works are rejected by the inspector. Furthermore, the redundant welding works will increase much time and cost in the production itself. Therefore, the allowable limits on the gap size for the joints made by CO_2 gas shielded welding should be modified. Many standards, codes and classifications were published the requirements of welding gap size. However, most publications were based on the experimental and empirical results from the welded joints made by manual metal arc welding.

Therefore, the present study in the chapter 4 would become as references in order to the future development of the standard publications. Investigation of the structural integrity and the fatigue performance of the non-load-carrying fillet welded joint with large gap sizes made by CO_2 gas shielded is conducted by the experimental work. The welded specimens were made from mild steel and high tensile steel with two types of welding position i.e.: horizontal and vertical. In addition, gap sizes for the welded specimens were zero, 20mm and 25mm. Hardness, tensile, bending and fatigue capacities are investigated in order to ensure the welding quality. This study is limited to sound welded joints which no defect like undercut, blow hole, root cracking and incomplete fusion are contained in application of large gap sizes. The fatigue test results for the non-load-carrying welded joint specimen with large gap presents higher performance compared to the fatigue design S-N curves proposed by the International Institute of Welding (IIW) and the Health and Safety Executive of United Kingdom (UK-HSE).

Finally, overall conclusion is drawn in the chapter 5. The improvement of existing hull construction quality standards can be done by considering the numerical and experimental studies on butt welded joint with undercut and fillet welded joint with large gap sizes. The studies found by considering the thickness in the allowable limit of undercut could allow for some extension in the standards. Again, stress concentration factor and stress gradient should be considered in the evaluation of the fatigue strength. Besides, the standards could extend the allowable limit of gap size since the study found large gap size at non-load-carrying fillet welded joint shows better structural performance compared to IIW fatigue design S-N curves.