8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

A STUDY ON THE DEVELOPMENT OF NUMERICAL FATIGUE DAMAGE ANALYSIS METHOD FOR WELDED STRUCTURES

Chi-Seung Lee[1a], Young-Hwan Kim[1b], Myung-Hyun Kim[1c] and Jae-Myung Lee[1d]*

[1]Naval Architecture & Ocean Engineering, Pusan National University, 609-735 Busan, Korea
[a]rich@pusan.ac.kr, [b]nodisc1@pusan.ac.kr, [c]kimm@pusan.ac.kr, [d]jaemlee@pusan.ac.kr
*Corresponding author

Key Words: *Welded Structures, Fatigue Damage, Continuum Damage Mechanics, Inherent Strain, Residual Stress.*

ABSTRACT

It is well known that welding process is very commonly employed for making structural joints for ships, offshore structures, and steel structures because of the advantages such as high joint efficiency, air and water tightness and so on. However, it is also recognized that ensuring the structural strength is very important because several cases of structural collapse caused by fatal defects in welded joints. Among the various defects, due to the uncertainties with respect to geometrical type and scatters of the experimental investigation, fatigue performance of welded joints has been categorized as one of the most important issues for the structural integrity of welded joints. Therefore, these have necessitated rigorous evaluations associated with welded joints.

It is evident that there are several crucial influence factors on the welding induced defects including diffusible hydrogen, preheating temperature and residual stresses, etc. Among these factors, it is well recognized that high residual stresses, set up in the region close to the welding, will promote fracture or failure. Residual stress that exists in the welded joints could be regarded as a result of incompatible thermal strain. This residual stress rapidly decreases the fatigue life of welded structures, especially when the tensile stress is close to the yield stress. While accurate predictions of this residual stress are difficult to obtain in practice especially for complex welded structures, it is of crucial importance to consider the effect of residual stress on the fatigue assessment of welded joint. In this study, the simplified predicting method of butt, T-joint, and I-joint welding structures of residual stress based on the inherent strain method is carried out [1]. This method is considered as a time/cost effective method as compared with the experimental method and/or the thermal finite element analysis.

The lifetime of welded structures subjected to cyclic loading consists of two phases: crack initiation and crack propagation to final failure. The problem of crack propagation up to failure of structures has received much attention through development of fracture mechanics. In this framework, the assumption of a pre-existing crack is required to estimate the growth of a crack through the final failure. However, it is difficult to assume the pre-existing crack size in advance. Thus, an effective procedure for life prediction of welded structures based on continuum damage mechanics is proposed [2].

Continuum damage mechanics could describe both crack initiation and propagation in multi-axial loading condition with appropriate failure criteria. For high cycle fatigue, materials do not exhibit such a macroscopic plasticity and damageable behaviour. However, it is considered that plastic deformation and damage occur at microscopic scale. Therefore, a two-scale model is introduced to evaluate the damage evolution at the microscopic scale by using the law of localization of self-consistent scheme [3].

In this study, numerical fatigue damage analysis method for welded structures is developed using inherent strain method and continuum damage mechanics. The residual stress distribution is calculated by inherent strain method and is implemented to welded joint finite element model. The material parameter is identified using thermal finite element analysis coupled with damage [4]. The structural analysis is performed by commercial finite element analysis code and the stress/strain information of weld joint finite element model can be obtained. Based on this information and damage evolution equation, the fatigue damage distribution can be simulated and fatigue life can be predicted.

Numerical fatigue damage analysis result is compared with T-joint welded structures fatigue test results in order to verify developed method. Fig. 1 shows the fatigue damage distribution of T-joint welded structures and Fig. 2 shows the comparison results of Wöhler curve between experiments and numerical analysis. By virtue of the developed method, it is possible to predict the fatigue life of welded structures under the consideration of welding defects.

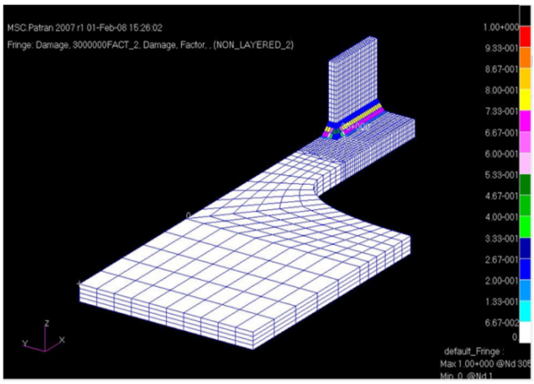

Fig. 1 Fatigue damage distribution of T-joint welded structures

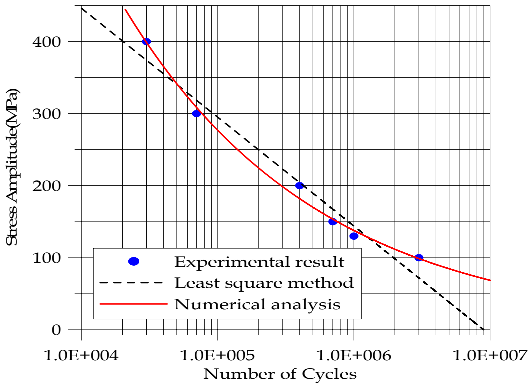

Fig. 2 Fatigue life prediction of T-joint welded structures

REFERENCES

[1] M.G. Yuan and Y. Ueda, "Prediction of residual stresses in welded T- and I-joints using inherent strains", *J. Eng. Mat. Tech.*, Vol. **118**, pp. 229-234, (1996).

[2] J. Lemaitre, *A course on damage mechanics*, 2nd Edition, Springer-Verlag, 1992.

[3] J. Lemaitre, J.R. Sermage and R. Desmorat, "A two-scale damage concept applied to fatigue", *Int. J. Fracture*, Vol. **97**, pp. 67-81, (1999).

[4] C.S. Lee, Y.H. Kim, T.W. Kim and J.M. Lee, "Numerical fatigue test method based on continuum damage mechanics", *J. Kor. Weld. Join. Soc.*, Vol. **1**, pp. 63-69, (2007) (in Korean).