Fatigue behavior of the fillet welded joints under plate bending

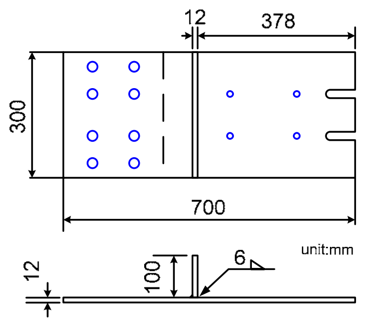
Nagoya University Student Member ○Biehn Baik
Nagoya University Member Kentaro Yamada
Nagoya University Member Toshiyuki Ishikawa

1. Introduction

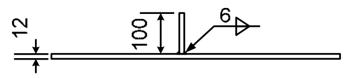
Fatigue cracks have been issued as one of main causes against durability of the welded structures. Some of orthotropic steel deck plates built in the past started raising fatigue problem at their welded joints. It is largely because the increase of heavy vehicle loading causes the flexural deflection of deck plate, then the fatigue crack occurring at the welded joints. Therefore, it is necessary to explore the fatigue crack initiation and propagation at the welded joint under plate bending and evaluate its fatigue strength and life properly. In this study, a fatigue test is carried out on three types of the fillet welded joint, such as single-side fillet welded joint, double-side fillet welded joint and cruciform joint, demonstrated the fatigue crack initiation and propagation behavior of them under plate bending. In addition, 1mm method[1)] is used to evaluate fatigue lives of these welded joints as an analytical approach.

2. Fatigue test of the fillet welded specimens under plate bending

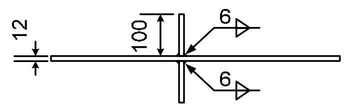
Three types of test specimens have the attachment fillet welded transversely on structural steel plates made of JIS-SM400A. Details of the specimens are shown in Fig. 1. The fatigue test was carried out using a fatigue testing machine[2)] generating a plate bending type of loading. We set up to give the tension pulsating to each specimen by the static preloading. Then, this test was conducted under the stress ratio, R > 0. To monitor stress ranges, all four gages were placed 5mm away from the weld toe. The strain gages, G2 and G4, at the center are selected as the applied stress range indicator. To detect the crack initiation, some copper wires of 0.04mm in diameter were glued on the surface of weld toe. Dye penetrant and beach mark test were applied to shape crack path on the fractured section.



(a) Single-side welded joint (SS)



(b) Double-side welded joint (SD)



(c) Cruciform joint (CR)

Fig.1 Fatigue test specimens

3. Fatigue test result

All specimens failed from cracks developed at the weld toe. These cracks initiated at the weld toe and propagated in the plate width and thickness directions. Fig. 3 shows the fracture surface of each type of specimen. N_{dye} is defined as a number of cycles when fatigue crack is first detected and dye marking is applied. N_f is a number of cycles when specimens failed. From the result, it is found that most fatigue cracks propagated to about 83% of plate thickness before fracture, shaping relatively large semi-elliptical curves. Then, these curves allowed us to figure out how fatigue crack shape varied during the crack growth. Fig. 4 shows the relationship between crack depth and length under plate bending, compared with the past result of similar weld details under tension loading. The ratio of crack depth and length, a/b ranged from 1/5 to 1/2 when crack depth was small. It is then changed to be in 1/20~1/10 when crack depth increased. Therefore, it is proved that the crack propagation behavior is much different between under plate bending and under tension. Fig. 5 shows the relationship between fatigue crack depth and the remained life, corresponding to the nominal stress range, 200MPa. The remained life increased significantly under bending in comparison with the result of under tension during crack propagation. Fatigue life versus the recorded nominal stress range

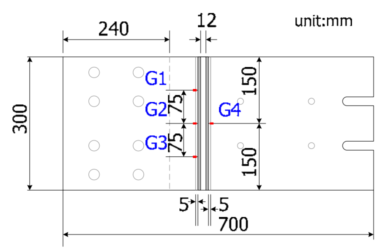
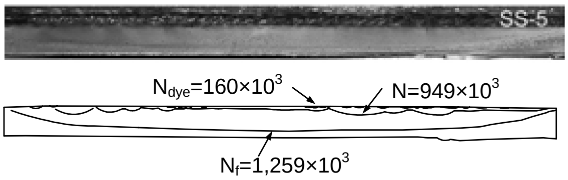


Fig.2 Strain gages location

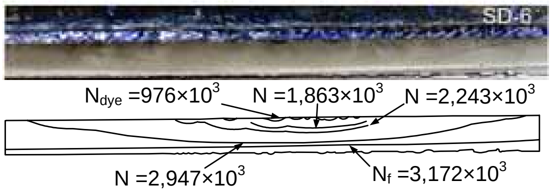
data was plotted on current JSSC specified S-N curves along with the results of previous research on similar details in specimens under tension conducted by Tanaka[3] and Kim[4]. As can be shown in Fig. 6, all weld details exceeded JSSC-D under plate bending. Test data achieved higher fatigue strength than the past result from the test under tension. In addition, all weld details were examined by 1mm method[1] to predict fatigue life and strength under bending. In Fig. 7, the prediction result is in good agreement with the test data of SD and CR types. But, the SS type has to some extent safe prediction for the test result. It is required to examine more about the 1mm method application for the welded joint under bending.

4. Summary

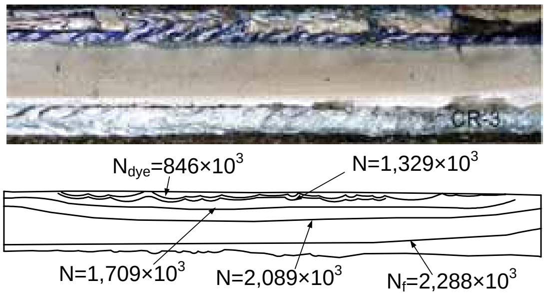
Fatigue test was conducted on three types of fillet welded joint under plate bending and the behavior of fatigue crack initiation and propagation was investigated. Additionally, fatigue life prediction was analyzed by 1mm method. As a result, it is found that the fatigue crack propagation under bending is much different with under tension.



(a) SS



(b) SD



(c) CR

Fig. 3 Fractured surfaces

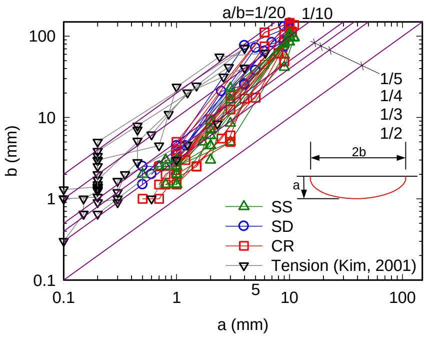


Fig. 4 crack depth (a) and length (b)

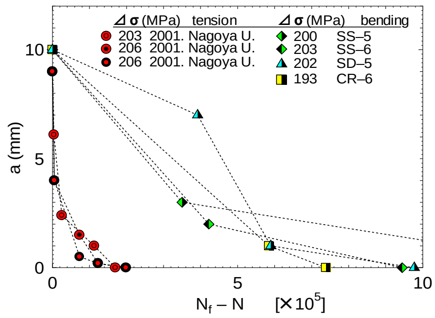


Fig. 5 crack depth and remained life

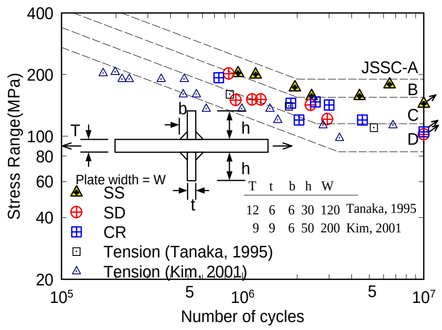
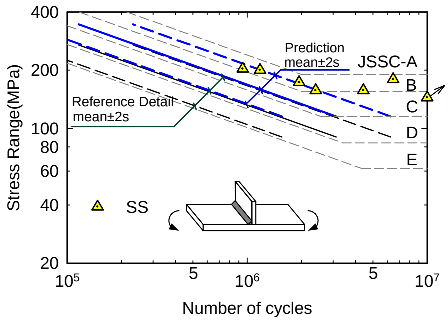
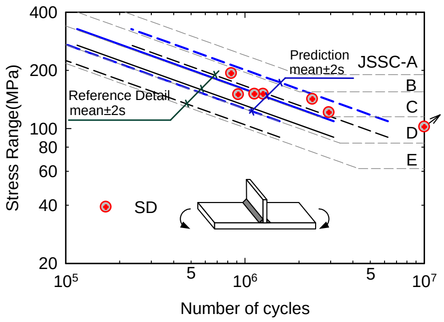


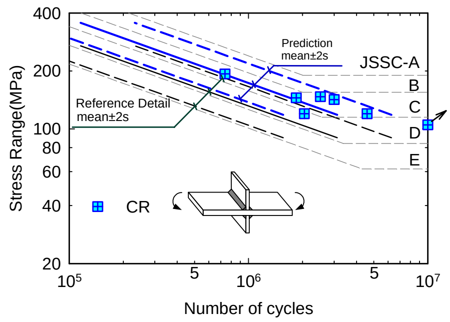
Fig. 6 S-N curves



(a) SS



(b) SD



(c) CR

Fig. 7 Fatigue life prediction by 1mm method for bending

5. References

1) Xiao, Z. and Yamada, K., A method of determining geometric stress for fatigue strength evaluation of steel welded joints, International Journal of Fatigue 26, pp. 1277-1293, 2004
2) Yamada, K., Ya, S., Baik, B., Torii, A., Ojio, T., and Yamada, S., Development of a new fatigue testing machine and some fatigue tests for plate bending, IIW DocumentXIII-2161-07, International Institute of Welding, 2007
3) Tanaka, M., Mori, T., Irube, T., and Miyasita, R., Fatigue strength of non-load carrying one side fillet welded cruciform joints, Journal of Construction steel, Vol.3, pp.403-410, November, 1995 (in Japanese)
4) Kim, I.T., Fatigue of welded joints under combined stress cycles, Doctoral dissertation, Department of Civil Engineering, Nagoya University, Nagoya, Japan, 2000 (in Japanese)