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Fatigue behavior on welded joint for JT-60SA Vacuum Vessel

JT-60SA真空容器の連続プラグ継手の疲労強度

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JT-60SA Vacuum Vessel (VV) has D-shaped cross section and double-walled structure. It consists of the inner and outer wall reinforced by poloidal ribs and is made of SUS316L (Co<0.05wt%) [1-2]. The welding outer wall on rib (so called continuous plug) is performed from the outside of double-wall. Since it is difficult to confirm the penetration bead from the inside of double-wall, an incomplete penetration is assumed to be included in this welded joint. In this study, the fatigue test of continuous plug welded joint with an artificial incomplete penetration was performed to investigate the effect of the incomplete penetration on fatigue behavior and fatigue strength.

1. Introduction

The VV of JT-60SA has D-shaped cross section and double-walled structure to circulate boric-acid water between the walls for neutron shielding. It consists of the inner and outer wall reinforced by poloidal ribs as shown in Fig.1 and is made of SUS316L (Co<0.05wt%).

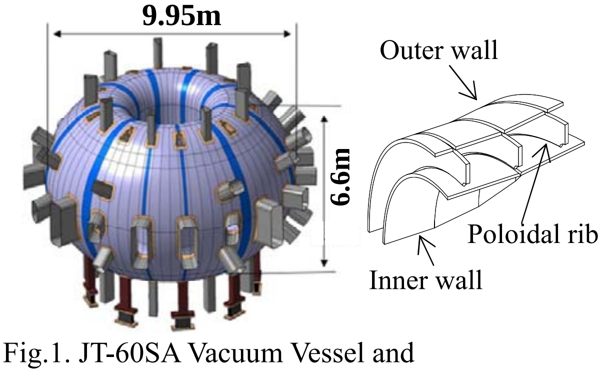


Fig.1. JT-60SA Vacuum Vessel and cross section (Inboard R segment)

The welding of the outer wall on the rib is performed by GTAW(TIG) followed by GMAW(MAG) from the outside of double-wall. Since it is difficult to confirm the penetration bead from the inside of double-wall, an incomplete penetration is assumed to be included in this welded joint (so called continuous plug) that is not qualified in the conventional design standards for a light water nuclear reactor.

In this study, the fatigue test of continuous plug welded joint was performed to investigate the effect of artificially introduced incomplete penetration on the fatigue behavior and strength.

2. Experiment

2.1. Welded joint and welding conditions

The cross-sectional view of the welded joint is shown in Fig.2. The thickness of the outer wall and rib were selected as 18mm and 22mm, respectively in accordance with the actual VV. The material of the specimen was SUS316L without control of cobalt content. The welding conditions are presented in Table I. The welding condition of GTAW was adjusted to produce incomplete penetrations on both sides of the rib.

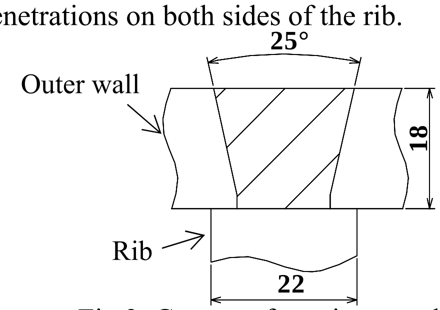


Fig.2. Groove of continuous plug

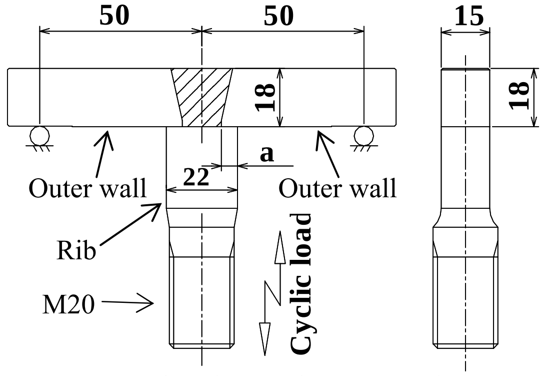
Table I. Welding conditions (Flat position)

Process	Pass	Current [A]	Voltage [V]	Consumable
GTAW	1	200-300	10-15	Y316L
GMAW	2-last	140-200	24-30	TS316L-FC1

As the results of PT and RT, defects were not detected in the weld metal.

2.2. Fatigue test

Test configuration and the specimen are shown in Fig.3. The length of the incomplete penetration, which is shown as “a” in the Fig.3, is ~ 3.0mm at the most because of its maximum wrap length between outer wall and rib.



“a”: Length of incomplete penetration

Fig.3. Configuration of fatigue test

Both sides of the outer wall was supported symmetrically and cyclic load was applied to the rib at the frequency of 5Hz by the triangular wave form. Produced shear stress near the tip of the incomplete penetration was estimated by introducing Tresca stress at the state of plane stress to evaluate fatigue strength. Crack growths were measured in a microscope.

Table II. Fatigue test conditions

#	Applied Stress σmax [MPa]	Eq.amplitude Saeq [MPa]	Stress ratio R
Case1	453.5	222.2	0.02
Case2	340.1	166.6	0.02
Case3	226.7	111.1	0.02

As is shown in Table II, three combinations of applied stress and equivalent stress amplitude were selected as the test conditions. As crevice-like incomplete penetration was closed by the residual stress of welding, a crack initiation life was evaluated, instead of a fracture life, as fatigue strength. The cycle when a crack observed in a microscope reached to 0.5mm was defined as crack initiation.

3. Results

The crack propagation through the weld metal is presented in Fig.4. In this case, “a” is ~ 2.5mm. As the crack propagates in mixed mode, curving appears and the bending stress mainly contributes to the crack propagation in this test configuration.

Obtained data of crack initiation lives from six specimens for each test condition are plotted in Fig.5. Compared with the design fatigue curve quoted from JSME S NC1, all data are above the fatigue curve which relates one fourth of the stress amplitude with the number of cycles. Therefore the fatigue strength reduction factor K_f is evaluated about 4.

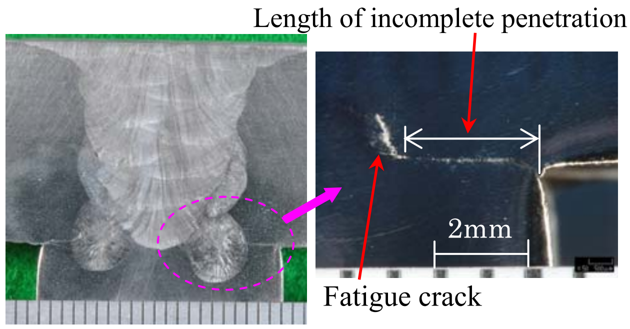


Fig.4. Macroscopic cross-section (Case1)

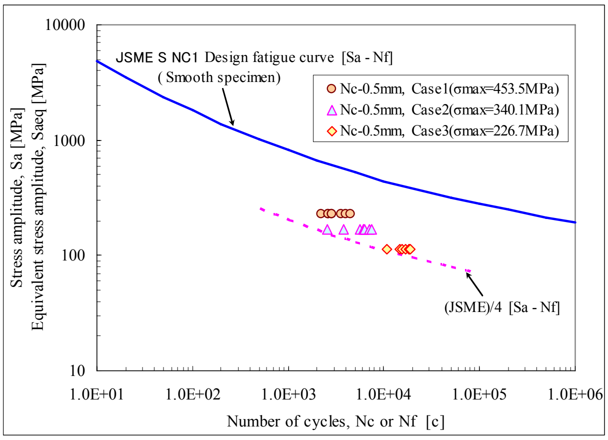


Fig.5. Comparison of experimental data with design fatigue curve (JSME S NC1)

4. Summary

The fatigue test of continuous plug welded joint was performed to investigate the effect of artificially introduced incomplete penetration on the fatigue behavior and strength.

The fatigue strength reduction factor K_f was evaluated about 4.

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