Change in Residual Stress by Ordering Treatment and Isochronal Annealing Treatment in CW Alloy 600

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1. Introduction

It is understood that the ordering reaction occurs below 520°C in Alloy 600 [1, 2]. It is reported that the ordering treatment have shown a retardation effect on PWSCC initiation in Alloy 600 and Weld 182 [3].

It is curious how this effect has occurred, since the ordering treatment temperature is too low to cause annealing effects. That effect of PWSCC initiation may come from both the effect of elimination of lattice contraction in primary water environment and the decreasing effects of residual stress. This is not easy to separate clearly.

The change in residual stress by an ordering treatment and an isochronal treatment in cold worked Alloy 600 is measured systematically by XRD.

2. Experimental procedure

An HTMA Alloy 600 tube is flattened and cold rolled by 10%. The cold worked specimens were cut to be about 40 mm long, and were vacuum sealed using Pyrex and quartz tubing to conduct an ordering and an isochronal annealing treatment. The ordering treatments were carried out at 480°C, and the isochronal annealing treatments were conducted at 480 ~ 800°C for 2 hours. All specimens were air-cooled after heat treatments. The specimen surface was electro-polished to remove oxide formed during heat treatment. The surface color changed after heat treatment, even though those specimens were vacuum sealed before heat treatment.

CuKa source were used to measure the residual stress measurement. In order to determine the residual stress, (331) diffraction measurements were done in 13 tilt angles along the tangential direction. The variations in full width half maximum (FWHM) were measured to examine the annealing effect during the isothermal and the isochronal heat treatments.

3. Results and discussion

The residual stress variation according to the ordering treatment at 480 °C is shown in Fig. 1. The residual stress is decreased by 80 MPa in the axial direction, but negligible in transverse direction.

The measurement n residual stress is to measure the spatial variation of a certain lattice plane, if simply explained. Then, the lattice strain is calculated using a stress free spacing. The trend of the strain variation according to tilt angle was calculated. A strain in the tangential normal plane was calculated from the trend. Then the residual stress is determined using the strain.

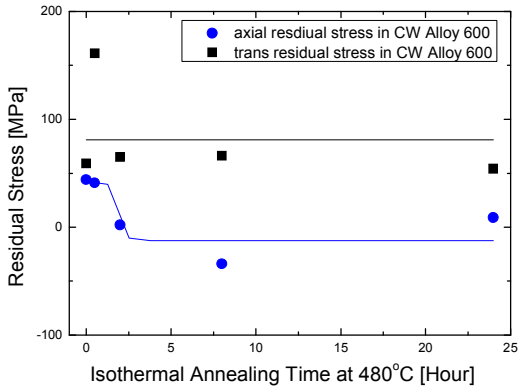

Fig. 1. Change in residual stress with an ordering treatment time at 480°C.

The retardation effect of PWSCC by the ordering treatment may be due to the reduction in residual stress in CW Alloy 600 and Weld 182. However, the ordering reaction causes lattice contraction in Alloy 600 and Weld 182 [3]. Therefore, the decrease in residual stress by the ordering treatment is not clear, since the ordering reaction causes a lattice contraction and this lattice contraction should reduce the residual stress. On the other hand, it is clear that the PWSCC retardation effect is related to the ordering reaction, because it is understood that the temperature of isothermal treatment at 480 °C is relatively low to provide the annealing effect in Alloy 600

Meanwhile, it is reported that the stress produced by the lattice contraction due to the ordering reaction was calculated to be 40 ~ 150 MPa according to the angle between grains. This can be doubled by the combination of neighboring grains [3]. The decreasing magnitude of residual stress by the ordering reaction is 1/2 ~ 1/4 of stress formed. This ratio seems to be small. However, this may be important, since this reduces the level of effective stress.

It is confirmed that the cold work in Alloy 600 lowers the ordering temperature from 450 °C to the 100 ~ 300 °C region. It is expected that the ordering reaction below 500 °C does not remove all defects formed by cold work and the ordering reaction rearranges the distribution of short range order (SRO) recovers the unfavorable bond mainly. This means that the fact of the existence of the ordering reaction in Alloy 600 is more important than the effect of cold work. It is concluded that all possibility of these variations happening in Alloy 600 at this lower temperature range is due to the existence of the ordering reaction.

The lattice defect formed by cold work is effectively removed by the annealing treatment at higher temperature, since the rate of the atomic movement can be increase exponentially with temperature.

The quantity of lattice defects can be measured simply by full width half maximum (FWHM) using the XRD. It is known that the number of defects is proportional to the lattice strain.

The changes in FWHM parameter in the isothermal and isochronal temperature are shown in Figs. 2, and 3, respectively. The square of FWHM in the axial and the transverse direction is plotted, they are very similar. The relative ratio based on cold work state in both directions is plotted. The ratio is decreased by up to 0.8 by isothermal annealing. This means that there is a certain annihilation effect during the ordering treatment.

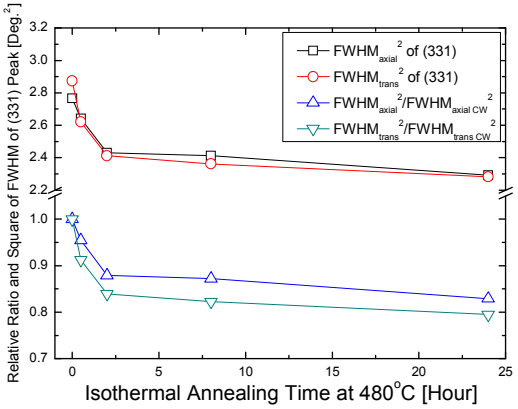

Fig. 2. Change in FWHM^2 and its ratio by an ordering treatment.

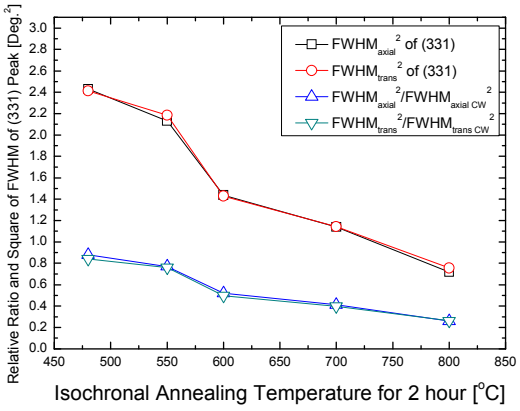

Fig. 3. Change in FWHM^2 and its ratio by an isochronal annealing treatment for 2 hours.

The ratio is decreased by up to 0.2 at 800 °C by isochronal annealing for 2 hours. The decreasing trend is pronounced above 600 °C. It seems that the disordering reaction occurs above at 600 °C in Alloy 600.

The residual stress variation is shown in Fig. 4. The residual stress increased with annealing temperature, unexpectedly. This increasing trend is pronounced above 600 °C. The annealing above 600 °C causes the disordering reaction. This expands the lattice plane by the disordering reaction and the thermal expansion. Therefore, the residual stress appeared to increase. It is understood that the lattice defects are annihilated during the isochronal annealing, as shown in Fig. 3.

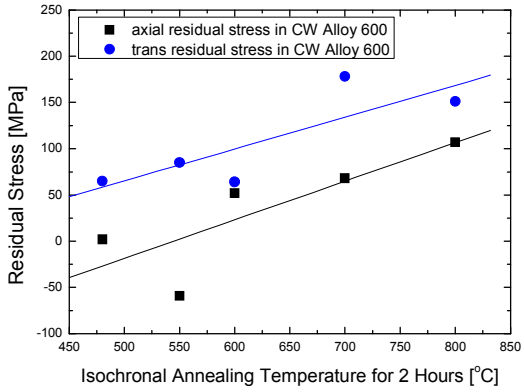

Fig. 4. Change in residual stress by an isochronal annealing treatment for 2 hours.

4. Conclusions

The decreasing magnitude of residual stress by the isothermal treatment is 1/2 ~ 1/4 of stress formed during the ordering treatment. It is not clear now that the PWSCC retardation effect is due to the ordering reaction or reduction in residual stress, since both effects occurs simultaneously. However, it is concluded that all possibility of these variations happening in Alloy 600 at this lower temperature range is due to the existence of the ordering reaction. The increase in residual stress by the isochronal annealing treatment seems to be due to the lattice expansion by the disordering above 600 °C or the residue of thermal expansion during annealing.

ACKNOWLEDGMENTS

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