F. The Microstructure Characterization of Synchronous Vibratory Welding

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Introduction

The application of vibration during casting and welding had been studied before. These researches showed some benefits on the workpiece, such as lower distortion, finer grain, and dendrite fragmentation, which may possess better mechanical properties when vibration applied during solidification. Previous studies seldom considered the effect of phase transformation due to the change of G/R. For concerning about the phase transformation, AISI 304 stainless steel was chosen in the study. The existence of δ-ferrite in 304 austenite stainless steel is a result of composition and temperature gradient variations. If vibratory force was applied in the metal liquid, the reduction of composition variations, lower G/R, and δ-ferrite content was expected.

Procedure

The material used was as-received AISI 304 austenitic stainless steel plate. In order to have the same cooling rate in each specimen, a steel plate with a relative large area, and a relative small welding current was selected. The plate measured 70mm long x 25mm wide and was 3mm thick. Specimens were welded using the GTAW process without filler metal, the welding current was 60A, voltage 9V, and the traveling speed was 96mm/min. Additional parameters were tungsten rod, 2.4 mm diameter, protective argon gas, 15 IPM; and the pre-weld cleaning was done with acetone. Before deciding the vibratory frequencies for the synchronous vibratory welding, the welding table was vibrated continuously for 20 minutes until the system reached a stable natural frequency. Then the harmonic curve was measured. The sub-resonant frequency was 39.4Hz and the resonant frequency of the welding system was 43.3 Hz.
The specimens were welded while being subjected to 0, 20 (low frequency), 39.4 (sub-resonant), 43.3 (resonant), and 60Hz (high frequency) vibration respectively.
For making both the primary as well as specific secondary structures visible, LB1 (0.5g $K_2S_2O_5$, 20g $NH_4F{\cdot}HF$,100ml) color etching was used.

The residual δ-ferrite content was measured by X-ray diffraction. It is easy to measure δ-ferrite content by measuring the ratio of δ andγ peak intensity. X-ray scan from 42~47°(2θ), scan speed 0.5° per minute.

Results and Discussion

In this study, a synchronous vibratory welding was made by GTAW process without filler metal and welding with specific vibration frequencies. The results showed the use of synchronous vibratory welding can decrease the δ-ferrite content, which was measured by the ferrite scope and X-ray diffraction. Even if the welding cooling rate is so fast but synchronous vibratory welding actually reduces the δ-ferrite content, it is due to the applicable vibration can educe Cr diffuse into γ-phase. Without vibration, the diffusion coefficient inγ-phase is lower than in δ-ferrite by a factor of 100. The decrease of the segregation reduced the residual δ-ferrite content. On the other hand, the smaller δ-ferrite grain size shows the dreasing of G, because they have the same cooling rate.

Conclusions

Under fixed welding conditions, vibrations level down the content of non-equilibrium phase and make an uniform composition. By depressing liquid temperature gradient G, and local cooling rate R, the synchronous vibratory welding decrease the δ-ferrite grain size and the constitutional supercooling of welding pool. Among the vibration frequencies of 20, 39.4, 43.3, and 60Hz, the residual δ-ferrite content was the lowest and the grain size was the smallest at 39.4Hz. Grain refinement, uniform composition of weldment, and residual stress relief, can be observed as welding with vibration technique.