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Improving the Weldability of Nickel-Based Superalloy by High Frequency Vibration

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Abstract

The objective of this paper is to discuss the weldability of Mar-M-004 nickel-based alloy by simultaneous proceeding vibration. Three kinds of vibration modes were chosen to compare the results, including high frequency vibration, subresonant and without vibration. We used x-ray diffraction (XRD) to quantize the residual stress of each sample, also the microstructure and crystal structure were investigated by using optical microscopes.

The results showed that the grain size will get refined after vibration welding, especially in high frequency vibration. From XRD and microstructure results, by using the high frequency vibration method, there has a significant effect of having lowest residual stress and lowest stress relaxation; furthermore, the formation of cracks was also inhibited and having the shortest crack length.

Keywords: vibratory stress relief, residual stress, welding crack, nickel-based superalloy, high frequency vibration

1. Introduction

Nickel-based alloy has the properties of high strength and high corration resistance in high temperature [1]. However, Mar-M-004 nickel-base superalloy contains high levels of titanium and aluminum. While cooling after welding, a large number of γ 'phase will be precipitated, and produce large shrinkage stresses, which will result in cracking and having poor weldabilities [2].

Vibratory stress relief (VSR) is effective in reducing the residual stress, prevending deformation and increasing the material's strength. Furthermore, it has advantages of energy saving, without pollution, low cost, high efficiency and easy to operate [3].

Besides, simultaneously apply the vibration force while welding, which can properly increase the atoms' mobility in high temperature, will have a better effect of stress relief and refine the microstructure [4].

Bonal Corporation has developed a technique of subresonant vibration, which uses the frequency of 1/3 of resonant amplitude to do VSR. This discusses have got the world wide adoption,also been recognized in the papers published[5].

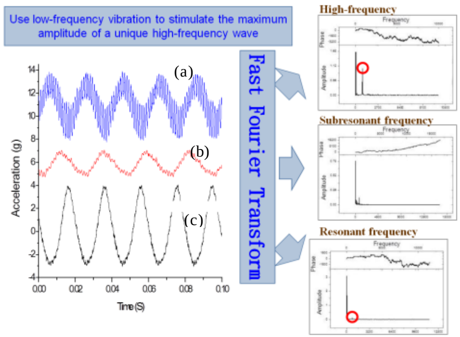

Fig. 1 Waveforms and spectrums of different VSR modes, (a) high frequency vibration (b) subresonant (c) resonant

We have developed a new approach of high frequency vibratory stress relief, which use a low-frequency wave to stimulate a high frequency complex waveform. Thus, this technique has been proved to be more effective to promote local dislocation movement and reduce the residual stress [6].

2. Method

This experiment is the use of Nd: YAG laser welding simultaneously input vibration to fill

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blind holes. Both the filler and the base material are Mar-M-004 nickel-base superalloy.

As Fig. 2, the VSR apparutus composed of a vibration motor input a vibration wave to the workpiece and scaning the operating frequency of different VSR modes.

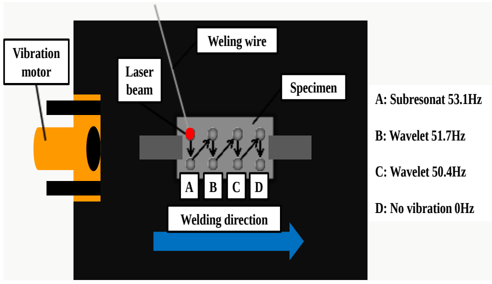

Fig. 2 Schematic of vibration welding process

2.1. Processing Steps

(1) Scanning the spectrum, subresonant and high frequency point of the workpiece.

(2) Using subresonant53.1Hz, high frequency 51.7Hz 50.4Hz and without vibration to do simultaneous vibration welding.

(3) For each vibration modes, fill two blind hole on the nickel-based alloy plate.

2.2. Sample Analysis

(1) Using Cr-XDR to measure the residual stress value.

(2) Using OM and SEM to observe the micro-structure.

3. Results and Discussion

From Fig. 3, the residual stress in weld bead is highest without vibration and lowest while using high frequency vibration, also, by cutting the weld bead to relax the stress.

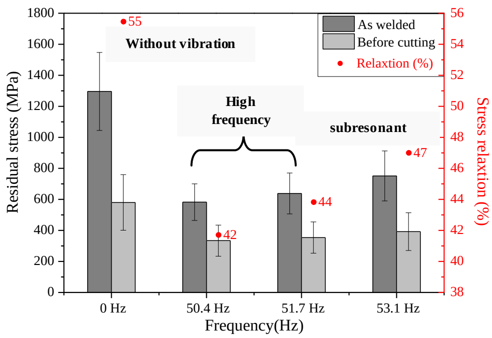

Fig. 3 Vibration modes-residual stress diagram

Fig. 4 shows the microstructure of the weld bead. While using high frequency vibration welding, there has the least cracks in fusion line and the shortest crack's length in fusion zone.

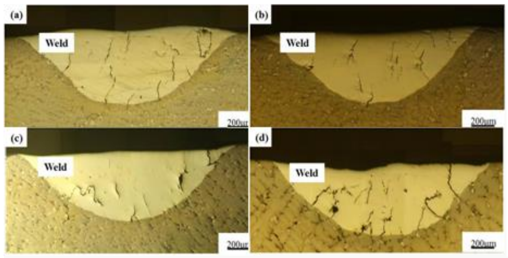

Fig. 4 Bead cross-section (a) no vibration 0Hz (b) high frequency vibration 50.4Hz (c) high frequency vibration 51.7Hz (d) subresonant 53.1Hz

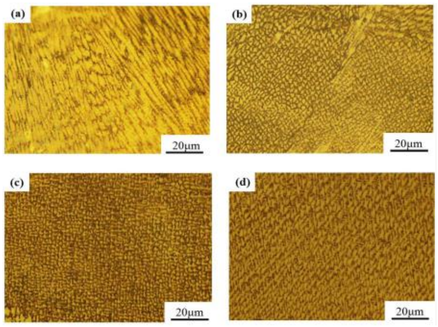

Fig. 5 Microstructure of weld bead (a) no vibration 0Hz (b) high frequency vibration 50.4Hz (c) high frequency vibration 51.7Hz (d) subresonant 53.1Hz

As the crystal structure in Fig. 5, vibration welding can form equiaxed dendritic grains in contrast to the columnar dendritic grains without vibration. It represent that the solidification and cooling rate are faster, and have the better grain structures. Furthermore, the high frequency vibration can form a optimum structure as compare with other vibration methods.

4. Conclusions

Summarize the total results, high frequency vibration welding possessed grain refinement, lowest residual stress and reduce the cracks, which can effectively get a better mechanical properties and weldability of nickel-based super alloy.

Acknowledgement

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