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Harmonic Imaging and Thickness Measurement of Thermal Spray Coating by Immersion Local Resonance
水浸局部共振高調波法を用いた溶射皮膜の厚さ測定と内部散乱波源の可視化

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1. Introduction

Thermal spray coating (TSC) is widely used for temperature and oxidation protection of gas turbine components, and corrosion and wear protection of various mechanical components. The TBC generally contains many voids and oxides and imperfect bonding at TBC/base metal interface, therefore, nondestructive evaluation of TSC is indispensable. The disbonded area is visualized by thermography technique, however, voids and oxides are not imaged. By the conventional ultrasonic technique, disbonded area is also visualized, however, the technique fails to visualize the interface between TBC and base metal, the change in void density after re-heating, and other anomalies in TBC.

Higher harmonic imaging (HHI) technique which detects the waveform distortion of the scattered wave at defects within metals by transmitting large amplitude sinusoidal burst wave has been proved to have high sensitivity for nonmetallic inclusions [1] in continuously cast steel slab and local plastic deformation around a circular hole [2] and the plastic zone at fatigue crack tip [3].

In this study, we apply the HHI technique for visualizing the TBC/base metal interface and the change in void density after fusing. In addition, the thickness of TSC is estimated by the change in through-thickness resonance frequency.

2. Experimental

As shown in **Fig. 1**, the incident sinusoidal burst wave is severely deformed at the partially closed crack [4] like the oxides and TSC/base metal interface. This waveform distortion is expressed by higher harmonics in frequency domain. By using selectable analog high-pass filters, we capture the higher harmonics of any order of interest. To visualize the small defects and to measure the TSC thickness, we used an immersion HHI system shown in **Fig. 2**. A through-thickness local resonance technique shown in **Fig. 3** and the angle beam technique were used for thickness measurement and imaging defects, respectively.

A sinusoidal tone-burst wave pulser, RITEC RPR-4000, was used for transmission and reception of ultrasonic waves. For imaging the void density, a focused transducer with a diameter, central frequency and focal length of 6 mm, 30MHz, 25mm, respectively was used. A 60MHz analog high high-pass filter (HPF) is inserted in the reception circuit. Another focused transducer with a diameter, central frequency and focal length of 9.6 mm, 5MHz, 76mm, respectively, was used for the local resonance technique.

Two kinds of TSC samples are tested; Ni based self-fluxing alloy and WC-10Co-4Cr by high Velocity oxygen fuel (HVOF) method. The former coating thickness is 0.5, 1.0 and 1.5mm. The latter thickness is 0.5mm. These coatings are formed on carbon steel plate of 20mm in thickness.

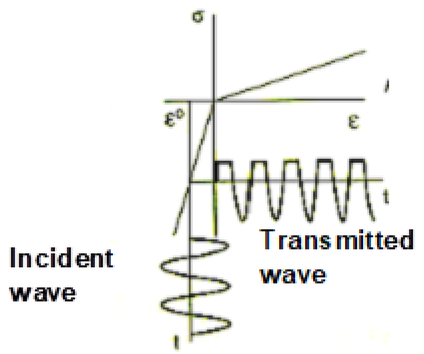

Fig.1 Waveform distortion at closed cracks [4].

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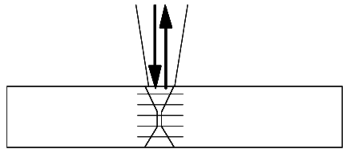


Fig.2 Through-thickness local resonance.

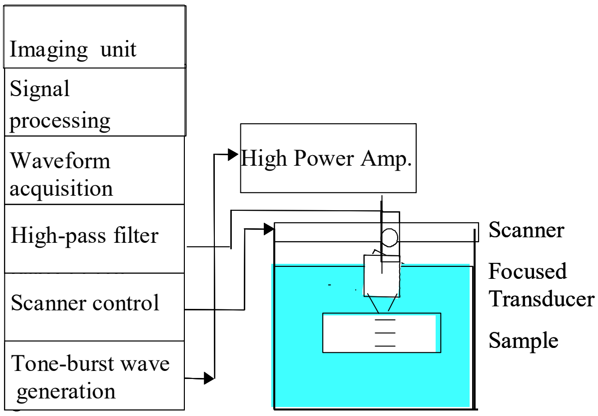


Fig.3 The immersion HHI system.

3. Harmonic images and thickness measurement

The third harmonic images and cross section micrographs of Ni based self- fluxing alloy before and after fusing treatment are shown in Fig. 4. Before the fusing treatment, HHI shows high density of scattering sources due to many voids and oxides. After fusing, some of them disappear, thus the density of the scattering sources in HHI is markedly reduced.

The disbonded area at WC-10Co-4Cr TSC /base metal interface is shown in Fig. 5. With tone burst wave of 2.77MHz and 22 cycles, local resonance amplitude with 8MHz HPF are mapped. The yellow area is well bonded, while green and blue areas are partially disbonded. The cross section macro image has good correlation with HHI.

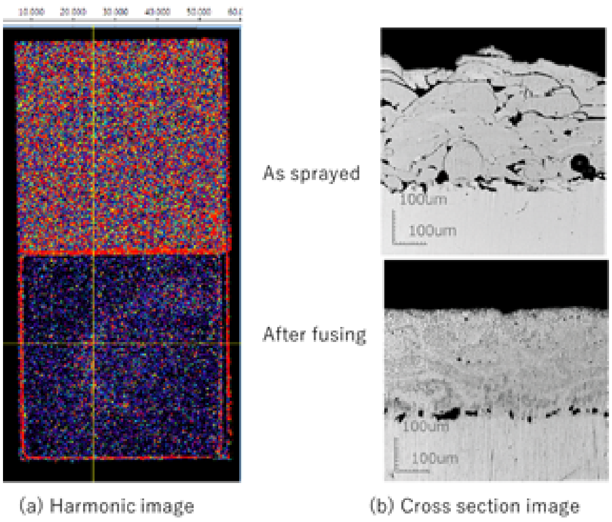
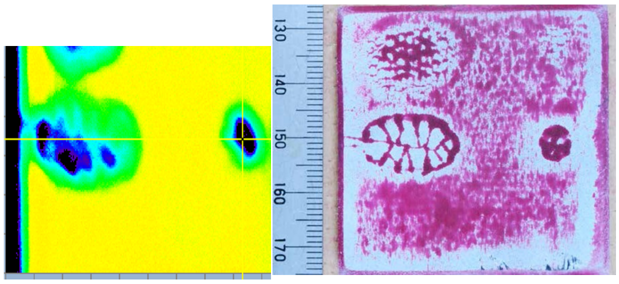


Fig.4 HHI and micrographs of Ni based self-fluxing alloy before and after fusing.



(a) Resonance HHI (b) cross section image

Fig. 5 Image of WC-10Co-4Cr TSC defects.

The relation between TSC thickness and resnance frequency is shown in Fig. 6. By sweeping resonance requency for each TSC thickness, the frequency of a maximum amplitude is measured. The resonance freqency shows good correlation with the thickness. The red lines shows scattering amplitude at the resonance frequency of 3.3 MHz.

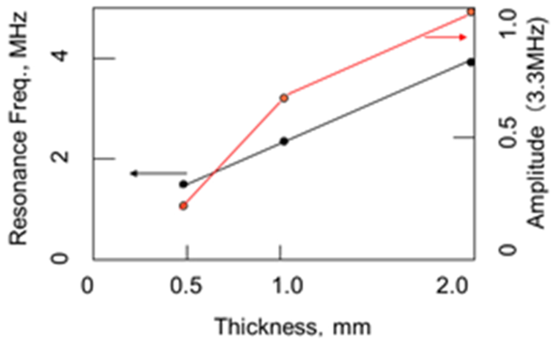


Fig. 6 Change in resonance frequency with thickness.

4. Conclusion

With immersion higher harmonic imaging together with local resonance technique, the density change in void and oxides after fusing in Ni based self-fluxing alloy is clearly imaged. The TSC thickness could be estimated by resonance frequency .

References

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