Nondestructive Evaluation of a Be/Cu Diffusion Bond using a Shear Horizontal Wave

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1. Introduction

The International Thermo-nuclear Experimental Reactor (ITER) blanket first wall includes Beryllium(Be) amour tiles joined to a CuCrZr heat sink with stainless steel cooling tubes. This first wall's panels are one of the critical components in the ITER which is exposed with a surface heat flux of 0.5 MW/m^2. As a qualification program, ultrasonic test (UT) of a Be/CuCrZr diffusion bond has to be applied according to the proper procedure. Ultrasonic test can detect the presence of unbonded regions and is based on an amplitude change and a phase inversion in a signal reflected from a bond interface. [1]

The purpose of this study is to investigate the feasibility of EMAT (Electro-Magnetic Acoustic Transducer) technology for an in-situ inspection of a Be/Copper alloy joining interface under a high temperature and high radiation environment.

2. Preparation, Method and Results

Mock-up for the first wall of an ITER was fabricated by a Hot Isostatic Pressing (HIP) with Be of a S-65C grade, CuCrZr and SS316L. Dimensions of the mock-up is 80mm long, 80mm wide and 85mm thick including 10mm of the Be tile and 22mm of the Cu alloy. This mock-up was tested under a high heat flux (HHF) and damaged. Due to a hazardous Be tile, a sealed vinyl was applied in order to protect the environment. A photograph of a mock-up is shown in Figure 1. Large delaminated defect was found at the upper side of the square area and the lower side could be evaluated to be a good bonding region. [2]

Fig. 1 Photograph of the sample

2.1 EMAT Measurement of the Be/Cu diffusion bond

EMAT transducer consisted of a permanent magnet with 3500 Gauss and a pan-cake coil was connected to a high power ultrasonic gated amplifier system RPR-4000 with 8 kW tone burst signal to obtain the maximal output power. EMAT measurements were performed with an ITER first wall mock-up using with a personal computer having an internal analog/digital converter board and a four axis motion control board, and a three-axis scanning tank..

EMAT transducer used for this experiment is a self fabricated sensor having a center frequency of 2 MHz (nominal), a coil diameter of 22 mm with a protective layer.

A typical EMAT waveform is shown in Figure 2, representing shear horizontal (SH) waves into the target material through a surface movement for a wall thickness measurement of a 10 mm Be plate at a delaminated position.

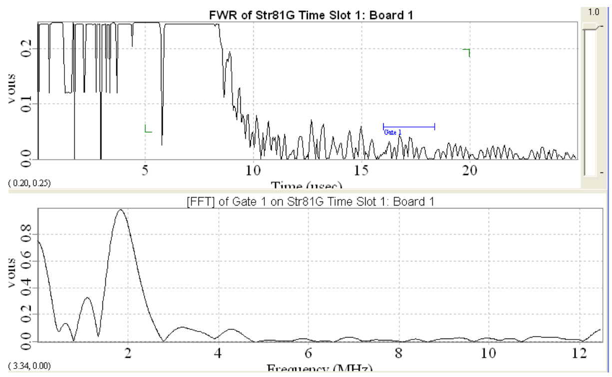

Fig. 2 Typical zoomed waveforms at a delaminated position

2.2 C-scan Image of a Be/Cu diffusion bond

In order to construct a C-Scan image, a manual scan is needed because of the many noises from the step motors. C-scan image with a low resolution was made in figure 3 which is similar to the ultrasonic image of the referenced paper. [2]

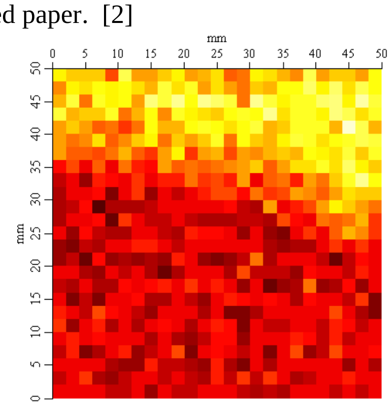

Fig. 3 EMAT C-scan image of the sample

2.3 Test Results

Figure 3 shows that the EMAT ultrasonic signals from the bad bonded region were characterized with a higher amplitude than that of a good bond. This is the same characteristics as the longitudinal ultrasonic techniques. This problem can arise where there is a kissing bond. In this case, a compressive wave would be able to penetrate the defective interface. One advantage of using an EMAT in such a measurement is that there is a total reflection at a kissing bond interface which is not under compression. [3]

Another feature of the EMAT signals showed multiple peaks in the frequency domain from the bad bonded region. This shows the thickness mode resonances with a 430 kHz interval which is related to the Be thickness of 2.3 μ sec as shown in figure 4. A SH wave can provide an effective tool to detect a debonding due to its property of a full transparency of an interface. [2]

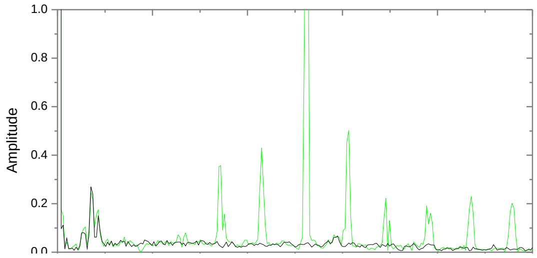

Fig. 4. Signal Spectrum at the good bond and delaminated position

3. Conclusions

The EMAT technique which provides a good penetration through a good bond interface and many reflections from a bad bond interface is a convenient inspection method for detecting a defect in a diffusion bond layer in spite of a lower conversion efficiency. EMAT can produce a SH wave with ease which is a more sensitive probe of an interfacial condition than the conventional longitudinal waves that are generated and detected by contact probes. EMAT is also needed to increase the sensitivity and resolution for an application to an ITER first wall qualification and an in-service inspection.

Acknowledgements

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