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Subharmonic Ultrasound Generation Depending on Crack Opening and Incident Wave Amplitude

き裂開閉口と入力超音波変位によるサブハーモニックの発生挙動

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1. Introduction

Ultrasonic inspection has been needed for quantative evaluation for industrial aging structures. However accurate crack tip detection is sometimes difficult especialy for a closed crack due to the residual stress [1] or for a complicate shape of Stress Corrosion Crack (SCC). To improve the identification of crack tip, subharmonic wave mesurment and SPACE have been expected as new reliable inspection techniques[2].

So, in this study, several kinds of fatigue cracks were introdused in three kind of steels (JIS SCM440, SUS304 and S50C), with different stress conditions, and subharmonic wave behavior depende on inicident wave amplitude have been investigated.

2. Materials and test specimen

The materials used in this study were, SCM440, SUS304 and S50C. Vickers hardness HV of materials was 230, 170 and 220, respectively. Specimen configuration was shown in **Fig. 1**. Fatigue crack was introduced in single edge notched bend specimens and its length was 20 [mm]. Fatigue cracks introduced in several ΔK value in order to research relation between crack opening and incident wave amplitude. ΔK [MPam$^{1/2}$] and HV used were shown in **Table I**.

3. Experimental setup

Subharmonic(ω/2) and fundamental(ω) wave image were measured by SPACE system imdependently. For the comparison of subharmonic signal intensity affected by crack opening level, test specimens were under bending load in measured by SPACE system. Band pass filter was used as digital filter. 4.0-6.0MHzBPF and 2.0-3.0MHZBF were used in ω and ω/2 images, respectively. Maximum stress intensity factor for crack opening was called as K_{max} [MPam$^{1/2}$] in this study. The crack opening becomes longer as increasing K_{max}.

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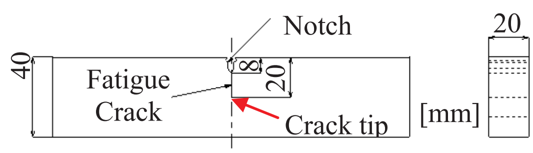

Fig. 1 Specimen configuration

Table I. HV and ΔK for crack growing

Material	HV	ΔK[MPam$^{1/2}$]
SCM440	230	20
		17
		14
		12
		10
		9
SUS304	170	12
		11
S50C	220	12

Therefore several conditions between crack opening and incident wave were obtained from one fatigue crack specimen. It is useful for reducing test sample amount. In this study, exciting voltage was 1000[V] in order to generate large incident wave amplitude. Fundamental frequency, exciting voltage, Exciting waveform, and wavenumber were shown in **Table II**. Mesurement system was shown in **Fig. 2**

Table II. Experimental condition of incident wave

Exciting voltage	1000[V]
Fundamental frequency	5[MHz]
Exciting waveform	Burst
wavenumber	10

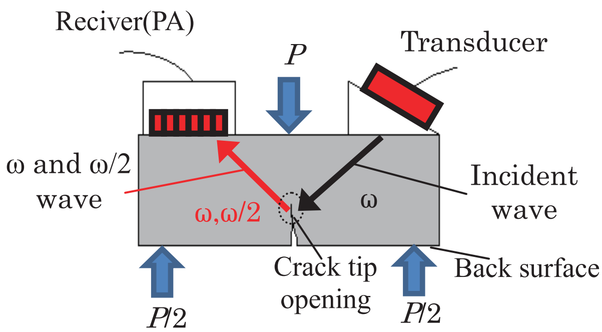

Fig. 2 Schematic illustration of measurement system

4. Results and discussion

Fig. 3 shows the ω and ω/2 signal intensity images of the SUS304 test specimen using SPACE system when stress intensity at crack tip was K_{max} = 0 [MPam$^{1/2}$] and 1.50[MPam$^{1/2}$], respectively. When K_{max} = 0, ω/2 signal was not obtained. On the other hand, ω signal was obtained. The distance from buck surface to crack tip seemed to be 18.03 [mm] from ω image. When K_{max}= 1.50[MPam$^{1/2}$], ω/2 signal was obtained. Distance from buck surface to crack tip from the ω/2 image was 19.46 [mm]. it was longer than the distance from buck surface to the point of fundamental wave signal obtained. However it also may be affection of the incident wave which has subharmonic frequency. Therefore wavelet transformation was also used to these results. **Fig. 4** shows results of wavelet transformation image. When K_{max}= 1.50[MPam$^{1/2}$], subharmonic wave ingredient was confirmed. Therefore, point of closed crack tip could be obtained due to crack opening in this condition. On the other hand, when K_{max} is bigger than 2.25[MPam$^{1/2}$], ω/2 ingredient was not obtained at crack tip of SUS304. The other materials, SCM440 and S50C cannot be obtained ω/2 signal in several condition. It means the condition to generate subharmonic ultrasound is depending on material properties which are not only hardness. However, in this study, exciting voltage was fixed 1000[V]. When a voltage used for generating amplitude of incident wave is higher than 1000 [V], it expected that relationship between crack opening and amplitude was expected to be changed.

5. Conclusion

Relationship between crack properties and incident wave was discussed. We obtained following conclusions.

1. Subharmonic wave signal was only observed at the crack tip of SUS304 when stress intensity factor range for fatigue crack growingΔK was12 [MPam$^{1/2}$] and maximum stress intensity

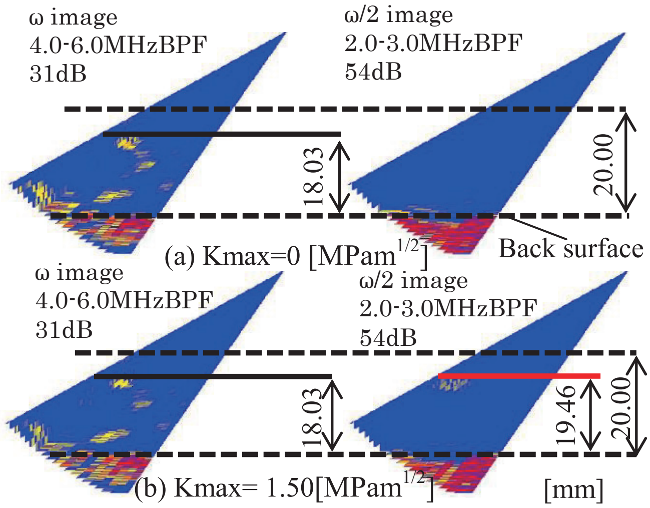

Fig. 3 Fundamental and subharmonic images of SUS304 (ΔK =12 [MPam$^{1/2}$])

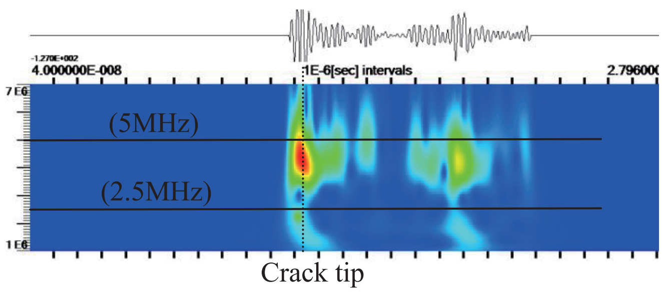

Fig. 4 Wavelet transformation imaging of SUS304(ΔK =12[MPam$^{1/2}$] and K_{max} =1.50[MPam$^{1/2}$])

factor K_{max} is 1.50[MPam$^{1/2}$]. It means specific distance between crack surfacesis needed to generate subharmonic ultrasound.

2. Subharmonic wave signal was not obtained in SCM440 and S50C specimens. It means the condition to generate subharmonic ultrasound is also depending on material properties.

Acknowledgment

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