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DIAGNOSIS OF FATIGUE CRACK PROPAGATION BY DETAIL ECHO WAVE ANALYSIS

Kitami Institute of Technology Student Member Muhammad S. Rahman
Kitami Institute of Technology Member Mikami Shuichi
Japan Steel Works Ltd. Member Tanaka Hideaki
Kitami Institute of Technology Fellow Toshiyuki Oshima
Kitami Institute of Technology Student Member Takada Naoyuki

1. INTRODUCTION

Nondestructive testing methods provide unique diagnosis capabilities for structural integrity of steel structures. Methods to assess fatigue damage in structures are well developed, whereas study about fatigue damage due to crack propagation by echo wave analysis is much more limited. Detection of fatigue crack propagation is essential for rehabilitation and maintenance of today's highly developed infrastructure. Objective of our research can be stated as- (a) Monitoring of fatigue crack propagation by ultrasonic scanning (b) Detecting nature of micro-structural change around crack tip due to stress concentration (c) Conformation of initiation and propagation of crack which could not be visible from outside by detail wave analysis and (d) Visualization of fracture process zone for 3-D crack analysis. We also worked to investigate ultrasonic technique for flaw detection under painted surfaces without removing the paint.

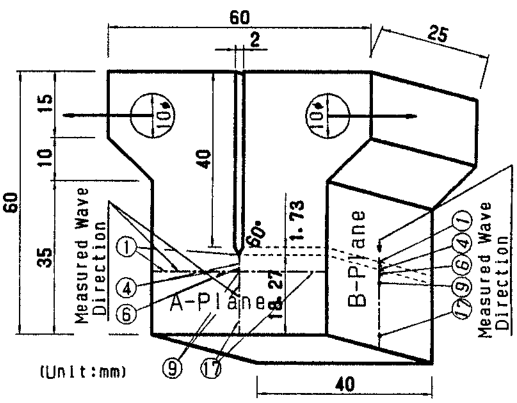

Fig.1 Specimen Showing Measured Wave Alignments

2. EXPERIMENTAL PROCEDURE

2.1 Ultrasonic Testing:

Under water ultrasonic scanning technique performed all over the experiment. Automatic scanning control system has scanning range(mm) of 500(W)×500(L)×250(D), scanning pitch of 0.005~9.95 mm and scanning speed of 10~150 mm/sec. Reflection waves recorded by Digital Storage Oscilloscope (DSO) of frequency range up to 300 MHz, sampling speed of 500 mega samples per second and vertical resolution of 10 bit.

2.2 Fatigue Testing:

For fatigue loading hydraulic equipment of survo-pulser unit subjecting the specimens to tensile cyclic loading. Cyclic loading performed under constant load range 5.0 KN ~ 1.0 KN and of frequency 10 Hz. Ultrasonic scanning and loading was done simultaneously.

2.3 Test Specimens:

The SS400 steel Y-shaped V-notch compact tension test specimen is shown in Fig.1. Specimen No.1 and 2 are of same size, shape and notch angle of 45° except slit width variation of 2 mm and 1 mm respectively. Specimen No.3 and 4 are notch angle of 60° and same slit width variation. For specimen No.3 and 4 we have additional paint coated specimen on A and B-plane.

3. EXPERIMENTAL RESULTS

3.1 C-Scan Image Analysis:

C-scan image display is a 2-D plan view of the part with the horizontal and vertical positions of defect location. In this scan mode images of defects and other interior conditions are displayed with 16 grades of color display with echo height and time travel data. 3-D representation of crack tip area displayed from time of flight data of reflection echoes is shown in Fig.2. Images here are two-dimensional array of pixels displayed by 200×200 (mm) size of 8 bit per pixel. Crack propagation nature from different angles can be shown

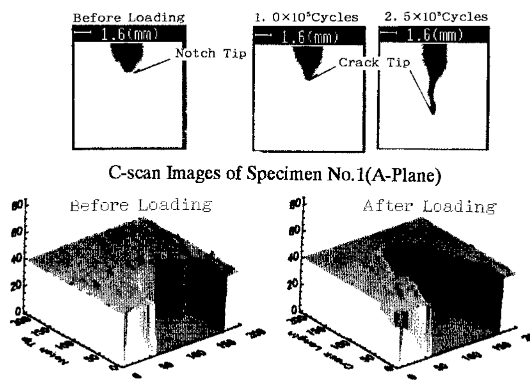

Fig.2 C-scan images and 3D Display from TOF data

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Address: *Koen-Cho 165, Kitami-city, Hokkaido, 090-0015 Tel: 0157-26-9471, Fax: 0157-23-9408*

here by rotation. Hence comparing the before and after loading images crack length, depth and crack propagation rate could be calculated. Propagated crack length measured from C-scan images are plotted as damage accumulation curve is shown in Fig.3.

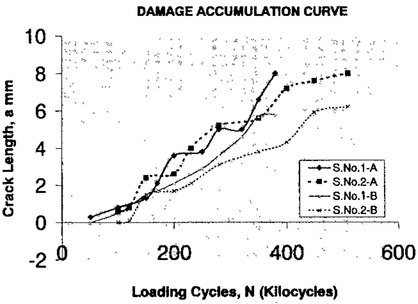

Fig.3 Damage Accumulation Curve from C-scan Images

3.2 Echo Wave Analysis and Discussion

DSO can receive 4096 point digital values for every single wave. The reflection wave that is echo amplitude verses time stored in floppy disk for detail analysis. Measured wave number and location are shown in Fig.2. For A-plane waves are recorded from both horizontal and vertical alignments. It is observed from reflection waves of A-plane that when transducer moves on crack tip bottom echo amplitude becomes smaller. Attenuation may be due to dissipating of energy of reflection echoes near crack tip. For B-plane, waves are recorded from center vertical alignment. Wave No.①~③ from slit area, Wave No.④ is from notch tip and gradually increasing number is far from notch tip. From notch tip to 4 mm distance wave measured at 0.50 mm pitch. Comparing waves from before and after loading as Wave No.④ and ⑥ shows significant variation. Bottom echo appears in Wave

Specimen No.3 B-Plane(With Paint)
Before Loading

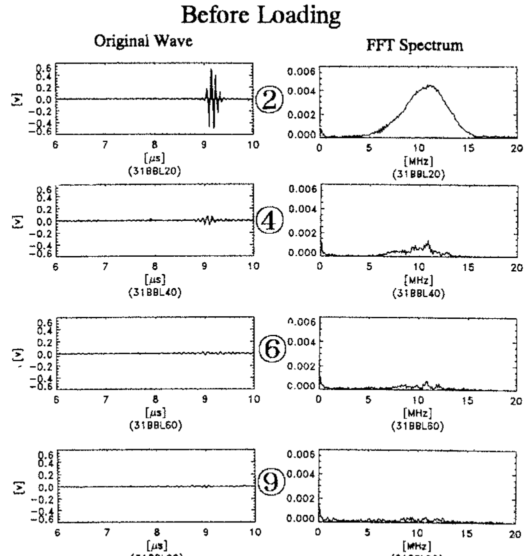

Fig.4 Original Wave and FFT Spectrum (B-Plane)

Specimen No.3 B-Plane (With Paint)
After Loading 2.0×10^5 Cycles

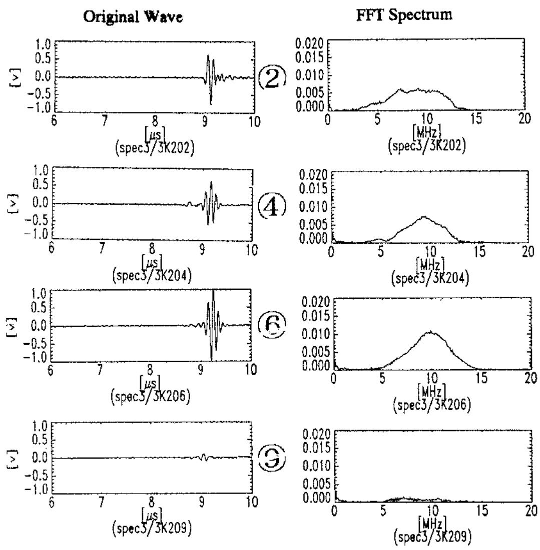

Fig.5 Original Wave and FFT Spectrum(B-Plane)

No.⑥ which reflected from cracked area (Fig.4 and 5). Gradually appearance of bottom echo from loaded specimen indicates that crack has propagated. Here we can measure crack tip elongated about 1 mm. Reflection waves propagated through water and paint couplant losses its energy transmission on interfaces. As the crack propagation surface is very smooth so the original waves does not show any noticeable change in before and after loading condition. But several peaks with flatted shape in the spectrum waves is significant indication which may be due to undulations of the cracked surface. Sometimes it is not clear from C-scan images that crack is elongated but echo wave is the reliable information to confirm the presence of crack.

4. CONCLUDING REMARKS

Fatigue crack propagation of V-notched steel specimen due to cyclic loading monitored by ultrasonic scanning. When crack initiated is really difficult to detect. Elongation of crack tip is clearly estimated from C-scan images, which also plotted in the damage accumulation curve. For spherical diameter transducer lens due to overlapping focal point dissipation of spread beam energy occurs which affects on accuracy of the results. Appearance of bottom echo from cracked area significantly indicates the presence of defaults, which needs more detail analysis to characterize.

5. REFERENCES

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