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In Situ Inspection with Ultrasonic Creeping Wave for Rabbet of Turbine Blade

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Abstract:
The properties of ultrasonic creeping wave were stated. Experimentations on the rabbet of aeroengine turbine blade were applied with ultrasonic creeping wave testing. The result indicates that the creeping testing method is feasible to inspect the rabbet of turbine blade in situ.

Keywords: creeping wave, original position testing, rabbet of aeroengine turbine blade

1. Introduction

Cracks are always found at the edge or in the first rabbet of aeroengine turbine blade. Eddy current testing and liquid penetrant testing are applied after blades are disassembled from engine. But blades are assembled in the teeth of turbine wheel. Probe is unable to arrive at the detection place in the original position. See Figure1. Cracks in the first rabbet of blade can't be checked. Ultrasonic creeping wave testing has gained broad acceptance as a Nondestructive Test (NDT) method for numerous in-service and manufacturing applications in the aerospace, power generation and automotive industries. It has got better effect in the welding seam and porcelain rod testing [1].

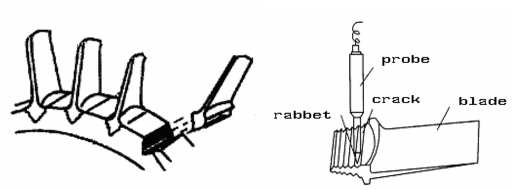

Fig.1 assembly position and detecting method of turbine blade

2. Property of creeping wave

Ultrasonic creeping wave is generated when longitudinal sound propagates to the interface of different double mediums and the incident angle is exactly equal to the first critical angle a_{1m}. For the organic glass and steel, the first critical angle is about 27.5 deg [2].

Creep Waves are high angle ultrasonic longitudinal waves. The creeping wave is actually the upper part of the envelope of a 76 deg compression wave beam which propagates just under the component surface, see Figure 2. These are not true surface waves and the energy is concentrated within a few millimetres of, and almost parallel to, the surface. Hence, the technique is very sensitive to shallow surface-breaking cracks whilst at the same time being relatively insensitive to surface condition. The maximum working range is typically 45 mm in front of the probe because the creep wave rapidly loses energy in the form of 33º indirect shear, or 'head', waves as it propagates. However, these head waves will re-convert to a creep wave at the inner surface of the component [3]. Like the top surface creep wave, this inner surface creep wave is very sensitive to inner surface breaking cracks and as it runs parallel to the inner surface it will not be sensitive to the presence of weld roots. Creep waves have the advantage that they are far less attenuated in rough and unshaped metal than other type waves.

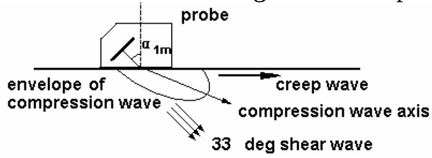

Fig.2 waves distribution

3. **Experiment**

3.1 Testing conditions

Equipment: KK-30 digital ultrasonic wave detector

Probe: 5M frequency, 4mm×6mm size, 27.5 deg incident angle, narrow pulse, convex surface, single element creeping wave transducer.

Test block: Several turbine blades rejected as useless with a man-made flaw in its first slot shown in Figure 3. Depth of simulative cracks is respectively 0.5,1,1.5,2,2.5,3mm.

Couplant: 201# lubricating grease

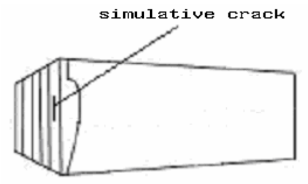

Fig.3 test block

3.2 **Procedure and result**

A creeping probe is placed on the surface of turbine blade and points to the simulative crack. Adjust the instrument and set testing data: restrain 0%, gain 60dB, gate1 50%, gate2 60%, absolute dB mode. Adjusting the reflected pulse from 0.5mm simulative crack to 60% of full screen is regarded as the testing sensitivity. Move the defect pulse to the sixth graduation and accomplish regulating the time-base line. See Figure 4.

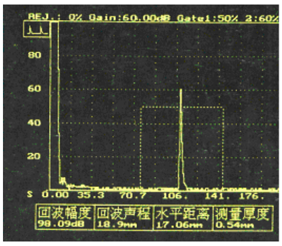

Fig.4 creeping wave signal

Don't change the state of device and keep the testing sensitivity. The other blades with different depth simulative cracks can be tested. The testing result is shown in Table 1.

Table1 absolute height data of different depth cracks

Depth of simulative crack(mm)	absolute amplitude of echo(dB)	Depth of simulative crack(mm)	absolute amplitude of echo(dB)
0.5	98.1	2	105.4
1	101.3	2.5	107.1
1.5	103.7	3	108.8

4. Application

Sixty turbine blades were inspected with ultrasonic creeping wave method before they were going to be separated from aeroengine. Move probe slowly whose front side touches the edge of blade rabbet. The suspicious area lies in the middle of rabbet. If a pulse appears at the sixth graduation in the screen, it shows a crack maybe exists. Detector will alarm when the pulse exceeds 50% of full screen. Move probe forth and back along the axis to judge whether it is a false flaw. The true flaw pulse will change its poison at this time. However, the echo of false flaw doesn't change.

Suspicious echoes were found in the rabbets of three turbine blades. Record the numbers of suspicious blades. Verify the testing results with eddy current and liquid penetration methods after turbine blades were disassembled from engine. The verification result is shown in Table 2 where indexes is respectively absolute height of echo, amplitude of signal voltage and phase, length of indication for creeping wave testing, eddy current testing and liquid penetrant testing.

Table 2 contrasts to the other methods

? ? ? ?	Creeping wave testing (dB)	Eddy current testing (mV,rad)	Liquid penetrant testing(mm)
12891-26	102.5	116,62	4
12891-45	106.3	131,55	5
12891-51	96.7	98,34	3

5.Conclusion

Experiments show that ultrasonic creeping wave testing is feasible to inspect rabbet of engine turbine blade in original position. Cracks with 0.5mm depth can be found. Our experiment proved that creeping wave testing offers unprecedented speed, sensitivity, and ease of use. It is the perspective method of aircraft safety investigation.

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