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Borescope and Eddy Current Dual Probe for In Situ Detecting Cracks in an Aeroengine Labyrinth Disc

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Abstract

Cracks often arise in an aeroengine labyrinth disc, which endanger flight security. Non-destructive testing (NDT) must been carried out in the labyrinth disc during the aeroengine working time. In situ detecting cracks in the labyrinth disc, the probe need pass through three layers narrow holes of aircraft skin, engine shell and outlet duct. Ultrasonic, radiography and liquid penetrant inspection cannot be employed. A probe containing several NDT devices will be a feasible means. Borescope is a most widely used method for detecting and examining surface cracks inside narrow tubes or difficult-to-reach chambers. But borescope cannot detect subsurface defects and cannot estimate the depth of cracks. Eddy current testing is sensitive to surface and subsurface defects of metal material. But when the interface between the eddy current probe and the object cannot come into view, it is hardly to operate correctly. These two techniques are complementary, and no detrimental interference is observed. A dual probe containing an eddy current probe and a borescope was designed for aeroengine labyrinth disc in this paper. An aeroengine labyrinth disc containing manufactured and real defects was detected using the dual probe. The results of testing show that borescope and eddy current dual probe can completely achieve in situ detecting cracks in an aeroengine labyrinth disc.

Keywords: Borescope, Eddy Current Testing, Non-destructive Testing,
In Situ Detecting, Aeroengine

1. Introduction

Cracks often arise in a certain type aeroengine labyrinth disc, which endanger flight security. NDT must been carried out in the labyrinth disc during the aeroengine working time. If teardown the aeroengine to overhaul, it is troublesome and time-consuming. In situ testing needn't disassemble equipment and structures. So it can save time and prevent from the breakdown and damage resulted from disassembly [1]. In situ detecting the labyrinth disc, the probe need pass through three layers narrow holes of aircraft skin, engine shell and outlet duct. Ultrasonic, radiography and liquid penetrant inspection cannot be employed [2-4]. A probe containing several NDT devices will be a feasible means.

Borescope inspection belongs to visual inspection. It is an important nondestructive testing technique that provides a means of detecting and examining a variety of surface, such as corrosion, contamination, surface finish, and surface discontinuities. Borescope allows the inspection of surfaces inside narrow tubes, walls, ducts, large tanks, other dark areas, or difficult-to-reach chambers [5]. Borescope is used in equipment maintenance programs, in which borescope can reduce or eliminate the need for costly teardowns [6]. But borescope inspection has some limitations. Borescope inspection can only detect surface macroscopical flaws, cannot detect jerkwater flaws, and cannot evaluate the depth of cracks.

Eddy current testing is another important nondestructive testing technique. Eddy current testing need not use coupling medium, so can detect defects quickly. It is sensitive to surface and subsurface flaws of metal material and can evaluate the depth of cracks [7,8]. But eddy current testing has limitations too. When the interface between the eddy current probe and the object cannot come into view, it is hardly to operate correctly.

Borescope and eddy current testing techniques are complementary, and no detrimental interference is observed. A dual probe containing an eddy current probe and a borescope was designed and realized. The dual probe can completely achieve in situ detecting cracks in an aeroengine labyrinth disc.

2. Introduction of the Aeroengine Labyrinth Disc

The labyrinth disc is an important component of a certain type aeroengine. It is made of nickel alloy that is ferromagnetic material. Its thickness is 4mm. The labyrinth disc is shown in figure 1 after teardown the aeroengine. There are 32 balanced holes in outer annulus of the labyrinth disc. The diameter of balanced holes is 5.2mm. The labyrinth disc bears vibration stress at work. The stress fastens on the balanced holes. Fatigue cracks easily arise at two sides of balanced holes. The cracks start at surface of labyrinth disc. The length of cracks would lengthen, and the depth would largen. If the cracks continue grow, they would cause labyrinth disc burst and damage areoengine. The local megascopic picture of a crack is shown in figure 2.

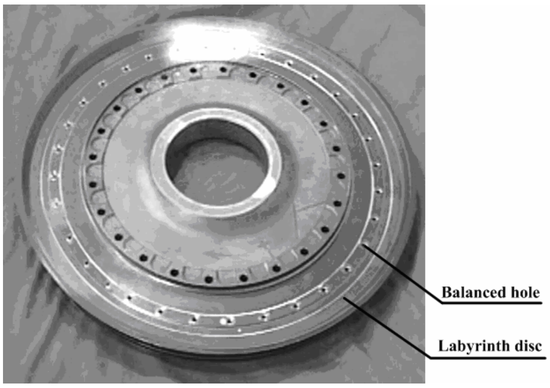


Fig.1 the Picture of Labyrinth Disc

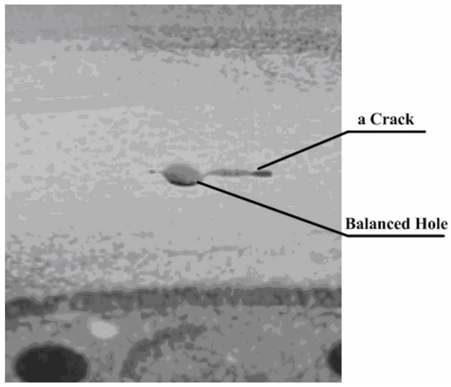


Fig.2 the Megascopic Picture of a Crack

The labyrinth disc is located in the casing of the aeroengine combustor. In situ detecting cracks in the labyrinth disc, the probe need pass through three layers narrow holes of aircraft skin, engine shell and outlet duct. Ultrasonic, radiography and liquid penetrant inspection cannot be employed. A special dual probe containing an eddy current probe and a borescope was designed for aeroengine labyrinth disc.

3. Design of the Borescope and Eddy Current Dual Probe

The schematic structure of the borescope and eddy current dual probe is shown in figure 3. The dual probe is composed of the high sensitive eddy current probe and subminiature video CMOS borescope. Considering the positional particularity of the labyrinth disc, the dual probe is designed using especial structure. The eddy current probe and video borescope are built in a long shank. The eddy current probe is in the top of the dual probe and can be rotated 90 degrees through the press-button on the knob. Through seeing the image of the video borescope, the eddy current probe can be inserted into the balanced holes of the labyrinth disc to detect cracks.

According to the thin wall structure of the labyrinth disc, the eddy current probe adopts separate excited coil and pick up coil which are Orthogonal (figure 4). A varying current is driven in the excited coil. This will generate a varying magnetic field, and in turn an eddy current in sample, which will generate a magnetic field opposing that from the excited coil. A defect in the sample will disturb this field, and the change can be measured by the pick up coil [9,10]. The excited coil is circular and hollow. The pick up coil is rectangular and hollow and located inside the excited coil. Owing to this special structure the eddy current probe is high sensitive, and has little lift-off effect and edge effect produced instantaneously when the probe is inserted into the balanced hole. The excited coil is winded using brass wires of 0.12mm diameter, while pick up coil is winded using brass wires of 0.06mm diameter. The actual size of excited and pick up coils is shown in table 1.

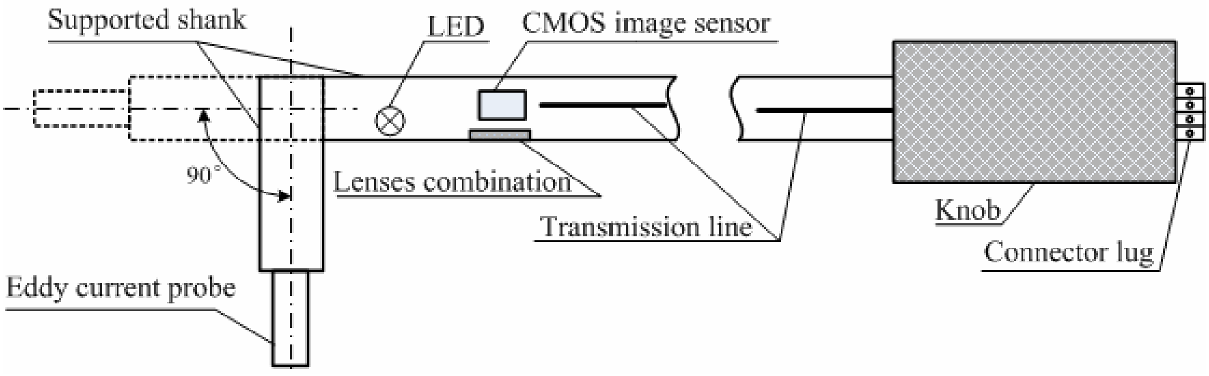
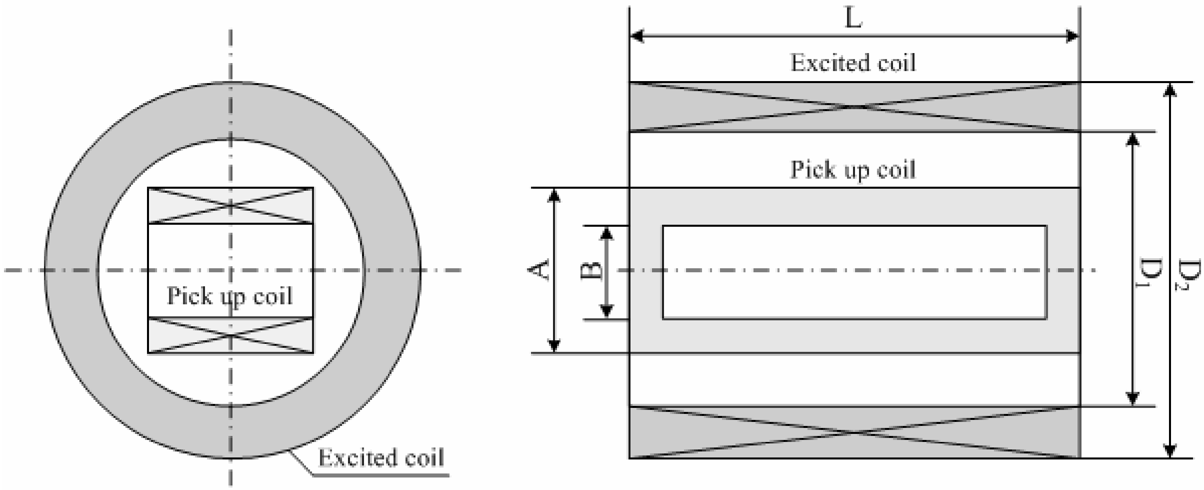


Fig.3 the Schematic Structure of the Borescope and Eddy Current Dual Probe



(a) the Cutaway Vertical the Axes of Excited Coil (b) the Cutaway Vertical the Axes of Pick Up Coil

Fig.4 the Structure of the Eddy Current Probe

Tab.1 the Actual Size of Eddy Current Probe Coils

Length of coils L(mm)	Inner diameter of excited coil D_1(mm)	Outer diameter of excited coil D_2(mm)	Inner size of pick up coil B(mm)	Outer size of pick up coil A(mm)	Turns of excited coil	Turns of pick up coil
6	3.6	5.1	2.15	3	400	600

The video borescope is mainly composed of lenses combination and CMOS image sensor. The lenses combination adopts reverse-telephoto configuration. It has character such as large angle of view, large depth of field, low distortion, long back working distance, large relative aperture, and small exterior size. CMOS Image sensor uses OV7670 camera chip of OmniVison. The OV7670 camera chip is a low voltage CMOS image sensor that provides the full functionality of a single-chip VGA camera and image processor in a small footprint package. Its output is digital video signal. The available array element is 640×480, the pixel size is 3.6μm×3.6μm, and the image transfer rate is 30fps. The illumination uses high luminance white light LED which size is small.

One important consideration when using a dual probe system is interference between the two probes. The principle of the borescope and eddy current is different. In theory there is no detrimental interference between the two probes.

4. Experiment

4.1 Experiment Setup

The testing experiment was conducted on an aeroengine labyrinth disc containing manufactured and real defects. The size of manufactured flaw is 10mm in length, 0.5mm in width, and 1mm in depth. The size of real flaw is smaller. The eddy current testing frequency is 400KHz. The NDT system block diagram using borescope and eddy current dual probe is shown in figure 5. The testing system is based on Personal Computer. It is composed of micro-controller unit (MCU), DDS waveform generator[11], power amplifier, borescope and eddy current dual probe, preamplifier, lock-in amplifier[12], A/D converter, driver & control unit, image processing and Personal Computer (PC).

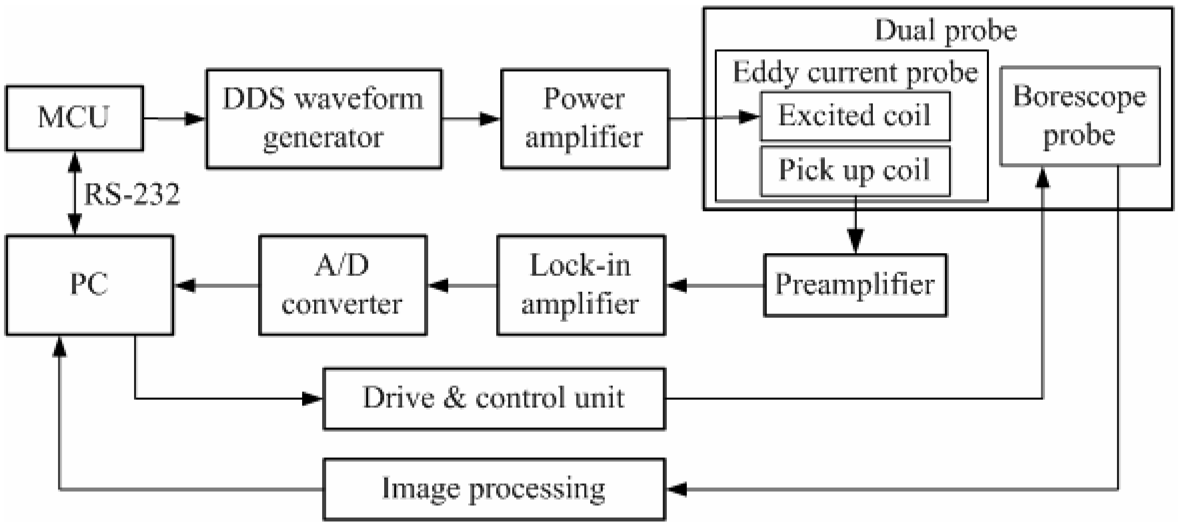


Fig.5 the NDT System Block Diagram Using Borescope and Eddy Current Dual Probe

4.2 Experiment Results

In experiment no detrimental interference is observed. Figure 6 shows the borescope image. In the image the eddy current was inserted into a balanced hole of the labyrinth disc.

Figure 7 shows the inducted voltage amplitude-time response curve of pick up coil when the eddy current probe was inserted into the balanced holes of the labyrinth disc. The inducted voltage amplitude of pick up coil almost did not change when no crack arose at sides of balanced holes. But when crack arose the inducted voltage amplitude of pick up coil appeared a peak value. The peak value of the manufactured crack is larger than that of the real crack. The reason is that the size of the manufactured crack is bigger.

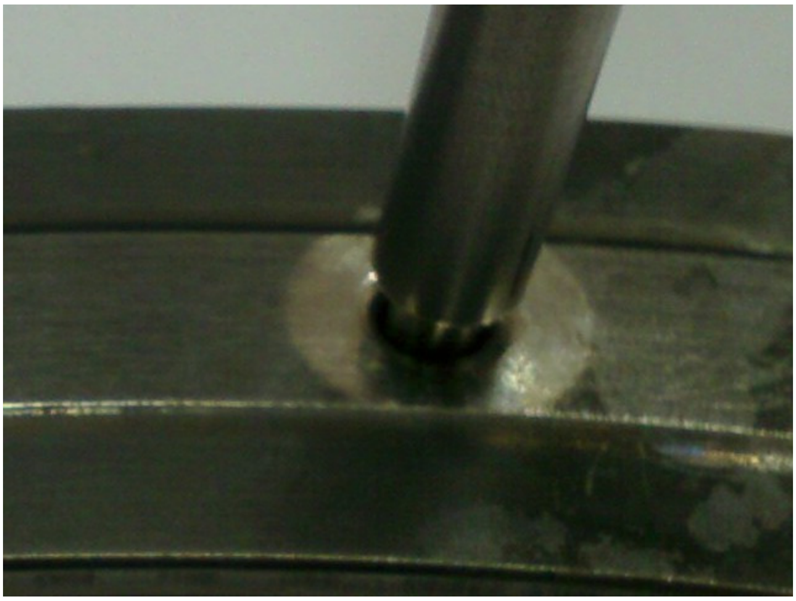


Fig.6 the Borescope Image

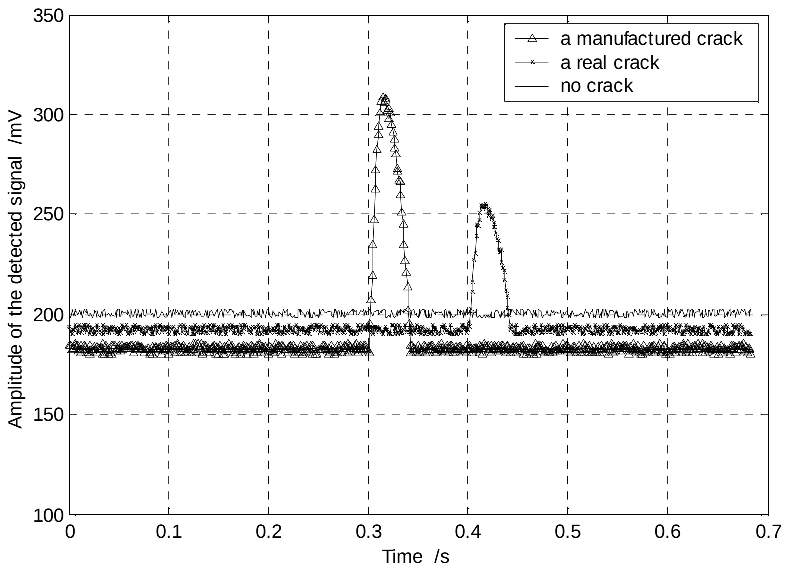


Fig.7 the Inducted Voltage Amplitude-time Response Curve of Pick up Coil

5. Conclusion

This paper presents a new borescope and eddy current dual probe. It has the advantages of these two NDT techniques, and no detrimental interference is observed. The dual probe was designed and applied to in-situ detecting cracks in an aeroengine labyrinth disc. It can save time and prevent from the breakdown and damage resulted from disassembly. The experimental detection results are available. The dual probe can be used in other components of aeroengine such as compressor blade and turbine blade.

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