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Failure Analysis and Detection Technology Research of Hub Bolts of Aircraft Main Wheel

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***Abstract*—The hub bolt of the main wheel of a large civil aircraft is an important bearing part in the take-off and landing process of the aircraft. The bolt will be detected by fluorescence or magnetic powder in each tire disassembly process. It is found in the application that even if some bolts pass the magnetic particle detection, they will still break in the process of use. Bolt breakage not only increases the probability of tire damage, but also seriously endangers flight safety. In order to find out the cause of bolt fracture and put forward the corresponding solutions. In this paper, damage bolts are taken for failure analysis, and it is found that most of the fracture positions of threads are located at the root of the fourth thread. According to the characteristics of the fracture, traditional ultrasonic method was used to carry out in-service detection research. The results showed that the shear wave probe with a frequency of K2.2 and 2M could detect 1mm deep cracks at the end of the thread. This method is simple to operate, does not need to dismantle the bolt, can respect the spot construction. The realization of this method is of great significance for flight safety.**

Keywords—civil aircraft; failure analysis; hub bolt; ultrasonic detection

I. INTRODUCTION

The hub bolt of the main wheel of a large civil aircraft is an important bearing part in the take-off and landing process of the aircraft[1][2]. The bolt will be detected by fluorescence or magnetic powder in each tire disassembly process. The service life of bolts is 6 years [3], but it is found in the application that some bolts will still break even if they pass the magnetic particle test. Bolt fasteners may introduce defects in the process of design, production, assembly and maintenance, which may lead to local stress concentration or material damage. Therefore, bolt failure rate is high, the common features are not obvious, and the secondary damage is serious after the damage occurs, which makes it difficult to determine the initial cause [4].

A large number of research results at home and abroad show that the concave and convex characteristics of the ends of threaded components lead to significant clutter in ultrasonic detection[5], and the damage waves at the original fracture location are covered, so that the cracks cannot be directly determined [6] [7]. The early fatigue crack at the root of screw thread is a hot and difficult problem in ultrasonic flaw detection. It may be an important way to solve this problem to use ultrasonic probe at a specific Angle to establish ultrasonic detection method system for sensitive positions.

II. MICROSTRUCTURE ANALYSIS

The macroscopic morphology of the three bolts is shown in Figure I, where the fracture position of the first bolt on the left is located at the bolt head and the fracture position is close to the transition arc (arc chamfer) area (hereinafter referred to as bolt no. 1) of the bolt head. The fracture position of the middle bolt in Figure. I is at the thread position, and the fracture is in the fourth thread area (hereinafter referred to as bolt no.2).

The macroscopic morphology of the fracture position of the left bolt (hereinafter referred to as bolt no. 1) in Figure I is shown in Figure II. The bolt gasket is stuck at the fracture position and cannot be removed. The surface fluctuation of the fracture is large, the macroscopic morphology of different regions of the whole fracture is greatly different, and some regions have the characteristics of suspected fatigue beach grain.

Figure I macroscopic morphology of the fracture of the intermediate bolt (hereinafter referred to as bolt no. 2) is shown in Figure III. The fatigue damage characteristics of the bolt fracture are very significant, with obvious fatigue beach grain characteristics.

FIGURE I. MACROSCOPIC MORPHOLOGY OF BOLTS

FIGURE II. MORPHOLOGY OF THE FRACTURE OF LEFT BOLT

Figure III shows the microscopic morphology of the location near the fatigue crack source of no.2 bolt, which can be seen in the fatigue grain distribution on the sand beach. The fatigue crack takes the crack source as the origin and extends outward along the vertical direction of the fatigue sand grain. The micro morphology of the fatigue crack source area is shown in FIG. III. The fatigue crack originated from the thread root area, which was the point crack source, and originated from an indentation with a length of about 10 microns at the thread root.

FIGURE. III. MACROSCOPIC MORPHOLOGY OF INTERMEDIATE BOLT (HEREINAFTER REFERRED TO AS BOLT NO.2)

The microcosmic morphology of the fracture of bolt no. 1 is shown too. There are fatigue sand streaks in different directions at the fracture, indicating that there are multiple fatigue cracks extending successively or simultaneously at the bolt fracture. According to the morphological features of fatigue beach lines, the fatigue crack propagation direction is from bolt rod to screw core, as shown by the red arrow in the figure.

The crack source of bolt A has a large expansion area and may be the main crack source. The micro morphology of the crack source location which is a linear crack source. The crack source area reverses to the inside of the bolt, indicating that the crack source location may have been squeezed by external objects. The crack source location has layered cracking characteristics formed after extrusion deformation. The microscopic morphology of crack source of bolt no. 1 B. The crack source is fatigue crack source and its origin is located at the bolt edge. The gasket of bolts on the left side. It can be seen from the figure that the source area of crack B is located.A total of 5 fatigue crack sources with different degrees of development were found in the circumferential direction of the fracture of no.1 bolt, among which there were obvious marks of gasket contact with bolt, extrusion and deformation in some positions.

The fracture of no. 1 bolt is characterized by multi-source fatigue fracture, and there are traces of gasket contact, extrusion and deformation at the origin location of multiple crack sources. It shows that the fracture of bolt no. 1 is related to the gasket. The structural characteristics of both sides of the gasket are different, the inner ring edge on one side is a right-angle transition, and the other side is an r2-3 transition arc chamfer. In this case, the right-angle transition side is installed on the nut side.

Refer to other relevant information (737-800 structural repair manual), which requires that the radian side of the gasket is installed relative to the radian side of the bolt. If the installation is reversed, the edge of the right Angle chamfering Angle will contact the transition arc of the bolt to form local point contact or line contact. Under the action of bolt torque, local stress will be concentrated to form micro-damage, which will lead to fatigue cracking in the subsequent service process.

Bolt no.2 is a point source fatigue fracture. The origin position is located at the root of the fourth thread, which is usually the maximum stress position. According to the fracture morphology of no.2 bolt and dimple structure of the instantaneous fracture area, the fracture is a normal stress tensile fracture.

III. DETECTION METHOD RESEARCH

Bolt breakage directly endangers the life safety of aircraft and personnel. It is especially important to strengthen the inspection of bolts. In the past, bolts were removed for magnetic powder and colour detection when running, in order to improve the detection sensitivity, improve the inspection speed, reduce lab. intensity, we use ultrasonic automatic detection technology. The bolt is a small specification component M14, which is not mentioned above in the bolt testing standard. For example, the detection range in DL/ t694-1999 standard: "high-temperature fastening bolts greater than or equal to M32 or above" shall be subject to ultrasonic detection, which brings difficulties to the detection; Furthermore, the cracks occurred within the range of 20mm to 80mm from the upper surface and occurred frequently at 20 + / -3mm, which was the near-field area of the ultrasonic probe .The range of clutter is large and not linear. This makes detection difficult, which is why M32 and above are mentioned in the standard range.

In view of the above analysis, we changed the single-crystal probe into the dual-crystal focusing probe, and the focus of the probe was placed at F=20mm. This is based on the fact that the dual-crystal probe adopts one piezoelectric wafer and one piezoelectric wafer, effectively eliminating the clutter caused by the reflection of the interface between plexi-glass and steel. Because the initial pulse can’t enter the amplifier all the time for amplification, the blocking phenomenon is overcome and the blind area of flaw detection is greatly reduced, which is very beneficial to the detection of near-surface defects. In addition, two piezoelectric wafers form a rhomboid region, as shown in Figure IV.

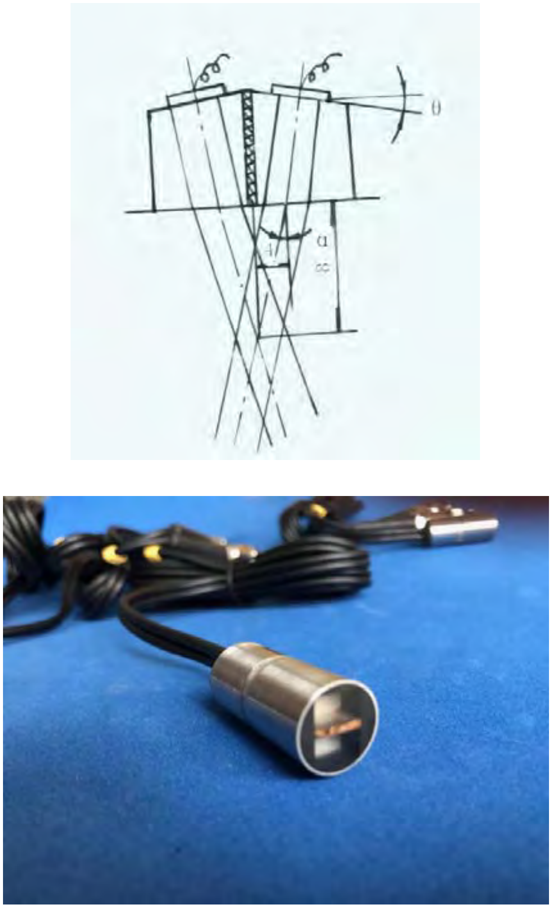

FIGURE. IV. SCHEMATIC DIAGRAM OF TWIN - CRYSTAL PROBE AND TWIN - CRYSTAL PROBE

The probe is shown in Figure IV. The reflection signal in the rhombus region is strong, which solves the flaw detection problem in the near region. In the actual flaw detection, the appropriate inclination Angle B should be selected according to the thickness of the workpiece under inspection, so that the focus of the two piezoelectric wafers falls on the part where the defect of the workpiece under inspection is prone to occur. The smaller the Angle B is, the deeper the focus distance from the detection surface and the longer the rhombus region will be. The larger Angle B is, the shallower the focal distance from the detection surface and the shorter the rhomboid region is, which is conducive to the detection of thinner workpieces. This kind of bolt is often broken 21 to 23mm away from the upper surface, that is, the nut and the workpiece joint, here is the maximum bearing part of the bolt, generally for the entire bolt bearing 60-70%, but also the maximum stress area. When we develop the probe, we put the focus of the probe at 20 + or + 3mm, which is the optimal value, so that the defect can be found more advantageous, which is also conducive to the detection of minor defects.

IV. Equipment Debugging

Good will probe to connect to the instrument is used after 80, 60 mm two steps to adjust the scanning speed, find Φ 2 flat bottom hole, respectively, on the flat surface to a depth of 10, 30, 50 mm Φ 2 flat bottom hole at the reflection of equivalent draw distance amplitude curve as shown in Figure IV can be tested. Figure V shows the cutting of 1mm groove waveform at 22mm of the actual bolt.

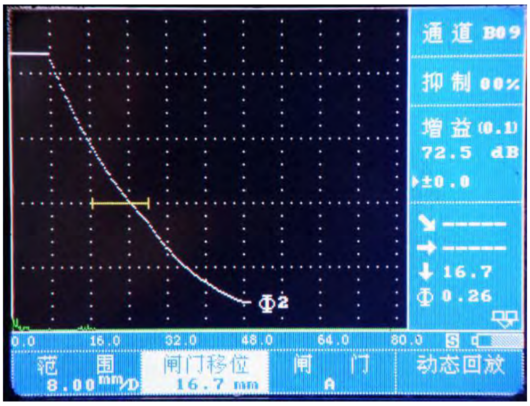

FIGURE. V. DAC (DISTANCE AMPLITUDE CURVE) FOR TEST

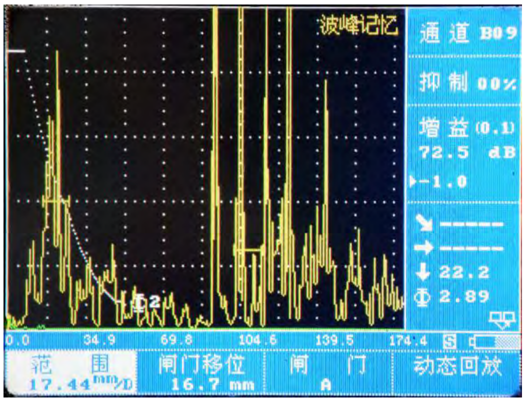

FIGURE. VI. REFLECTION WAVE OF 1MM WIRE-CUT GROOVE

V. Conclusion

1. The fracture of no. 1 bolt is characterized by multi-source fatigue fracture, and there are traces of contact between gasket and bolt, extrusion and deformation at the origin location of multiple crack sources. The fracture of the thread may be related to the mounting mode of the gasket on one side of the nut.

2. Bolt no. 2 is a point source fatigue fracture, originated at the root of the fourth thread.

3. An ultrasonic detection method was build, and the shear wave probe with a frequency of K2.2 and 2M could detect 1mm deep cracks at the end of the thread.

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