

Quality Control and Management of Nondestructive Testing Process in Aircraft Fatigue Test [†]

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Abstract: Aircraft fatigue test is a critical step for new aircraft models to obtain certification. The primary task of fatigue test is to detect damage promptly and gather damage data. Therefore, to ensure the timeliness and effectiveness of non-destructive testing (NDT) data, it is essential to control and manage the quality of the NDT process in aircraft fatigue test. This paper, based on the characteristics and work features of NDT in aircraft fatigue test, aims to achieve the goal of timely damage detection by focusing on the five key aspects of NDT quality control, namely: personnel, equipment, materials, methods, and environment. It elaborates on the quality control process, identifies key aspects of quality management, and enhances the quality of NDT in aircraft fatigue test.

Keywords: aircraft fatigue test; non-destructive testing; quality control and management; NDT quality



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1. Introduction

Non-destructive testing itself is a means of quality control [1–3]. Managing and controlling the quality of NDT can further ensure the quality of aircraft structures and components, thereby guaranteeing flight safety [4–6]. Aircraft fatigue test is a necessary prerequisite for new aircraft models to obtain type certification. NDT during aircraft fatigue test can identify weak points of early fatigue, facilitating design modifications, and verify crack detection methods and repair solutions. The NDT process in aircraft fatigue testing is unique, and its quality control differs from conventional NDT.

2. Characteristics of NDT Work in Aircraft Fatigue Test

Aircraft fatigue test includes component test and full-scale fatigue test. The primary feature of full-scale fatigue test is that it involves a complex assembly of various connected components rather than a single part. The unique characteristics of full-scale fatigue test lead to distinctive features in the NDT process, which can be summarized as follows:

- (1) Complex and varied detection structures: The presence of both single-layer and multi-layer structures limits the effectiveness of automated equipment.
- (2) Diverse material types: Materials include high-temperature alloys in engines, aluminum alloys in skins, frames, and beams, high-strength steel in landing gear, nickel-plated bolts, and an increasing proportion of composites distributed in wings and fuselage.
- (3) Complex and hazardous detection environments: The exterior of the fuselage and the lower fuselage are covered with adhesive tapes and actuator loading devices, limiting the movement range of detection personnel. High-altitude detection on the upper fuselage requires safety harnesses.
- (4) Heavy detection tasks: Besides routine inspections specified in the task book, additional non-stop inspections are required, as cracks that have undergone loading are easier to detect and observe.

3. Quality Control and Management Process in NDT During Aircraft Fatigue Test

Generally, the quality control process involves five aspects, namely: personnel, equipment, materials, methods, and environment. NDT in aircraft fatigue test is no exception to this rule.

3.1. Personnel Management

Due to the large area and complex structure, visual inspection detects 70% of surface cracks in full-scale fatigue test. Quality management requires inspectors to obtain visual inspection qualifications and other relevant certificates. Human factors are dynamic and uncontrollable. Inspectors must possess responsibility, patience, experience, and familiarity with the aircraft structure to avoid missing damage during extensive visual inspections. Regular internal training improves inspection capabilities.

3.2. Equipment Management

The reliability of inspection equipment directly determines the accuracy of detection results [7]. Equipment management includes developing maintenance plans, periodic calibration, checking equipment suitability, repairing failures, and recording usage status. Daily maintenance, such as using protective covers for probes and proper storage, prevents damage and loss.

3.3. Materials Management

All NDT materials undergo inspection by specialized aviation departments. Before use, ensure materials are within their validity period. For example, check the expiration date of dye penetrant spray cans and inspect the oil–water contamination of magnetic suspension fluids.

3.4. Methods Management

Methods focus on standardizing on-site management. The quality management processes differ for component test and full-scale fatigue test.

3.4.1. Component Inspection Quality Management

The standard process for component inspection is illustrated in Figure 1 as follows:

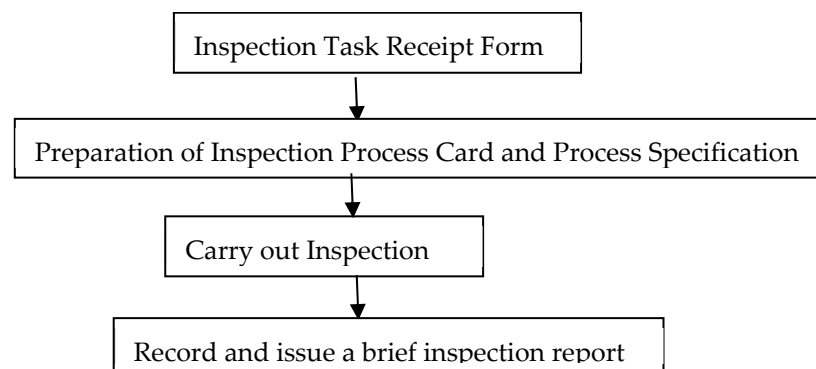


Figure 1. The standard process for component inspection.

The inspection process flow specifies the test blocks, inspection methods, inspection steps, etc., for different inspection techniques. The inspection records need to detail the inspection parameters and the detected damage morphology to facilitate the issuance of brief inspection reports.

3.4.2. Full-Scale Fatigue Inspection Quality Management

The standard process for full-scale aircraft fatigue inspection is illustrated in Figure 2. The NDT outline, tailored to the task book, outlines the implementation of NDT. Inspectors

must communicate with the client about inspection locations and times and select the most suitable methods. Technical coordination forms are used if requirements cannot be met. Before or after the commencement of fatigue test, there may be revisions to the task instructions or adjustments to non-destructive testing, resulting in significant changes to the inspection time, locations, and methods. The non-destructive testing outline must continuously undergo reforms and upgrades in order to meet the new inspection requirements. The inspection process must be strictly carried out in accordance with the inspection outline, and daily inspection and various levels of inspection record forms must be filled out. In the event of any damage being detected, the client must be promptly notified of the location, appearance, and length of the damage in the form of a damage notification. After the inspection is completed, a summary of all damaged areas, occurrence times, and occurrence patterns should be made, and an inspection report should be issued.

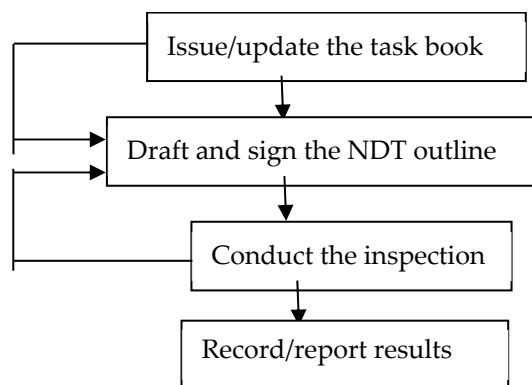


Figure 2. The standard process for full-scale fatigue inspection.

3.5. Environment Management

A healthy and safe work environment improves inspection quality [8]. Environmental management includes maintaining a clean and safe environment. During full-scale aircraft fatigue tests, external inspections of the fuselage may require the use of ladders or scaffolds to ensure safety, while internal inspections necessitate the cooperation of the test party to turn on lights, to ensure good visual lighting conditions. Due to the complex conditions at the test site, inspections cannot be carried out when the environment does not meet safety requirements. The magnetic particle inspection room requires a reasonable layout, terrazzo flooring, and good ventilation conditions. For radiographic testing, radiation meters must be equipped, to measure whether the radiation levels within the inspection distance are safe for humans [9,10].

4. Conclusions

Based on the characteristics of NDT work in aircraft fatigue test, this paper discusses the uniqueness of quality control in NDT processes, focusing on five key aspects, namely: personnel, equipment, materials, methods, and environment. It identifies critical elements and implementation plans for quality control and management in NDT during aircraft fatigue test, providing valuable insights for related professionals.

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