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Research Article

Non-destructive testing of aircraft wing with liquid penetrant method

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ABSTRACT

Today's aviation industry is developing, renewing, and growing day by day. More growth in this developing sector means more damage and accidents that may occur. In order for the flight to be safe and secure, there must be daily, weekly, monthly and annual maintenance with the maintenance procedures mentioned in the aircraft maintenance manuals. In addition to being economical, non-destructive testing methods are of great importance in the maintenance of aircraft structures due to their rapid application and clear results. Visible or invisible failures on aircraft components are detected by non-destructive control methods applied by the qualified persons. With the liquid penetrant method, which is one of the non-destructive testing methods, surface discontinuities or defects of materials can be detected effectively. In this study, non-destructive testing of aircraft wing parts by the liquid penetrant method was investigated. As a result of the control process with the liquid penetrant method, the impact damage and various scratches at the wing were detected.

Keywords: Airplane Wing; Failure; Liquid Penetrant Method; Non-destructive Testing

1. Introduction

Non-destructive testing (NDT) is an inspection of materials and structures to obtain information about the physical, chemical, metallurgical and mechanical condition without disturbing the robustness and serviceability of materials and structures [1]. NDT with its simplest definition; inspections to determine the presence or absence of discontinuities and other material properties on the part, regardless of the part's size, shape, type or material. The terms non-destructive examination (NDE), non-destructive inspection (NDI), and non-destructive evaluation (NDE) are commonly used to describe these examinations [2]. NDT methods are used in the design, development, manufacturing, unserviceable and replacement stages of a product, that is, in a life cycle from "cradle to grave". The methods produce knowledge by using separately or in combination [1]. NDT can be performed on metals, composites, polymers (such as rubber, plastics and adhesives), ceramics, and coatings. The methods can detect cracks, surface cavities, internal voids, incomplete defective welds, delamination and any type of flaw which would lead to premature failures [1, 3]. In worldwide, visual or optical inspection, ultrasonic testing, magnetic particle testing, eddy current testing, liquid penetrant inspection and radiographic testing are the most commonly used NDT methods [3, 4].

Aircraft maintenance activities include the application of effective non-destructive testing methods that can be used to detect foreseen defects. These methods reveal two important facts. First, they must guarantee the defect-freeness of the structure, which is of great importance for safe service life. The other is that they enable monitoring of whether the current failures have reached the critical level. Failure tolerance analyzes cannot be conducted without non-destructive testing practices as these controls are based [5]. The Federal Aviation Administration (FAA) has allowed failure-tolerant design and certification by periodically checking failure growing with non-destructive control practices for military and civilian aircrafts [6].

Liquid penetrant inspection (LPI) is an NDT method used to detect surface discontinuities in the material. With LPI, aluminum, steel, titanium, copper, etc. metals, most ceramic materials, glass, rubber, and plastic materials can be examined [3]. In liquid penetrant inspection; liquids with low surface tensions, which wet the solids well and have the ability to penetrate the discontinuities on the surface of the part, are used [7, 8]. Penetrant liquids can be applied to the material to be examined by brushing, washing, spraying, and sometimes dipping [7]. Liquid penetrant inspection, which is convenient, fast and easy to apply on the part, is based on the principle of capillarity [9]. Penetrant liquid containing dye penetrating the surface discontinuities with capillary effect creates a visual contrast between the discontinuity and the surrounding surface. This increasing the visibility of the discontinuity [10].

Liquid penetrant inspection consists of the following basic steps:

- Surface preparation

Cleaning and drying of the surface to be inspected from oil, water and other contaminants for the full detection of defects.

- Penetrant application

After surface preparation, applying liquid penetrant to the surface and waiting for a while to fully penetrate the surface discontinuities.

- Removal of excess penetrant

It is the process of removing excess, penetrant from the surface of the part properly for effective inspection. According to the properties of the penetrant liquid used, it can be made with special solvents or water.

- Development

Development is applied to the part surface to detect any failures. It ensures that the penetrant liquid that has penetrated the development defect rises to the surface with the reverse capillary effect and the apparent width of the defect on the surface increases.

- Inspection and assessment

After the development, the failure on the surface of the part is evaluated with the eye, a magnifying glass or glasses that improve the part contrast. At this stage, the surface of the part is examined under appropriate light. The examination is performed under UV light when fluorescent penetrant liquid is used and in the daylight of appropriate intensity when colored dye penetrant liquid is used.

- Final cleaning

After the inspection and assessment phase, the surface of the part is cleaned of residues that may cause damage such as corrosion. After the final cleaning, the part is dried and given to the service [7, 8, 11].

Liquid penetrant inspection (LPI) is one of the most commonly used NDT techniques in aircraft maintenance activities. Detection of surface defects or structural damage in all materials of aircraft is possible with LPI [12]. Unlike other NDT methods with LPI, parts with large surface areas or large volumes can be examined at once. This makes the liquid penetrant technique the most sensitive and cost-effective NDT method in investigations such as turbine blades failure detection [13].

Guirong et al. mentioned that LPI effective method to ensure the quality of the aircraft parts' surface in the development, manufacture, use and maintenance phases [14]. LPI of the main landing gear wheel of a small aircraft was performed using fixed penetrant inspection equipment by Uludağ. The presence of various discontinuities in different places on the wheel surface was determined [8]. A Boeing 737-400 type aircraft's 2024-T3 aluminum aft cargo door entrance's surface corrosion was detected with LPI by Korkmaz [15]. Turkish Air Force uses LPI for the detection of stress corrosion at H-type joints on aircraft wheels and landing gear [16]. A crack was detected at a Boeing 737 type aircraft's front passenger door by Onursal [17]. Visual inspection and LPI have primarily used NDT techniques for the F110-GE-100 jet engine's fan, compressor, combustion chamber and turbine parts [18].

In this study, NDT of the taken part from the wing of a wide-body aircraft by LPI method was performed within the aircraft maintenance activities. As a result of the inspection, impact damages and various scratches were detected at the wing part.

2. Material and Method

The wing part of the Airbus A330 aircraft donated to Selcuk University was inspected by the LPI method. The part of the wing without coating and painting was divided into four equal parts to use for application (Figure 1).

Fig.1. Wing Part

The surface was cleaned by applying the cleaner (Figure 2.a) to the surface to remove contaminants such as oil, grease, dirt or dust on the part that may prevent the penetrant from entering the surface.

(a) **(b)** **(c)**

Fig. 2. Chemicals used for LPI: (a) Cleaner, (b) Penetrant, (c) Developer

Liquid penetrant (Figure 2.b) was sprayed on the cleaned surface from a distance of 30 cm from the surface to cover the entire surface to be inspected (Figure 3) and the penetrant was left at the surface 25 minutes for penetration.

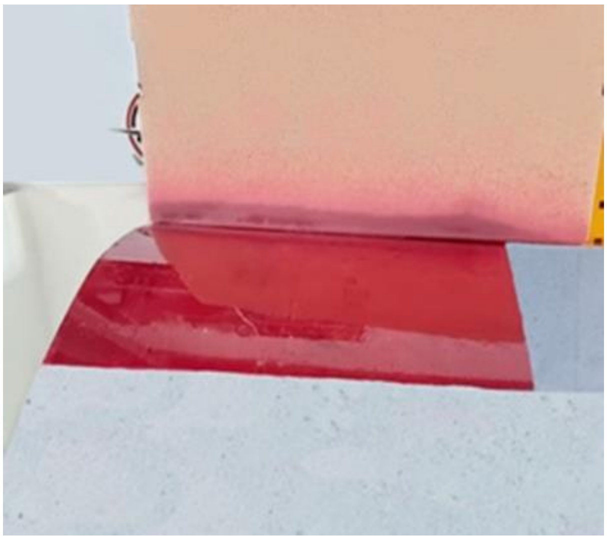

Fig. 3. Liquid penetrant applied on the surface

To clean the penetrant liquid from the surface, the cleaner was sprayed on a damp towel (Figure 4) and the surface was cleaned without pressing too hard. The developer (Figure 2.c) was applied to improve failures' visibility. The developer material ensures that the penetrant liquid, which penetrates the discontinuities that can be detected by the LPI method, is drawn back to the surface by reverse capillary action so that the discontinuities can be seen [7].

Fig. 4. Spraying cleaning spray to wet towel

3. Results and Discussion

LPI method was applied to the four equal wings part. Service failures were observed rather than manufacturing defects on the wing part surface. Impacts with irregular shapes were detected by this method (Figure 5 and 6). Shallow and plain scratches could not be detected (Figure 7 and 8). Deep and irregular scratches were detected (Figure 9 and 10). The capillarity of penetrant liquids is mainly used for LPI method. Penetrant liquid with appropriate viscosity should enter the discontinuities on the surface of the part being inspected [8]. It was thought that the liquid penetrant used for the experiment was not compatible with shallow and plain defects due to all penetrant was cleaned with cleaning spray sprayed wet towel. The penetrant was effective for deep and irregular defects.

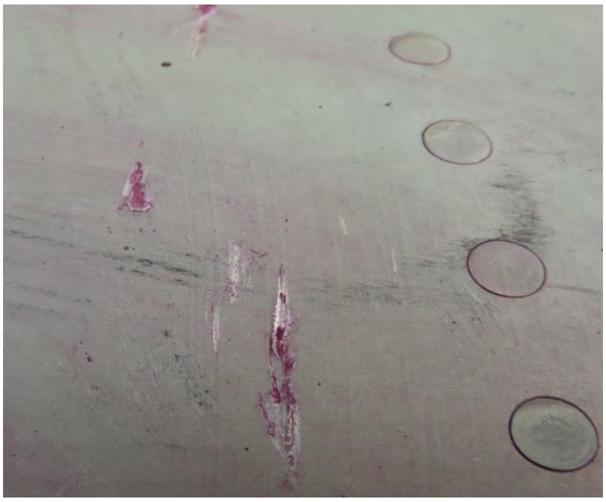

Fig. 5. Impact damage

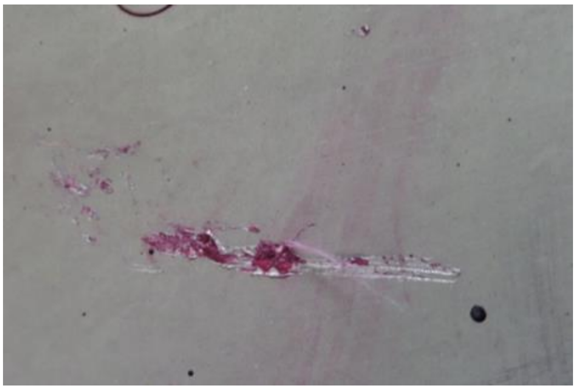

Fig. 6. Impact damage

Fig. 7. Scratch damage

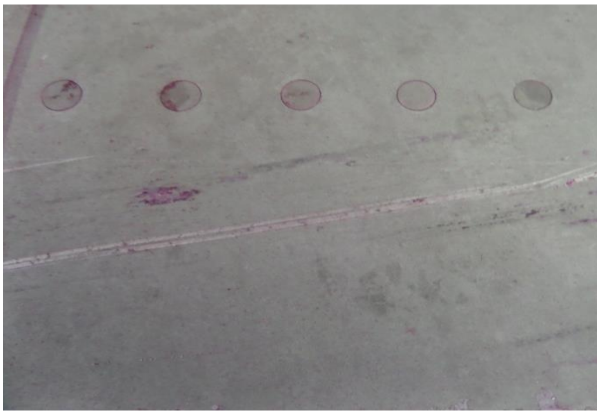

Fig. 8. Scratch damage

Fig. 9. Scratch damage

Fig. 10. Scratch damage

4.Conclusions

In terms of flight safety, it is necessary to ensure that the parts are undamaged. In the selection of the non-destructive testing method used for the control of aircraft parts; the shape of the part, the material from which it is produced, the compatibility of the nondestructive testing method to be used with the part to be examined are important.

In this study, the liquid penetrant method was applied to the aircraft wing, impact damages; deep and irregular scratches were detected. Detection of shallow and plain scratches could not be performed with this method. In order to detect these damages, another non-destructive testing method should be used combined with the liquid penetrant method.

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