Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 3 Issue 12, December - 2016

The Magnetic Particle Inspection Examination of Aircraft Propeller Mounting Bolts

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***Abstract* — The structural integrity of aircraft component is very important for airworthiness, safety and performance of aircraft. Defects, which may occur in service life of critical aircraft components, can result in failures and affects structural integrity of aircraft. Non-destructive inspection methods are the most economical and effective method to detect defects in aircraft components during their service life.**

Non-destructive inspection methods such as Visual Inspection, Liquid Penetrant Inspection, Magnetic Particle Inspection, Eddy Current Inspection, Ultrasonic and Radiographic Inspection methods are widely used in Aircraft Maintenance Applications. The effectivity and sensitivity of non-destructive inspection methods differs for a particular material or component. Magnetic particle inspection can be used for detecting surface and near surface discontinuities in ferromagnetic materials such as iron and steel. In this article, non-destructive inspection of the propeller mounting bolts, which connects the propeller to aircraft engine, was investigated by use of magnetic particle testing method.

Keywords—magnetic particle inspection; mounting bolt; propeller; aircraft maintenance; non-destructive inspection;

I. INTRODUCTION

An operational aircraft can suffer from many defects such as structural damage, corrosion and cracks, which may reduce the structural integrity or serviceability of the aircraft. This is very important especially for the critical aircraft components. These components of the aircraft are highly stressed and, if damaged, may cause failure of the aircraft and loss of life of the aircrew [1]. A propeller is one of the most highly stressed components on an aircraft. During operation, the components of propeller are exposed to different operational loads such as torque, aerodynamic and gyroscopic vibratory loads [2]. In rapidly rotating, reciprocating, vibrating, highly stressed aircraft parts, such as propeller components small defects often lead to excessive stress and develop to the point that they cause complete failure of the part and affects structural integrity of aircraft [3]. Therefore, it is very important to detect small defects before they reach to the point causing complete failure of the part.

The assessment of structural integrity of aircraft components and structures is very important for the determination of Airworthiness which is an indication of an aircraft's serviceability to maintain safety [4]. The airworthiness of aircraft is assured by performing scheduled inspections and preventive maintenance applications. The one of those maintenance applications is non-destructive testing applications. The aircraft parts or materials can be examined to identify defects or cracks without damage or destruction of the parts or materials under examination by use of proper non-destructive inspection (NDI) methods. After performing of proper NDI methods, assessment such as serviceable, repairable, or rejected can be made for the inspected parts according to manufacturer's specific criteria [3].

NDI methods such as Visual Inspection, Liquid Penetrant Inspection, Magnetic Particle Inspection, Eddy Current Inspection, Ultrasonic and Radiographic Inspection methods are widely used in Aircraft Maintenance Applications. Some of these methods are simple, requiring little additional expertise, while others are sophisticated and require that the technician be trained and specially certified. Since each NDI method has advantages and disadvantages, one or some them may be more suitable method for a particular material or component. Because of that selection of right method for inspection is very important for the highest sensitivity and reliability [3]. Magnetic particle inspection method is widely used to inspect fasteners, landing gear components, and other steel components such as engine and empennage attach fittings [5]. Magnetic particle inspection has proven extremely reliable for the fast detection of such defects located on or near the surface. The location of the defect can be detected with the approximate size and shape [3].

In this article, non-destructive inspection of the propeller mounting bolts, which connects the propeller to aircraft engine, was investigated by use of magnetic particle testing method. Therefore, firstly the construction and maintenance operations of propeller component were explained and then theory and principle of magnetic particle inspection were given. Lastly, the inspection procedure of magnetic particle method and application on the propeller mounting bolts

were explained and the results obtained in the inspection were shown.

II. PROPELLER CONSTRUCTION AND MAINTENANCE

Today, most general aviation or private aircrafts use propellers and piston/turbine engines. There are many type of propeller and engine systems ranging from wood propellers on piston engines to specific metal or composite propellers on turbine engines [6].

The basic function of the propeller is to convert torque or power from the engine into thrust force. During propeller rotation the mass of air is directed to rearward and this rearward motion of air produce forward force on the propeller blades. This forward force is used to move the aircraft through the air (Fig. 1).

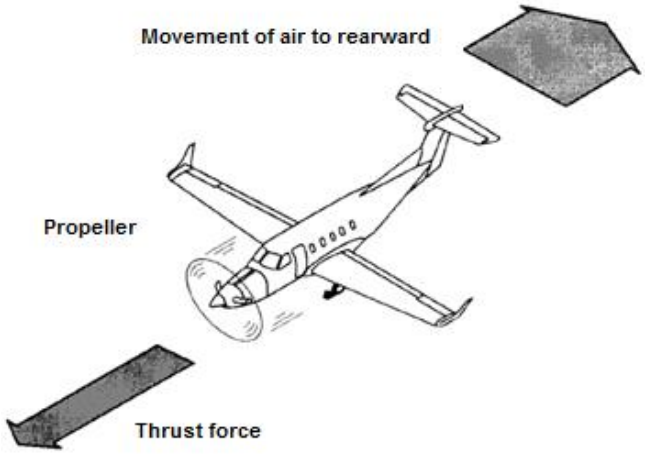

Fig. 1. *Thrust force produced by the rotation of propeller*

The propeller blades with a central hub is connected to the engine crankshaft through a propeller drive shaft and a gearbox. Attachment of the propeller on a drive shaft varies with the design of engine crankshaft. The propeller shafts may be either of flanged, tapered or splined installation type [6]. Most modern piston and turboprop engines use flanged propeller shafts. One side of the shaft is flanged with drilled holes to install or remove the propeller mounting bolts (Fig 2). The flange has threaded inserts and, mounting bolts are screwed into the inserts. The mounting bolts are used to hold on the propeller (Fig 3).

In rapidly rotating, reciprocating, vibrating, highly stressed aircraft parts, such as propeller components small defects often lead to excessive stress and develop to the point that they cause complete failure of the part and affects safety and structural integrity of aircraft. Safe operation of an aircraft depends strongly on periodic inspection of high risk parts, particularly rotating parts that are subjected to complex dynamic loads. For the highest level of flight safety, maintenance operations and rules, such as limits and intervals should be applied carefully [7].

The regularly scheduled inspections and preventive maintenance assure airworthiness of aircraft and its components. The methods used in propeller inspection are similar to methods used in inspecting the aircraft. The type and level of propeller inspections depend on specific material and type of propeller system. The walk-around inspection, detailed inspection and overhaul operations are the general and basic types performed in propeller maintenance operations [2].

The preflight or walk-around inspection as its name implies the process of inspecting aircraft prior to a flight or a takeoff. It is a general steps to assure the airworthiness of aircraft for flight. A detailed propeller inspection is done at each aircraft annual inspection, or as required in the aircraft maintenance procedures. During a detailed propeller inspection, the entire propeller is disassembled and all components are inspected in accordance with the manufacturer's specifications [2]. When the propeller is disassembled, the mounting bolts should be examined for cracks, using a suitable non-destructive testing method such as liquid penetrant inspection or magnetic particle inspection method, as required in the aircraft maintenance procedures [8].

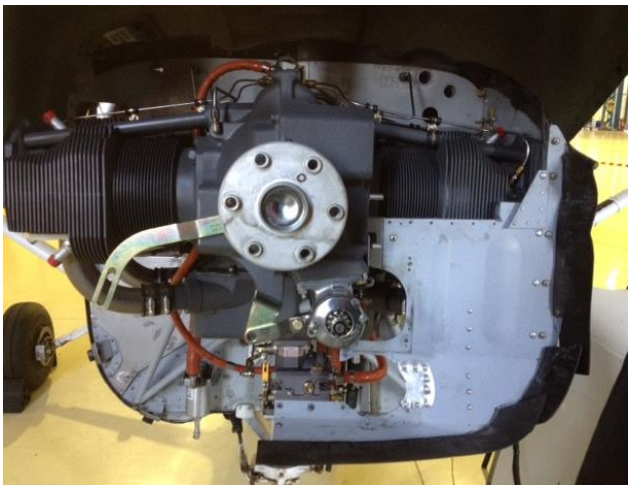

Fig. 2. . *Flanged propeller shaft*

Fig. 3. *Propeller mounting bolts*

III. MAGNETIC PARTICLE INSPECTION METHOD

Magnetic particle inspection is a non-destructive inspection method for detecting surface and near surface cracks and discontinuities in ferromagnetic materials that can be easily magnetized such as iron and steel [8083]. The magnetic particle inspection (MPI) can be considered as a combination of two nondestructive testing methods which are magnetic flux leakage testing and visual testing.

In MPI method, magnetization and small magnetic particles are used to detect surface cracks in components.

There are different equipment used to establish the magnetic field in MPI method. Some of them are portable used for field inspection and others are stationary used in laboratory or special facility. The wet horizontal bench system is one of the most common stationary system used for batch inspections of different components.

During the inspection process, the component to be inspected is magnetized and then magnetic particles either in a dry or wet suspended form are applied over the component. When a component is magnetized, the magnetic field introduced into the part as magnetic lines of force. If any discontinuities on or near the surface are present, the discontinuities will disturb magnetic lines and create a leakage fields (Fig. 4).

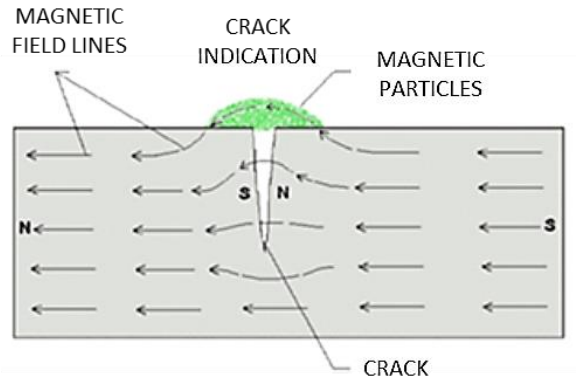

Fig. 4. *Disturbed magnetic field lines and attraction of magnetic particles due to a crack*

The magnetic particles will be attracted and holded at these flux leakage fields and make discontinuities visible under proper light. Since the magnetic particles are in good contrast to the surface of the component, discontinuities can be visually detectable. Depending on what kind of particles used in inspection, required light conditions change. If fluorescent particles are used, black or ultraviolet lighting is required.

The important point for MPI process is direction of magnetization during the process. If the discontinuities lies between 45° and 90° to the magnetic lines, those discontinuities can be detectable efficiently. Therefore magnetization process can be applied in longitudinally or circular which are called longitudinal magnetization and circumferential magnetization respectively. The affectivity of longitudinal magnetization and circumferential magnetization on the attraction of magnetic particles at defects are shown in Fig. 5 and Fig 6.

Fig. 5. *Longitudinal magnetization [3]*

Fig. 6. *Circumferential magnetization [3]*

The basic stages of performing an inspection of mounting bolts using wet suspensions can be summarized as follows.

- Surface preparation,
- Application of suspension,
- Application of magnetizing force,
- Inspection and evaluation of indications,
- Application of demagnetizing force,
- Post examination cleaning.

IV. APPLICATION OF MPI METHOD AND RESULTS

During a detailed propeller inspection (aircraft annual inspection), the entire propeller was disassembled according to aircraft maintenance manual (Fig 7). The propeller mounting bolts must be magnetic particle inspected, refer to ASTM E-1444 or

liquid penetrant inspected, refer to ASTM E-1417, or replaced at every overhaul [9].

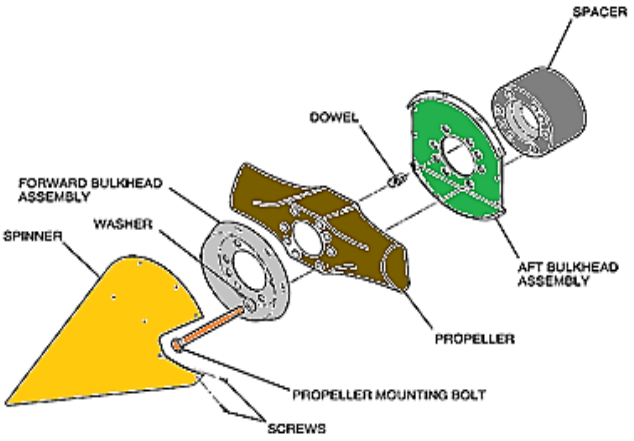

Fig. 7.. *The components of a basic propeller system [9]*

The MPI of mounting bolts was performed for aircraft annual inspection in accordance with the ASTM E-1444 standard by use of MPI test bench. Fig. 8 shows the wet horizontal bench system used in this study. Standard Practice for Magnetic Particle Testing (ASTM E-1444) document establishes minimum requirements for magnetic particle testing used for the detection of surface or slightly subsurface discontinuities in ferromagnetic material [10].

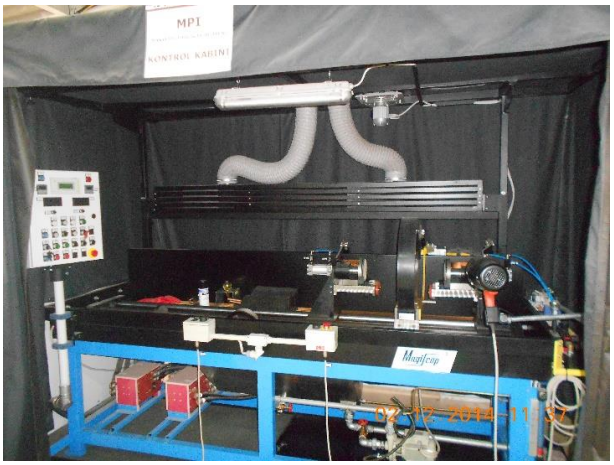

Fig. 8.. *Magnetic particle inspection test bench*

The first step in a magnetic particle inspection is to surface preparation of part. The surface of part being inspected must be free of grease, oil and other moisture. The wetting the surface and movement of particles freely can be prevented due to grease, oil and other moisture. And test sensitivity can be affected. The cleaning procedure was performed according to maintenance manual to remove any loose dirt, paint, grease, oil or scale on the mounting bolts.

After cleaning process, fluorescent magnetic particles suspended in a liquid applied over the mounting bolts by spraying. Each of bolts were located on the coil of magnetic particle inspection test bench (Fig 9 and Fig 10) to create magnetic lines of force by longitudinal magnetization (Fig 11). The magnetizing force applied by use of required direct current (DC) in two shots to improve magnetic particle mobility.

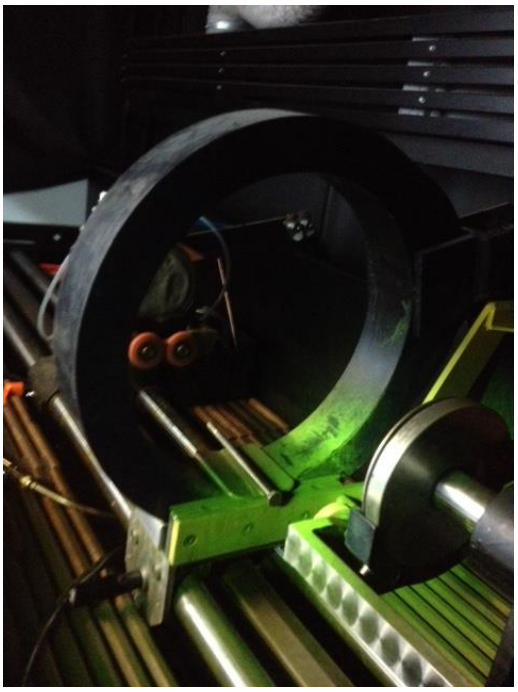

Fig. 9.*Longitudinal magnetization with wet horizontal bench system*

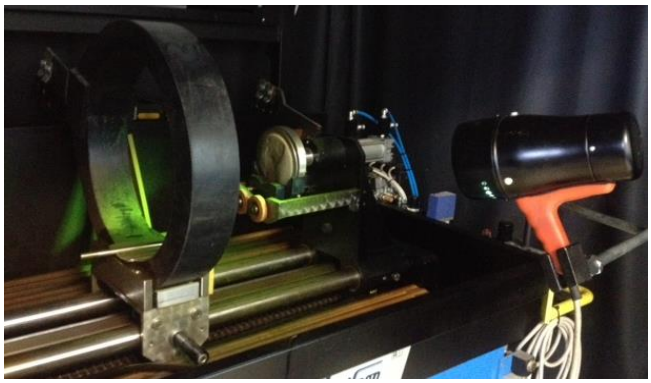

Fig. 10. *Different view of longitudinal magnetization with wet horizontal bench system*

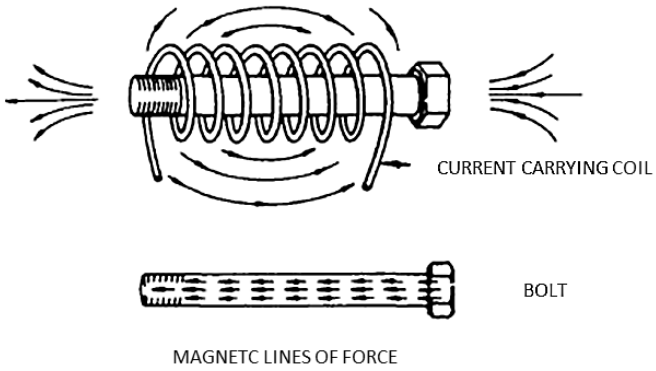

Fig. 11. *Illustration of longitudinal magnetization [5]*

Since local magnetic flux leakage fields attracts the magnetic particles and accumulation of particles happen in those fields, looking for leakage fields is necessary during examination process.

After magnetization, bolts were examined in a dark environment under black light (UV) to reveal local magnetic flux leakage fields. Because, the fluorescent magnetic particles has better visibility for indications of defects in a dark environment under black light (UV). The mounting bolts parts were examined for indications. All indications were identified as relevant or non-relevant. Surface discontinuities showing a sharp indication were determined and photographs of results were taken and recorded.

Following examination, the mounting bolts were demagnetized to remove residual magnetic fields by use of AC demagnetization. Demagnetization process is generally necessary, because residual magnetic field on the components being inspected may interfere with electronic equipment such as compass and also abrasive magnetic particles may increase wear on the parts [10]. After demagnetization, the mounting bolts were cleaned by suitable solvent and air blower.

Fig. 12 and Fig. 13 shows the photos which were taken while examination. As it can be seen in these photos, there were some sharp indications which were glowing regions on the bolts. These indications were determined as cracks and some corrosion products. These bolts were rejected to return service.

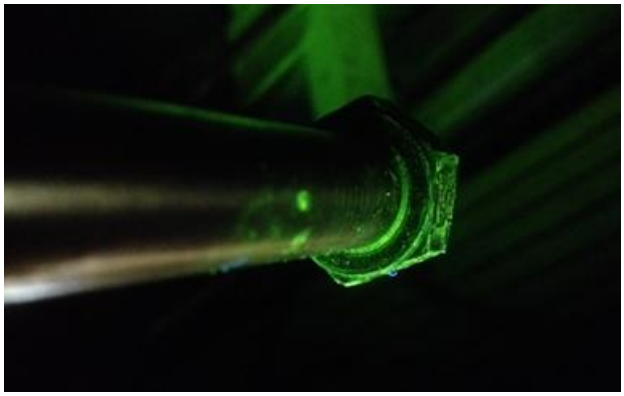

Fig. 12. *Indication of cracks on a bolt*

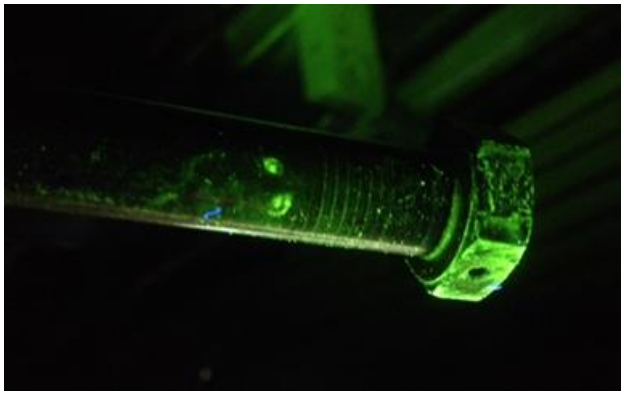

Fig. 13. *Schematic Indication of cracks on a bolt*

V. CONCLUDING REMARKS

In this study, non-destructive inspection of the propeller mounting bolts, which connects the propeller to aircraft engine, was investigated by use of magnetic particle testing method. Some indications found during examination. These indications were determined as cracks and some corrosion products. These bolts were rejected to return service. Detailed microscopy and chemical analysis is required to determine exact cause of these discontinuities.

Magnetic Particle Inspection method has proven reliable for being fast and relatively easy NDI method to apply. These characteristics make MPI one of the most widely utilized non-destructive testing methods for detecting surface and near surface discontinuities of ferromagnetic materials.

ACKNOWLEDGMENT

I would like to thank Mrs. Tugba Burcin ULUDAG for performing MPI applications and useful discussions.

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