An Evaluation of Shearography and Neutron Radiography for the Non-Destructive Inspection of Helicopter Main Rotor Blades

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Abstract

Defencetek was approached by a client to investigate a problem with helicopter main rotor blade debonding in response to the Original Equipment Manufacturer requiring the mandatory rebuild or replacement of blades that had previously been considered repairable. After the results of a preliminary investigation had become available the client decided to proceed with the rebuilding of the blades.

Use was made of the opportunity offered by the blades being rebuilt to investigate the potential use of two new NDT techniques, shearography and neutron radiography, for the detection of debonding and corrosion respectively. Once the blades had been stripped a visual inspection was performed and the results compared to those obtained using the respective inspection methods.

The shearographic method detected eighteen of twenty disbonds found during the visual inspection, although eleven false indications were also obtained. The false indications were due either to the presence of previous repairs (six), oil (two) or for unknown reasons (three).

The neutron radiographic method detected five of the nine instances of corrosion found during the visual inspection. The four instances of corrosion not found were all characterised as minor in the visual inspection reports.

INTRODUCTION

Defencetek was approached by a client to investigate a problem with helicopter main rotor blade debonding in response to the withdrawal of the approved repair scheme by the Original Equipment Manufacturer (OEM).

The withdrawn repair scheme, which allowed for the repair of skin / spar debonding in certain areas of the blade root, had been replaced by a mandatory replacement or rebuild of blades that had previously been considered repairable. The main concern of the client was that implementation of the replacement / rebuild programme would have a major impact on fleet availability.

PRELIMINARY INVESTIGATION

A preliminary investigation was conducted in order to determine whether the client could safely continue implementing the withdrawn repair scheme.

On investigation it was found that the reason for the withdrawal of the repair scheme was as a result of the recent catastrophic failure of two rotor blades, one of which resulted in loss of life.

Based on the results of a finite element analysis of the blade root area it was concluded that the location and size of the debonding that was allowable before repair was required was unlikely to act as the primary mechanism resulting in the structural failure of the blade.

It was therefore concluded that corrosion and corrosion fatigue in the area of the blade root and spar was the most likely cause for the failures. The corrosion in this area would be due to moisture ingression between the time that the debonding occurred and the time that a repair was done. The withdrawn repair scheme makes no provision for either the removal of trapped moisture or for the detection of corrosion during the repair process.

As a result of the findings of the preliminary investigation the client decided to proceed with the rebuilding of the rotor blades.

DETECTION OF DEBONDING OF THE MAIN ROTOR BLADE

Tap testing is the method specified by the OEM for the detection of the debonded areas of the main rotor blades. This inspection method requires the removal of the rotor blades from the helicopter in order to minimise the occurrence of false indications and is costly in both man-hours and aircraft down time.

The tap testing method [1] requires that the operator listen to the sound resulting from the tapping of the structure using either a coin or a tapping hammer and is based on the sound resulting from a bonded area sounding different to that resulting from an unbonded area.

Tap testing suffers from a number of limitations that reduces the effectiveness of the method for the detection of debonds. Those limitations that are of greatest concern are the reduction of the sensitivity of the method due to the increase in skin thickness and the difficulty of using the method to detect small defects near edges. Although this method is in general use in the aerospace industry it is not recommended, as it is highly subjective and dependent on the use of a skilled operator.

A number of techniques were considered for the detection of debonding in the area of concern. These included dye penetrant and magnetic particle methods, eddy current and ultrasonic inspection, X-radiography, electronic pattern speckle Interferometry (ESPI) and shearography.

Although the client had decided to proceed with the rebuilding of the main rotor blades, it was decided to investigate shearography using research funding. Use was made of the blades that were to be rebuilt for this investigation as they would be stripped and could therefore be visually inspected to verify the results of the inspection.

Twenty blades were made available and sent to the University of Cape Town for inspection using their portable shearographic inspection equipment.

SHEAROGRAPHIC INSPECTION METHOD

Shearography is an interferometric method in which use is made of coherent light to measure surface displacement derivatives. Because strain is a function of the displacement derivates and the presence of defects usually result in strain concentrations, the method can be used for the detection of debonding. Because rigid body motions do not produce strain there is no need for vibration isolation, as required by holography, which makes the method suitable for field inspection.

SHEAROGRAPHIC TEST PROCEDURE

The helicopter main rotor blades were bolted to a steel plate attached to a long bench using the rotor blade attachment points and were supported along their entire length using the packing blocks as supplied with the cradle box.

A video image of the blade in the area of interest was obtained and stored for further reference. After heating the area for approximately five seconds using a heat lamp, a shearographic fringe pattern was obtained. This process was repeated until images of both the leading and trailing edges of the blade on both the upper and lower surfaces was obtained.

SHEAROGRAPHIC TEST RESULTS

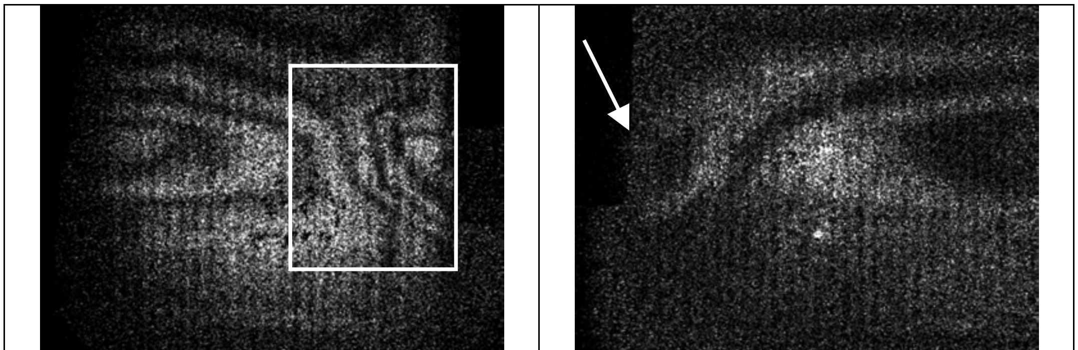
Of the twenty delaminations found in the area of the leading edge of the blade, shearography successfully detected eighteen (Fig. 1).

Of the seventeen delaminations found in the area of the trailing edge of the blade, shearography successfully detected only one.

Of the other eleven defect indications obtained six may be explained as being due to the presence of previous repairs in the area, two by the presence of oil (Fig. 2) and three are unknown.

Leading Edge Lower Surface

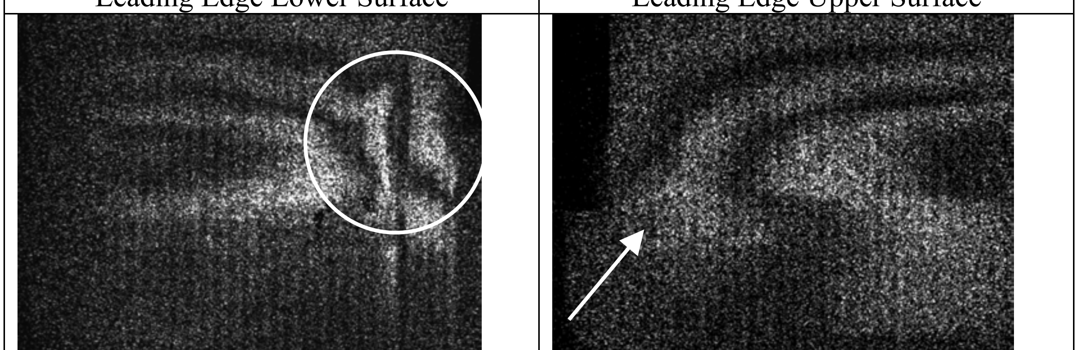
Leading Edge Upper Surface



Leading Edge Lower Surface	Leading Edge Upper Surface

Figure 1: Successful detection of delamination in the area of the leading edge.

Leading Edge Lower Surface	Leading Edge Upper Surface



Leading Edge Lower Surface	Leading Edge Upper Surface

Figure 2: False indication due to presence of an oily substance in the area of the leading edge.

DETECTION OF CORROSION OF THE MAIN ROTOR BLADE

Visual inspection is the non-destructive inspection method specified by the OEM for the detection of corroded areas on the main rotor blade.

A number of techniques were considered for the detection of the debonding in the area of concern. These included eddy current, X-radiography and neutron radiography.

Although the client decided to proceed with the rebuilding of the main rotor blades, it was decided to investigate of neutron radiography using research funding. Use was made of blades that were to be rebuilt for this investigation as they would be stripped and could therefore be visually inspected to verify the results of the inspection.

Twenty blades were made available and sent to NECSA for inspection using their SAFARI-1 research reactor.

NEUTRON RADIOGRAPHIC METHOD

Neutron radiography is a radiographic inspection method in which a radiographic image is formed using neutrons. Unlike X-rays, where there is a uniform increase in attenuation with an increase in atomic number, the attenuation of neutrons is random. As certain light elements, such as hydrogen, are strong absorbers of neutrons, while heavier elements, such as iron or lead, are reasonably transparent to them, neutron radiography is a suitable method for the detection of corrosion products.

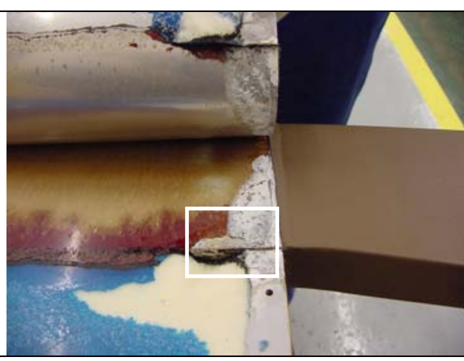
NEUTRON RADIOGRAPHIC TEST PROCEDURE

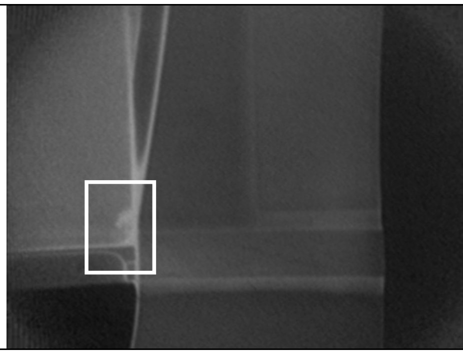
The blades were hoisted by crane and lowered through the roof of the NRAD facility into a position in front of the CCD camera system. A rope and a wooden profile positioning catch were used to support the blades.

Four radiographs of the cuff area of the blade as well as two of the tip area of the blade were obtained.

NEUTRON RADIOGRAPHIC TEST RESULTS

Of the ten instances of corrosion found neutron radiography successfully detected five (Fig. 3) and showed no obvious defect indications for the other four. The final instance was outside of the area inspected.

	
Leading Edge Cuff Area	Detailed Image



Leading Edge Cuff Area

Figure 3: Successful detection of corrosion in the area of the blade cuff.

CONCLUSIONS

Shearography has been demonstrated to have potential for the detection of the delamination in the area of the spar to skin interface, with eighteen of the twenty delaminations found in this area being detected. Some concern could be expressed about the false indications given by previous repairs that had been performed in this area. This should not present a major problem, as some other method will be used to map the size of the damage. Although not in a critical area as far as this investigation is concerned further work needs to be done to determine why the method failed to detect the majority of the delaminations, seventeen out of eighteen, on the trailing edge of the blade. It is felt that shearography, if used in conjunction with the inspection methods as specified by OEM, could improve the efficiency and reliability of the early detection of delaminations in the area of concern.

Neutron radiography has shown some potential for the detection of corrosion on the main rotor blade, with five of the nine corroded areas within the inspection area being detected. The areas of corrosion that were not detected were characterized as follows in the visual inspection reports, (a) “small area of corrosion”, (b) “corrosion”, (c) “minor corrosion” and (d) “very early stages of corrosion”, which is an indication that when the corrosion was sufficiently well developed the method was successful in detecting it. It is felt that as the rotor blades contain a number of sources which are rich in hydrogen, for example the foam core, adhesive and paint, and considering the success of the method when applied to purely metallic components, the apparent lack of success in the detection of the early stages of corrosion may be explained by the masking effect of these sources of attenuation.

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REFERENCES

[1] The Pitfalls of Tap Testing, ISASI Forum, April - June 1998, pp.18 - 21.