Eddy Current Inspection in Aircraft Industry

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Abstract

Failure of any part of aircraft like wheel, turbine blades or aircraft lap splices is decidedly hazardous. To avoid such disasters, periodic Non-Destructive Inspection of aircraft parts is essential and has been mandatory for many years. This paper describes some Eddy Current Inspection techniques like surface crack detection on aluminum alloys, bolt hole inspection, automated inspection of aircraft wheels and subsurface corrosion detection in Aircraft Lap Splices using Single as well as Dual Frequency Eddy Current techniques.

Keywords: *Corrosion, Fatigue cracks, SD-PC-12, Rotary, Scanner, Probe array*

1. Introduction

Technofour's association with aerospace industry goes back three decades, when we took a challenge and designed, developed and submitted a prototype of Eddy Current Crack Detector for the Indian Air Force. This was approved and we were awarded the first order for supply of twenty-five portable instruments for inspection of landing gear of MIG-21 aircraft. Since then we have supplied more than 150 Crack Detectors to Indian Air Force, Naval Bases and commercial airlines. Corrosion and fatigue cracks are expected in aging aircraft structure and different aircraft components. Corrosion causes thinning of aircraft structure skins, degrading structural integrity. This along with fatigue cracks affect airworthiness of an aircraft.

To maintain a high degree of quality and reliability, inspections in critical areas and maintenance of aircraft structure is essential. Non-destructive testing is used at fixed time intervals in different critical areas such as surface crack detection on aluminum alloys, bolt hole inspection, automated inspection of aircraft wheels and subsurface corrosion detection in aircraft lap splices. Although aircraft structures are assembled with various types of materials, Eddy Current method is widely used considering the accessibility and cost.

This paper describes these techniques applying Technofour's modern portable eddy current tester SD-PC-12 (Fig. 1) with both single- and dual-frequency operation.

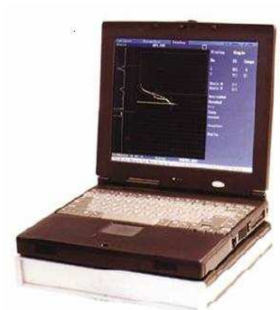

Fig. 1: Technofour's modern portable eddy current tester SD-PC-12

2. Various Aerospace Eddy Current Applications

2.1 Surface Crack Detection on Aluminum Alloys

Aircraft structures having flat or moderately curved surfaces are inspected for surface cracks using either shielded or un-shielded eddy current pencil probes. Generally a standard block of aluminum alloy with EDM notches of 0.5 mm and 1.0 mm depth is used for calibration of the instrument. It is normal practice to adjust phase such that lift-off signal is horizontal and going to left of screen. This enables basically to look at the y-component of the signal, which has the defect information free from lift-off. We can thus reliably detect small cracks even in the presence of the inevitable probe wobble.

TECHNOFOUR SD-PC-12 Eddy Current Instrument has a convenient "Auto lift-off" feature which takes care of adjusting lift-off horizontally. Also seen in following screen shot is an alarm box near the tip of the signal. This is a typical threshold used with static tests. We can change the size and the center of the box so that we can enclose any signals of interest. Further, the alarm can be configured to go off when the signals are inside the box, or otherwise when the signals go outside the box (Fig. 2).

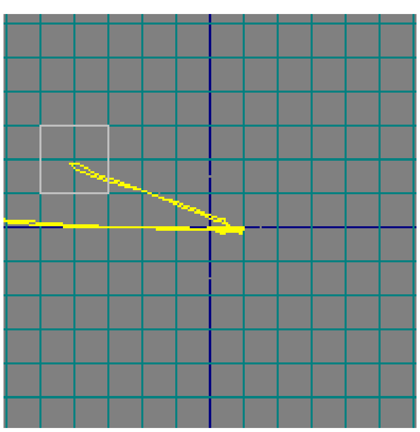

Figure 2

2.2 Bolt Hole Inspection

This is for detecting discontinuities that initiate from or intersect the inner surface of holes in the component to be inspected. This is done to detect defects that are too small to be detected with fasteners or hardware installed in the hole, or when surfaces are not accessible for inspection by other method. One can use a special bolt-hole probe with manual scanning or hand held rotary scanner for this inspection. Typical calibration standard consist of a block of a material identical to the one to be inspected, having appropriate hole sizes representing the range of holes to be inspected. Each hole will have an EDM notch of say 0.5mm depth x 0.12mm width for calibration.

For using a hand held rotary scanner, Eddy Current Instrument should be set for Dynamic Mode of testing. The difference between Dynamic and Static testing is the presence of High pass filtering in Dynamic tests. Due to the high pass filter only rapid changes in signal, such as a probe scanning a defect at a certain speed, are allowed to pass through. All slow changes are blocked by the high pass filter. Thus, in Dynamic testing the ' flying spot ' of the xy-display remains at the center. We see characteristic sharp excursions from the origin.

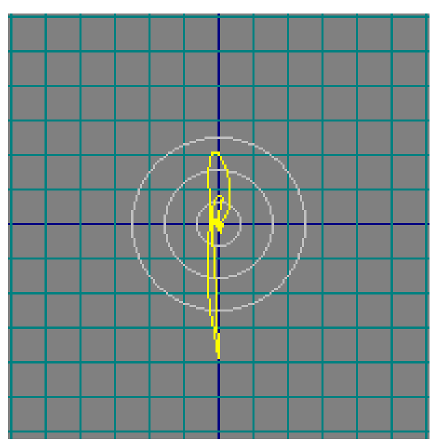

Figure 3

A typical response of a crack in 10 mm drill hole of aluminum block with Technofour's Eddy Current Tester SD-PC-12 looks as shown in Fig. 3.

2.3 Automated Inspection of Aircraft Wheels / Wheel Hub / Rotor Disc

Aircraft wheels have a very exacting task to perform. A few wheels must transmit the landing and braking forces of aircraft weighing say several tons at speeds up to 200kph. This leads to repetitive stress on the wheels, resulting in small imperfections or damage that can potentially grow into cracks. This might lead to an air leak and thus become apparent due to wheel deflation. In the worst case a wheel may break on landing. This necessitates periodic Eddy Current Inspection for detection of cracks on wheels. Normally a tire may last for 300 landings and will be replaced , which is the convenient time for Eddy Current Inspection. It is vital to detect any small defect that may, during next 300 landings, grow to a potentially dangerous size.

This wheel inspection can be done either manually using either pencil probe / contoured probe or automatically using scanner having turntable to rotate wheel along with Eddy Current Instrument. Both methods have their own advantages / disadvantages and a suitable method needs to be chosen depending on testing requirement.

4BRD Kanpur approached us for I Stage Disc checking. For calibration artificial EDM notch of 0.5 mm depth x 0.12 mm width was made on disc and TECHNOFOUR SD-PC-12 was used to check I Stage Disc. As per requirement frequency of 2.5MHz was used to get good S/N ratio for artificial notch as seen from Fig. 4.

With this calibration, I Stage Disc was scanned manually to detect two natural defects as shown in Figs. 5 & 6.

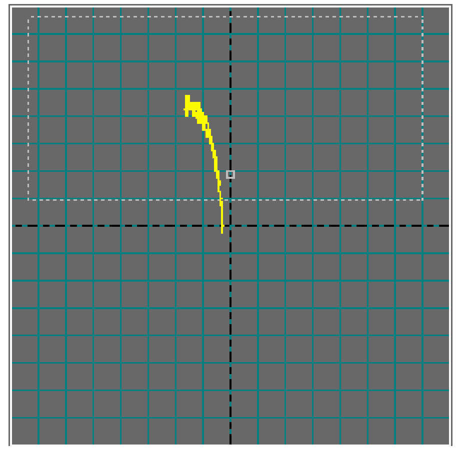

Figure 4

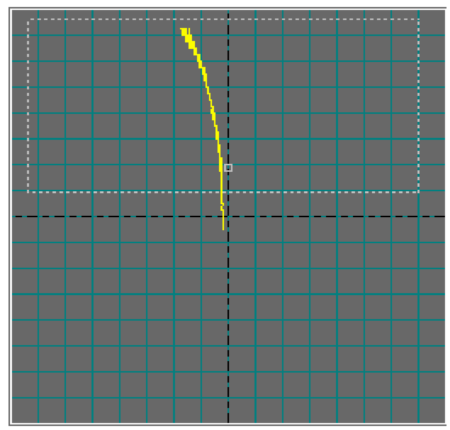

Figure 5

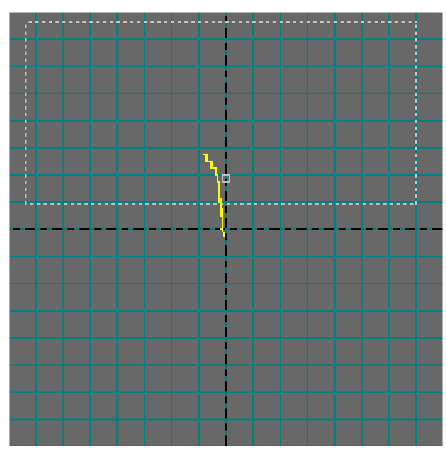

Figure 6

In addition to this, supplementary inspections such as conductivity or hardness testing are also carried out when there is any indication that the wheel has overheated.

2.4 Subsurface Corrosion Detection

Corrosion is a major concern to in-service airplanes as it can degrade fatigue performance of the airplanes. Though primary flight loaded structures of airplanes are designed using damage tolerant (fail safe) concepts, scheduled inspections are essential to detect possible damage in early stages. Bonded or riveted lap splices are susceptible to corrosion. Initial corrosion detection in splices is done by close visual inspection and after evidence of corrosion is visually detected, verification is done with Eddy Current Inspection. Lap splices consist of a top layer and a second layer of thickness between 0.8 mm to 3.2 mm.

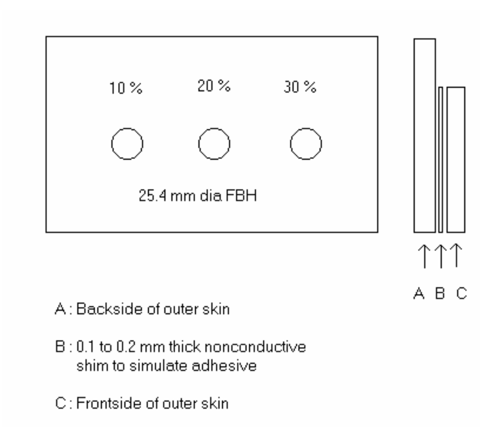

Figure 7

The optimum operating frequency for detection is selected based on thickness of skins, taking into consideration the instrument and probe performance. Reference standard is made from material that closely matches the skin conductivity and thickness of lap splice to be inspected. Conductive material loss due to corrosion is simulated in the reference standard by machined areas that represent reductions of 10, 20 and 30 percent of the skin thickness. A typical reference standard is as shown in Fig. 7.

Using reference standard as above, TECHNOFOUR SD-PC-12 Eddy Current Instrument was calibrated. A send receive probe was used for this application at 5 KHz. The standard defects were easily and reliably detected. Fig. 8 shows signal of 10 % defect.

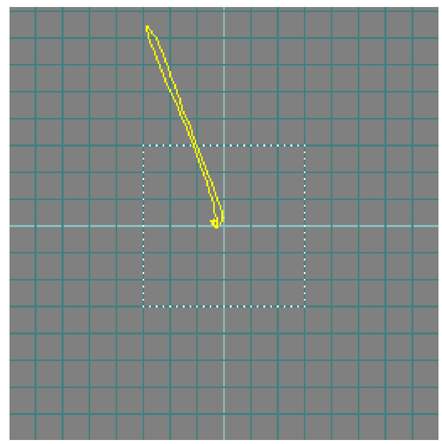

Figure 8

By decreasing the operating frequency, greater eddy current penetration can be achieved, allowing a single frequency inspection to detect second layer corrosion. However, in practice the presence of small gap variations between the skins produce signals that cannot be discriminated in magnitude and phase from second layer corrosion signals. This is why a single frequency instrument cannot reliably be used to detect second layer corrosion in practice.

Using SD-PC-12's dual frequency capability, the second layer corrosion can be reliably detected even with varying lift-offs. Fig. 9 shows lift-off signals for variable gap for 5 kHz while Fig. 10 shows lift-off signals for variable gap for 2 kHz.

The mixer channel was set to cancel out the gap signal and phase adjusted such that lift-off signal was horizontal as shown in Fig. 11.

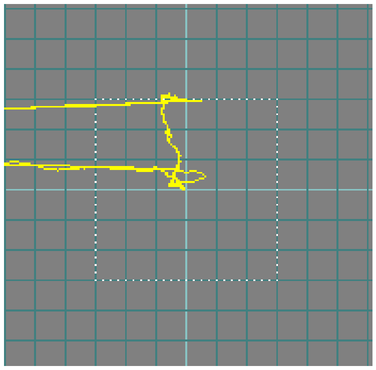

Figure 9

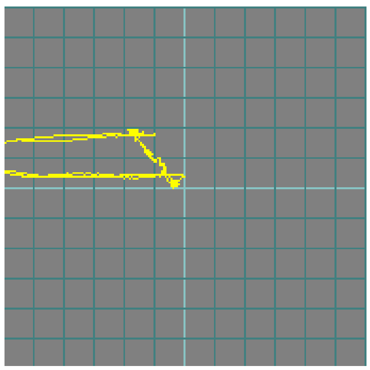

Figure 10

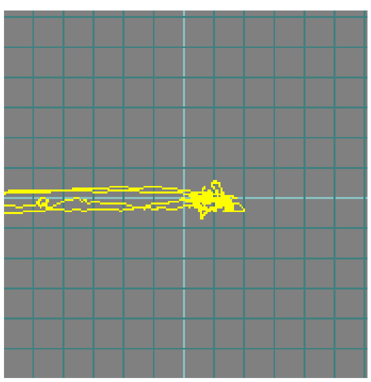

Figure 11

With this, even in presence of variable gap second layer corrosion of 10% was reliably detected, as shown in Fig. 12.

2.5 Surface Inspection with Array Probe

Traditionally, surface inspection was carried out using pancake surface probe and the entire surface to be inspected needed to be scanned manually. The main drawback of this was that the inspection was quite subjective, and the quality and dependability of the test varied with the person conducting the test.

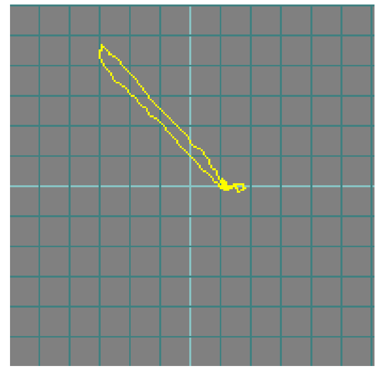

Figure 12

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If we have several pancake coils arranged over surface to be tested, say 8, 12 or 16 pancakes, to form an array probe , it can be used to scan a lot more area in single scan. Each element is energized one at a time. There exists a dead zone between two elements. To cover this zone, another array, skewed by half an element is arranged adjacent to the first. (Fig. 13). Micro-miniature circuitry is integrated in the probe itself. These circuits handle the required switching and multiplexing.

Figure 14 shows two sets of C-Scans generated, one each for Transverse defects and Longitudinal defects, which illustrates the signals due to artificial defects as shown in the Fig. 15 above.

Fig. 13: Staggered Arrays of Pancake Coils

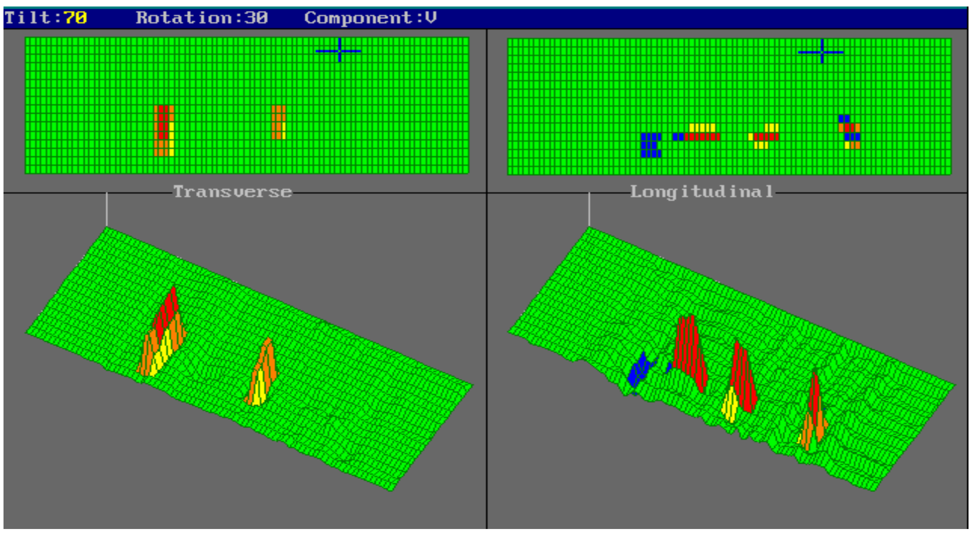

Fig. 14: Color-coded C-Scans showing transverse and longitudinal defects

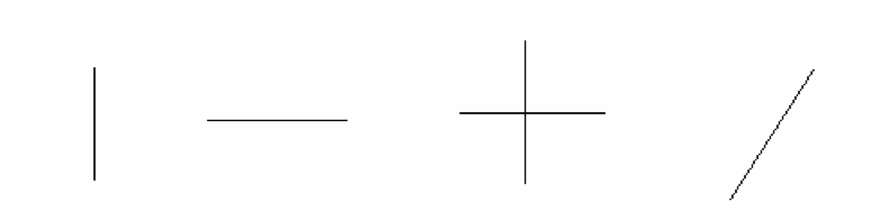

Figure 15

Spring loading arrangement keep the lift-off relatively constant. The system keeps track of the elements in the array that are energized at different times, and associates the corresponding signals in memory. Among other things, this also makes it possible to tell whether the defects are longitudinal or transverse.

The first from left is a transverse EDM notch on a steel plate. A longitudinal notch follows. Next is a cross, with both transverse and longitudinal components. The last defect is a 45-degree notch.

C-Scans have a 2-D and a 3-D component. The 3D scan can be rotated and tilted as required. The scans are color coded, where hot colors (yellow-orange-red) represent positive signals and the cooler colors (blue, dark blue and black) stand for negative signals of increasing magnitude. Greens are signals near zero.

Note that the transverse scan only shows indications for the transverse notches, with slight negative dimples for longitudinal components. The longitudinal scan shows signals due to longitudinal as well as 45-degree notches.

The blue area in longitudinal scan represents a higher negative signal corresponding to the transverse notch.

The location on the scans corresponds to the element of the probe array that generated the signal. Cursors can be positioned on the 3-D C-Scans and the corresponding eddy current signals can be seen in the conventional strip-chart and vector displays for further analysis along traditional lines.

3. Conclusions

Use of eddy current inspection during scheduled maintenance of aircraft structure and components is mandatory. In this paper a few eddy current inspection techniques for detection of defects in aircraft industry were discussed. With modern equipment such as SD-PC-12, with the advantages of digital precision, data acquisition, data archival and reporting, aircraft inspection has become more reliable and repeatable.