AN EDDY CURRENT ARRAY IMAGING SYSTEM

Glenn A. Geithman
The Boeing Company
P. O. Box 3707, MS 73-30
Seattle, WA 98124

INTRODUCTION

The early detection of fatigue cracks in the aging aircraft fleet has become the focus of increased attention in recent years. One area of particular concern is the fuselage lap joint. Repeated pressurization cycles can result in the formation of fatigue cracks which typically emanate from the fasteners and propagate longitudinally as illustrated in Figure 1. This problem can be exacerbated considerably by the presence of corrosion.

The currently accepted technique for detecting these cracks involves the use of a single eddy current coil in a hand scanning mode. Unfortunately, this method is time consuming, operator dependent and provides no permanent record. A prototype eddy current array imaging system was developed and evaluated in an attempt to address these deficiencies. The device consists of multiple eddy current coils mounted in a hand-held probe which interfaces to a personal computer (PC). The probe is moved along the surface of an aircraft in a manner analogous to the way information is supplied to a PC via a mouse. The resulting data is presented to the operator in a pictorial fashion on a video display.

PROBE DESIGN

The decision was made to use a total of 32 individual coils for the array. This number represents a compromise between excessive complexity and image quality. An operating frequency of 100 kHz was selected which produced a skin depth in aluminum of approximately 0.015 inches, giving good sensitivity to near surface cracks. The coils were fabricated using 0.030 inch diameter ferrite rods with a ferrite cylinder of 0.110 inch outside diameter providing shielding. A sufficient number of turns of magnet wire were wound on the center rods to produce a total inductance of 100 microhenries. This resulted in an inductive reactance of 63 ohms which was a reasonable value for the bridge circuitry. The coils were placed on .025 inch centers by arranging them in a pattern of 5 rows as shown in Figure 2. An incremental optical shaft encoder was incorporated in the probe and provides position information by means of an up/down counter. A sample pulse is produced every 0.025 inch of probe travel and serves as an interrupt signal to the computer. The probe assembly is attached to the main electronics unit by a 10 foot flexible cable.

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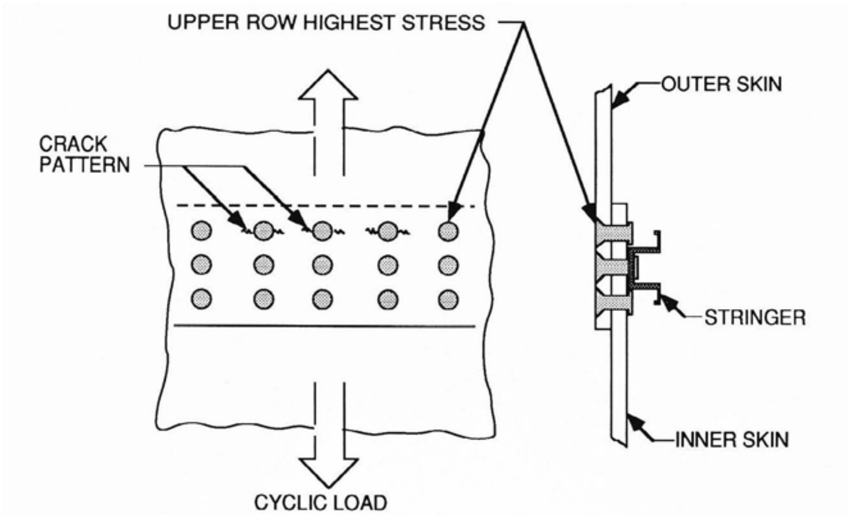

Figure 1. Fuselage lap joint area depicting a typical failure mode

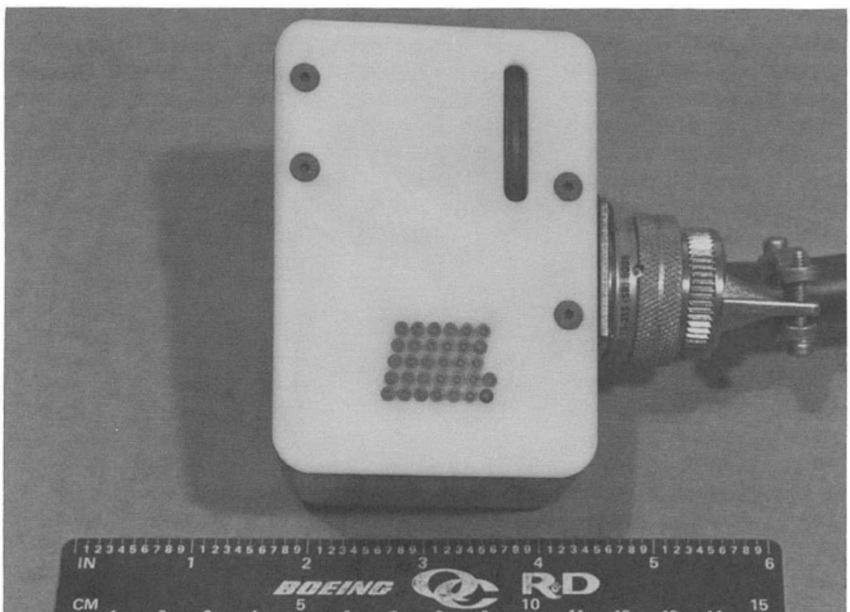

Figure 2. Eddy current array probe (bottom view)

MAIN ELECTRONICS UNIT

The analog eddy current electronic circuitry is of conventional design and is contained within an expansion chassis. This chassis is mounted on a GRiD Systems 386 based portable computer The completed prototype is shown in Figure 3. The circuitry consists of 32 separate bridge circuits and associated differential amplifiers. The output of each of the amplifiers is fed to a pair of synchronous detectors which provide the in phase and quadrature components of the eddy current signal. A crystal controlled oscillator is used to supply the sinusoidal excitation to the probe together with the reference signal to the synchronous detectors.

The output of the 64 synchronous detectors is then low pass filtered with a maximum bandwidth of 1 kHz. The purpose of the filtering is to eliminate the 100 kHz component of the excitation signal while allowing the lower frequency components related to the probe motion to pass unimpeded. For example, a probe velocity of 10 inches per second, at a sampling interval of 0.025 inches, results in a bandwidth requirement of greater than 400 Hz. The output of the low pass filters is supplied to a 64 channel, 12 bit, 100 kHz analog to digital converter. This relatively high degree of resolution and speed is required to insure a sampling interval of less than 1 millisecond and a resolution sufficient to allow good computational accuracy in the software.

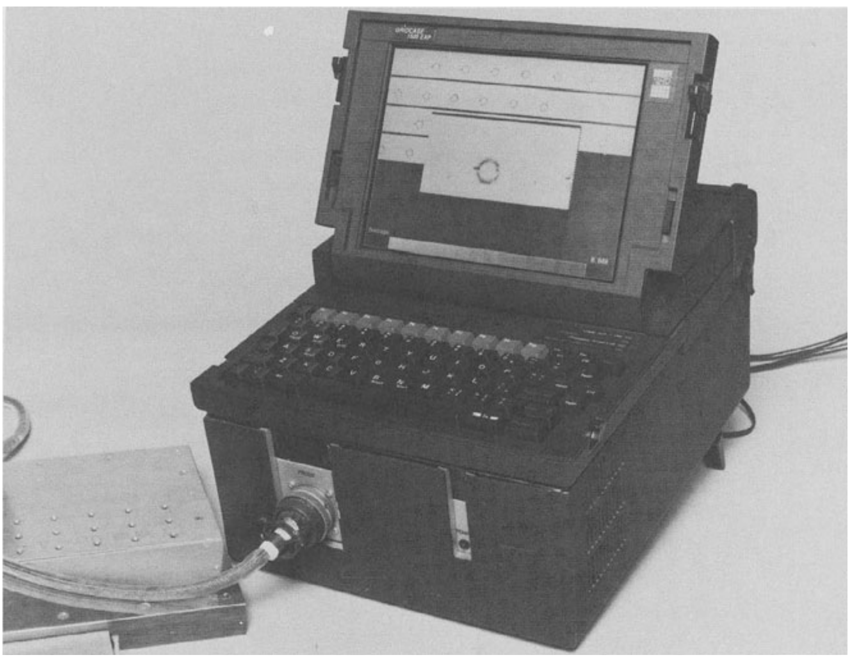

Figure 3. Main electronics unit

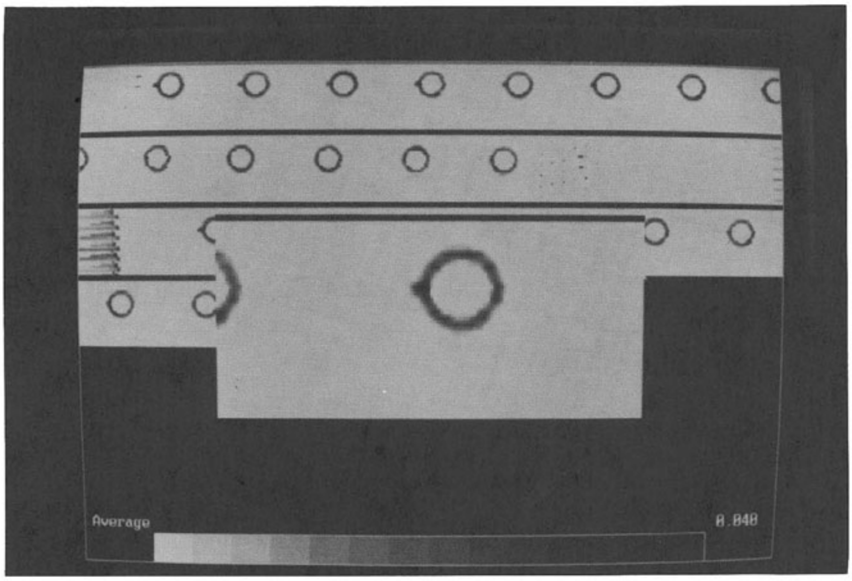

Figure 4. Typical video display showing zoom mode capability of a simulated crack.

SOFTWARE

The computer collects and stores the data from the analog to digital converter corresponding to the real and imaginary part of the eddy current response. A lift-off compensation is then performed in software by placing the probe on bare aluminum and inputting this fact via the keyboard. A suitable spacing material such as paper is then placed between the probe and the bare aluminum and this fact is again keyed into the computer. The software then does an appropriate coordinate rotation resulting in the lift-off vector being made orthogonal to the display vector.

Small differences in sensitivity between the various channels are also eliminated in software by normalizing the gain. This is accomplished by moving the probe over a simulated infinite crack and inputting this fact into the computer. The software then equalizes the channels. The process of lift-off compensation and gain normalization require only a few seconds of operator time and can be performed every few minutes if necessary.

OPERATION

Once lift-off compensation and gain normalization have been accomplished the operator is ready to proceed with the inspection. This is done by pushing the probe along a line of rivets using a straight edge for alignment. The picture unfolds in real time on the video display at this point. Scan speeds of up to 5 inches per second are possible using this technique. Figure 4 is a typical display showing the zoom capability of the software on a simulated crack of approximately 0.060 inch in length.

The unit is capable of detecting cracks as small as 0.050 inch in length measured from the shank of the rivet. Cracks of 0.100 inch and longer give unambiguous indications. This compares favorably with the best results obtainable by conventional hand scanning techniques.

It is felt that this approach to eddy current inspection shows a lot of promise and could be extended to many other applications. For example, larger coils and lower frequencies might make the device suitable for second layer crack inspection. The detection of corrosion damage is another area where arrays of this type might find application. At present, the prototype unit is undergoing further refinements in order to make it a more rugged and reliable unit for field use.

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