A STUDY OF INDEX STEP SIZES FOR VARING COIL DIAMETERS AND THEIR EFFECTS ON THROUGHPUT AND PROBABILITY OF DETECTION (POD) FOR IMPROVED AUTOMATED EDDY CURRENT INSPECTIONS ON AEROSPACE ENGINE-COMPONENTS

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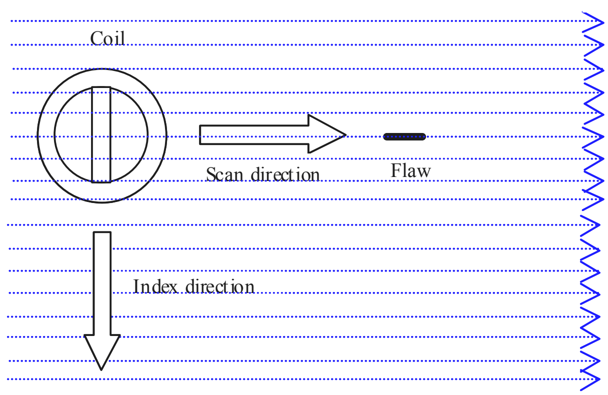
Abstract: The effect of index distance and coil size on eddy-current inspection throughput rate, and resulting POD, are being examined using the Eddy Current Inspection System (ECIS) developed under the USAF's Retirement for Cause (RFC) program. The index size (distance between adjacent scan lines) is typically set to a small fraction of the coil diameter. For USAF engine inspections, the index size was fixed in the early 1980s to be 0.010-inch, based on the coil size in use at that time. The inspection throughput rate could be increased by enlarging the index size with a possible associated increase in coil size, but the effect on POD is unknown. A systematic approach was examined by first determining a large index, followed by a reliability study for POD results and then a part inspection for throughput comparison. Results of increasing index size and their POD curves are presented.

Introduction: Increasing the index size without adversely affecting the acceptable POD results is the objective of this study. To achieve this goal, the index size is first estimated using a simple algorithm based on the data acquired through a fine index size. This extended index size is then tested on the reliability specimen for POD analysis. Both the throughput and POD results from extended and regular index sizes are then compared and discussed.

Results: (1) DATA ACQUISITION

To avoid the exhausting effort of taking data for a large number of different index sizes, an alternative is to take one set of data at a fine index (i.e., 1-mil or 0.001-inch) and obtain additional information by computer simulation. Figure 1(a) shows the scan and index direction of a coil passing over a specimen containing an EDM notch. Figure 1(b) shows the image of the notch region that was scanned by using the 1-mil index.

(a)



(b)

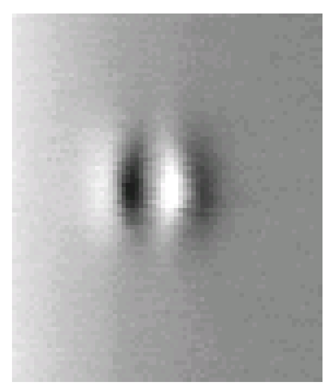


Figure 1. (a) Experimental setup showing the scan and index range over a notched specimen for the initial test and (b) the resultant amplitude image for the area scanned with the brightness proportional to the amplitude.

(2) INITIAL TEST

Based on the 1-mil fine index data, a simple algorithm was performed to study the effect of the different index sizes on the signal. By re-sampling the amplitude profile below in Figure 2(a), the effect of increasing index sizes on the peak amplitude is shown in Figure 2(b). The peak amplitude at 10-mils, the current inspection index, was 5.8% less than that of 1-mil. The amplitude at 17-mils was 10 % less than that of 1-mil. Further tests were then performed based on the larger index size of 17-mils to investigate the impact on the POD and part inspection results.

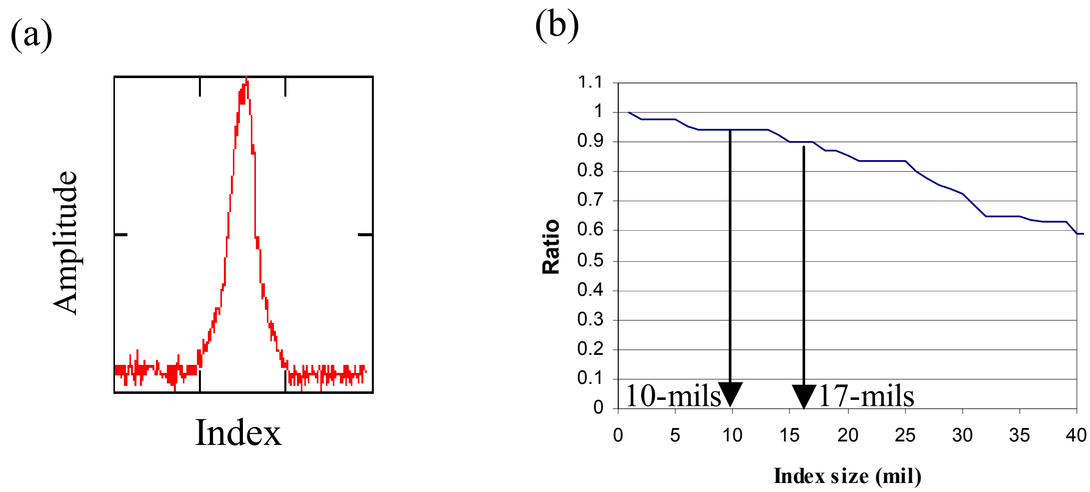


Figure 2. Initial test results showing (a) the eddy current signal amplitude resulting from stepping over the EDM notch at 1-mil index size and (b) the variation of the peak signal amplitude when the index size is increased.

(3) THRESHOLD PLOT COMPARISON

A series of tests have been made on five probes of different coil sizes at various index sizes. Table 1 lists a test matrix showing these combinations. A POD test was performed on seventy Waspaloy specimens containing fatigue cracks of interest. The same probe was first used to collect the data using the regular index size and then repeated for the large index size. A POD analysis was then conducted on both data respectively. The results indicated that less than 1-mil of difference in the POD results was noticed even at the lower threshold levels. This difference is typically within the variation typically caused by other inspection system factors (i.e., probes).

Table 1. Test matrix of different coils at various index sizes (unit: 0.001-inch).

	D20	*D40*	*D50*	*D80*	*D100*
Regular index size	5	10	12	17	22
Extended index size	7	17	17, 22	22, 34	34

Figures 3 through 7 present threshold plots for the five coil sizes that were analyzed. Either two or three indices were used for each coil size with the smallest index being a small fraction of the size of the coil. In all five of the figures, if a threshold for a target a90 value is determined from the smallest index, the a90 value for other indices will be within one mil of that of the smallest index. This degree of difference has been judged to be acceptable as differences of one mil or so due to probe change or recalibration without a probe change have often been observed in ECIS evaluations.

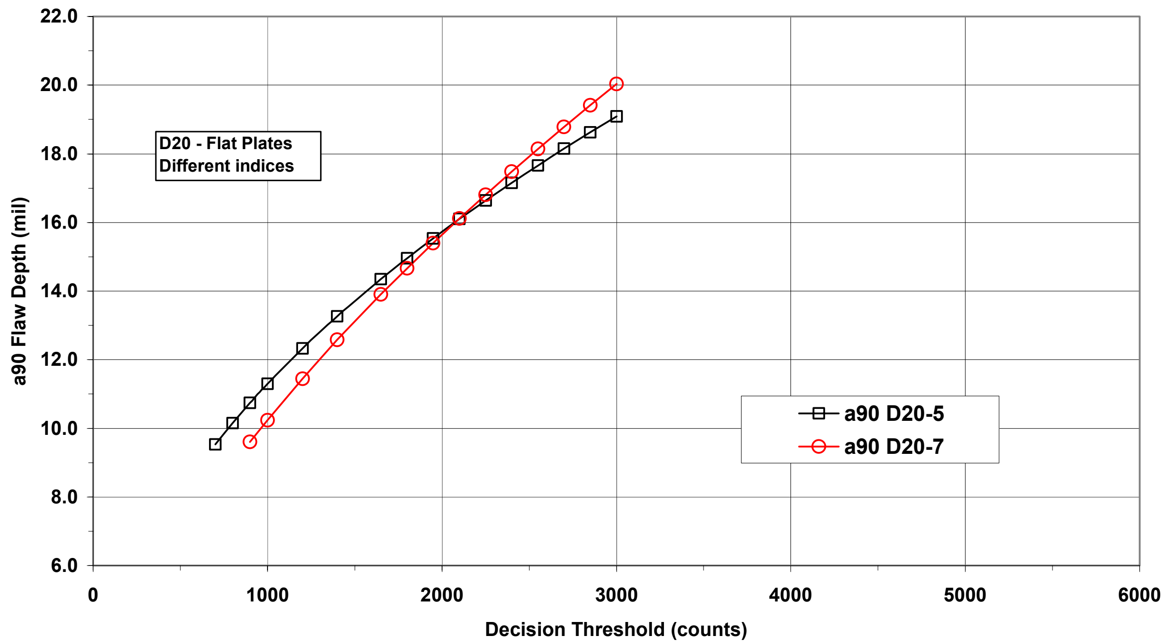


Figure 3. Threshold plots for the D20 coil size with index sizes of 5 and 7 mils.

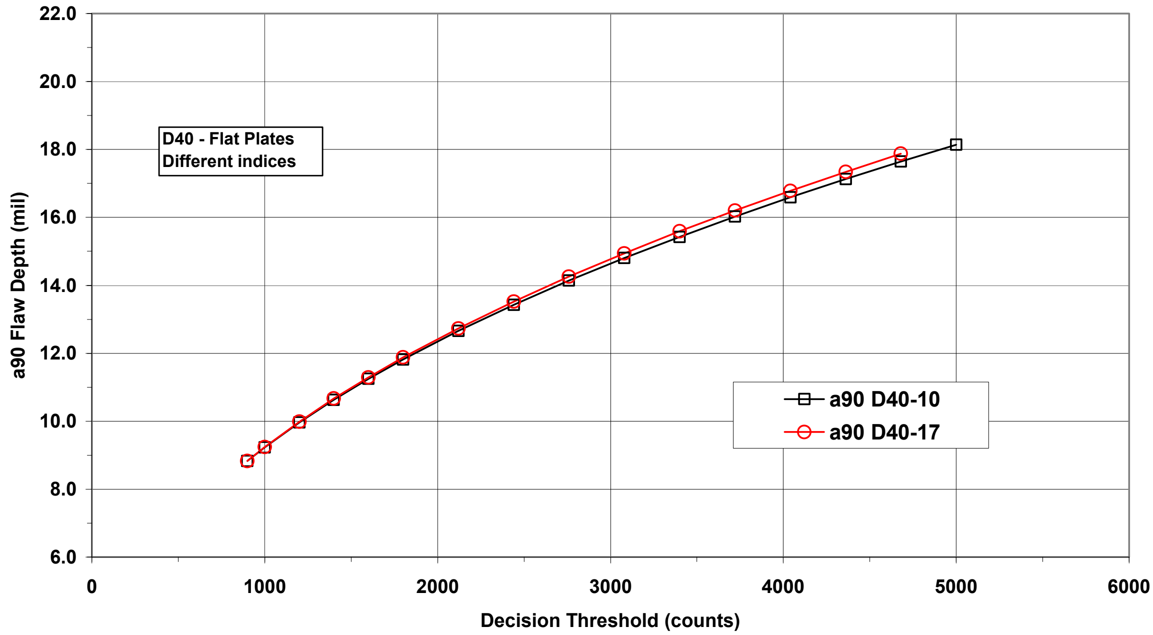


Figure 4. Threshold plots for the D40 coil size with index sizes of 10 and 17 mils.

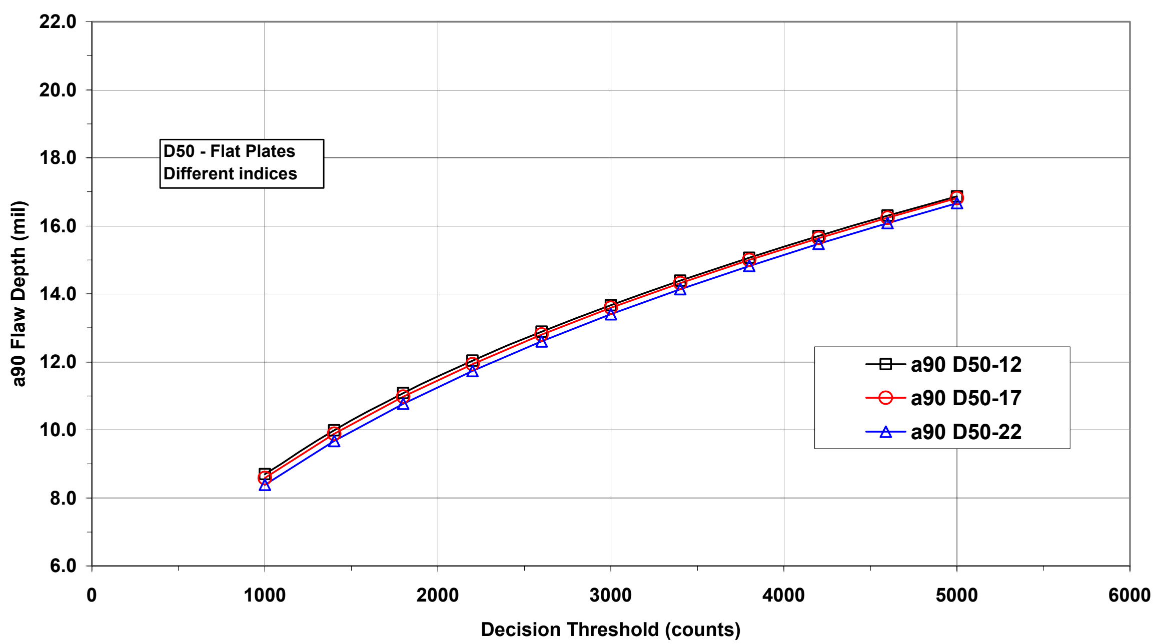


Figure 5. Threshold plots for the D50 coil size with index sizes of 12, 17 and 22 mils.

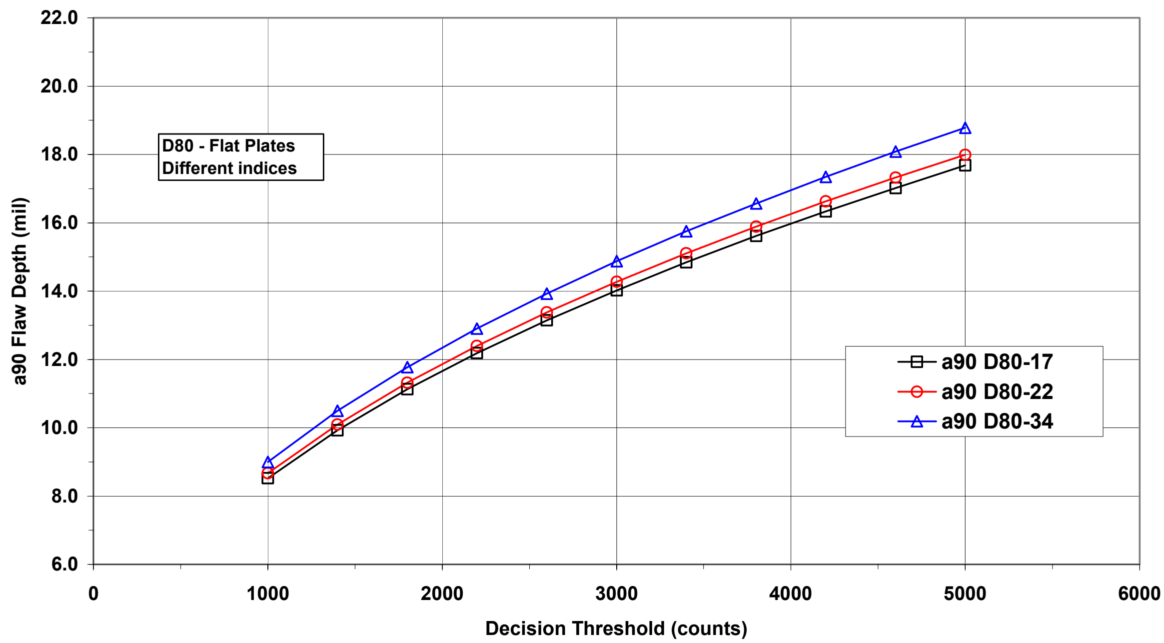


Figure 6. Threshold plots for the D80 coil size with index sizes of 17, 22 and 34 mils.

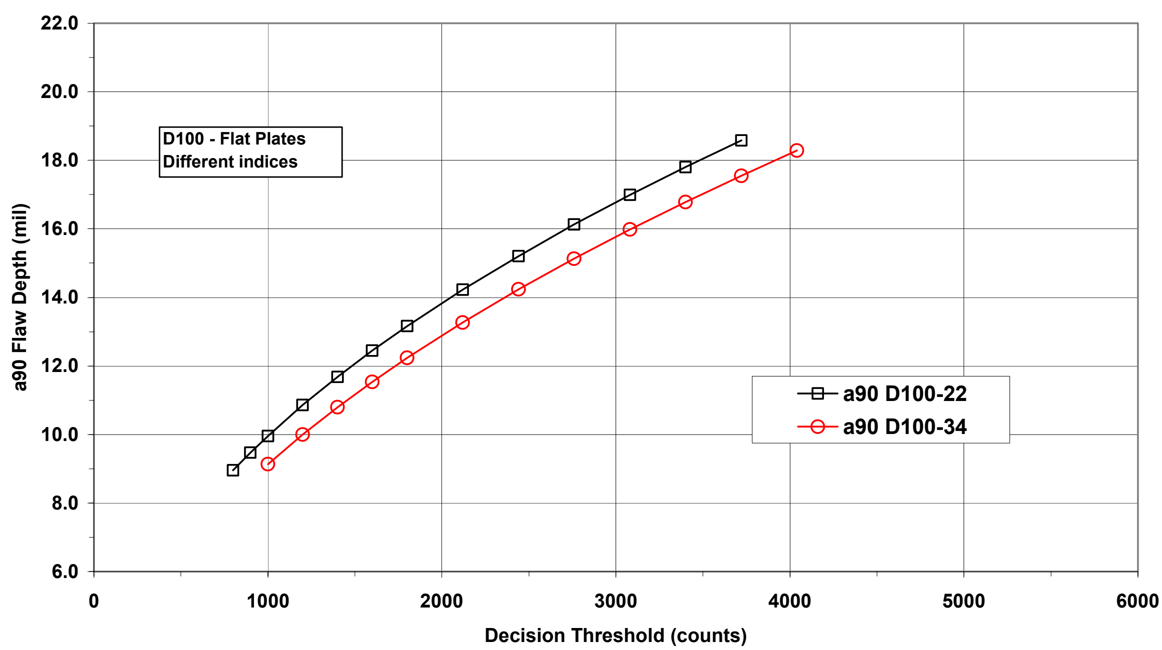


Figure 7. Threshold plots for the D100 coil size with index sizes of 22 and 34 mils.

The differences in the a90 values for a fixed threshold are not always consistent with expectation. For example, it is reasonable to assume that a larger index would result in smaller â values because of the chances of missing peak readings. However, for the D100 coil, the threshold for a target a90 value for an index of 34 would be larger than that for an index of 22. Equivalently, the a90 value for a specific threshold was smaller in the index 34 data than in the index 22 data. Although not as pronounced, a similar trend exists in the D50 threshold plot. It is hypothesized that such non-intuitive results are due to the recalibration scatter exceeding that due to the changes in index.

(4) PART INSPECTION

Based on the threshold derived from the above POD tests, an engine part inspection was performed at the USAF's RFC/ECIS station using both the regular and the extended index sizes. The part selected has the same material type as the reliability specimen. The thresholds were calculated based on the critical crack size required for the part. By comparing both inspection results, no extra indications were observed in either case. Using the large index size, however, substantially reduced the inspection time. Figure 8 illustrates the inspection results using the D40 coil. The ratio of inspection times for the regular index to the extended index was 1.7 to 1.

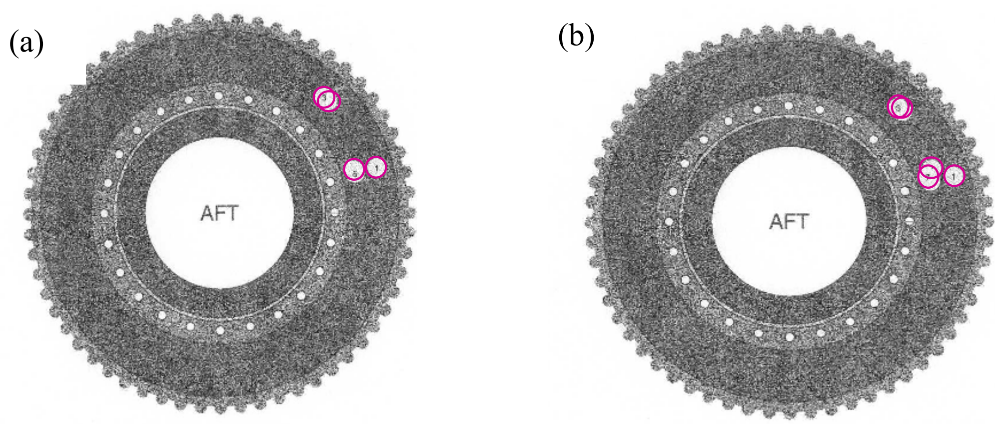


Figure 8. Inspection results of an engine part using D40 coil with (a) regular index size at 10-mils and (b) extended index size of 17-mils. The ratio of time used is 1.7 to 1.

Discussion: Two approaches were taken in the evaluation of potential POD differences due to the coil and index size combinations: 1) to determine if a coarser index could be used without performing a complete POD evaluation for the proposed indices, threshold plots were generated and compared for relevant combinations of coil size and index, and 2) to determine if the scatter in â values is reasonably equivalent to that obtained in the original ECIS evaluations, the scatter associated with different indices for a fixed coil size were compared with the scatter caused only by recalibration and probe change.

For the first approach, the above results from all five of the figures indicated that if a threshold for a target a90 value is determined from the smallest index, the a90 value for other indices will be within one mil of that of the smallest index. For the second approach, repeat inspections of a crack display variability that is due not only to inherent noise that can result even when all system elements are kept constant but also to known changes in the system or its application that are not supposed to change the response. During the POD evaluation of the ECIS system, it was recognized that the effects of recalibration and probe change could be major sources of such variation and would need to be characterized. Accordingly, repeat ECIS inspections were performed that permitted quantifying the degree of variability due to: 1) recalibration with all other system parameters held "constant," and 2) probe change (with subsequent recalibration) with all other system elements held "constant." These measures of variability provide an indication of the minimum level of uncontrolled variability that will be present in the practical use of the ECIS system. As noted above, such scatter in â response often resulted in differences in estimated a90 values of about 1 mil or so.

Conclusions: A systematic approach was examined by first determining a large index with a simple algorithm based on data from fine index size, followed by a reliability study for POD results and then a part inspection for throughput comparison. Results of increasing index size and their POD curves were compared with those from the regular index sizes. The scatter of the POD results with increasing index sizes in this study falls within those normally acceptable variation ranges in repeated ECIS inspections. The part inspection, using the threshold from the POD analysis, also shows similar inspection results. A reduction of inspection time with increased index size was observed. The results in this study suggest that a throughput increase of inspection could be achieved without adversely affecting the acceptable POD results.

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References:

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