EVALUATION OF AN EDDY-CURRENT TAPE-HEAD PROBE

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INTRODUCTION

SRI International is performing basic evaluation and characterization of eddy-current probes that are fabricated using ferrite tape-head technology. Tests conducted during the previous two years using both absolute and differential probes, frequencies of 100 kHz and 1 MHz, and flat-plate samples made of aluminum and titanium demonstrated that such probes exhibit both high sensitivity to surface cracks and high spatial resolution.[1,2] To round out this evaluation, during the past year we studied tape-head reflection probes and measured their characteristics over a broad range of frequencies. This paper discusses reflection probes briefly and presents the results of comparative tests that were made using tape-head and coil-type reflection probes in conjunction with a commercial eddy-current instrument.

REFLECTION PROBES

In previous tests we worked exclusively with absolute and differential probes. These types of probes have one port (i.e., one pair of terminals) where both the excitation is applied and the impedance change produced by a flaw is measured. A third type of probe, the reflection probe, has been reported to detect flaws with high sensitivity.[3,4] This type of probe has two ports, one for excitation and one for detection. Reflection-probe construction is shown in Figure 1(a) for a conventional coil-type probe, and in Figure 1(b) for a tape-head-type probe. Figure 1(c) shows an approximately equivalent circuit for this type of probe. This circuit is known as a transformer hybrid; because its secondary is differentially wound, the circuit has the property that application of a voltage across the primary ideally produces zero voltage across the secondary. The differential construction of the secondary minimizes the effect of symmetric changes in probe environment (such as vertical lift-off); an asymmetric disturbance (such as a flaw), however, upsets the differential balance and produces a large output.

The high sensitivity of a reflection probe is due mainly to the control the designer can exercise over the numbers of primary and

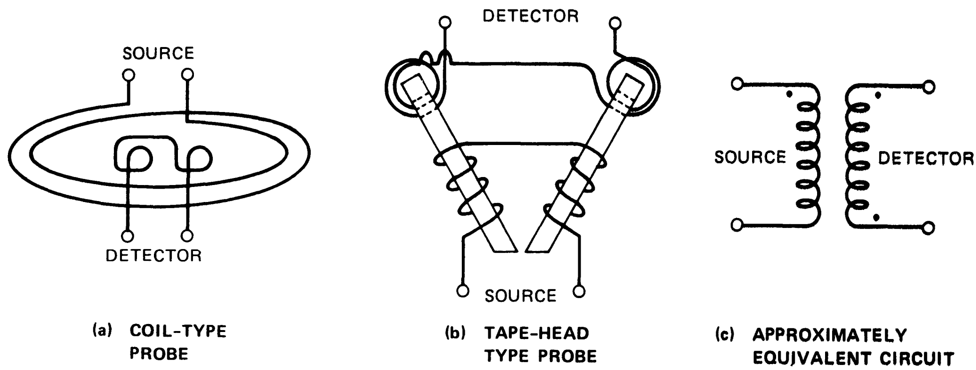


Fig. 1. Reflection probes.

secondary turns. This means that the designer usually can obtain a better impedance match between source and detector than is possible with a single-port probe. Also, using a large number of turns in the secondary enhances the voltage change produced by a flaw (assuming the detector has a high input impedance). In practice, the number of secondary turns is limited by the characteristic impedance of the cable that connects the probe to the detector.*

An advantage of the current tape-head reflection probe is that its ferrite-yoke construction permits a wider choice for the number of primary and secondary turns than do coil-type designs. On the other hand, care must be taken during construction to achieve good probe balance; unbalances can occur in both the primary and secondary windings.

EXPERIMENTAL APPROACH

A Nortec NDT-18 eddyscope was used to conduct the measurements in this phase of the probe evaluation. This eddyscope is a state-of-the-art analog instrument that contains a synthesized source that can be tuned from 50 Hz to 5 MHz and it can be used with reflection probes as well as with absolute and differential probes.

Three tape-head reflection probes with the general configuration shown in Figure 1(b) were made to SRI specifications by a tape-head manufacturer.† Based on the 20-Ω output impedance of the NDT-18 source, the number of primary turns, N_p, in these probes was made equal to 20. Each of the three probes was made with a different number of secondary turns, N_s, to try to determine empirically the optimum number of turns for high flaw sensitivity. The numbers chosen for N_s were 80, 100, and 120. The optimum number of turns depends on the connecting cable and

*This limitation might be overcome by using a buffer amplifier to match the probe to the cable.

†TAS Manufacturing Corp., San Jose California.

the instrument. For the test, we constructed a special high-impedance cable; tests showed that an N_S of 80 gave the best results when this cable was used to connect the tape-head reflection probe to the NDT-18. In these tests we also used a Nortec SPO-2065 coil-type reflection probe.

All tests were made using flat-plate samples of titanium alloy containing surface-breaking fatigue cracks approximately 0.030-in. and 0.055-in. long. The probes were scanned over the sample by hand; the flaw response was observed and measured on the phasor display of the eddyscope.

The phasor display of the NDT-18 is useful in this type of study because it allows peak flaw response to be determined easily. The differential and reflection probes that we tested produce a "figure-eight" flaw response (Figure 2). The distance between the tips of the figure eight in volts was used as the measure of flaw response.

Besides flaw sensitivity, lift-off discrimination also plays an important role in flaw detection. In our evaluation of lift-off discrimination, we used the qualitative ratings that are illustrated in Figure 2. To assign ratings, we evaluated figure-eight-loop size and orthogonality between the flaw and lift-off response; larger loops and better orthogonality were interpreted as better lift-off discrimination.

RESULTS

We first compared the tape-head differential probe evaluated last year and the new tape-head reflection probe. Typical results are shown in the two upper photographs in Figure 3. The reflection probe was 20 dB more sensitive. This excellent sensitivity was achieved even

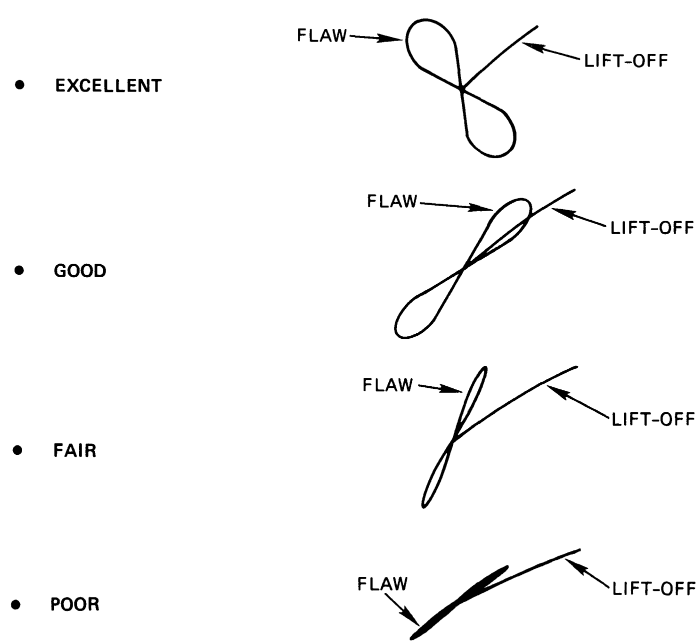
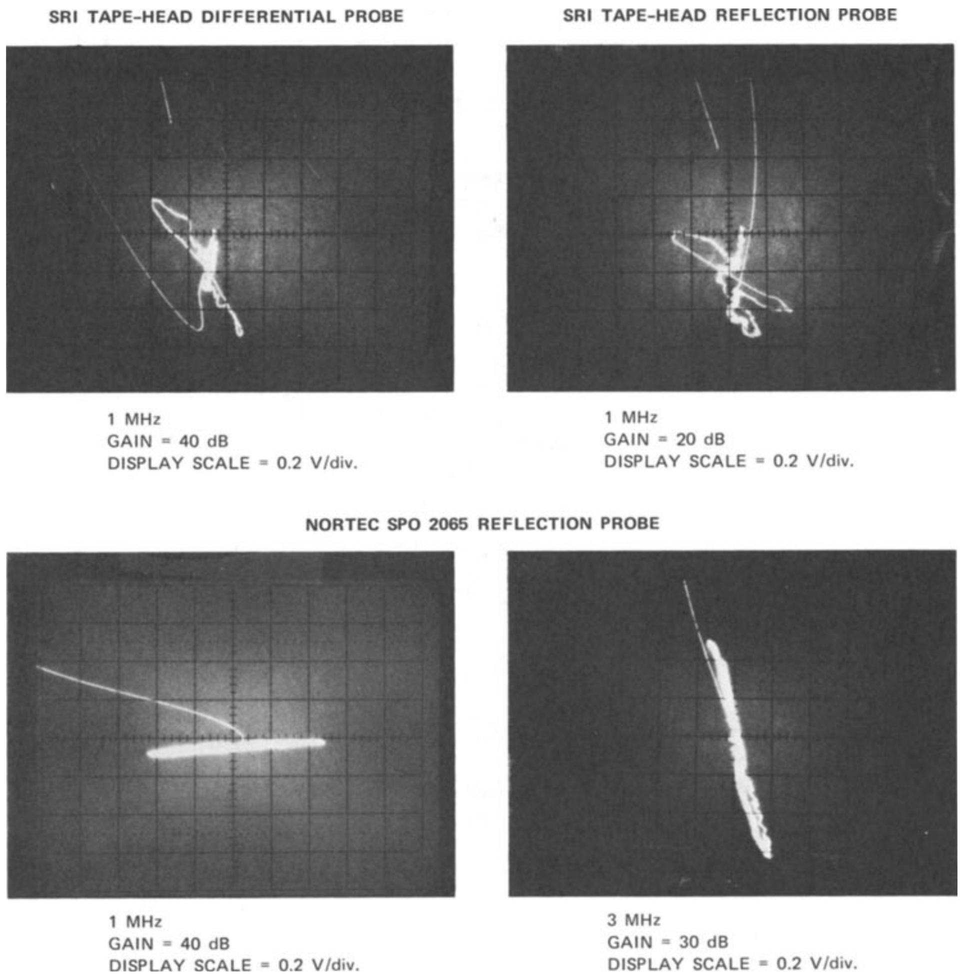


Fig. 2. Ratings of lift-off discrimination.



(Material: titanium alloy; crack length: 0.030 in.)

Fig. 3. Comparison of flaw signals.

though the secondary of the tape-head reflection probe had to be shunted by 3.3 kΩ to avoid saturating the NDT-18 detection circuitry.

Typical results for the SPO-2065 reflection probe are shown in the two lower photographs in Figure 3. This probe performed very well, but it was not as sensitive as the tape-head reflection probe. On the other hand, it was better balanced, which resulted in lower lift-off sensitivity. However, its lift-off discrimination was worse, particularly at frequencies above 3 MHz, where saturation effects in the NDT-18 occurred with this probe.

Figure 4 shows measured reflection-probe sensitivity for two crack sizes as a function of frequency. Both the tape-head and SPO-2065

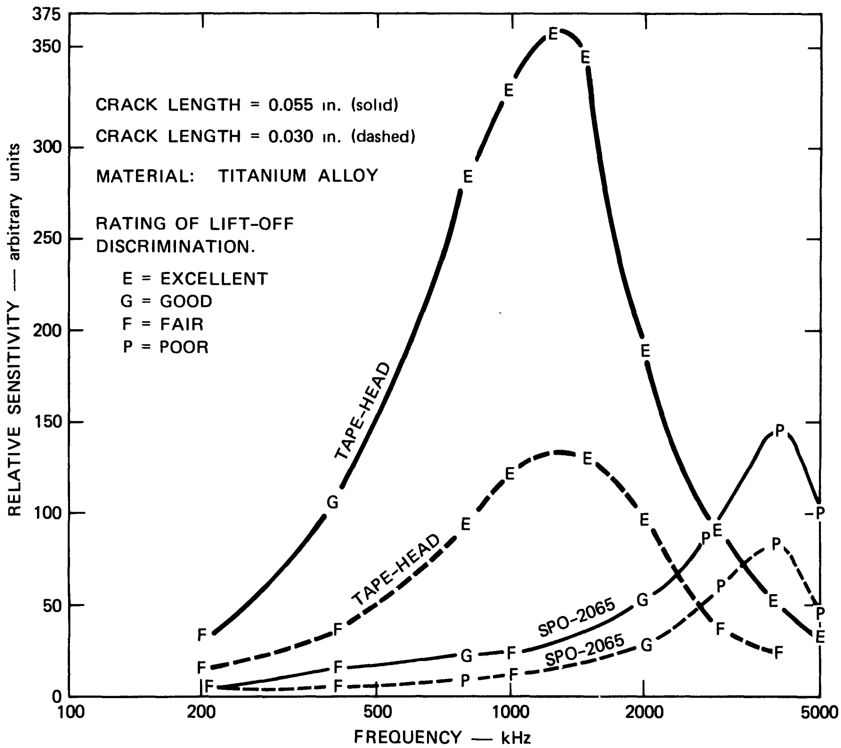


Fig. 4. Reflection-probe frequency responses.

probes exhibit peaks in their responses. We believe that the roll-off at high frequencies is chiefly a system characteristic rather than a probe characteristic.

The curves show that the flaw signal produced by the tape-head probe increases more with increasing crack length than does that produced by the coil-type probe. This effect may be related to the higher spatial frequencies contained in the fields generated by the tape-head probe.

The letters on the curves show our rating of lift-off discrimination at each measurement frequency. The tape-head probe was generally better in this regard than the SPO-2065.

SUMMARY AND CONCLUSIONS

The tape-head eddy-current probe has been demonstrated to be capable of detecting surface flaws with very high sensitivity, high spatial resolution, and good lift-off discrimination. Its performance in these areas exceeded that of commercially available coil-type probes that were tested. Tape-head probes can be configured as absolute, differential, or reflection probes, and they are completely compatible with conventional eddy-current instruments. Finally, tape-head probes use an established fabrication technology.

Future work on tape-head probes should include miniaturization and application to nonplanar geometrics. Also, the application of tape-head probes to eddy-current arrays is an interesting possibility.

ACKNOWLEDGMENT

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