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APPLICATION OF DATA PROCESSING TO EDDY CURRENT MEASUREMENTS
DESIGN, PREPARATION AND USE OF EDDY CURRENT MAPS

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Mapping provides an eddy-current image of the surfaces examined which is independent from the data acquisition method. Optimization of viewing angle, contrast and perspective plotting contributes to enhancement of image quality. Image interpretation is facilitated by signal pre-processing in the form of filtering, removal of spurious repetitive patterns, or non-linear amplification.

1. INTRODUCTION

Requirements for increasingly detailed eddy-current examinations of surfaces have led to the widespread use of point-probes. Thus we no longer deal with probes moving in a definite direction as when examining tubes with a annular coil, but with an infinite number of possible directions which provide individually a very limited insight into the phenomena under investigation. A signal processing method is therefore required to eliminate process-related features and restore a direct relationship between the image and the surface being examined.

2. SUPPRESSING ANISOTROPY IN MEASUREMENTS

DIRECTION of deplacement is one of the factors conventionally associated with measurement quality : a basic rule is to move the probe in the direction which provides the strongest fluctuation gradient over the defects, to improve the contrast with drift and other spurious phenomena. The only disadvantage is that in this case, we need to assume that the problem has been solved before we can select the direction, even through simulation after the examination.

The use of DIFFERENTIAL PROBES to minimize drift implies a specific orientation of receivers with respect to the direction of motion. However, if the travel concept vanished, or if direction is changed as a result of simulation, it is found that the probe pattern is thoroughly anisotropic.

LINEAR DISPLAY of the X(t), Y(t) signals leads to eliminating proximity relationships between those points which are not on the probe direction. It is therefore necessary to arrive at a display which restores all proximity relationships, i.e., a two-dimensional display relating to the surface under examination.

The 3-D MAPPING concept is derived from an analysis of the above three anisotropy factors. Figure 1 is a strictly illustration of the initial analog process : a parallelline display is associated with the motion of a differential probe along parallel paths (top left). When moved actually or conceptually in directions perpendicular to the above, the probe gives another plane display (top right). By superimposing the two acquisitions, we obtain a map in which the travel concept no longer has the same meaning : it is a plane image (center). Using a third dimension to separate eddy-current signals from position variables gives a 3-D perspective view (bottom). However, it should be noted that this last view retains an anisotropic appearance because it was obtained through a differential probe (presence of a trough-peak pair indicating a single defect).

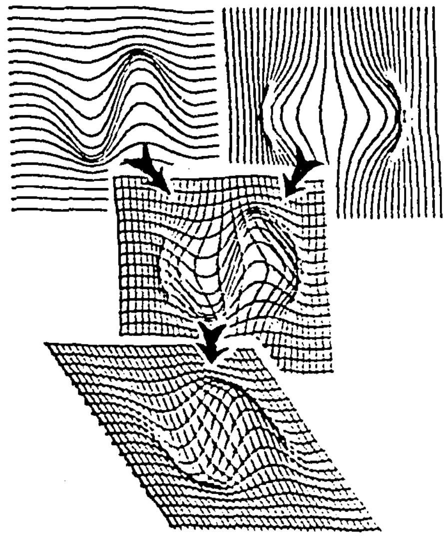


FIG. 1 THE WAY FROM PARRALEL LINES TO A THREE DIMENSIONS MAP .

3. INVESTIGATION EQUIPMENT

Two micrometric POSITIONING BENCHES have been used for mapping investigations and software development :

- a three-motion, XYZ bench with HPIB interface, having 10-micron resolution in all directions, is now used for the examination of plane or slightly warped surfaces.

- a bench, also with HPIB interface, for tube examination. This bench features many fine adjustment facilities, e.g., probe rotation radius,probe axial offset, misalignment, etc...

Several Hewlett Packard Series 200 COMPUTERS were connected to the benches. These computers have a large capacity internal memory, hard disks with capacity of 64 Mbytes, removable storage units (flexible disks, 67 Mbyte cartridges).

Data are acquired through a fast multi-programmer or through the "CADET" specific tool. Maps are produced on graphic plotters.

All the CEA Saclay SOFTWARE has been linked with one structure, which permits inter-connection of mapping jobs, signal enhancement processing and probe simulation (shape and travel).

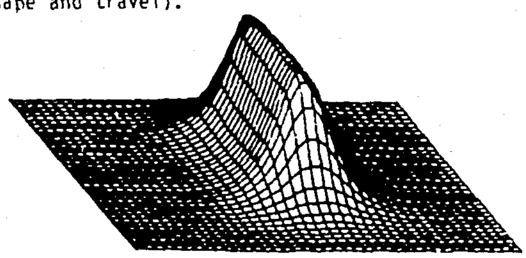


FIG. 2 DELETING HIDDEN LINES AND EXPANDING TOP CONTOUR LINE IMPROVE REPRESENTATION OF LARGE SIGNALS

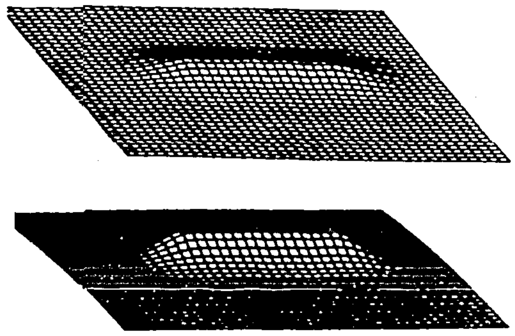
4. RESULTS

Specific features of the mapping technique relate to two categories of considerations :

- characteristics and performance of mapping instrumentation,

- characteristic and performance factors linked with the signals used for mapping.

Satisfactory mapping results from the optimization of the above two aspects.



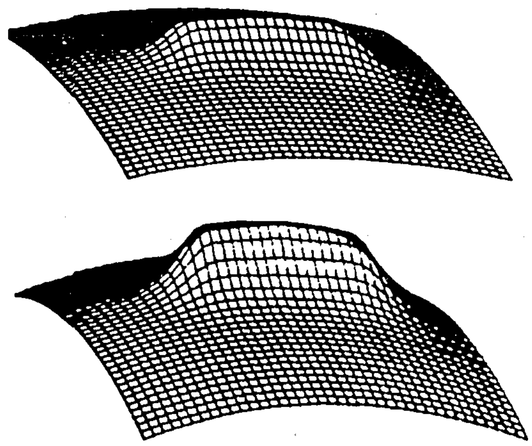
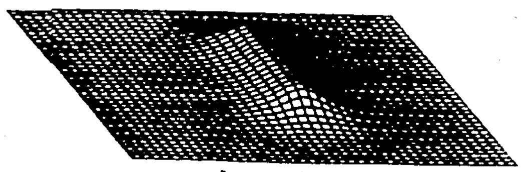
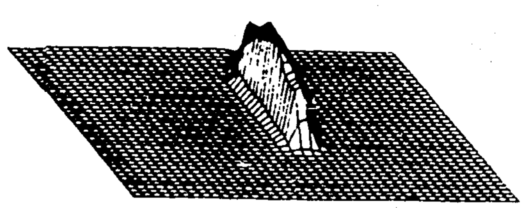


FIG. 3 BENDING THE MAP MODIFIES THE BLACK / WHITE RATIO AND CAN INCREASE CAPABILITY OF DETECTING DEFECTS .



normal mapping



exponential mapping

FIG. 4 EXPONENTIAL PROCESSING INCREASES ACCURACY OF A CRACK MAPPING

As regards the MAPPING PROCESS, the first point is the PLOTTING MODE. The technique used consists of connecting the measuring points together to obtain a grid covering the surface. This method was chosen because of its simplicity, and also because this type of cross-line display gives a good 3-D representation irrespective of orientation. Figure 1 is a perfect illustration of how the 3-D effect is produced, mainly through perception of individual line motion, and to a lesser degree through the size of the meshes formed by these lines.

DELETION OF HIDDEN LINES permits relief enhancement without line folding. The top contour line is always made heavier to obtain a signal which stands out better against the image background (fig. 2). HALF-TONES have been obtained by adjusting the width ratio of black lines to white squares. Under certain conditions, very small signals may change significantly the black-to-white surface ratio giving images with higher contrast in which tone variations are used. 3-D perception can be enhanced by an appropriate viewing angle : a grazing angle makes small irregularities more visible, but would not be suitable for a strongly marked relief, in which there would be too many hidden parts. A 90° rotation around a vertical axis improves the chances of detecting small irregularities, because the image contrast (change in white/black ratio) is dependent on relief orientation with respect to the point of observation. In some cases, it may be necessary to introduce SURFACE CURVATURE to further enhance image contrast by creating a shadow behind the fault or a grazing light in front of it (figure 3).

SIGNAL-RELATED PERFORMANCE depends first on the appropriate selection of the component used, i.e., the module in some cases, or in others the component perpendicular to the lift-off effect, or a combination of both. RELIEF WISE is important : small signals are generally more visible as salients than as recesses. SIGNAL PRE-PROCESSING improves picture quality : IMAGE FILTERING significantly enhances the signal-to-noise ratio and makes hidden signals clearly visible. DELETION OF UNWANTED SIGNALS, possible through computation in the cas of repetitive signals, facilitates interpretation in the case of edge effects or periodic-type distrubances (e.g. rotary probe running off-center).

NON-LINEAR SIGNAL DISPLAYS will be found useful in many cases. Logarithmic processing extends the useful dynamic range of signal detection, permits reducing hidden areas and minimizes specific features observedwith certain defect types (e.g., presence of two extrema for a single defect). In contrast, exponential processing sharpens curve peaks (fig. 4) and is more effective in determining the orientation of long defects or distinguishing indications which are close to one another, provided there is not a great difference in amplitude.

5. CONCLUSION

The useful features of 3-D mapping have been discussed above. First, we no longer consider sensor travel, but instead an isotropic measurement which produces an image consisting of pixels intrinsically connected to the surface under examination. This image shows relief which has no material significance but represents the electromagnetic phenomena present in the metal.

Signal pre-processing, the appropriate selection of mesh scale and viewing angle, and non-linear signal display are factors which contribute to mapping quality.

Many applications are under development in the Saclay Laboratory, particularly in the tube area (figure 5). An example has been given in this conference [1]. Analysis of signal acquired on site is scheduled for the first quarter of 1985.

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C. FERRE, R. LEVY (INTERCONTROLE)
A. GOURMELON (EDF)

INVESTIGATION OF AN EDDY CURRENT EXAMINATION PROCESS FOR PERTURBED ZONES OF PWR STEAM GENERATOR TUBES (presented in this conference)

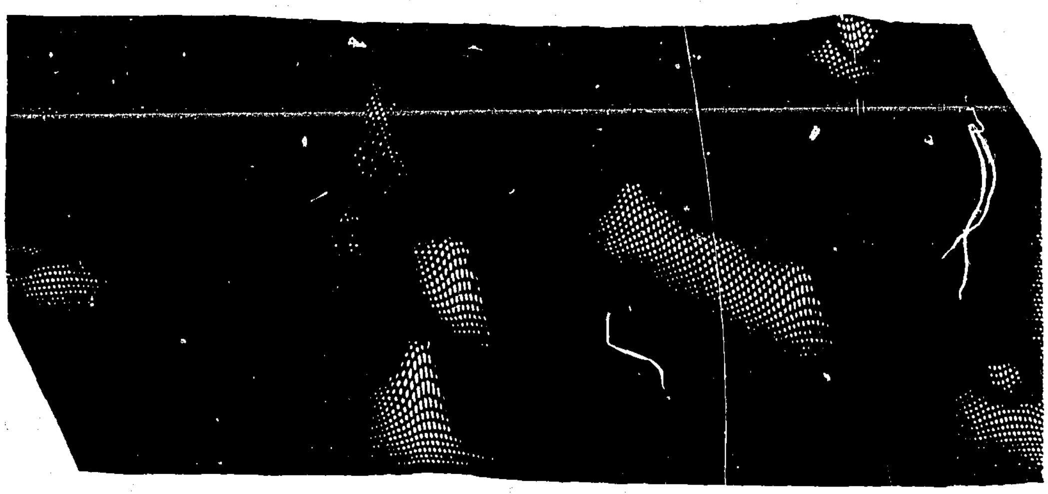

FIG. 5 AN EXAMPLE OF MAPPING INSIDE OF A TUBE WITH CRACKS AND HOLES