Introduction of a Base-Model for Eddy Current Testing of Printed Circuit Boards

学術論文

Introduction of a Base-Model for Eddy Current Testing of Printed Circuit Boards

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In this paper we propose a model to reproduce a PCB pattern eddy current testing signal based on 3D FEM package and scanning simulation. In this method we consider some common PCB elements as test pieces while a simple Meander-type coil is utilized as excitation coil above the elements. Numerical solution to the above problem with the help of a 3D FEM provides the magnetic flux density in the region above the PCB test elements. Shifting the test element's position step by step and repeating the numerical calculation for each of the test elements new positions, the scanning process of a PCB test piece is simulated. Analysing and smoothing the magnetic field data from all of the aforementioned steps provide the final PCB pattern signal. Image processing technique was applied to obtain the PCB part image.

Key words: PCB inspection, Eddy current testing, Meander coil, FEM.

1. Introduction

Eddy current testing (ECT) is an important non-destructive method used for inspection and locating defects on conducting materials such as metallic pipes, wings of airplanes or even the conductive strips of a printed circuit boards (PCB) [1], [2].

The advantages of this method are fastness and low mechanical stress resulting from its non-contact nature, which are suitable for the inspection of delicate objects. Another feature of this method is that we can get the information in the direction of thickness by choosing an adequate excitation frequency considering surface effect. Therefore when it is used in the inspection of PCB, it can find not only disconnection of the printed pattern, but also chipping defect and imperfection of thickness which are hard-to-find by conventional image processing methods.

For the realization of the PCB inspection by ECT method, however, there are two difficulties to be solved. First, eddy-currents should be induced efficiently in thin and narrow printed circuit. For this purpose a Meander-type excitation coil is used [1]. The Meander structure is preferable to the induction of the eddy-currents along the line conductor like printed circuit.

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Second, the pattern of the conductor on PCB is not uniform, different from conventional testing material for ECT. In other words eddy currents in a PCB strip are constrained to a specific path. Hence, the output of the ECT probe includes many kinds of signal originated from not only defects but also PCB pattern. Consequently, introducing a technique which it selects only the defect signal is indispensable for this application. Data processing technique which is already developed [3] could be used to extract the defect signal from the ECT probe output; however the difficulty of distinguishing some defects where they are close to each other still limits the application of this method.

Hence we introduce a method which we call the Base-Model method, to overcome the problem of extracting defect signal from the ECT signal. In this way we obtain an image from existing defects on a clear background. In other words, one needs to locate existing defects, like disconnections, on a PCB conductive strip, hence, the ECT signal obtained from PCB scanning which includes the whole information of a complex PCB pattern, is not required

Our aim here is to find a way to remove the signals having the information of the non-defected strips and just keep the signals related to the defects on the strips. This procedure could be done by applying the method we introduce in this paper. Base-Model method provides the required tools for getting the signals produced by a non-defected PCB. If one subtracts the Base-Model signal from the ECT output signal of a defected PCB, the defect signal is obtained. In this method we simplify a complicated PCB pattern geometry to many simple basic parts; however there is just a few numbers of such simple parts geometry. The next step includes the simulation of scanning process of simple parts individually. This simulation is based on a numerical calculation using a 3-D FEM package. Finally by assembling the individual results from each basic part one can obtain the final signal.

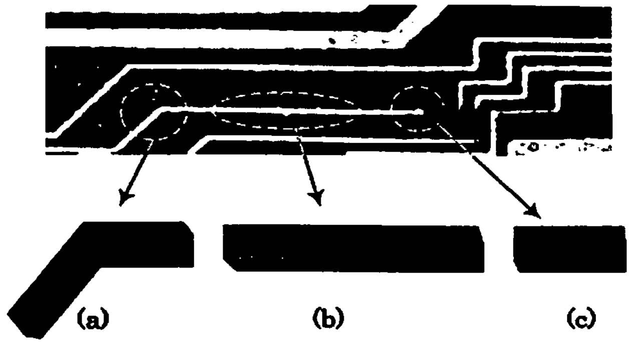


Fig. 1: PCB pattern could be separated into many basic parts such as: (a) open elbow, (b) straight, and (c) half part.

2. Base-Model Method

As the aim of our model is to reproduce the pattern of a non-defected PCB in a theoretical way by simulating the scanning process, the following issues should be worked on carefully:

2.1. Disassembling the PCB pattern

It is possible to consider a PCB pattern geometry as an assembling of some basic parts as seen in Fig.1. In this way a complicated pattern could be separated into basic parts. The pattern reproducing process could be applied to the different basic parts individually to get the final image for each of the parts. These images are then assembled to get the whole PCB image.

Even though the pattern of a typical PCB is quite complex, the repeatability of the basic parts in the pattern can be taken as an advantage to limit the number of calculations.

Here we investigate three different basic parts as shown in Fig.1: open-elbow, straight, and half part. The width and thickness of each part are considered to be 100 and 10 μm, respectively.

2.2. Probe details and physical quantity measurement

A long Meander-type coil is utilized as excitation coil. To simulate the coil, we use four straight long conductive strips located parallel to each other. The distance between each strip is considered to be 50 μm. The width and thickness of each strip is also assumed to be 200 and 35 μm respectively as seen in Fig.2.

In a real experiment, a SV-GMR sensor is located in the middle point of the Meander coil in such a way that it

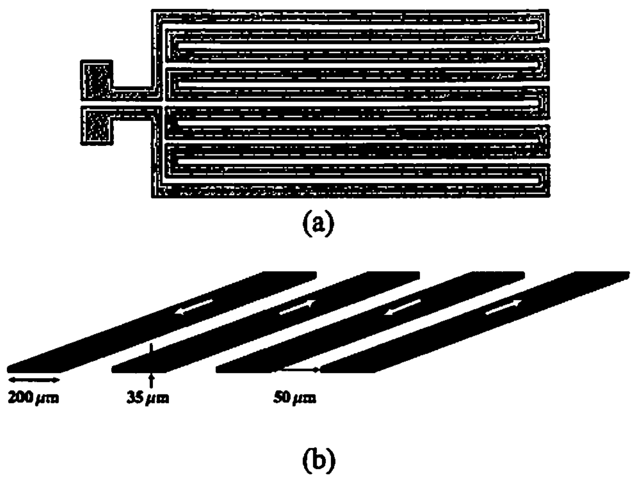


Fig.2: (a) Top view of a Meander-type coil, (b) Four-leg conductive strip used to model a Meander-type coil in which white arrows show the surface current densities which are opposite in direction on adjacent legs.

measures the magnetic flux density in the scanning direction. Because of that the physical quantity which we calculate here is the magnetic flux density due to interaction between the Meander coil and a PCB basic part. Unfortunately there is no analytical solution to such a problem; hence, we use numerical solution to find the magnetic flux density. Using FEMLAB package, we simulated a Meander coil above a basic part in a 3D model as shown in Fig.3 for a typical open-elbow basic part.

In the 3-D FEMLAB calculation it is very important to choose "quadratic" element to obtain an acceptable smoothed result. We also considered a finer mesh size in the

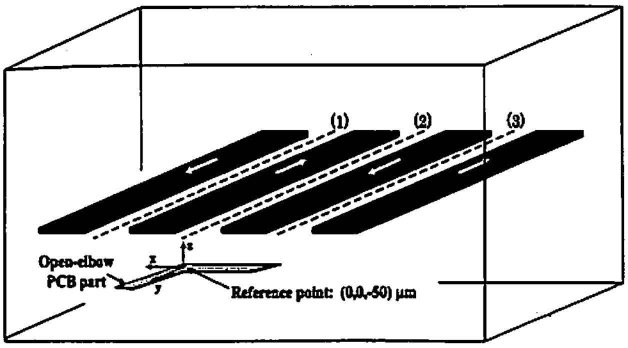


Fig. 3: Simulation of scanning procedure using FEM package. The calculation was repeated for 10 different positions of PCB part on x axis to simulate the scanning in x-direction. The y-component of magnetic flux density was obtained on three central dashed lines for each of the 10 x-steps to simulate the scanning in y-direction. Dashed lines are numbered with (1), (2), (3). As the coil legs are considered to be very long in y-direction and they are also periodic in x-direction, the Neumann boundary condition is considered.

regions of our measurement interests. In this case the number of degrees of freedom for the FEM package solver was about 220,000. The frequency was considered to be 5 MHz.

Since the legs of the coil was supposed to be very long in y-direction and they had periodicity in x-direction which can be seen in Fig.3, the magnetic field has only tangential component at infinity. Hence, the Neumann boundary condition was applied to the problem.

2.3. Simulation of scanning process and image processing

A 2-D scanning system includes scanning in two directions, i.e. x-direction and y-direction, which we should consider both of them in the scanning procedure simulation.

To simulate the x-direction scanning process we repeated the FEM calculation for many different PCB part positions on the x-direction relative to the Meander coil. It means first we put the part in a reference position and run the package to obtain the magnetic flux density. Then we move the position of the PCB part one step on the x-direction. Here we considered each step to be 25 μm as in the experiment. After running the program and getting result, the same procedure was repeated for a new position of the PCB part. We repeated the procedure 10 times or in other words for 10 steps.

For simulating the y-direction scanning process we measure the magnetic flux density on each central line between the strips of the Meander coil which are shown by dashed lines in Fig.3. The magnetic flux density along the dashed line number (2), while the PCB part was set on the reference position is shown in Fig.4.

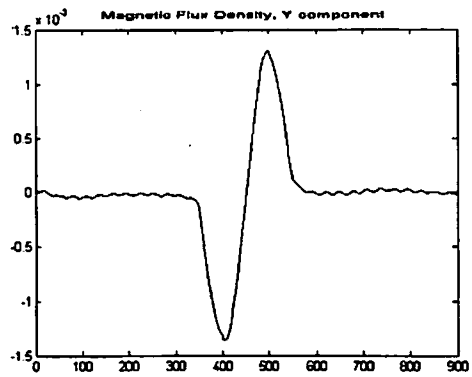
As we moved the PCB part 10 steps and we also had 3 central lines, we got 30 columns of data. These data was gathered in a matrix to be used for image processing step. To obtain an image of the PCB part, the gradient of the aforementioned matrix was taken as an edge detection process. A median filter was also applied to get a clearer image. Fig.5(a), (c), and (d) show the result of a scanning simulation produced by the Base-Model method, while the scanned test pieces were supposed to be open-elbow, straight and half part. Notice that the scanning direction was in an up-down direction, i.e. y-direction.

One of the most important points in the calculation is related to the width of the sensing area of magnetic sensor which we should take into account. The GMR sensor used in the experiment has a sensing area about 100 μm by 100 μm; hence, we should consider the effective sensing area as a surface, not as a point, to obtain a more realistic result as close as possible to the experimental result. The wide-area sensing effect causes the final image to be a little blurred in comparison with the result of a point-sensor as seen in Fig.5(b), (d), and (f). On the other hand, calculated results obtained by the Base-Model shows that the resolution of the final image of the basic part is inversely proportional to the scanning step size.

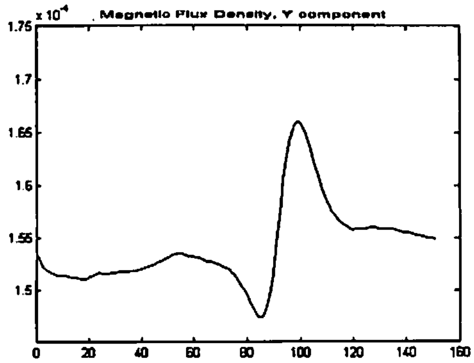
The whole above procedure could be applied to any of the other basic parts. In this way the image produced by each of the basic parts is obtained, and could be assembled to get the image of a complicated PCB pattern shown in Fig.6.

3. Experiment, Comparison and Results

The probe used in the experiment consists of a long Meander coil as an exciter and a SV-GMR sensor to measure the magnetic flux density. The sensor was mounted on the long Meander coil and its sensing axis was set to detect the magnetic flux density, only in the scanning direction. The use of the long Meander coil provides the advantage of easily developing a multisensor, which is



(a)



(b)

Fig. 4: (a) FEM result for y-component of magnetic flux density on dashed line number (2) in Fig.3 while a straight PCB basic part is located on the reference point. The line resolution is 1000.
(b) The same above result obtained by experiment. Note that the magnitude of the flux density is not important here because it depends on our choice of deriving current density in the FEM model. However, the produced pattern is of importance.

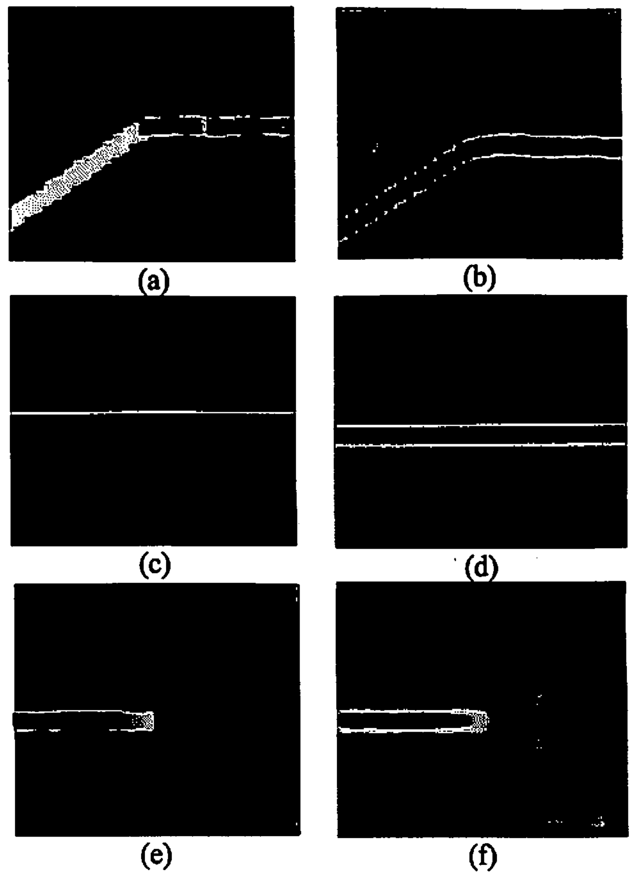


Fig.5: (a), (c), and (e) are the images of an open-elbow, a straight, and a half PCB basic part produced by FEM package and image processing tools while the magnetic sensor was assumed to have a point-sensing structure and (b), (d), and (f) are the images of the same PCB parts while the magnetic sensor was assumed to have a wide-area sensing structure.

another technique that can improve the scanning speed. In addition, it provides a short distance between the SV-GMR sensor and tested PCB. As a result, the sensor easily acquires the ECT signal at defect point with high SNR.

Magnetic field excitation was generated by feeding high-frequency exciting current to the long Meander coil. In this research, sinusoidal current of 200 mA at a frequency of 5 MHz was fed to the Meander coil. A lock-in amplifier was used as a data acquisition system for measuring the ECT signal from the sensor.

Scanning a small part of a PCB in an experimental situation consists an open-elbow, a straight, and a half part, applying image processing technique; we get the patterns which can be seen in Fig.7(a), (c), and (e). Fig.7 (b), (d), and (f) show the comparison between our method results and the experimental results.

The results show that our method could be a good candidate for producing a PCB pattern when a real scan of the PCB can be deemed needless. On the other hand subtracting the pattern obtained by the Method from the pattern by the experiment gives the defect pattern on a clear background without the complicated PCB conductor pattern.

It is a very important point to get an easy

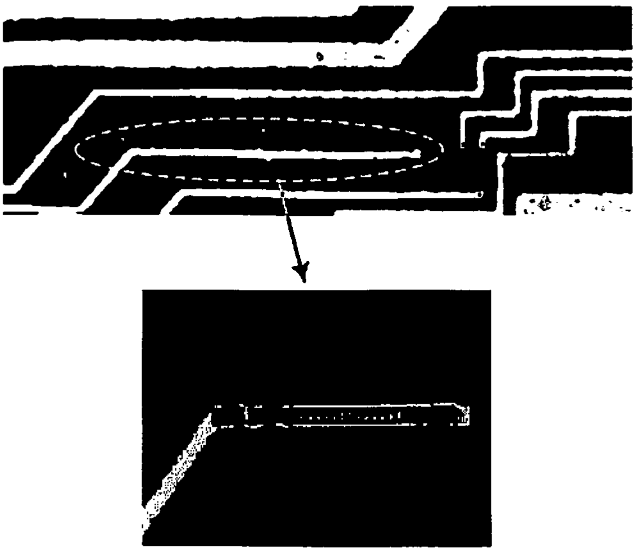


Fig. 6: Assembling the results from different parts gives the image of the whole part.

distinguishable image of a probable defect on a complicated PCB instead of a complicated maze of lines. The Base-Model method which we introduced is under development to get such a result.

4. Conclusion

We introduced the Base-Model method to provide a PCB pattern image using a numerical method, without the necessity to do any experiment. Using the resultant image from the method and comparing it with the experimental result, probable defect on PCB conductor strips could be identified on a very clear background.

As the model is based on a FEM calculation, calculation time, smoothness and precision of the result depends on the PC and the number of degrees of freedom of the model. For example if one chooses a linear element the result will not be as smooth and precise as needed. Having the result for a few number of basic PCB parts as mentioned in Fig.1 is enough to reproduce a complicated pattern. However if the dimensions of a real PCB parts changes, for example the width of a part in some area, the method should be applied to the new basic part to get a new image related to the part.

The method shows a considerable development in PCB inspection and could be extended to other areas of ECT inspection where the test piece is made of a complicated pattern as well.

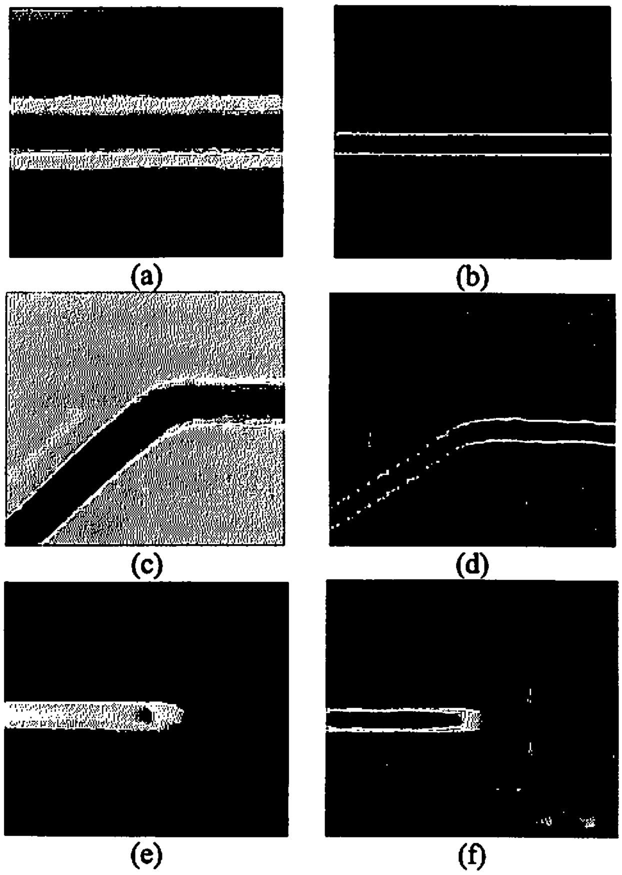


Fig. 7. (a), (c), and (e) are the images obtained from experiment and (b), (d), and (f) are the images produced by the Base-Model method. Scanning was done in an up-down direction.

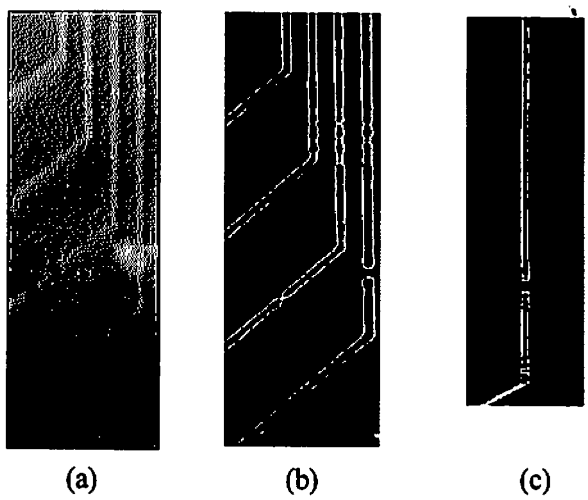


Fig. 8: (a) Photo of a real PCB, (b) image of the PCB obtained by experiment after applying image processing technique, (c) image obtained by Base-Model method for a small part of the PCB.

5. Acknowledgements

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References

[1] S. Yamada , H. Fujiki, M. Iwahara, S.C. Mukhopadhyay and F.p. Dawson, *Investigation of Printed Wiring Board Testing By Using Planar Coil Type ECT Probe* , IEEE Trans. Mag. VOL. 33, No. 5, Sep. 1997.

[2] K. Chomsuwan, S. Yamada, M. Iwahara, *Application of Eddy-Current Testing Technique for High-Density Double-Layer Printed Circuit Board Inspection*, IEEE Trans. Mag. VOL. 41, No. 10, Oct. 2005.

[3] T. Taniguchi, D. Kacprzak, S. Yamada, M. Iwahara, and T. Miyagoshi, *Defect Detection of Printed Circuit Board by Using Eddy-Current Testing Technique and Image Processing*, Electromagnetic Nondestr. Eval. (IV), IOS Press, 2000.