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RESPONSE OF PULSED DIPOLES IN CONDUCTORS*

by

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Summary:

In the nondestructive testing of metals using pulsed electromagnetic waves,[1] small defects in the metals appear to act as radiating dipoles whose presence may be detected by observing the waves in the air above the metal surface. A pulsed source in the air above the metal produces the fields which penetrate into the metal producing currents flowing in the metal. A defect will prevent or reduce the current flow and thus acts as if a current dipole with a reversed current were located at the position of the defect. The electromagnetic waves from the defect propagate through the metal, penetrate into the air and may be observed there with a suitable receiver. The presence of the defects may thus be detected.

The work reported here consists of four main parts, a two-dimensional dipole in the metal, a three-dimensional dipole with axis perpendicular to the surface of the metal, a three-dimensional dipole with axis parallel to the metal surface and some special cases of the latter dipole. For the two-dimensional dipole, it was assumed that the z axis was perpendicular to the surface of the metal and pointing away from the metal. Both the x and y axes lay in the surface of the metal but it was assumed that there was no variation with y. The dipole was at $z = -z_1$ on the z axis and the pickup or receiver was in the air between the surface of the metal at $z = 0$ and a metallic mask for the source at $z = z_0$. The mask was assumed to be a plane perfect conductor parallel to the surface of the metal. The pickup was at the point $(x,0,z)$. A Fourier transform for the source using space coordinates was employed. Laplace transforms were used for the time, and the Helmholtz equation was solved in the metal and in the air. In the metal the displacement current was assumed zero, and the driving function was assumed to be an impulse in time. Boundary conditions at the air to metal interface at $z = 0$ and at the perfect conductor at $z = z_0$ were satisfied. In the air the magnetic field intensity perpendicular to the surface of the metal was taken as proportional to the output voltage of the pickup coil. It was assumed that the velocity of the waves in air was much larger than the velocity in the metal. The inverse Laplace transform of the pickup voltage was found and all of the variables presented were normalized in such a way that they became dimensionless quantities. Some computed results are presented.

The three-dimensional solution for the dipole with its axis perpendicular to the surface of the metal was similar to that for the two-dimensional dipole. The dipole was assumed on the z-axis at $z = -z_1$ in the metal. The fields were assumed to be independent of the angle φ in a plane parallel to the surface of the metal. The pickup coil was assumed to be in the air at the point γ units from the z-axis and z units above the surface of the metal. Again the Laplace transform of the Helmholtz equation in both the metal and the air was obtained, the boundary conditions were satisfied and the voltage of the pickup coil found. This case is not very important in the development of the response of defects because the currents in the

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metal flow almost entirely parallel to the surface of the metal.

In a similar fashion the three-dimensional solution for the dipole parallel to the surface of the metal was obtained. In this case the voltage picked up depends on the angle ϕ. This case is the more important one in the study of defects. The result is the voltage of the pickup coil and is presented as an infinite integral that may be evaluated numerically by the use of a computer.

A number of special cases of this last result for the three-dimensional dipole parallel to the surface of the metal were studied. These included the case where the mask was far distant from the surface of the metal and its opposite case when the mask-to-metal spacing approached zero. Another special case was that where the dipole was very deep in the metal, and still another was that where the dipole was on the surface of the metal.

The results of this work are being used presently to compute the response of defects under the surface of metals when the electromagnetic waves in the metal are excited by a mask-aperture assembly.

Reference:

1. D. L. Waidelich, "Pulsed Eddy Currents" in Research Techniques in Nondestructive Testing, Academic Press, New York, N.Y., 1970, pp. 383 to 416.