Crack detection and measurement in metals using an eddy current sensor

Introduction

Eddy current testing (ECT) is a non-destructive testing (NDT) technique used widely in industry. The purpose of NDT is to check the structural integrity of a manufactured object, before it is used. NDT has the benefit that it can be carried out without harming the object being analysed – the object is tested and then fixed or discarded before a problem can occur. Objects vary from pipelines to aircraft skins, so the need for NDT is obvious.

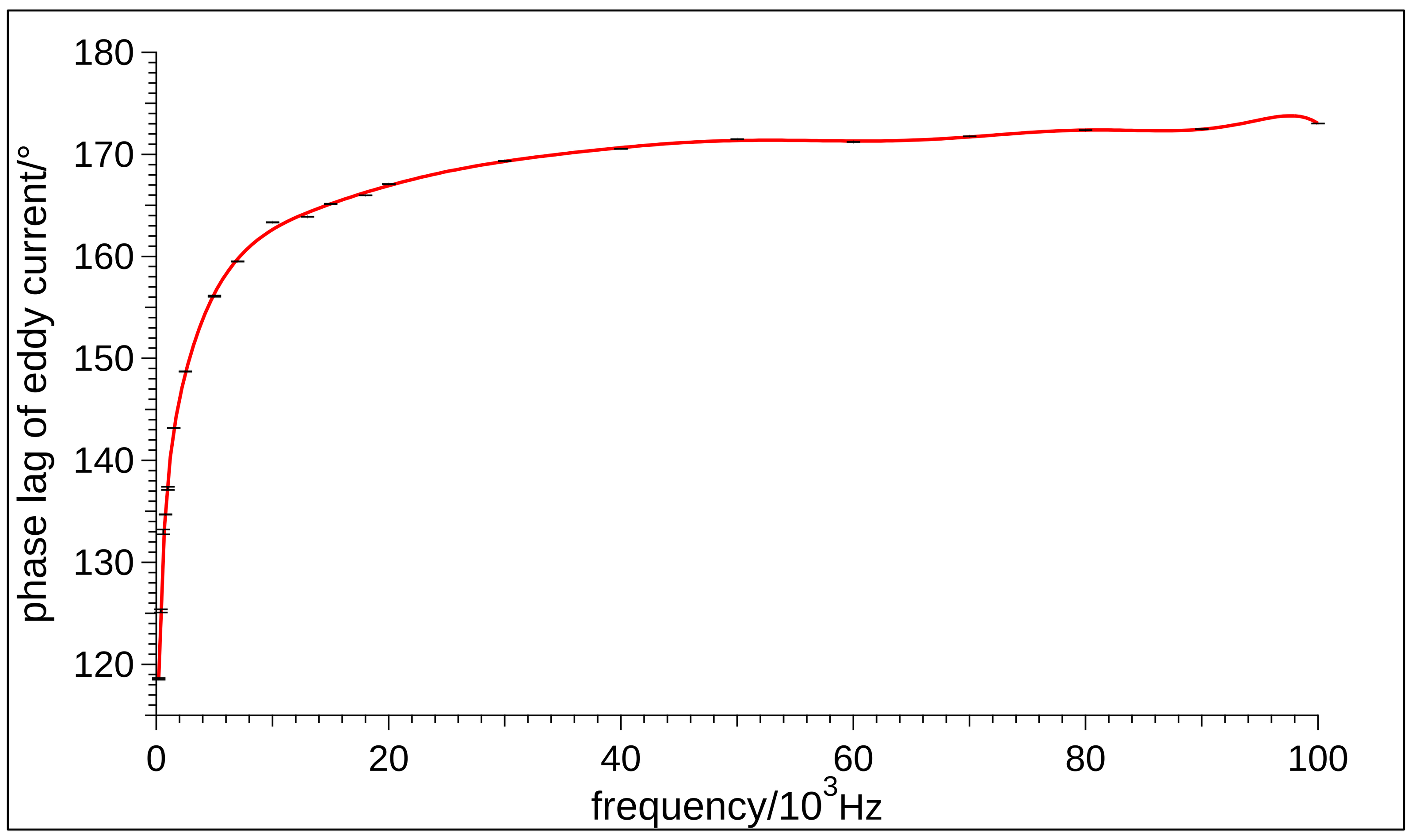
Eddy current testing pros
- Can detect very small cracks, near or on the surface;
- Physically complex geometries can be analysed;
- Minimal preparation of surfaces required.

Eddy current testing cons
- Used solely on conducting materials, due to the method being based on electromagnetic induction;
- Can only detect cracks and defects near to the surface of the object.

However the main con for ECT is that it is very poorly understood in the literature; there are many papers showing how to perform ECT, but there is no complete explanation about how and why it works. Helping to understand this was the purpose of the research I undertook.

Practical area of research

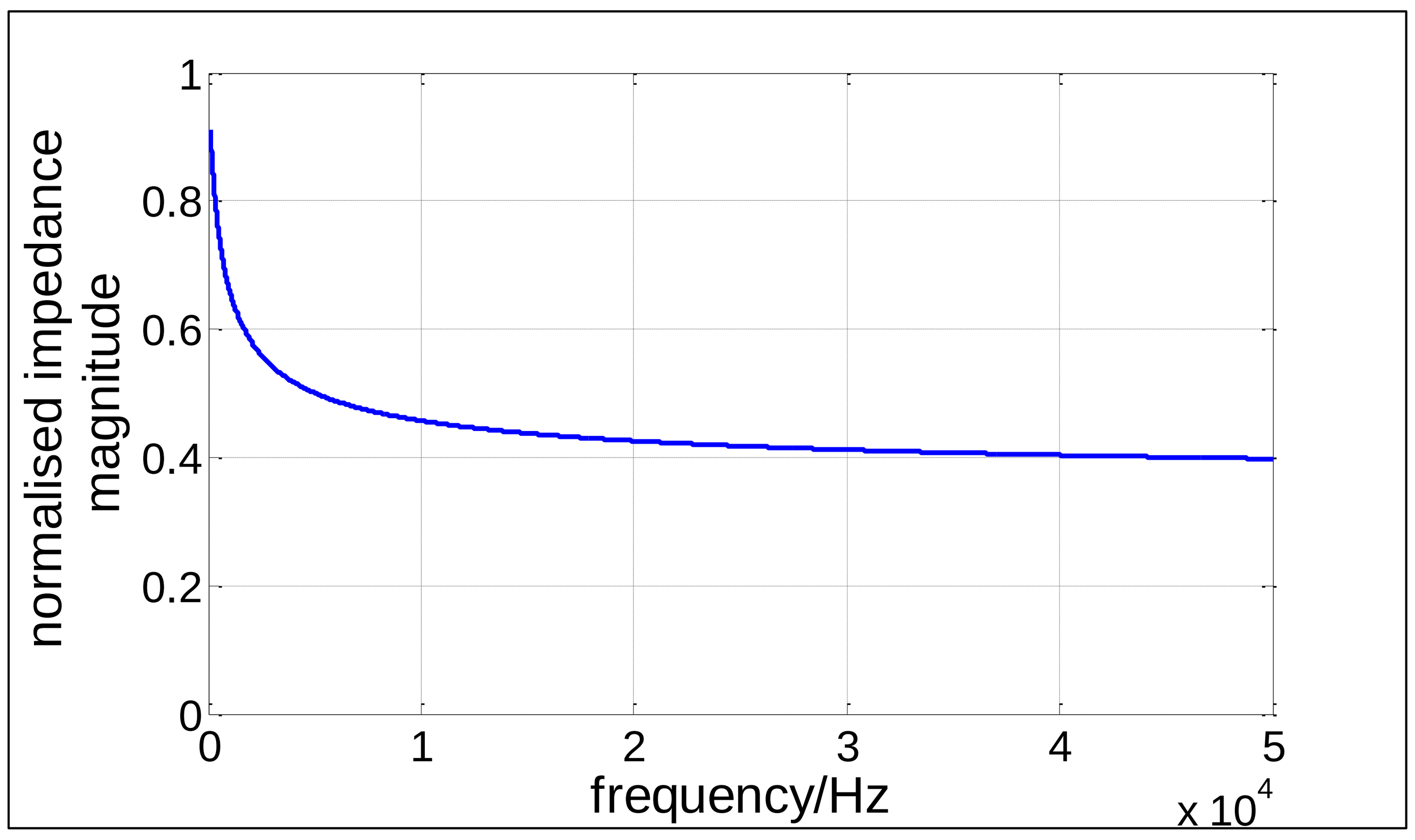
The first half of the project was spent in a lab, with a real, hand-made eddy current tester. This involved two coils, one driving current at a set frequency, and another that detecting the magnetic field of this current. When placed against the Al sample used, the detector coil recorded a phase change and amplitude drop. In the literature, a simplified model predicts, a 180° phase lag between the current in the coil driving the eddy current, and the magnetic field created by the eddy current. Allowing for the eddy current to change phase with depth, an improved but simplified plane wave theory predicts a phase lag of 135°.



The graph above shows for the apparatus used, the phase lag never reached 180°, and neither is it 135° across all frequencies studied. At high frequencies, capacitance of the coil comes into effect, causing the phase lag to be higher than predicted by the plane wave model. At low frequencies, the skin depth approaches the sample geometry and the plane wave assumption breaks down. This plot shows that the often quoted 180° expected phase lag is incorrect.

Theoretical area of research

The second half of the project focussed on modelling the eddy current and electrical response of the coil, using MATLAB. The formulae were taken from a key, early paper in this field Dodd and Deeds[1]. Models for single loops of wire were investigated, as these were mathematically simpler. For a closer to real pancake coil test, models for finite coils were then investigated, but this remains an area for further work.



Above is the calculated impedance of a single coil. The equation was presented in full in Dodd and Deeds; there was no reliance on the past programs. It produces a pattern that intuitively correct. The values are however inaccurate, meaning further work is required. This part of the project was done in collaboration with B. Smith.

Conclusions

The main conclusion is that the often quoted 180° phase lag is incorrect. A check for agreement between real and theoretical impedances was attempted, but this requires further work. This emphasises the need for an accurate model of the Dodd & Deeds equations, which should lead to a better understanding of ECT.

Reference 1 C.V. Dodd and W.E. Deeds, *Analytical solutions to eddy-current probe-coil problems*, J. Appl. Phys. **39**, 2829 (1968).

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