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# DETECTION OF SHORTS IN MAGNET COIL WINDINGS AS THEY ARE BEING WOUND

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## Introduction

Coil windings are built up turn-by-turn. If the wire insulation is fragile, sometimes a turn-to-turn short or layer-to-layer short may happen during the fabrication process, yet not be detected until later. The idea to be described is a way of monitoring the coil for shorts during winding. It is particularly applicable to production quantities of coils all of the same construction.

## Discussion

As the coil is being wound, its cross-sectional area A and number of turns n change. The product nA should increase monotonically. Idea: Use the coil as a search coil in a weak A.C. magnetic field provided for the purpose at the winding machine. During winding, as nA increases, the voltage picked up by the coil will increase with each added turn and progress can be watched by the person doing the winding. A reduction in the voltage indicates a problem which can be investigated and corrected on the spot. A satisfactory winding will exhibit a progressively increasing voltage that follows the same course as that of a known good coil. If many identical coils are being wound, the expected pattern will become established and a coil defect will be easy to spot.

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Method

Establish a uniform weak A.C. magnetic field flooding the magnet coil winding fixture. Flat one-turn conductors on the floor and near the ceiling will suffice. Field direction can be vertical, horizontal or adjustable if one uses 2 sets of coils. This way one gets the equivalent of large Helmholtz-like coils, out of the workers' way. A 100 milliGauss, 1 kHz field will give $200\pi\mu V$ per turn in a coil of 100 $cm^2$ area; this signal level is sufficient for the purpose. The magnetic energy in 100 cubic meters

$$U = \frac{1}{2}\int \frac{B^2 dV}{\mu o} = \frac{1}{8o\pi} \quad \text{joules,}$$

the required power, given a Q of 20 for the Helmholtz coils,

$$P = \frac{\omega U}{Q} = 1.2 \text{ watts.}$$

There are 60 Hz fields of 100 milliGauss or greater already present in industrial buildings due to ovens, motors, flourescent light fixtures and assorted electrical power wiring.

To detect the desired signal, we employ a conventional amplifier and phase-sensitive detector. (This combination is called a lock-in amplifier by some workers). The lock-in amplifier rejects signals not correlated with the (here, 1 kHz) transmitted signal, and therefore permits operation in the electrically noisy environment. One second R-C filtering on the phase detector output narrows the bandwidth to 0.3 Hz, allowing good sensitivity with sufficient speed of response.

Making contacts to the coil under construction deserves some mention. Let us assume that the "start" wire can be contacted by a slip ring. We could for the other connection clip on to the magnet wire, but what about the insulation? Rather than invade the covering of insulated wire, I would construct a capacitance-coupled probe. The probe would mechanically look like an insulated trough a half-inch wide and a foot long that the magnet wire feeds through as it comes off the reel and on to the coil.

The probe would electrically look like three nested U-shaped metal channels, the outer at ground, the next at the output of a unity-gain op-amp, and the innermost connected to the op-amp input and seeing the magnet wire electrostatic field. In this scheme, the probe's stray capacitance is nullified; the probe picks up the full signal on the wire without a D.C. connection.

Remarks

1. I believe this short-circuit detection system could be made easy to use, not interfere with winding operations, and have a sensible readout arrangement that gave an obvious indication. Consultation with experienced coil fabricators like W. Hanson would evoke solutions to the various aspects of human engineering.

2. Cost of parts for a system is estimated to be around $2000. Certainly, to make a test one uses borrowed amplifiers, etc. and the testing cost is principally some man-hours of experiment.

3. The addition of a phase-sensitive readout may be warrented.

In principle, a short-circuit suddenly-created in the coil during winding will be evidenced by a concomitant jump in phase angle as compared to the reading just before. Whether a phase readout should supplement the amplitude readout would be one of the subjects for experiment. The phase angle is hard to compute because the conducting metals of the mandrel and fixturing introduce phase shifts of their own, (hopefully constant). The amplitude increase as more turns are added is unequivocal.