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Electrical and capacitive methods for detecting degradation in wire insulation

Abstract:

Motivated by a need within the aerospace industry to detect and characterize degradation in the insulation of onboard wires, this thesis reports testing of several extant methods and development of novel capacitive sensors. The work focuses on measuring the electrical parameters resistance and capacitance that are directly related to the material parameters conductivity and permittivity, respectively, of the insulation. It is shown that the measured electrical parameters successfully indicate degradation in the wire insulation.

Insulation resistance tests were performed on 17 wire samples, removed from various locations on a retired aircraft, and compared with those conducted on pristine wire samples, in order to assess any change in conductivity exhibited by degraded insulation. Timed resistance tests were also performed to determine the dielectric absorption of the insulation. Curved patch-electrode sensors were applied in order to measure the capacitance and dissipation factor of the same wires. Results from the resistive and capacitive tests both identified wire samples that were apparently significantly degraded, as indicated qualitatively by visual inspection.

Further, a novel cylindrical interdigital capacitive sensor was developed. The interdigital sensor is designed with the goal of achieving a good signal-to-noise ratio, the lowest instrument error possible at 1 MHz, full circumferential coverage of the wire, and the ability to adjust the penetration depth of the electric field into the insulation layer by adjusting the separation of the sensor digits. With the aim, ultimately, of quantitative measurement of insulation complex permittivity, a numerical model was developed using a cylindrical Green's function and the Method of Moments to calculate theoretically the capacitance of the interdigital sensor. Benchmark experiments were carried out on large-scale dielectric-coated conductive cylinders to test the validity of the model. Experimental results agreed with measured results to within 5% for sensor configurations with 22 and 30 digits of each polarization, tested on insulation polymers acetal copolymer, acrylic and PTFE. A design method by which the penetration depth of the electric field into the insulation layer may be optimized is also introduced.

Plans for future work, to develop interdigital capacitive sensors with a convenient hand-held clamp design for in-situ testing of aircraft wiring insulation, are also presented.