Optimization – Application Project

Drone Aircraft EMI Shielding

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Subject: **Application Project**

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Enclosures:

A. APMoniter Model Solution

B. APM Model Solution Key

C. Matlab Contour Plot Solution Key

Introduction:

Our group chose to optimize the design of Electromagnetic Interference (EMI) shielding for a small unmanned drone in aerospace applications.

Description of Report:

The first section of the report contains a homework-like description of the chosen problem with relevant variables, constraints, and relationships between the variables.

Interpretation of Results:

The optimal solution for the problem resulted in a maximum conductivity of 3.199e6 S/m and a minimum mass of 16.41 kg. The active constraints were the lower bound of surface area, the lower bound of thickness, and the upper bound of the filler volume fraction. The feasible design region has been shaded on the contour plots in *enclosure C.*

ME 575: Drone Aircraft EMI Shielding

The specifications and modeling equations for drone aircraft electromagnetic interference (EMI) shielding are described below. We are to determine the parameters of EMI shielding that maximizes conductivity and minimizes mass within specified constraints of surface area, thickness, and filler volume fraction.

Design Problem:

This problem determines the optimal thickness and conductive filler packing density that maximizes the conductivity of the composite EMI shielding for a small unmanned drone aircraft.

Geometric Variables:

The drone is small, and so the shielding mass should be minimized and cannot exceed a preset design limit of 20 kg. The drone's design leaves a range of functional sizes and thus surface areas that can be used as part of the design problem.

Material Properties:

The chosen material for the EMI shielding is silicone rubber with nickel as the conductive filler. Silicon rubber has a density of 1030kg/m^3. Nickel density is 8880kg/m^3 with a conductivity of 14.43e6 S/m (Siemens per meter).

Necessary Equations:

Conductivity is determined by the following relationship

$$C_t = C_n\left(F_f - F_c\right)^t$$

Where:

C_t = shielding conductivity

C_n = conductivity of nickel

F_f = Filler volume fraction

F_c = critical filler packing density fraction

t = conductive power law exponent from experimental curve fit

Rule of Mixtures:

$$\rho_{mix} = \rho_{filler}F + \rho_{matrix}(1 - F)$$

Where:

F = the filler volume fraction

You will also likely need to calculate volumes, densities, and masses of the composite material.

In order to properly optimize the EMI shielding, you will need to make the following assumptions:

- Conductive filler is spherical, with a max filler volume fraction (packing density) of 0.74
- The radius of the conductive filler is 5 micrometers which, according to percolation theory and experimental result, yields a percolation packing density threshold (minimum filler volume fraction for a conductive material) of 0.35.
- The conductivity of the material must follow 3D percolative behavior, so the critical exponent is chosen for a 3D system. The critical exponential constant is on the conservative end of the range of experimentally observed exponents, $t = 1.6$ is assumed in order to calculate conductivity.
- The size of the filler is such that for this to be considered a 3D percolation, problem, the minimum thickness of the material is 4 mm. Maximum manufacturing thickness is 6mm.
- Material properties taken from www.matweb.com

HINTS:

- The maximum conductivity should be within 5e5 of 3.2e6 S/m
- The minimum mass at the above maximum should be around 16 kg.