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电工理论与新技术

多层导电结构厚度电涡流检测解析模型及实验验证

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摘要： 从准静磁场条件下的Maxwell方程组出发，采用矢量磁位法，推导了位于任意多层导电结构上方圆柱型电涡流探头的阻抗解析模型。在阻抗计算中引入符号运算法求解矢量磁位表达式系数，大大减小了程序计算量，提高了程序效率。将阻抗解析模型应用于单层和两层导电结构厚度检测，分别研究和分析了单层厚度、铝基体上铜涂镀层厚度及铜基体上铝涂镀层厚度变化对探头阻抗变化的影响规律。仿真及实验结果表明，所推导的理论模型正确，可应用于导电结构厚度和材料属性检测的反演以及电涡流检测系统的参数优化。

关键词： 多层导电结构 厚度检测 电涡流检测 解析模型

Analytical Model for Eddy Current Testing of Thickness of Multi-layered Structures and Experimental Verification

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Abstract: The analytical model of a cylindrical eddy current probe placed above semi-infinite arbitrary layered structures is deduced by introducing magnetic vector potential based on the magnetoquasistatic Maxwell equations. During the impedance calculation, a symbolic operation is used to solve the coefficients of the magnetic vector potential expressions and as a result the impedance calculation becomes more efficient and less time-consuming. The presented analytical impedance model is applied in thickness measurement of a single layer metal and a conductive coating on a metal substrate in eddy current testing. The probe impedance response regularity due to the variation of thickness of single layer and conductive coating is investigated. Simulation results based on the presented model are in good agreement with the experimental ones and thus the correctness and effectiveness of the developed model is verified. There is every reason to believe that the impedance model can be applied in thickness measurement and be employed to determine other material properties of conductive structures and even used for the optimal design of eddy-current measurement systems.

Keywords: multi-layered conductive structures thickness measurement eddy current testing analytical model

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