

电工理论与新技术

混合电磁结构磁性部分元等效电路建模技术的解析及实验研究

潘启军 马伟明 赵治华 孟进 张磊 张向明

舰船综合电力技术国防科技重点实验室(海军工程大学) 舰船综合电力技术国防科技重点实验室(海军工程大学) 海军工程大学电力电子技术研究所 海军工程大学电力电子技术研究所 海军工程大学电力电子技术研究所 海军工程大学电力电子技术研究所

摘要: 磁性材料在电磁结构中广泛应用, 而传统(标准)部分元等效电路(partial element equivalent circuit, PEEC)方法对包含磁性材料的各种结构进行分析时已无能为力。针对基于几何平均距离和空间磁介质均匀化处理的新型磁性PEEC建模方法(magnetic PEEC, MagPEEC), 该文提出使用同轴电缆解析计算以及大型钢板耦合与邻近效应实验对该建模方法进行验证。利用解析法对给定同轴电缆单位长度电阻与电感参数进行了计算, 并将计算结果与由MagPEEC建模计算的结果进行了比较; 分大型舰船钢板差模回路耦合和共模回路耦合干扰两种情况, 对MagPEEC建模计算的耦合阻抗进行了实验验证; 利用所研制的钢板地电流测量装置在钢板中部进行测量, 并将测量结果和MagPEEC理论计算的结果进行比较, 从而实现金属壳体地电流测量和MagPEEC理论计算方法的直接验证。利用该文所提供的解析方法和3种实验方法, 对MagPEEC建模技术进行了充分证明, 为MagPEEC建模技术的推广使用奠定了基础。

关键词: 磁性部分元等效电路 解析方法 差模回路耦合 共模回路耦合 邻近效应

Analytical Method and Experimental Validation of MagPEEC Modeling Technique for Hybrid Structure

PAN Qi-jun MA Wei-ming ZHAO Zhi-hua MENG Jin ZHANG Lei ZHANG Xiang-ming

Abstract: Magnetic materials are applied widely, whereas the conventional or standard partial element equivalent circuit (PEEC) is unable to deal with them. As for the proposed novel magnetic PEEC (MagPEEC) modeling technique based on geometrical mean distance (GMD) and the homogenization process of the magnetic materials, the paper puts forward analytical calculation of the coaxial line and the coupling and proximity experiments to verify the MagPEEC technique. The unit length resistance and inductance of the given coaxial line via analytical method are calculated, which are compared with those from MagPEEC. Furthermore, the DM and CM loop coupling experiments of large steel plate are designed and completed. The tested loop coupling impedances from the exciting loop is consistent with the calculated results via MagPEEC. In addition, a mutual direct verification experiment is carried out between steel plate ground current testing and MagPEEC modeling with proximity effect, which verifies the correctness of the measurement approach and the modeling methodology simultaneously. Summarily, the paper provides the systematic and thorough study of the MagPEEC modeling verification via theoretical analysis and three kinds of experiments, which is a base of the extending application of MagPEEC in engineering.

Keywords: magnetic partial element equivalent circuit analytical method DM-loop coupling CM-loop coupling proximity effect

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通讯作者: 潘启军

作者简介:

作者Email: pqijun@163.com; panqijun@sina.com; panqijun02@sohu.com

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