HIGHLY ACCURATE 3D FIELD GRADIENT COMPUTATION USING LOCAL POST-SOLVING

Koen Delaere, Uwe Pahner, Ronnie Belmans and Kay Hameyer
Dep. EE (ESAT), Div. ELEN, Katholieke Universiteit Leuven, Leuven, Belgium

Accurate computation of field quantities

To enhance the accuracy of finite element (FE) based computations of field and force quantities, a post-solving technique with superconvergent properties is used. These techniques use an analytical series expression for the magnetic field potential inside a closed region. The coefficients in the analytical expression for the magnetic field potential are evaluated using the FE solution as a boundary condition. Several applications have been investigated, both in 2D and 3D [1][2][3]. The derivative of the analytical expression can be calculated without numerical differentiation. This leads to a more accurate value for the flux density B. This digest presents the calculation of the derivatives of the flux density B, using the same principle, i.e. double differentiation of the analytical expression for the magnetic potential. This results in a highly accurate value for the field gradient (Oe/nm). This quantity is important in evaluating recording head performance, e.g. the edge write gradient in a notch write head [4].

Theory

Inside a closed spherical region without sources, the magnetic field potential $u(r,\theta,\phi)$ satisfies Laplace's equation. The general solution in spherical coordinates can be formulated as [3]:

$$u=\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}\left[p_{mn}\cdot c_{mn}(\theta,\phi)+q_{mn}\cdot s_{mn}(\theta,\phi)\right]\cdot r^{n} \tag{1}$$

where c_{mn} and s_{mn} are the surface harmonic functions (determined by the associated Legendre polynomials of the first kind and the trigonometric functions). The coefficients p_{mn} and q_{mn} are determined using a FE solution as a boundary condition for (1) on a finite number of points on a sphere with radius R. Both the flux density B and its derivatives are related to the magnetic potential u and can be expressed in terms of the coefficients p_{mn} and q_{mn}:

$$\left(B_x,B_y,B_z\right)=-\mu_0\cdot\left(\frac{\partial u}{\partial x},\frac{\partial u}{\partial y},\frac{\partial u}{\partial z}\right)=-\mu_0\cdot\left(p_{11},q_{11},p_{01}\right) \tag{2}$$

1. Koen Delaere
Dep.EE (ESAT), Div.ELEN, Katholieke Universiteit Leuven
Kardinaal Mercierlaan 94
B3000 Leuven, Belgium
tel. +32 16 321020
fax. +32 16 321985
koen.delaere @ esat.kuleuven.ac.be
2. Computational Magnetics
3. Either presentation

The authors are grateful to the Belgian "Fonds voor Wetenschappelijk Onderzoek Vlaanderen" for its financial support of this work and the Belgian Ministry of Scientific Research for granting the IUAP No. P4/20 on Coupled Problems in Electromagnetic Systems. The research Council of the K.U.Leuven supports the basic numerical research.

$$\left(\frac{\partial B_x}{\partial x},\frac{\partial B_y}{\partial y},\frac{\partial B_Z}{\partial z}\right)=-\mu_0\cdot\left(\frac{\partial^2 u}{\partial x^2},\frac{\partial^2 u}{\partial y^2},\frac{\partial^2 u}{\partial z^2}\right)=-\mu_0\cdot\left(2p_{22}-p_{02},2p_{22}-q_{02},2p_{02}\right) \quad (3)$$

These and similar expressions for the other six cross-derivatives will be derived in the full paper.

Field of Application

As a typical application for this technique, Fig.1 shows the FE model of a notch write head where the field gradient $\partial B_y / \partial y$ is calculated along the airgap (y-axis is vertical). In Fig.2, the field gradient calculated using post-solving (solid curve) is compared to the one calculated using two numerical differentiations (dashed line curve). In the full paper, it will be shown that the post-solving technique assures an enhanced accuracy for the field gradient.

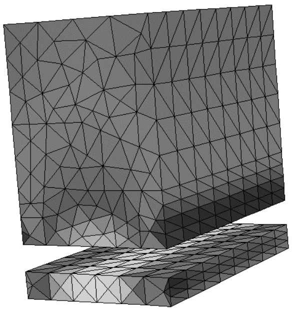

Fig.1 3D mesh of notch write head

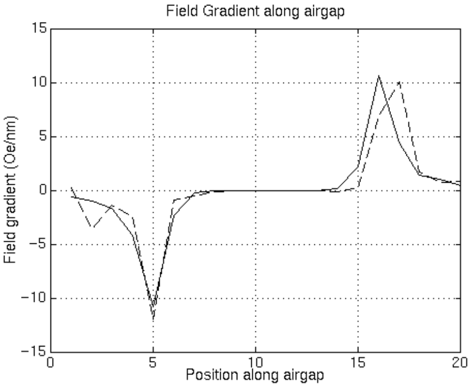

Fig.2 Field gradient along airgap.

References

[1]M.Kasper, J.Franz, , "Highly accurate computation of field quantities and forces by superconvergence in finite elements", *IEEE Trans.Magn.*, Vol.31 no.3, pp.1424-1427, 1995.

[2]K.Hameyer, U.Pahner, R.Belmans, "Enhanced accuracy of 2D finite element field quantities by a local post-process", IEE 3rd Int.Conf. Computation in Electromagnetics, Bath, April 1996.

[3]K.Hameyer, U.Pahner, R.Belmans, "Higher accuracy of 3D finite element solutions for field and force computations", 7th International IGTE Symposium on Numerical Field Calculation in Electrical Engineering, Graz, Austria, 23-25 Sep 1996, pp.04-6.

[4]T.Chang, "Modeling Assessment of the Side Writing Properties of a Notch Write Head", *IEEE Trans.Magn.*, Vol.33 no.5, Sept. 1997.