The Development of Calculation Methods for Complex Magnetic Systems

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In contrast to some programs, intended for modeling 2D magnetic fields, widely known commercial 3D CAD programs do not have special routines for users to control the accuracy of computations to a full degree. It does not permit to estimate with sufficient confidence the magnitude of magnetic fields in regions where the magnitude is comparable with approximation error of the finite element method used in calculations. An example of this situation is a problem of estimating the mutual influence of magnetic fields in the magnetic systems of experiments ALICE (CERN, Geneva), PANDA (GSI, Darmshtadt) consisting of solenoid and dipole magnets. Another example is a problem to estimate the magnitude of magnetic field in the region of beam channel protected against the dipole field of a spectrometer.

The paper [1] presents an algorithm for construction of spectrometer dipole computer models with quality control. Fig. 1 shows a computer model elaborated by the authors for the PANDA experiment. The peculiarity of the model is an iron plate in the median plane of the dipole for shielding a beam against magnetic field. The radius of the beam channel inside the plate is 3.5 % of the distance between poles of the magnet. Fig. 2 gives the calculated distribution of bending power homogeneity in the magnet working region. Under the model developing the authors suggested to use the sum of modules of local computed divergence and curl of the magnetic field as an error indicator function. The permissible values of the error indicators were taken from practice of testing the magnetic field functions based on measured data.

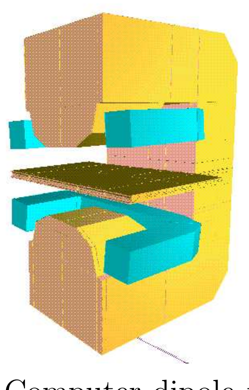

Fig. 1. Computer dipole model for the PANDA (1/2 symmetrical part)

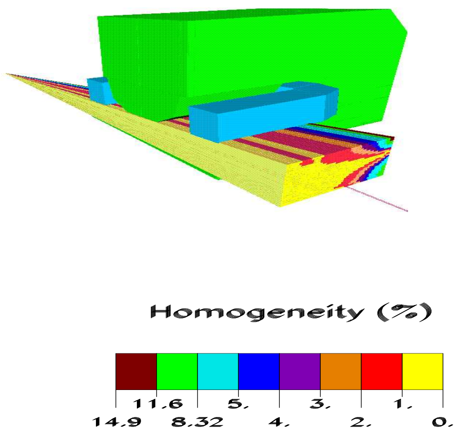

Fig. 2. Distribution of bending power homogeneity in the working region (1/4 symmetrical part)

The paper [2] gives new formulas for representation of the difference between exact solution $\mathbf{B}$ of the nonlinear magnetostatic problem and approximate solution $\mathbf{B_h}$ with the help of $div\mathbf{B_h}$, $rot\mathbf{B_h}$ without using the theory of Richardson's method. For this representation in nonmagnetic region the following estimate is correct for a finite element w_e:

$$|\mathbf{B} - \mathbf{B_h}| \leq (|div\mathbf{B_h}| + |rot\mathbf{B_h}|) \cdot h + C_1 \cdot h^2 + C_2 \cdot h^3, \quad x \in w_e,$$

where h is the element diameter, C_1, C_2 are positive constants. For magnetic region the estimate for $\mathbf{B} - \mathbf{B_h}$ has more complex form and it is not presented here.

The accuracy control of computations is needed in one more class of problems. This is a process of projecting the magnets with high uniform magnetic field. For example, in some polarizing magnets the field in the region of target polarization must be more than 2 T with permissible deviation of $\pm$ 0.02 % [3]. In [3] an algorithm for a numerical solving of the problem of homogeneous magnetic field formation by varying a ferromagnetic volume around the region of homogeneity is presented.

References

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