NUMERICAL SIMULATIONS FOR FIELD FORMATION IN CYCLOTRON CC12

Abstract

R&D results are presented for the magnet system of the cyclotron CC12 being built for the Russian Cardiology Centre (Moscow). The software package KOMPOT, which enables precise 3D magnetic field simulation, was applied to optimise geometry of the sectors and shims and location of the active coil. A precision finite-element model allows consideration of non-linear effects and the actual geometry specifics. The simulated radial distribution of an average field complies with the given isochronous curve.

The cyclotron CC12 is designed for the Russian Cardiology Centre in Moscow. This paper presents results of the CC12 field formation based on numerical modelling. Details of the numerical method applied to form a desired field distribution with the use of 3D KOMPOT [1] modelling are presented in Ref. [2], [3].

To summarize briefly, the numerical procedure of the CC12 field formation included 4 main stages.

1. At the first stage basic parameters of the magnet system were determined from the magnetooptic calculations performed at Efremov Institute.

2. The second stage involved the development of a realistic 3D model for the DC60 magnet system. The model used detailed descriptions of the magnet geometry, media interfaces, and non-linear properties of steel. For initial calculations a standard near-realistic B-H curve was used as reference. Then steel properties were corrected using the results of magnetic measurements on samples of steel used in the fabrication of the magnet. The curves *B(H), μ(H), μ(B),* $\partial\mu/\partial H$) obtained for the real magnet were used to simulate the expected field distribution and to choose the shimming method. Figures 1,2 present a part of the finite-element model of CC12 magnet system (magnetic circuit and coils only). The model covers a 1/16 of the magnet system and includes boundary conditions with respect to the magnet symmetry. The external boundary for the calculated region was taken so that to avoid the influence of the boundary conditions on the field behaviour inside the working zone and type of field decay with distance from the magnet. The finite-element mesh has about 230000 nodes.

3. The finite-element model was applied to preliminary analyse a spatial field distribution. From the magnetooptic analysis a required isochronous curve was found. The next step was to vary geometrical parameters in order to calculate the influence functions [2] for different magnet components and select the shimming method. From the results of the calculation, the azimuthal shimming by shaping the sector sides was chosen to form a desired field distribution.

4. The influence functions obtained were used to form an isochronous field with the accuracy required. Figures 3,4 show calculated field distributions over typical cross sections for the optimised magnet configuration. Figure 5 shows an averaged field distribution in the reference and optimised magnet system in comparison with the desired isochronous field. The field was optimised iteratively. Each iteration had a prediction phase and a correction phase. During the prediction phase the magnet geometry was varied slightly, and a new magnet circuit configuration was formed

from the field distribution of the previous iteration and known influence functions having regard to the required isochronous curve. In the correction phase, a field distribution was calculated for the obtained magnet configuration taking into account the saturation effect. After several iterations, the trajectory analysis was performed on the basis of the generated field map to correct the isochronous curve and to close the solution of the self-consistent problem. If the iterated geometry differed markedly from the reference configuration, the influence functions were re-calculated.

The proposed numerical method allowed effective field formation in CC12 taking into consideration realistic properties of steels used in the fabrication. The influence function obtained made it possible to estimate manufacture/assembly tolerances, which will be used for magnetic measurements and magnet adjustment.

References

[1] *Program package for 3D simulation of stationary magnetic fields, analysis and synthesis of magnet system for electrophysical devices (KOMPOT/M 1.0).* Registration Certificate # 2003612492 of Nov.12, 2003. Computer program register, Moscow

[2] A.Belov, V.Belyakov, T.Belyakova et al. *KOMPOT 3D field simulations for cyclotron magnet systems* // ICAA Proc., this issue

[3] Gulbekian G.G et al. *The method of the magnetic field formation in cyclotron DC-72.* Nukleonika 48(4), 2003, pp.207-210.

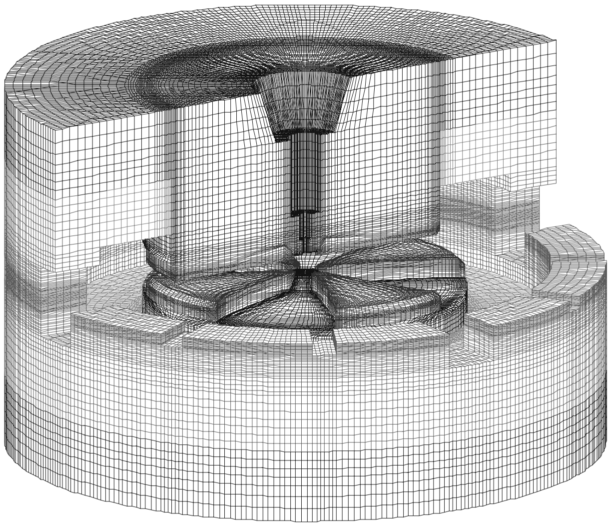

Fig.1. Finite-element model of CC12 magnet system

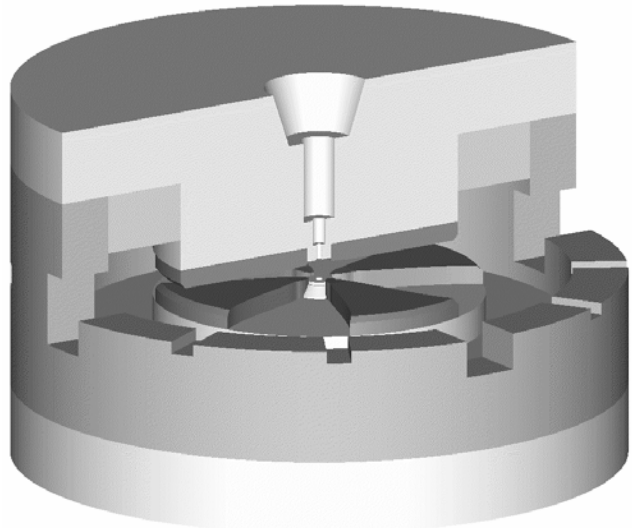

Fig.2. CC12 solid geometry generated from FE model.

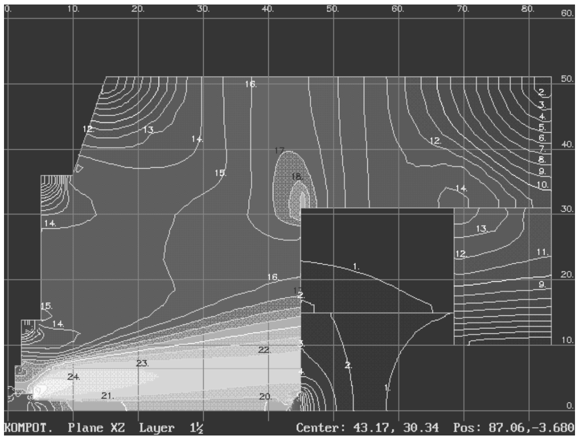

Fig.3. Simulated field map in CC12 vertical plane.

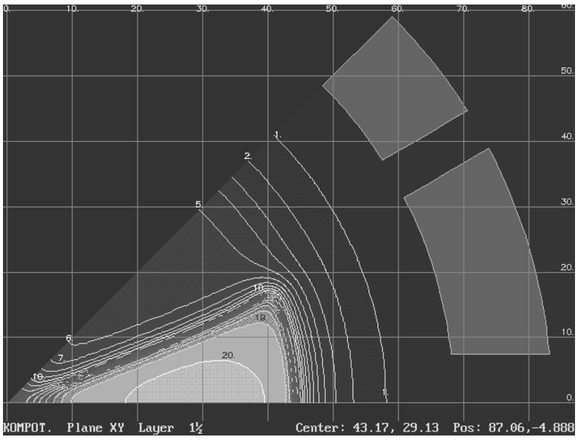

Fig.4. Simulated field map in CC12 median plane.

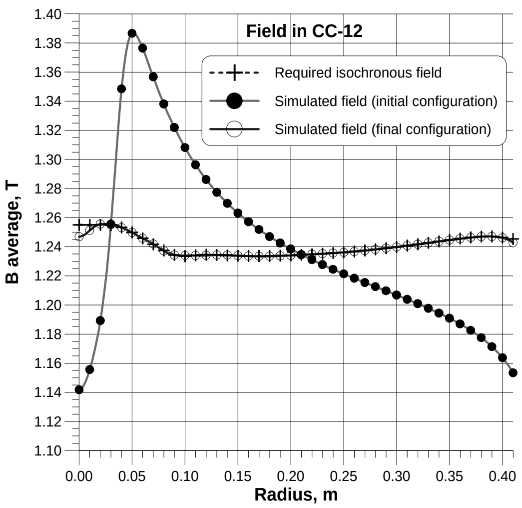

Fig.5. Averaged field variations with radius.