CyclSyntWin Software Application for Synthesis and Optimization of Cyclotron Magnetic Structures and Magnets

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Abstract—The Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research in Dubna is developing and creating new cyclotrons. In the initial stage of development, it is necessary to analyze several variants of their magnetic structures in a relatively short time. Examined herein is the Laboratory’s developed CyclSyntWin software application which allows preliminary analysis of several variants and determination of the main physical and geometrical parameters of the cyclotron magnetic structure and magnet itself. The data obtained thereby can subsequently be used in 3D software applications, which substantially accelerates the final synthesis of the cyclotron magnetic structure and magnet. The CyclSyntWin application can be used to synthesize and optimize the near-azimuthally symmetric magnetic structures of straight and spiral sector cyclotrons, close to azimuthally symmetric. The ratio of their air gaps in the valley and in the region of the sectors shouldn’t exceed 25 and the average magnetic field shouldn’t be more than 2 T.

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1. INTRODUCTION

Both simpler and more accessible software applications (Poisson [1]) and 3D applications developed by commercial firms (ANSYS [2], Opera3D-Tosca [3], MERMAID [4], Kompot [5, 6], etc., are used for synthesizing and optimizing cyclotron magnetic structures and magnets.

The Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research in Dubna is the physical center where several cyclotrons were developed and created.

The laboratory is also developing new cyclotrons whose goals and purposes are different. In the initial stage of development, it is necessary to analyze several variants of magnetic structures in a short time. The requirements imposed on accuracy of such preliminary analysis are not very high since one of the aforementioned 3D applications is most often used for final synthesis of the selected structure.

Practice showed that the use in the given application with the error limits shown below meets these requirements.

The diversity of designs of magnetic structures in the database mainly affected the error limits of these dependences and limits their area of use.

The difference in the magnetic properties of the steel used for their construction has a less effect on the accuracy of the results of using these analytical dependences.

Examined herein is the Laboratory’s developed CyclSyntWin software application which allows preliminary analysis of several variants and determination of the main physical and geometrical parameters of the cyclotron magnetic structure and magnet itself.

The data obtained thereby can subsequently be used in 3D software applications, which substantially accelerates final synthesis of the cyclotron magnetic structure and magnet.

The CyclSyntWin application can be used to synthesize and optimize the near-azimuthally symmetric magnetic structures of straight and spiral sector cyclotrons. The ratio of their air gaps in the valley and in the region of the sectors shouldn’t exceed 25 and the average magnetic field shouldn’t be more than 2 T.

The CyclSyntWin application operates under the Windows operating system.

2. DESCRIPTION AND MAIN POSSIBILITIES OF SOFTWARE APPLICATION

Underlying the algorithm of the first version of the CyclSyntWin application operating under the DOS operating system were the earlier published results of analyzing certain dependences of magnetic structures obtained experimentally both on model and on actually operating cyclotron magnets [6].

In recent years the Laboratory developed and created the DC72 cyclotron for Slovakia [7, 8, 9, 10] and the DC60 for Kazakhstan [11]. The physical—technical substantiation of a new DC350 cyclotron project for Kazakhstan was also developed [12]. During these works, new data were obtained both as a result of experimentally measured maps of the fields of magnetic structures (first two cyclotrons) and by 3D calculations of these structures [13, 14]. The data obtained were used for checking and refining the analytical dependences of the parameters of magnetic structures used in the first version of the CyclSynt application.
Practical work with this application necessitated broadening the possibility of its use beyond the limits of the analytical dependences used in it.

To broaden these limits, a model of the magnetic structure with deeper variation of the magnetic field (with a ratio of the air gaps in the valley and in the region of the sectors up to 25) was created and analyzed by a three-dimensional program. New analytical dependences of certain parameters of magnetic structures were obtained in this way in a broader range and formed the basis of the latest version of the CyclSyntWin application.

The application allows selecting (as an option) one of two initial parameters—energy of ions or magnet pole diameter, which determine the logic of development of the calculation (Fig. 1).

Several “experimentally” obtained parameters, which rarely change (Fig. 1), are used in the application, as are parameters whose determination is examined below.

Figure 2 visually shows determination of the first of these parameters—the ratio of the beam structure aperture $BeAper$ to the vertical beam dimension $BeDim$.

The ampere-turns density $kATu_{dens}$ is determined as the ratio of the number of ampere-turns of one of the two coils of the main coil to the geometrical cross-sectional area of this coil.

Several more input parameters are assigned in the next step (Fig. 3). Determination of two of them, the beam aperture $BeAper$ and air gap for the correction coils $CorCoDim$ is also visually displayed in Fig. 2.

After entering all input parameters and starting calculation, the application puts out on the screen the bulk of the results of calculating both the physical and geometrical parameters of the magnetic structure and parameters of the cyclotron H-shaped magnet (Fig. 4).

The complete set of all calculation results (including geometrical parameters of the compact-type magnet) can, at the user’s discretion, be written in the text documents provided for this.

Most of these parameters are calculated by well-known formulas, but the analytical dependences obtained by us are used for some of them.