PROGRAM COMPLEX FOR MODELING OF THE BEAM TRANSVERSE DYNAMICS AND ORBIT CORRECTION IN NUCLOTRON, LHEP JINR

I.V. Antropov, V.A. Kozynchenko*, V.O. Khomutova, D.A. Ovsyannikov,
Saint-Petersburg State University, Saint-Petersburg, Russia
I.L. Avvakumova, O.S. Kozlov, V.A. Mikhaylov, A.O. Sidorin, G.V. Trubnikov,
JINR, Dubna, Moscow Region, Russia

Abstract

Program complex for modelling of transverse dynamic of particle beams and orbit correction at Nuclotron synchrotron (LHEP JINR) is considered in current work. The program complex provides calculation of transverse dynamic of charged particle beams in Nuclotron and its axis, based on linear model with transport matrix of lattice elements, calculation of Nuclotron Twiss parameters, acceptance and emittance of the beam. A possibility to optimize the location of beam position monitors (pick-up) and multipole correctors is foreseen as well as calculation of the orbit with measuring data of pick-up stations of Nuclotron. Program complex includes realizations of orbit correction algorithms with response matrix and provides correction of the orbit in Nuclotron. User's graphic interface provides interaction of user with program complex, including performance on demand of the user of separate functions of the program complex, providing input and maintenance of parameters, download from file and record into the file of parameters and calculation results, graphical view of the calculations results in program complex. Program software environment is integrated with MAD-X program (upload, processing of data to and from, visualization). Format of input and output data is compatible with relevant MAD-X format.

INTRODUCTION

At present, in the Joint Institute for Nuclear Research (Dubna, Russia) successfully operates the Nuclotron – a synchrotron for accelerating beams of multicharged ions, protons and deuterons [1]. To reduce losses in the Nuclotron, various orbit correction methods are used [2]. When studying the problem of orbit correction, the necessity has arisen for creating a package of programs that would allow making cooperative use of both the accumulated experience and new developments. The program comlex considered in the paper includes an extensive graphical interface and a variety of tool kits, methods and algorithms that allows the researcher mostly to be focusing on the model development. The package also includes the BDO Nuclotron laboratory, a general description of which is the subject of this article.

*v.kozynchenko@spbu.ru

DESCRIPTION OF THE PROGRAM COMPLEX

The program complex consists of a control program, laboratories and libraries.

BDO Shell [3],[4] – a control program having the rich graphical user interface, a library of model parameters, and system functions. One may refer to the specific features of this product the following:

- the possibility of dividing the calculation process into stages with specifying the groups of input and output data files;
- the ability to automate the simulation process for a given parameter ranges;
- using various case studies with pre-described sets of parameters, input and output data files, settings of calculation stages.

BDO Nuclotron - laboratory for modeling and optimization of particle beams dynamics in the Nuclotron. The laboratory consists of several models allowing computation of the linear transverse dynamics of the beam center of gravity, the beam transverse dynamics, and the structural features of the Nuclotron. There is also a library of initial distributions, and a library of the correction methods for a closed orbit.

MODULES

The Module for Calculating the Lateral Dynamics of the Center of Gravity of the Beam in the Nuclotron Based on a Linear Model

The module for calculating a transverse beam dynamics in the Nuclotron provides computing the lateral dynamics of the center of gravity of the beam at the Nuclotron that is based on a linear model and uses the transport matrices of structural elements of the Nuclotron (dipole bending magnets, focusing and defocusing quadrupole lenses, drift gaps, and multipole magnetic correctors). When calculating the dynamics, the structural elements intended for the slowed-down beam extraction from the Nuclotron channel are not considered. One can add other structural elements of the Nuclotron, as well as change the location of pick-up displays and multipole correctors. When calculating the dynamics, the own beam field is ignored. It is possible to take into account the errors of the magnetic field in the elements of the transport matrix. The module provides for the formation of the response matrix being made on the base of computing the transverse

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dynamics provided that a user specifies the locations of pick-up displays and multipole correctors in the drift gaps.

The Module for Calculating the Beam Envelope and Structural Functions of the Nuclotron

The module carries out the calculation of beam dynamics in Twiss parameterization, the calculation of the structural functions of the Nuclotron and the calculation of the acceptance channel of the Nuclotron.

The Module for Calculating the Orbits of the Nuclotron

The module calculates the Nuclotron orbits using the orbit data measured by the pick-up monitors of the Nuclotron. The orbit is calculated over the whole Nuclotron ring, including the insides of its structural elements. When calculating an orbit, it is possible to exclude the readings of some pick-up monitors.

Library of Functions Implementing the Initial Distributions

The library contains functions that implement the initial uniform and normal distributions of the beam. The transverse distribution is formed on the basis of specifying an input beam emittance.

The Module for Calculating a Transverse Beam Dynamics in the Nuclotron Using a Linear Model

The module for calculating a transverse beam dynamics in the Nuclotron calculates transverse beam dynamics in the Nuclotron on the basis of a linear model with the usage of the transport matrix of the Nuclotron structural elements (dipole bending magnets, focusing and defocusing quadrupole lenses, drift gaps and multipole magnetic correctors) without taking into account the structural elements for slowed-down beam extraction from the Nuclotron channel. The beam is represented by a set of model particles. One can add other structural elements of the Nuclotron, as well as change the location of pick-up monitors and multipole correctors. When calculating the dynamics, the own beam field is ignored. It is possible for the magnetic fields errors to be taken into account in the transport matrix elements. The initial distribution is generated using the library of the initial distribution functions. The possibility of calculating the beam emittance is provided.

Library of Functions Implementing Various Methods of the Orbit Correction

The library contains software implementations of the algorithms of orbit correction using the response matrix: SVD [2] and MICADO. The SVD method provides the possibility of determining the currents in the correctors based on the use of the pseudoinverse matrix for the response one. Pseudoinverse matrix is calculated using the singular decomposition of the response matrix. MICADO method allows determining the most effective correctors from the available ones. One can add other methods of orbit correction.

The Module of Orbit Correction Using the Response Matrix

The module provides an orbit correction in the Nuclotron using the library of correction methods. The orbit correction is made on the basis of the response matrix. The response matrix can be calculated using the results of numerical simulation of the dynamics of the beam center of gravity or can be obtained on the results of measurements of the position of a beam center of gravity in the pick-up monitors of the Nuclotron.

CONCLUSIONS

In the presented program complex, implemented are the models for calculating the transverse dynamics and the models of the beam orbit correction in the Nuclotron based on the use of the response matrix. To ensure the effective orbit correction, the suggestion has been made to complement the software package with the optimization models that allow determining the real errors of the transport matrices of the Nuclotron structural elements. It is also planned to add new optimization methods for the orbit correction.

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