DeCA – Code for Analysing and Design of Cyclic Accelerators.

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Introduction

The program package DeCA (Design Cyclic Accelerators) is designed to solve a variety of problems involved in the development of cyclic accelerators and charged particle storage rings [1]. The package is convenient in usage, it offers wide possibilities for data display, has a flexible control system and a sufficiently high-level input language. The package is arranged on the block-functional principle, which ensures integrity and a high reliability of the package, simulteniously excluding the dublication of functions. All software components are made to a certain standard which ensures their compatibility. One of the principal advantages of the package is its extensibelity with the existing possibility of adding new package-control commands, new types of magnetic lattice elements or new models of the element types described previously. All application modules are written in the FORTRAN 77 language, the program size is 15000 lines, the number of subprograms is 190, the working memory being 2 megabytes.

The functions of the package.

The proposed version 2.2 of the DeCA package has been aimed at simulating multiturn processes involving many particles (1000 as a maximum). It consists of three independent functional blocks and the system part. Given the latter, any combination of the blocks can be used independently.

The system blocks of the package provide the package control, diagnostic message printing, input of the magnetic lattice, inclusion of perturbations in the magnetic elements installation (geometrical coordinates and fields), and data display.

The functional blocks of the DeCA version 2.2 perform the following operations:

1. Geometry of Accelerators (GAC) block: calculation and plotting of space coordinates of the lattice elements [2].

2. Reference Trajectory Linear (REFTL) block: calculation of focusing functions and reference trajectory coordinates in the linear approximation [2]:

- amplitude functions and their derivatives: $\beta_x, \dot{\beta}_x, \beta_z, \dot{\beta}_z$;
- dispersion functions and their derivatives: $\psi_x, \psi'_x, \psi_z, \psi'_z$;
- betatron phase: μ_x, μ_z;
- betatron frequency: Q_x, Q_z;
- synchrotron frequency and the momentum compaction factor: Q_x, α;
- energy losses per turn and the synchronous phase: E_1, φ_s ;
- chromaticity: $\xi_x \xi_z$;
- emittance and partial damping times: $\varepsilon_x, \varepsilon_z, \tau_1$;
- reference trajectory coordinates: $x, x', z, z', s, \Delta E/E$.

The block makes the correction of the reference orbit by the Hereward-Baconier method.

Two models can be used: with and without taking into account synchrotron oscillations.

3. Modelling Dynamics of Particles (MDP) block: simulation of beam dynamics with calculation of nonlinear fields to the 5th order in the thin-lens approximation, and of the second-order aberrations in linear elements. The block can also efficiently be used to simulate such processes as:

- beam injection (including multiturn injection by means of pulsed elements);
- particle motion in a cyclic lattice (including the analysis of the dynamic aperture);
- beam extraction from the ring (including the chromatic extraction).

To save the computer time, using it most efficiently, the block also allows for:

- simulation with and without taking into account synchrotron oscillations;
- folding the groups of linear magnetic elements into a single element;
- carrying out a long-term simulation as several separate sessions.

To make the simulation more realistic in terms of real physical processes, provision is made for:

- initialization of particle coordinate values (i) in an explicit form, or (ii) by distributing them in a phase 6-dimensional ellipsoid oriented in space in a particular way, or (iii) by combining the both methods;
- the employment of magnetic elements with variable parameters (fields, angles, etc) which can be changed in accordance with the assigned law during one or more turns of the beam; these are: pulse lenses, kickers, RF-cavities (with a variable amplitude), etc;
- representation of the beam as one or several bunches distributed in the ring (this procedure is used on simulating with pulsed magnetic elements when the pulse length is comparable with the duration of the turn).

The package offers the following types of output data display:

- tables and plots of the focusing functions and the reference orbit coordinates for an arbitrarily chosen part of the lattice;
- phase maps of the beam in any phase plane for one or several elements (the largest number of mapping azimuths being 16);
- tables and plots of the tracks of individual particles for the chosen turn (the greatest number of the mapped particles is 4);
- tables and plots of the envelopes and rms size of the beam for the chosen part of the lattice;
- binned distributions of lost and extracted particles (in turns or lattice elements).

The time intervals of data accumulation and display are set up by independent control parameters.

Computation examples.

The DeCA program package has been used to calculate physical parameters of the 3 GeV electron pulse stretcher ring PSR-2000 [3]. Figure 1 shows amplitude and dispersion focusing functions of one period of the lattice for operation conditions with oscillation frequencies Q_x=8.31, Q_z=7.17. Figures 2 and 3 show the coordinates of the perturbed reference orbit before and after making the correction, respectively. The rms errors in installation of the magnetic elements were found to be 0.1 mm and 0.1 mrad. Figures 4 and 5 illustrate the process of the chromatic beam extraction from the PSR-2000. They show the RF separatrix and the beam phase map in the X-X' plane. Figure 6 presents the binned distributions of the beam extraction in turn. Figure 7 contains the information on the dynamic aperture of the circulating beam with the sextupole fields present in the lattice. This information is presented as a phase plane X-Z, where the initial coordinates of the particles left in the ring, and also of lost and extracted particles are marked in a particular way. The beam envelope, rms size and also the coordinates of the cms of the beam per 100 turns are presented in Figure 8.

Package development.

As mentioned above, the DeCA program package can be extended if need shoud arise. In the subsequent versions of the package we intend to add the following functions: calculation of synchrotron radiation parameters, simulation of spin-orbital motion of the electron beam, optimization of the machine parameters.

References

[1] P.I.Gladkikh, A.Yu.Zelinsky, M.A.Strelkov,"DeCA application package. Package organization (in Russian). KhFTI preprint 89-42.Moscow, TsNIIAI pub.,1989.

[2] P.I.Gladkikh, A.Yu.Zelinsky, M.A.Strelkov,"DeCA application package Version 1.1. A physical model (in Russian). KhFTI preprint 89-44. Moscow, TsNIIAI pub.,1989.

[3] V.F.Boldyshev et al. "A design of 3 GeV CW accelerator facility" in Proceedings of the IEEE Particle Accelerator Conference,1988,vol.2, pp. 883-883.

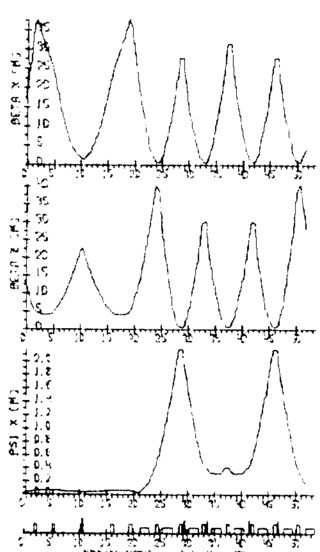

Fig.1. Amplitude and dispersion focusing functions of one lattice period for oscillation frequencies Q_x=8.31, Q_z=7.17 of PSR-2000.

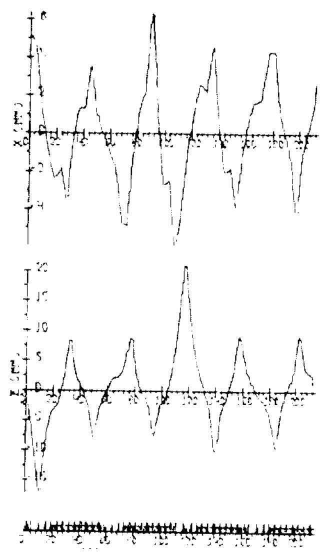

Fig.2. Coordinates of the perturbed reference orbit of one lattice period. RMS errors of magnet element installation are 0.1 mm,0.1 mrad.

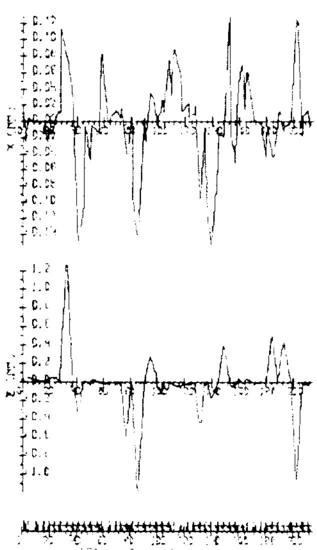

Fig.3. Coordinates of the perturbed reference orbit of one lattice period after introducing the correction.

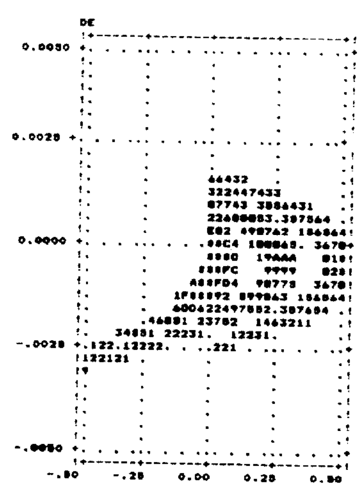

Fig.4. RF separatrix of the beam with chromatic extraction from the PSR-2000.

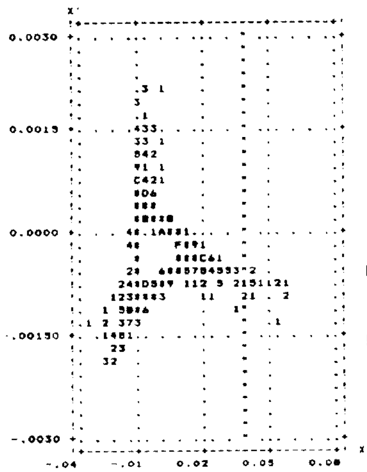

Fig.5. Beam phase map (X-X'plane) for chromatic extraction from the PSR-2000.

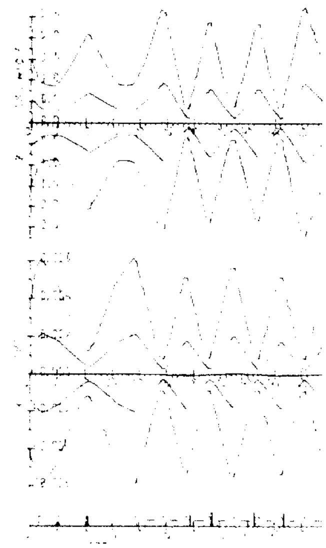

Fig.8. Envelopes, rms size and cms coordinates of the beam per 100 turns for one period of the PSR-2000 lattice.

	EXTR		
TURNS	HIST	PART	%
1 - 50	!!!!!!!!!!!!!!!!!!!	7	38
51 - 100	!!!!!!!!!!!!!!!!!!!	7	38
101 - 128	!!!!!!!!!!!	4	22

Fig.6. Binned distributions of beam extraction and losses in turns for chromatic extraction from the PSR-2000.

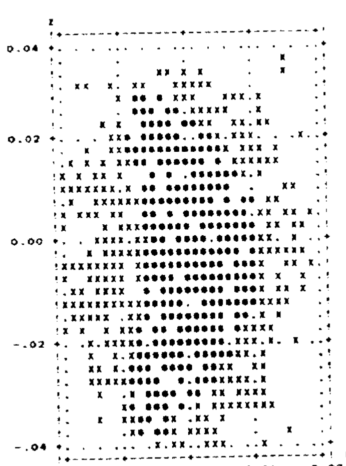

Fig.7. Dynamic aperture of the PSR-2000 at the β_x minimum with the sextupole fields taken into account.

$ - the particle is involved in stable oscillations;

X - the particle is lost.