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Manual for COMSYN - A Orbit Integration Code

For The Study of Beam Dynamics In Compact Synchrotrons

Y. Huang october, 1991

1. Principle

COMSYN is a numerical integration code which is written for the study and design of the compact synchrotrons. An improved 4^{th}-order Runge-Kutta method is used in COMSYN to integrate the exact equations of motion in a rectangular coordinate system. With time as an independent variable, the equations of motion have the following form:

$$\ddot{x} = \frac{e}{m}(E_x + B_z\dot{y} - B_y\dot{z})$$

$$\ddot{y} = \frac{e}{m}(E_y + B_x\dot{z} - B_z\dot{x})$$

$$\ddot{z} = \frac{e}{m}(E_z + B_y\dot{x} - B_x\dot{y}).$$

The magnetic field components of the dipole B_x, B_y and B_z can be obtained from either measurement or directly computed data (MAGNUS, TOSCA). A spline interpolation method is then used to get the field value at the particle position. For standard quadrupole and sextupole, the analytical expression is employed to compute its field distribution.

The coordinate system is shown as the following figure. The origin coincides to the center of the lattice structure. Starting from the center of the sextupole, an iteration is made on a reference particle's momentum to find the equilibrium

orbit for the real lattice structure. Then, four particles are selected, which have initial small departures in horizontal and vertical coordinates, x, x′, y, y′ with respect to the reference particle, respectively. Based on their tracking simulation over one superperiod, one four-dimensional transport matrix for the transverse oscillation can be determined numerically. By comparing its elements with that of the parameterized matrix described by Courant and Snyder[9], both β and α functions can be obtained. The values of β , α and γ at any position can be evaluated in terms of transformations of twiss parameters. The linear horizontal and vertical tunes are given in terms of the matrix trace. For those particles with big amplitude, the fast Fourier translation(FFT) method is used to analyse their tune spectrum. The dispersion function, η, is calculated through the definition $\eta = x_p(\delta p/p)|_{\frac{\delta p}{p}\to 0}$ where x_p is the distance between the reference orbit with momentum p and the off-momentum(δp) particle equilibrium orbit. The natural chromaticity, ξ, is computed by formulae $\xi = \delta\nu/(\delta p/p)|_{\frac{\delta p}{p}\to 0}$, where $\delta\nu$ is the difference of tune between the oscillation around the reference orbit and the off-momentum orbit. The synchrotron radiation integrals I_1 through I_5 are evaluated by the procedure as described by Helm[2].

2. Major Subroutines and Their Function

BLOCK DATA: input physics constants;

MAIN: coordinate subroutine's work;

ORBIT: execute orbital integcking calculation;

DRK: Runge- Kutta procedure;

EQUATION: equations of particle motion;

AMATRI: computation of the transfer matrix;

YINITI: input initial definition of particles;

ANAMAG: lattice description and analytical magnetic field expressions;

FIELD: computation of field value at particle position;

SPLINEB: read in ordered field data;

SPVAL1: function subroutine for spline evaluation;

CUBIC2: calculation of second derivatives for spline;

CHECK, HITLIST: check whether particle hits the wall of beam pipececk, if so, output the information and romove the particle;

ROY, DATAIN, SOURCE, BARCS, STRT, STRBAR, BEND, DBEND: a set of subroutines for field computation by TOSCA;

READIN: read in measured field data of phase I;

HUANG: field calculation at particle position by coefficient spline based on the measured field or TOSCA-generated field data.

3. Input Formalism

The following is an example of input data file.

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```
H
HI
HL
S
L
M
O
5                              No. of particles
0 0.5  1  1                    Start and end of turn no.
300                            Step no. each half superperiod
1.D-13  10.                    Error requirement fitting magnet boundary
5 0.0525D0  0.126D0 0.2035 0.281D0  1.1775D0  Boundary No. and position
2.2919945372771l9D0 1.314863714D0          Initial Betax and Betay
196.00596D0  0.d0  1.D-03 Designed energy and Momentum dispersion
.6067D0   0.d0   0.d0  -3.181d0   -39.19D0  R0,B1,B2,QF,SF
0.d0  0.D0 0.d0   0.d0  0.d0
1.d-03  0.D0 0.d0   0.d0  0.d0
0.d0  0.D0 0.d0   1.d-06  0.d0
0.d0  0.D0 1.d-03   0.d0  0.d0
0.d0  0.D0 0.d0   0.d0  1.d-06
EX
```

In the input data file,

Line 1-6 are input commands which define the requirements for computation and output. There are fifteen main commands optional in this code. The following list their functions:

H : Help. List the available commands and their functions.

B : Use isomagnetic field approximation.

DA: compute dynamic aperture. Output data file space.dat.

E : Use analytical edge field defined by user in subroutine ANAMAG.

FT: Output data file fft.dat for fast fourier tranisform.

HI: Read in measured magnetic field data for phase I.

HL: Stop tracking after half superperiod and output result.

I : Compute and output synchrotron radiation integrals.

M : Compute transfer matrix and output data file matrix.dat.

N : Call in interpolation subroutine SPLINEB. A file name of field data to be interpolated should follows.

O : Call in subroutine ORBIT and execute particle tracking.

S : Introduce sixtupole field.

T : Use analytical field inside combined function dipole.

TA: Use TOSCA-computed field directly.

TS: Output magnetic field value along particle trace for test.

EX: Exit.

Line 7-15 have been explained partly by the attached statement in the input data file.

The inital betax and betay in line 13 are the beta values at the center of the sextupole, which are needed by the synchrotron integral calculation. These value can be obtained from first lattice function computation.

The first one in Line 14 is reference particle energy in MeV and the momentum dispersion is defined by $\frac{\delta P}{p}$.

In line 15,

R0: the radius of equilibrium orbit in meter;

B1, B2: the quadrupole in T/m and sextupole field amplitude of the combined function magnet in T/m^2;

QF, SF: field strength of the quadrupole in T/m and sextupole elements in T/m^2.

Line 16-20 are definitions of particle by five coordinates x, y, z in mm and x', y' in rad.

Line 21: end of input data

4. Output and Data Analysis

Depending on the commands the user gives in the input file, the code can create some of the following data files(in form of *.dat):

BETAH(unit 8), BETAV(unit 9): horizontal and vertical β values;

ALPHAH(unit 10), ALPHAV(unit 11): horizontal and vertical α values;

PHASE(unit 12): phase advance values;

ETA(unit 14): dispersion function values;

MATRIX(unit 7): output of transfer matrix after each element and lattice functions after half of superperiod. To evaluate the chromaticities the user has to run the program twice to get tunes of the reference particle and the one with off-momentum orbit.

SPACE(unit 18): particle coordinates(x, x', y, y') at specific position over a number of turns which is used for dynamic aperture print;

TEST(unit 19): particle position and magnetic field values(BX, BY, BZ) at the point;

FFT(unit 15): particle coordinates(x, y) at specific position over a number of turns which are used for FFT analysis. To compute tunes from the data user needs to run code TWODTUNE which is available from my directory.

5. Accuracy and Speed of Computation

This code has been written in the double-precision. A further enhance of computation accuracy may be reached by an increase of step number per super-

period with a cost of cputime consumed. With 300 steps per half of superperiod, it takes about 10 minutes of CRAY time to track a particle over 1000 turns using interpolated field. The computational accuracy was tested by tracking the reference particle in SXLS for over 10^4 turns and the deviation of the particle from the ideal orbit is less than 10^{-8} meter in radial distance and 10^{-12} rad in radial slope, respectively.

END

DATE FILMED

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