SLAC-PEP-NOTE--360

DE89 006264

PROGRAM BB FOR CALCULATION OF PEP CORRECTOR STRENGTHS FOR BEAM-BUMP EXCITATION*

S. Khaifets
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Excitation of a beam-bump (BB) can be effectively used for a number of goals. Since BB is sensitive only to perturbations of elements which are located inside it, errors and their consequencies spaced separately can be singled out and studied one by one. This technique in principle can be used to study the uniformity of the quadrupole distribution around the ring, the beam stay clear size of the machine at different locations, the polarity and probably even the strength of sextupole magnets, alignments of different monitors etc. It can be used also to increase the beam cross section if that appears to be desirable.

Design of PEP correctors (their number, location and connection) does not allow to use them for excitation of a halfwave BB (with two correctors only). The minimum number of correctors which can be used in this situation is three. The situation for horizontal plane is aggravated still more since most of horizontal correctors are hooked in pairs. Figure 1 presents schematic layout of horizontal PEP correctors.

The presence of sextupole magnets interlacing the correctors makes it necessary to use iterative procedure to find the corrector strengths for BB, since a perturbed orbit is influenced by a field of a sextupole magnet which in turn depends on the perturbed orbit value in the sextupole.

* Work supported by the Department of Energy, Contract DE-AC03-76F00515.

Since the strength of sextupoles are rather small as the first guess of corrector strengths for iterative procedure can be taken the linear solution neglecting sextupoles. Section 1 contains this solution. Section 2 describes the program BB itself, and Section 3 some results of calculations with BB for PEP.

1. Linear BB

The simplest way for calculation of corrector strengths for linear machine is one using the superposition principle[1]. I will show how it works on the example of six correctors (see Fig. 2). Suppose we know all transformation matrises T_{i6} which translate vector $(\bar{x}')$ from point i (positions of six subsequent correctors) to point i = 6 (i = 1, 2...6). Let us denote θ_i the horizontal kicks (still unknown), which i-th corrector gives to an orbit. Then the condition of perfect beam-bump exited by all six correctors is:

$$\sum_{i=1}^{6} T_{i6} \begin{pmatrix} 0 \\ \theta_i \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} , \qquad (1)$$

where $T_{16} = I$ (unit matrix). Due to special form of equation (1) only 1,2 and 2,2 elements of T_{i6} are important. To simplify formulae I use notations

$$T_{16}^{12} = q_{16} \qquad (2)$$

$$T_{16}^{22} = p_{16} \qquad (3)$$

They can be expressed[2] in forms of corresponding β-functions, their slopes $\alpha = -\beta'/2$ and their phases φ:

$$q_{16} = \sqrt{\beta_1 \beta_6} \sin(\varphi_6 - \varphi_1) , \qquad (4)$$

$$p_{16} = \sqrt{\frac{\beta_1}{\beta_6}} \left[\cos(\varphi_6 - \varphi_1) - \alpha_6 \sin(\varphi_6 - \varphi_1)\right] \qquad (5)$$

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

REPRODUCED FROM
BEST AVAILABLE COPY

Also because correctors are connected in pairs $\theta_1 = \theta_2$, $\theta_3 = \theta_4$ and $\theta_5 = \theta_6$, condition (1) is then equivalent to two following equations

$$(p_{16} + p_{26})\,\theta_1 + (q_{36} + q_{46})\,\theta_3 + l_{56}\,\theta_5 = 0, \qquad (6)$$

$$(p_{16} + p_{26})\,\theta_1 + (p_{36} + p_{46})\,\theta_3 + (p_{56} + 1)\theta_5 = 0 \qquad (7)$$

for three independent variable θ_1, θ_3 and θ_5. One of them is an arbitrary (in certain limits) number, which scales the amplitude of the BB. We choose θ_5 as this free variable and express two others in terms of its magnitude and two weight factors:

$$\theta_1 = k_1\,\theta_5 \qquad (8)$$

$$\theta_3 = k_2\,\theta_5. \qquad (9)$$

Equations (6) and (7) are easy to solve now with respect to k_1 and k_2:

$$k_1 = \frac{1}{\Delta}\left\{\sqrt{\beta_3\beta_5}\,\sin(\alpha_5 - \ell_3) + \sqrt{\beta_3\beta_6}\,\sin(\ell_6 - \ell_3) + \sqrt{\beta_4\beta_5}\,\sin(\ell_5 - \ell_4) + \sqrt{\beta_4\beta_6}\,\sin(\ell_6 - \ell_4)\right\}, \qquad (10)$$

$$k_2 = -\frac{1}{\Delta}\left\{\sqrt{\beta_1\beta_5}\,\sin(\ell_5 - \ell_1) + \sqrt{\beta_1\beta_6}\,\sin(\ell_6 - \ell_1) + \sqrt{\beta_2\beta_5}\,\sin(\ell_5 - \ell_2) + \sqrt{\beta_2\beta_6}\,\sin(\ell_6 - \ell_2)\right\}, \qquad (11)$$

where

$$\Delta = \sqrt{\beta_1\beta_3}\,\sin(\ell_3 - \ell_1) + \sqrt{\beta_1\beta_4}\,\sin(\ell_4 - \ell_1) + \sqrt{\beta_2\beta_3}\,\sin(\ell_3 - \ell_2) + \sqrt{\beta_2\beta_4}\,\sin(\ell_4 - \ell_2) \qquad (12)$$

Formulae (10-12) are used in program BB to calculate the kicks. In cases when some of correctors are single, i.e. not connected into pairs, they are internally made double to be able to use the same formulae. The output for corrector strength takes this into account and doubles the strength of a single corrector to give correct value.

2. Program BB

The input for program BB is a parameter NBSI, which codes the type of the BB one wants to produce, and a list containing sequential number, name, longitudinal position (in mm), β-function (in m), slope α, phase ℓ, code and integrated strength (for sextupole magnet only, m^{-2}) of correctors (code 108), monitors (code 105) and sextupoles (code 111), which are present inside the desired location of the BB (Format(3x, I9, A5, I9, 3F18.5, I8, F18.5).

All elements are listed in the natural order, i.e. in the order they are in the machine lattice. For each type of the BB there is a ready made input file (which is prepared for one of the PEP configurations $\beta_x^* = 4.21$ m, $\beta_y^* = 0.35$ m, $\nu_x = 21.32$, $\nu_y = 18.23$, $\eta^* = -0.00$ m). Table 1 contains information on the BB type, the number of the first and the last elements, the value of parameter NBSI and the name of the input file (on BATDO1 user SYK.RL) for each of BB type. Fig. 3 illustrates different types of BB calculated with the help of program PETROS[3].

The first line of the input list contains three integer parameters NLIST, NBSI and NPHS (format (3x, 3I8). NLIST is number of elements in the list, NBSI is the BB type code. If NPHS = 1 the ℓ-phases in the list are understood to be actually tunes and they will be multiplied by 2π. Otherwise the numbers will be left unchanged.

The output of the program contains the results of rearranging the element list, zero order approximation and the results of iterations to find the desired corrector strength. Of real interest are the three last lines which give (in the case of successful run) the number of iterations needed to reach the accuracy of displacement 10^{-8} m, kicks in radians for

each of three subsequent correctors (some of them or all can be actually pairs of correctors) and three weight factors k_1, k_2 and 1.0.

If program fails it usually tells a reason for that (like 'wrong number if horizontal correctors in beam-bump').

3. Some Results of Calculations

In a symmetric machine (i.e. in a machine with no errors) there are four essentially different types of horizontal BB - two types with NBSI = 0 one inside an arc (type OA), another crossing the symmetry point (type OS) and two types with NBSI = 1 (type 1) and 2(type 2). Table 2 gives summary of corrector positions, weight factors k and strengths for four different BB types. Tables 3-5 contain some relevant machine parameters for five typical BB values for different beam-bumps.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

References

1. I am obliged to R. Heim for advising me on this method.

2. See for example S. Kheifets, PTM-223, November 11, 1980

3. H. Wiedemann, PTM-146, April 14, 1978

Figure Captions

Fig. 1 Schematic layout of PEP horizontal correctors. Numbers give parameter NBST.

Fig. 2 Schematic illustration of BB calculation for six correctors.

Fig. 3 Different types of BB. Results of calculations with program PETROS.

Fig. 4 Example of a BB produced in PEP.

Table 1

#	NSBI	NLOW*	NUP*	FILI	Comment
1	0	10	92	BBX0	Three pair correctors inside an arc
2	0	32	117	BBX5	Three pairs crossing symm. point
3	1	181	243	BBX1	Single + two pair correctors
4	2	172	217	BBX2	Two singles + one pair
5	3	-	-	-	Pair + single + pair, used only internally in program
6	4	143	188	BBX4	Pair + two singles, symm. with NBSI = 2
7	5	117	179	BBX5	Two pairs + single, symm. with NBSI = 1

*) The numbers NLOW and NUP are the numbers of the first and the last elements of the lattice in the BB (as they are listed by program PETROS) counted from any interaction point.

Table 2

Parameters of SS for PEP

Type	Corr.	CX1 CX1	CX2 CX2	CX3 CX3	
OA Posit.	L	68762 76212	111812 119262	169212 176622	mm
weights	k	1.4666	1.7198	1.0	
strength	θ	0.29320	0.34397	0.20	mrad
weight	k	1.4307	1.7018	1.0	
strength	θ	0.50286	0.59564	0.35	mrad
OS					
	L	111812 119262	169212 176622	190044 197454	
	k	-1.2612	-1.3149	1.0	
	θ	-.25223	- .26288	0.20	
	k	-1.2638	-1.3167	1.0	
	θ	- .44231	- .46084	0.35	
1					
	L	13226	68762 76212	111812 119262	
	k	-.47330	.87264	1.0	
	θ	-.09466	.17453	0.20	
	k	-.47848	.86456	1.0	
	θ	-.16747	.30260	0.35	
2					
	L	2186782	13226	68762 16212	
	k	1.0445	.88306	1.0	
	θ	.20889	.17661	0.20	
	k	1.0255	.87485	1.0	
	θ	.35894	.30620	0.35	

Table 3

SS of Type OA

θ_5 mrad	x_{max} mm	ν_x	ν_y	ξ_x	ξ_y	β_{xmax} m	β_{ymax} m	σ_x^* mm	I_x	I_z
-0.35	-12.4	.3093	.1829	4.6	10.8	182.8	396.7	0.84	0.544	.956
-0.20	- 7.3	.3126	.2032	4.9	10.6	176.7	353.5	0.70	0.525	.975
0.	0.	21 .3172	18 .2294	5.2	10.5	168.1	310.0	0.69	0.500	1.000
0.20	7.2	.3222	.2552	5.5	10.6	176.3	317.2	0.77	0.476	1.024
0.35	12.8	.3260	.2743	5.7	10.7	183.6	324.2	0.96	0.459	1.041

Table 4

SS of Type OS

θ_5 mrad	x_{max} mm	ν_x	ν_y	ξ_x	ξ_y	β_{xmax} m	β_{ymax} m	σ_x^* mm	I_x	I_z
-0.35	-15.1	.3220	.2556	5.2	9.8	170.3	354.7	0.87	0.484	1.016
-0.20	- 8.6	.3198	.2444	5.2	10.1	169.3	335.8	0.73	0.490	1.010
0.	0	21 .3172	18 .2294	5.2	10.5	168.1	310.0	0.69	0.500	1.000
0.20	9.1	.3152	.2142	5.2	11.1	168.9	341.1	0.71	0.511	0.989
0.35	15.9	.3140	.2023	5.2	11.7	169.4	370.9	0183	0.519	0.981

Table 5

BB of Type 1

α_5 mrad	X_{max} mm	ν_x	ν_y	ξ_x	ξ_y	β_{xmax} m	β_{ymax} m	σ_x^* mm	I_x	I_z
-0.35	-13.5	.3171	.2211	5.4	10.7	172.9	321.7	0.73	0.530	0.970
-0.20	- 7.8	.3172	.2246	5.3	10.6	170.2	316.4	0.69	0.516	0.984
0.	0.	21 .3172	18 .2294	5.2	10.5	168.1	310.0	0.69	0.500	1.000
0.20	7.0	.3170	.2346	5.0	10.4	171.2	315.6	0.70	0.487	1.013
0.35	12.4	.3167	.2387	4.9	10.3	173.8	320.2	0.73	0.478	1.022

Table 6

BB of Type 2

α_5 mrad	X_{max} mm	ν_x	ν_y	ξ_x	ξ_y	β_{xmax} m	β_{ymax} m	σ_y^* mm	I_x	I_z
-0.35	-28.8	.3047	.2379	4.9	10.3	185.4	321.8	0.68	0.493	1.007
-0.20	-16.3	.3097	.2337	5.0	10.4	177.6	316.4	0.68	0.499	1.001
0.	0.	21 .3172	18 .2294	5.2	10.5	168.1	310.0	0.69	0.500	1.000
0.20	15.8	.3252	.2267	5.4	10.6	176.4	314.2	0.71	0.500	1.000
0.35	27.2	.3313	.2254	5.6	10.8	184.0	317.7	0.73	0.500	1.000

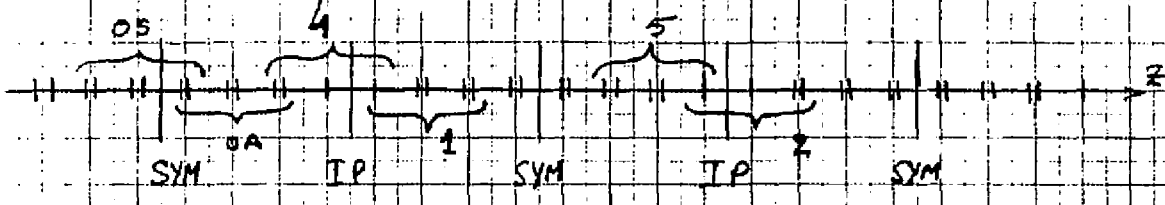
OS
4
5
Z
OA
1
SYM
IP
SYM
IP
F
SYM

Fig. 1

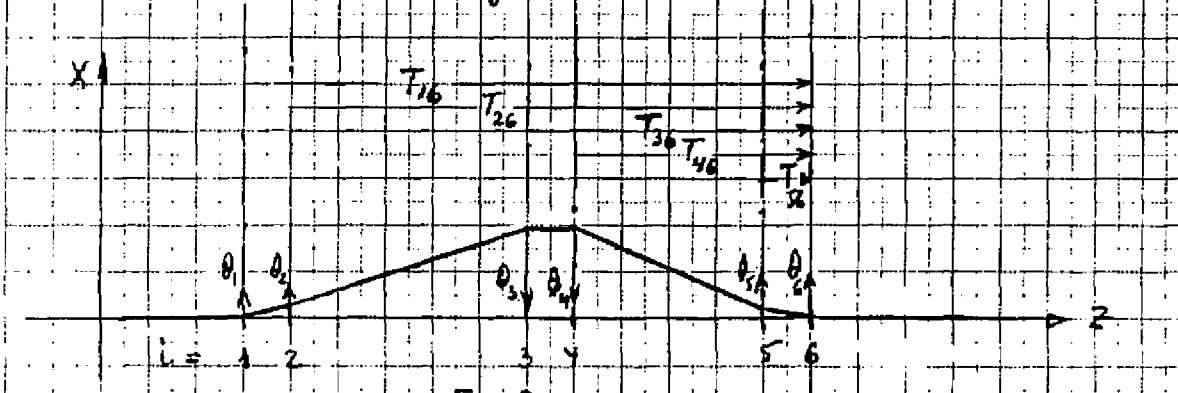
X
T_{16}
T_{26}
T_{36}
T_{46}
T_{56}
θ_1
θ_2
θ_3
θ_4
θ_5
θ_6
Z
L =
1
2
3
4
5
6

Fig. 2

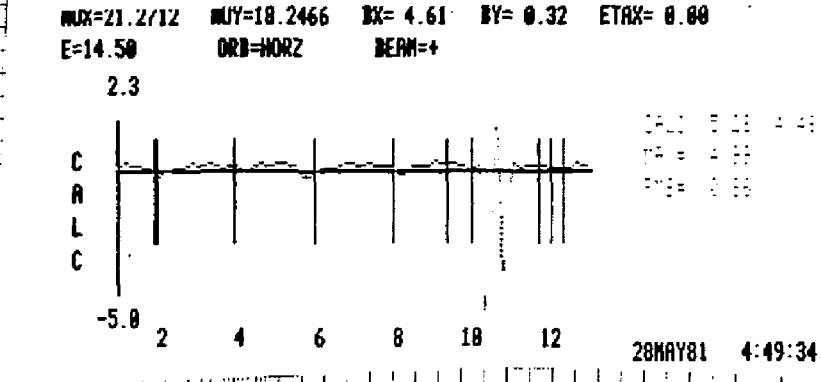
MUX=21.2712 MUY=18.2466 BX= 4.61 BY= 0.32 ETAX= 0.00
E=14.50 ORB=NORZ BEAM=+
2.3
C
A
L
C
-5.0
2
4
6
8
10
12
28MAY81 4:49:34

Fig. 4

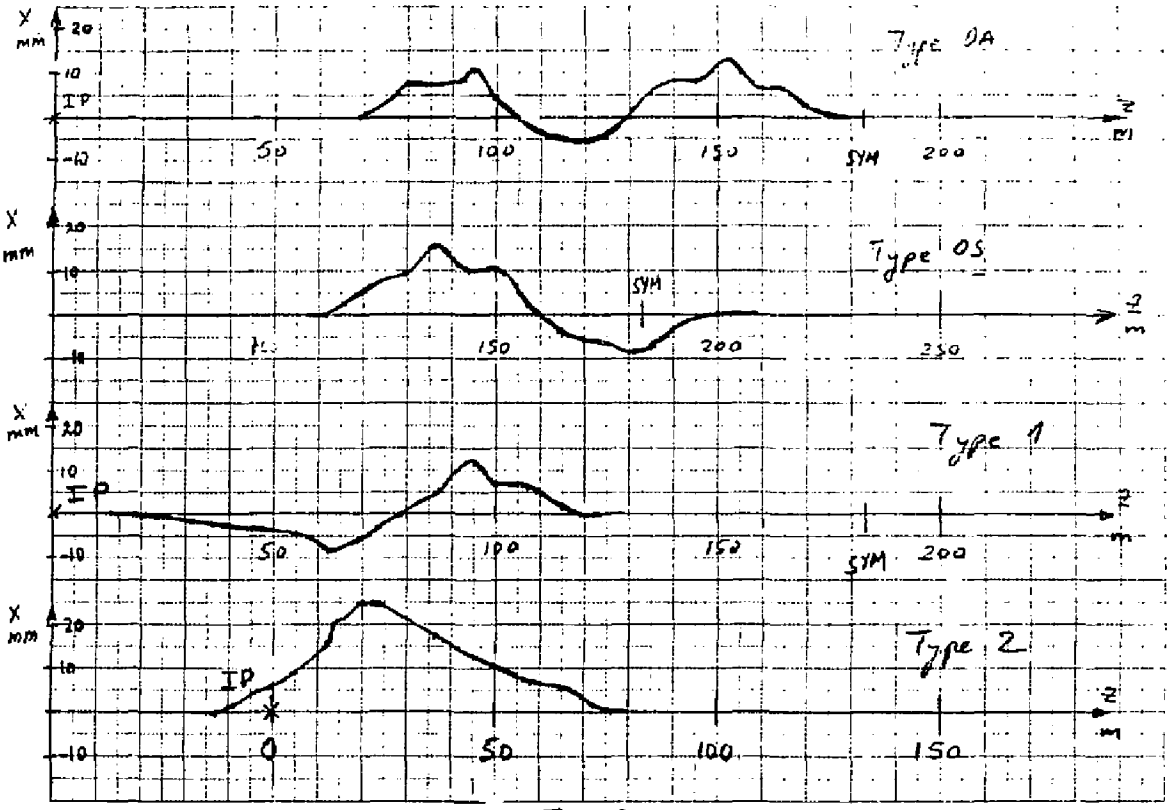
X
mm
20
10
IP
-10
50
100
150
SYM
200
Type 0A
X
mm
20
10
SYM
150
200
250
Type 0S
X
mm
20
10
IP
-10
50
100
150
SYM
200
Type 1
X
mm
20
10
IP
-10
0
50
100
150
Type 2

Fig. 3