The Estimation and Control of Closed Orbit in Fast Cycling Synchrotron

S.H.Ananian, R.H.Manukian, A.R.Matevosian
V.Ts.Nikogossian, A.R.Tumanian
Yerevan Physics Institute, Armenia, U.S.S.R.

The quality of the closed orbit regulation and optimization in synchrotron depends on the composition and the quality of the beam parameters measurements and the methods of the control action development based on this measurements. In the existing closed orbit correction systems the beam position monitors are used as an information source and the dipole corrector magnets are used as the control devices. The algorithms of the control actions are well known in this kind of systems /1/.

In the upgrading of the existing accelerators and equipping with the automatic control systems the most important and in some cases the decisive factor of their structure is the minimization of the extra equipments with maximum usage of existing control system.

In Yerevan synchrotron the beam observation system consists of the beam intensity monitors and the affairs of making precise BPM were failed because of bad noise immunity. From the other side the closed orbit correction 2 bump scheme /2/ doesn't give pure local correction, without distorting the closed orbit in the other part of the ring (the residual distortion is about 25% of the maximum local displacement /3/).

Here a set of algorithms of closed orbit estimation and correction on the magnetic field injection level is presented, which do not need the system of BPM.

1. THE ESTIMATION AND CONTROL ALGORITHMS.

The equations of particle horizontal motion are /3/

$$R_k(s)=R_{co}(s) + \phi(s)C^{k-1}\phi^{-1}(0)(R_o-R_o^{co}), \quad (1)$$

$$R_{co}(s)=\phi(s)[\int_0^s\phi^{-1}(t)BF(t)dt+ +(C^{-1}-E)^{-1}\int_0^L\phi^{-1}(t)BF(t)dt] \quad (2)$$

$$R_o^{co}=R_{co}(0)=\phi(0)(C^{-1}-E)^{-1}\int_0^L\phi^{-1}(t)BF(t)dt, \quad (3)$$

here

$R(s)=[R_1(s),R_2(s)]$ is the phase vector of the particle (coordinate and angle) on the s position;

$R_k(s)$ is the phase vector on the K turn on the s position;

$R_{co}(s)$ is the closed orbit;

R_o is the initial phase vector;

R_o^{co} is the closed orbit on the beam injection position;

$\phi(t)$ is the fundamental matrix of the differential equation of the particle motion;

C is the rotation matrix;

$B=[0,1]^T$;

F(s) is the distorting force, which acts on the particle.

If F(s) is the action of all bumps

$$F(s)=U=[u_1,u_2,\ldots,u_n]^T,$$

where U_i is the action of the i bump, then from (1)-(3) one has the following beam tuning strategy:

- the independence of beam transfer line tuning from linac to the synchrotron and main magnetic field of the synchrotron is provided in the case when the control U fullfils the condition

$$R_o^{co}(U)=0; \quad (4)$$

- the ideal input condition ($R_o=R_o^{co}$) is provided by the beam line tuning.

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As it was mentioned any U must fulfil the condition (4).

Here algorithms for the closed orbit estimation and correction are described.

PROBLEM 1 The 'ideal' bump forming .

The algorithms of 'ideal' bump forming is the result of solution of the problem of finding such control vector U which minimizes the functional

$$I=\sum_{l=1}^{n} \| R_{co}(l) \|^2 \qquad (5)$$

with the constraints

$$R_{co}(j)=R^{o}, \qquad (6)$$

$$R_{o}^{co}=0, \qquad (7)$$

$$\sum_{i=1}^{m} U_i=0, \qquad (8)$$

The solution of this problem forms local distortion of the closed orbit R^{o} in the middle of the foccusing blocks after j period of the magnetic lattice with the closed orbit minimal distortions in the rest part of the ring and without distorting the input condition and with the special conditions on the horizontal bumps power supplies (the constraint (8) /2/).

The beam trajectories are shown on fig.1.Dashed line is the trajectory formed by the 'ideal' bump and the full line is the closed orbit formed by the usual bump (with the condition (8)).The trajectories show that the maximum closed orbit displacement in the rest part of the ring for the ring for the 'ideal' bump is less by the factor of 3.5 than the one for the usual bump.

PROBLEM 2 The algorithm for the beam diagnostic (estimation) of the closed orbit and the input condition on the injection on the magnetic field injection level.

Here the algorithm 1 is used for every j=1,2,...N positions and

$$R_{-}^{oj} = [R_{1-}^{oj} ,0]^{T} , \qquad R_{+}^{oj} = [R_{1+}^{oj} ,0]^{T}$$

are calculated for the cases when the beam is lost on the inner and outer side of the vacuum chamber on the j position

$$R_1^{j}=(R_{1+}^{oj} - R_{1-}^{oj})/2, \quad R_o-R_o^{co} =R_m-(R_{1+}^{oj} +R_{1-}^{oj})/2$$

give the horizontal closed orbit estimation on the j position and the beam centre oscillation amplitude with respect to the closed orbit.R_m is the horizontal width of the vacuum chamber.It is obvious that $R_o-R_o^{co}$ shows the beam optimal input condition is satisfied.

PROBLEM 3 Closed orbit tuning algorithm.

This algorithm is the solution and realization of control algorithm

$$U_{opt}(s)=\sum_{j=1}^{n} U_{jopt}$$

where U_{jopt} is the solution of PROBLEM 1 for $R_{co}(j)$ =- $(R_1^{j},0)^{T}$,and R_1^{1} is the closed orbit displacement on orbit displacement on the N positions.

Algorithms 1-3 are solved with the least square method and on this final state one calculates only matrix multiplications.

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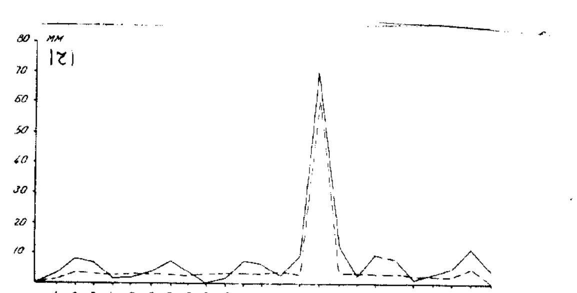

Fig. 1