COD MEASUREMENT AND CORRECTION SYSTEM IN HIMAC SYNCHROTRON

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Abstract

A COD measurement system has been made which has twelve and eleven electro-static monitors for the horizontal and vertical direction, respectively. The measured horizontal and vertical CODs have maximum values of about 10mm at daily operational point and are corrected down to less than 2mm in both directions.

1 INTRODUCTION

HIMAC synchrotron[1] has been designed to accelerate heavy ions from 6MeV/u up to maximum energy of 800 MeV/u for ions of e/m=0.5. Horizontal and vertical acceptances of the ring are 260π and 26π mm mrad, respectively. Slow beam extraction with third order resonance is used, and this process requires extra horizontal space for last three turn. Hence the maximum apertures are 122 and 28mm in horizontal and vertical directions, respectively. Non uniform contraction and deformation of the base concrete after final alignment deteriorate its accuracy, and increase the COD. To correct these CODs and maintain the machine acceptance large, the beam position monitor and the steering magnet systems have been constructed.

2 ELECTROSTATIC PICK-UP MONITORS

To measure the COD, electrostatic pick-up monitors with triangular electrodes have been used. These monitors are set at the same places of the steering magnets, where there are focusing and defocusing quadrupole magnets besides the horizontal and vertical monitors, respectively. These monitors with ICF306 Conflat flange are bakable up to 200°C. In table 1 the parameters of the monitors are listed.

Table 1
parameters of the horizontal and vertical monitors

	horizontal	vertical
monitor number	12	11
electrode length(mm)	260	235
electrode width(mm)	238	84
material of the electrode	SUS316L	SUS316L
capacitance(pF)	110	102
balance of capacitance(pF)	1.5	0.5

To check the output, test signal with an inserted rod in the monitor chamber has been used. Amplitudes of output signals from right and left electrodes have been measured as a function of the rod position. With simplified assumption the position [x] can be given as follows;

$$x = 0.5W(Vj-Vk)/(Vj+Vk),$$

where W is electrode width and (j,k)=(right, left) in the horizontal monitor, and (j,k)=(upper,down) in the vertical monitor. In figures 1 and 2 the measured values of (Vj-Vk)/(Vj+Vk) are plotted as a function of the rod position. This shows good linear dependence on x in the full aperture, but the measured coefficient value of 294 and 94mm is larger than the geometrical value of 238 and 84mm by 24% and 12%, respectively. The difference of this percentage can be attributed to the connecting plate of the triangular electrodes in the vertical monitor, which is not in the horizontal one. If there are unbalanced capacitance or setting error of the electrodes, measured beam position has offset error. In the case of larger error than 0.5mm, we have adjusted the capacitance balance to reduce the measured position error at the center.

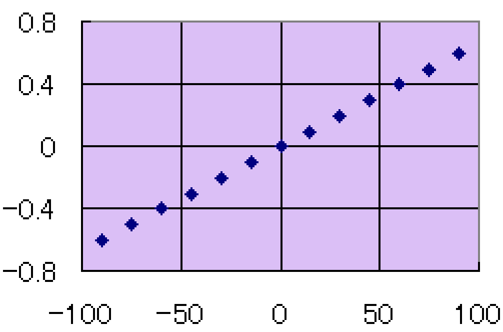

Figure 1. Output values of (Vr-Vl)/(Vr+Vl) versus horizontal rod position (mm).

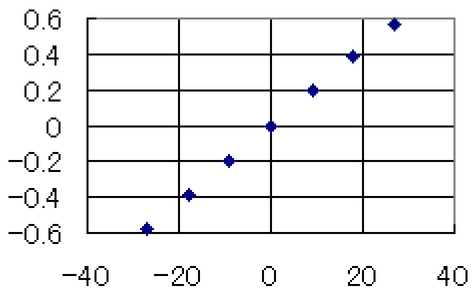

Figure 2. Output values of (Vu-Vd)/(Vu+Vd) versus vertical rod position(mm).

3 MONITOR ELECTRONICS

Monitor electronics is similar to the one[2],[3] in an acceleration system except for following points.

- Between pick-up electrode and first FET amplifier, there is semi-rigid cable of 40cm which has resister of 100Ω in the middle. As shown in figure 3 this attached resister permit to amplify the beam signal without distortion by the signal reflection. And this cable permit to locate the first amplifier away from the beam level and to decrease radiation damage of the FET amplifiers.
- There is only one beam signal processor for position detection, and the beam signals from twelve horizontal monitors and eleven vertical ones are selected with diode switches. Isolation between input channels are better than 62dB, which value is good enough for our purpose. Switching speed is 200ns and this fast speed make it possible to measure all beam positions of one direction (horizontal or vertical) in a short time as flat base period.

At the end of signal processor a low pass filter of 1kHz is used to reduce the white noise. The measured output values of the processor are shown in figure 4. In this monitor system, frequency range of input signal is from 1 to 8MHz, and gain range from 0 to 60dB (range used in daily operation).

With difficulty of the fine adjustment in the wide range of frequency and gain, monitor electronics have offset errors of ±2mm and ±1mm in horizontal and vertical directions, respectively. Owing to the wide horizontal aperture of ±122mm, this horizontal error is acceptable.

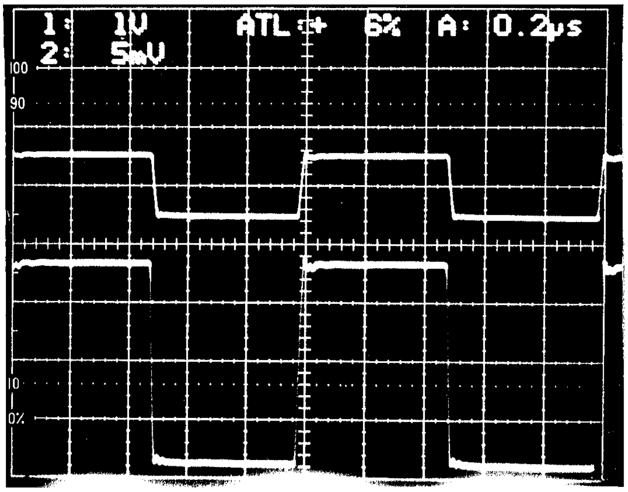

Figure 3. The upper signal is the input from signal generator and the lower signal is the measured output of the monitor electrode. Horizontal scale is 0.2µs/div.

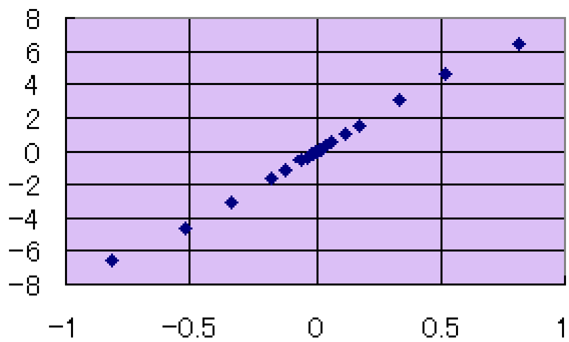

Figure 4. Output voltage (V) of the monitor processor versus input values of (Vj-Vk)/(Vj+Vk) in equation-1 with the monitor gain of 20dB and the frequency of 8MHz.

4 STEERING MAGNETS

Twelve and eleven steering magnets have been installed at the same place as monitors to correct the horizontal and vertical CODs, respectively. The magnets have been made with laminated core to allow the pattern operation for COD correction at flat top. Maximum field strengths are determined to correct the expected CODs at the flat top field. The values of horizontal and vertical steering magnets are 800 and 460Gauss with the magnet length of 10cm, respectively. The magnet power supplies are controlled with pattern data of 12 bits.

5 COD MEASUREMENT AND CORRECTION

5.1 check

To check the monitor, beam positions were measured for different RF capture frequencies (see Figure 5). Changing RF frequency (δf), the beam position (δx) varies as follows;

$$\delta x = -\eta\gamma^2\gamma_{tr}^2(\gamma^2-\gamma_{tr}^2)^{-1}\delta f/f,$$

where η is dispersion at the monitor, γ is the energy in units of the particle rest energy, and γ_{tr} is the value at the transition energy. In the HIMAC synchrotron γ_{tr}=3.67 η=2.5m, and γ=1.0 at injection energy. By use of these parameters,

δx = $2.7\times\delta f/f$(m), and this coefficient is consistent with the measured value of 2.8m

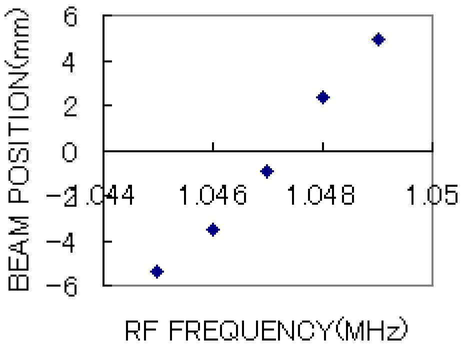

Figure 5. Measured beam positions with different RF capture frequency.

5.2 *COD Correction*

Assuming linear lattice for COD correction, displacements of beam positions can be expressed as follows,

$X = A\vartheta$

where Xi is displacement of beam position at the i-th position monitor, and ϑi is deflection angle with i-th steering magnet. The deflection angles to correct the COD is given with the inverse matrix of A as follows;

$\vartheta = A^{-1}$ X.

Measuring the displacement of beam position at the monitor with excitation of one magnet, this matrix elements of A can be determined experimentally.

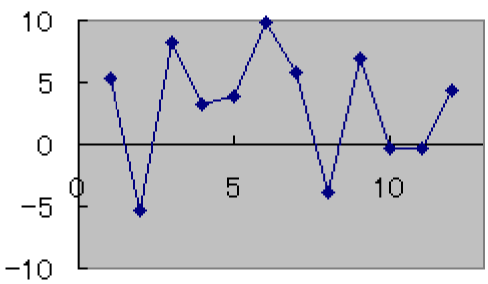

Figure 6-1. Measured horizontal COD (mm) before correction. Horizontal number is order of the monitors.

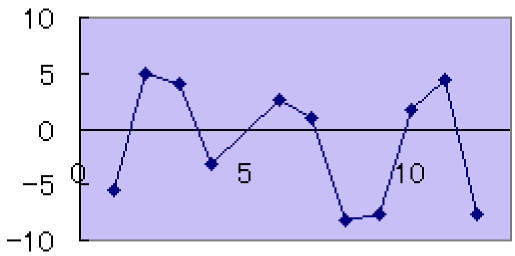

Figure 6-2. Measured vertical COD before correction.

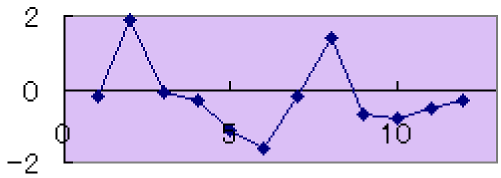

Figure 6-3. After horizontal COD correction.

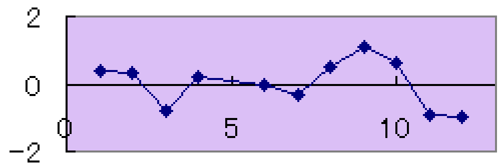

Figure 6-4. After vertical CODcorrection.

In figure 6-1 and 6-2 uncorrected CODs are shown at the flat base. These CODs were reduced to the value smaller than 2mm (see figure6-3 and 6-4) with steering magnets in both directions, whose field strengths were calculated with an equation above. Considering the large machine apertures, these corrected CODs are satisfactorily small.

4 ACKNOWLEDGEMENTS

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