EFFECT OF NON-IDENTITY OF BEAM POSITION MONITORS MANUFACTURING ON MEASUREMENT ACCURACY OF THE REFERENCE ORBIT COORDINATES

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Effect of geometrical and electrical non-identity of monitors manufacturing on accuracy of measurement of beam position has been studied. It has been shown, that even providing mechanical accuracy of monitor manufacturing of about $\pm 100\,\mu m$ and deviation of electric capacity of electrodes equal to $\pm 2\,\%$, their operating characteristics near the monitor center may differ from each other more than on $\pm 300\,\mu m$.

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1. INTRODUCTION

12 electrostatic beam position monitors (BPM) uniformly allocated along the ring orbit will be used to measure electron beam orbit position in the vacuum chamber of the storage ring N-100M of X-ray generator NESTOR [1]. The monitors measure coordinates of beam orbit and allow to make its correction by electromagnetic elements. Operating characteristics (OC) of monitors (expressions, which couple beam coordinate with BPM signals) depend on shape and sizes of cross-section of monitors chamber, value of electrical capacity of signal electrodes and their geometrical symmetry. The effect of the mentioned above factors on accuracy of measurement of the reference orbit coordinates has been studied in the article. This is extremely important for effective interaction of electron and laser beams of NESTOR facility.

Fig. 1 shows the layout of elliptic cross-section BPM (such shape has the vacuum chamber of facility) in the combined Cartesian and elliptic coordinates. In the Table 1 its main geometrical and electrical parameters are presented.

Table 1. *Parameters of BPM*

parameter	value
chamber shape	elliptical
big axis (2b)	79mm
small axis (2c)	28.7mm
electrode size (2ψ)	8mm
distance between electrodes	20mm
electric capacity of each electrode	5pF

At simulations of the OC of BPM in order to calculate signals taken from its electrodes the expression written in elliptic coordinates has been used [2]:

$$u_d = i_b Z_d = i_b \frac{2l}{\pi c C_d}\left[\psi + 2\sum_{n=1}^{200}\frac{\sin n\psi}{n}\times\right. \quad (1)$$
$$\times\left(\frac{\cosh n\mu_b \cos n\nu_b}{\cosh n\mu_d}\cos n\nu_d + \right.$$
$$\left.\left. + \frac{\sinh n\mu_b \sin n\nu_b}{\sinh n\mu_d}\sin n\nu_d\right)\right],$$

where: $d = (A, B, C, D)$ is electrodes, i_b is beam current, Z_d is couple impedance of electrode with beam, $2l$ is longitudinal size of electrode, c is velocity of light, C_d is capacity of electrode, μ_b is radial beam coordinate, ν_b is angular beam coordinate, 2ψ is angular size of electrodes, in metrical measurement it is equal to longitudinal size, μ_d is radial coordinate of electrode, ν_d is angular coordinate of electrode.

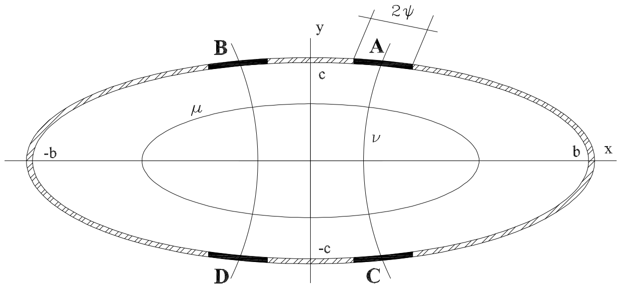

Fig.1. *The layout of BPM for N-100M storage ring*

The error of measurement of the beam reference orbit position depends on identity of manufacturing of the monitors housing, signal electrodes, isolators and also on accuracy of their installation in the housing of monitors.

As it is impossible to manufacture and install all the monitors absolutely identically, it is very impor-

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tant to know the permissible values of electric and geometrical deviations which will not lead to the considerable degradation of the measurement accuracy.

The simulation of OC for ideal monitors and 4 types of monitors with various deviations has been done in the article to study the stated above problems.

2. SIMULATION OF BEAM POSITION MEASUREMENTS

Coordinates of a beam as functions of the BPM signals in the Cartesian frame are defined as:

$$x_b = f_1(u_A, u_B, u_C, u_D) = \Phi_1(H, V), \quad (2)$$
$$y_b = f_2(u_A, u_B, u_C, u_D) = \Phi_2(H, V), \quad (3)$$

here: $u_{A,B,C,D}$ are the signals of electrodes, H, V are the normalized differential linear combinations of the measured signals:

$$H = \frac{1}{2}\left[\frac{u_A - u_D}{u_A + u_D} + \frac{u_C - u_B}{u_C + u_B}\right], \quad (4)$$
$$V = \frac{1}{2}\left[\frac{u_A - u_C}{u_A + u_C} + \frac{u_B - u_D}{u_B + u_D}\right].$$

The expressions (2), (3) are OC of BPMs. They were approximated by polynomials:

$$x_b = C \cdot \arctan[H] + \quad (5)$$
$$+D \cdot \sinh\left[\sum_{m=0}^{K}\sum_{n=0}^{m} E_{2m-2n+1,2n} H^{2m-2n+1} V^{2n}\right],$$

$$y_b = \sum_{m=0}^{K}\sum_{n=0}^{m} B_{2m-2n+1,2n} V^{2m-2n+1} H^{2n}. \quad (6)$$

OC were found by the method described in [3], as a seven order polynomials (K=3; root-mean-square error of approximation OC is equal to 10^{-4}).

Simulation of beam position measurement has been carried out in aperture with axes $x = \pm 10\,mm$, $y = \pm 8\,mm$. Twenty five points shown in Fig. 2 for the ideal monitor have been selected to estimate accuracy of measurements by different monitors. The points are combined into 4 groups: 0-monitor center, c-central area, m-middle area, r-far-field area.

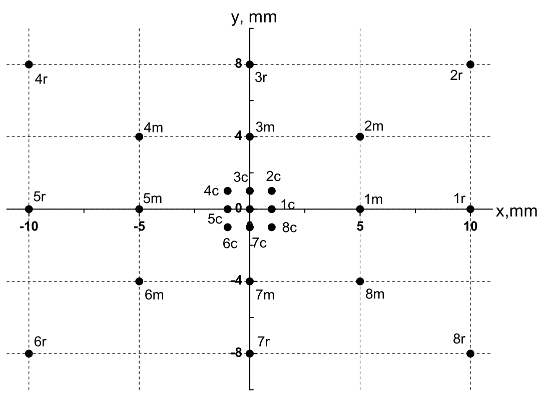

Fig.2. *The area of investigations of BPM*

The monitor options with the following errors of manufacture have been considered:

N1 - deviation of electrode capacity $\delta C_A = +0.5\,pF$, other parameters without deviations;

N2 - deviation of electrode center $\delta x_A = +0.2\,mm$, electrode capacities without deviations;

N3 - deviation of the monitor housing sizes: big axis $-0.6mm$, small axis $-0.4\,mm$; other parameters without deviations;

N4 - deviation of the electrode centers $0.1\,mm$ ($\delta x_A = \delta x_B = +0.1\,mm$, $\delta x_C = \delta x_D = -0.1\,mm$), deviation of the electrodes capacity $0.1\,pF$ ($\delta C_A = \delta C_B = +0.1\,pF$, $\delta C_C = \delta C_D = -0.1\,pF$).

Measurement errors of beam position by the monitors N1−N4 have been determined in the following way. OC of the all considered BPM were found. Signals H_i and V_i of the ideal BPM were calculated for the points shown in Fig. 2 using expression (1). Then, these signals were put in OC of the monitors No.1−No.4. The calculated coordinates were compared with the ideal ones. The obtained errors of measurements $\delta x_b, \delta y_b$ are shown in Table 2.

3. RESULTS OF SIMULATION

As it is clear from the obtained results, any inaccuracy in manufacturing of the monitor leads to considerable errors of measurements. The effect of deviation of electrodes capacity is especially strong.

At deviation of electric capacity of one electrode BPM N1 on $0.5\,pF$ (10 %) measurement errors run to $329\,\mu m$ near BPM center, and at the edge of the considered aperture even more.

Inaccuracy of electrode installation into the monitor housing (N2) in $200\,\mu m$ leads to errors of measurement $42 - 57\,\mu m$ in the center of the investigated area and considerable increase at moving out of center.

Considerable inaccuracy of manufacturing the BPM housing (N3) at preservation of its shape brings an error into measurement of coordinates $35\,\mu m$ in the central area and distinctly increases the error up to $423\,\mu m$ in the far-field area.

In the monitor N4 the error of installation of signal electrodes is decreased up to $\pm 100\,\mu m$, and the capacity deviations is decreased up to $\pm 0.1\,pF$ (2%), which might seem would lead to decrease of error of the coordinates measurement. But random combination of inaccuracies in manufacturing of BPM has lead to the error of measurement the y coordinate more than $360\,\mu m$ along the whole investigated aperture.

Table 2. *Errors of measurements*

	Beam coordinate of ideal BPM		BPM N1		BPM N2		BPM N3		BPM N4	
	x_b, mm	y_b, mm	$\delta x_b, \mu m$	$\delta y_b, \mu m$	$\delta x_b, \mu m$	$\delta y_b, \mu m$	$\delta x_b, \mu m$	$\delta y_b, \mu m$	$\delta x_b, \mu m$	$\delta y_b, \mu m$
0	0	0	-284	-329	-45	-52	0	0	0.6	-386
1c	1	0	-286	-329	-42	-48	-35	0	1	-385
2c	1	1	-281	-326	-45	-50	-32	-1	5	-384
3c	0	1	-282	-326	-49	-53	0	-0.4	-0.6	-384
4c	-1	1	-286	-327	-52	-57	32	-1	-4	-384
5c	-1	0	-285	-329	-48	-55	32	0	0	-385
6c	-1	-1	-282	-331	-45	-54	32	1	4	-388
7c	0	-1	-284	-332	-42	-52	0	0.4	0.6	-390
8c	1	-1	-289	-331	-39	-48	-32	1	-2.5	-388
1m	5	0	-316	-325	-26	-28	-168	0	5	-369
2m	5	4	-233	-305	-32	-43	-170	-30	75	-383
3m	0	4	-260	-331	-59	-72	0	-9	0.5	-399
4m	-5	4	-356	-352	-86	-84	170	-30	-74	-382
5m	-5	0	-319	-325	-62	-63	168	0	-3	-369
6m	-5	-4	-241	-343	-39	-56	170	30	70	-378
7m	0	-4	-267	-330	-33	-43	0	9	0.5	-398
8m	5	-4	-366	-303	-22	-18	-170	30	-68	-378
1r	10	0	-454	-340	11	8	-420	0	0.9	-351
2r	10	8	-135	-236	4	18	-423	-122	274	-365
3r	0	8	-208	-355	-71	-115	0	9	0.5	-469
4r	-10	8	-603	-402	-160	-95	423	-122	-273	-364
5r	-10	0	-450	-335	-95	-70	420	0	-7	-351
6r	-10	-8	-170	-545	-28	-105	423	122	268	-377
7r	0	-8	-218	-354	-22	-43	0	-9	0.4	-461
8r	10	-8	-665	-88	9	-8	-423	122	-268	-378

4. CONCLUSIONS

Non-identity of manufacturing of the monitors effects essentially on their OC. Deviation of value of electric capacity of electrodes effects especially greatly.

Simulation has shown that even providing the mechanical accuracy of the monitors manufacturing of about $\pm 100\,\mu m$ and deviation of electric capacity of electrodes $\pm 2\%$ their operating characteristics near BPM center may differ from each other on more than $\pm 300\,\mu m$.

Cross-sectional size of electron beam in the point of interaction with photon beam of NESTOR facility is of order $(300 \times 80)\,\mu m$, and photon is even less than $(50 \times 50)\,\mu m$ [4]. Hence, starting from these values, the accuracy of measurement of the reference orbit should be equal to $\pm 25\,\mu m$. To do this, it is necessary to provide accuracy of manufacturing BPM one order better than it has been considered at simulation, which is a very complicated problem.

The required accuracy of beam coordinates measurement can be provided by defining the operating characteristics of each BPM on the precision bench only.

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ВЛИЯНИЕ НЕИДЕНТИЧНОСТИ ИЗГОТОВЛЕНИЯ ДАТЧИКОВ ПОЛОЖЕНИЯ ПУЧКА НА ТОЧНОСТЬ ИЗМЕРЕНИЯ КООРДИНАТ РАВНОВЕСНОЙ ОРБИТЫ

В.Е. Иващенко, И.М. Карнаухов, В.И. Троценко, А.А. Щербаков

Изучено влияние геометрической и электрической неидентичности изготовления датчиков на точность измерения положения пучка. Показано, что даже при обеспечении механической точности изготовления датчиков ±100 мкм и разброса электрической емкости электродов ±2 % их рабочие характеристики вблизи центра могут отличаться друг от друга более чем на ±300 мкм.

ВПЛИВ НЕІДЕНТИЧНОСТІ ВИГОТОВЛЕННЯ ДАТЧИКІВ ПОЛОЖЕННЯ ПУЧКА НА ТОЧНІСТЬ ВИМІРЮВАННЯ КООРДИНАТ РІВНОВАЖНОЇ ОРБІТИ

В.Є. Іващенко, І.М. Карнаухов, В.І. Троценко, О.О. Щербаков

Вивчено вплив геометричної та електричної неідентичності виготовлення датчиків на точність вимірювання положення пучка. Показано, що навіть при забезпеченні механічної точності виготовлення датчиків ±100 мкм та розкиду електричної ємкості електродів ±2 % їх робочі характеристики поблизу центру можуть відрізнятись один від одного більше ніж на ±300 мкм.