ESTIMATION OF THE EFFECTIVE MAGNET MISALIGNMENTS OF THE ALS STORAGE RING*

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Abstract

New storage ring lattices have traditionally been commissioned using a trial-and-error approach, where the number of turns circulated is slowly built up until enough beam is stored to correct the orbit. We have found that by combining the calculated response matrix of magnet misalignments from a linear model of a new lattice with the measured steering magnet response matrix used during normal operations, it is possible to make an educated guess for the steering magnet settings that will immediately allow beam circulation in the new lattice. "Effective" magnet misalignments are simply those that are sufficiently close to the real misalignments to make the first guess good enough to circulate beam; the relationship between effective and real magnet misalignments is also discussed in the paper. This predictive steering method makes the process of establishing enough circulating beam for SVD-based orbit correction in a new lattice very efficient.

PRINCIPLE

In electron storage rings, various sources can contribute to a closed orbit distortion (COD), but transverse magnet misalignments generally have the strongest influence. By using the model of a lattice, we can calculate the effect of a misalignment of each individual magnet around the ring. Therefore, assuming the linearity of the lattice, we can calculate the magnet misalignments necessary to reproduce the observed COD. Then, we can pre-calculate the initial steering magnet settings for any given lattice.

METHOD

Response Matrix of the Magnet Misalignments

There are always more magnets than beam position monitors (BPMs), and so there are multiple sets of misalignments that can reproduce the uncorrected orbit. In order to zero in on a realistic estimate, we use singular value decomposition (SVD) to invert the matrix while taking the sensitivities into account. The number of singular values should be chosen carefully in order to not include the insensitive vectors.

Once the response matrix of the magnet misalignments is obtained, we can estimate the misalignments using the uncorrected COD.

Uncorrected Closed Orbit

When the measured uncorrected orbit is available, we can immediately use it to estimate the misalignments. Otherwise, we must estimate the uncorrected COD by removing the effect of orbit correction. By using the orbit correction routine in reverse, we can find the inverted response matrix of the steering magnets.

Evaluation of the Magnet Misalignments

The estimate of the magnet misalignments is based on the linear machine model, ignoring all nonlinearities. The transverse coupling will also be ignored for most of the cases. A different configuration of the lattice must be used to compare the results. If the linearity is good and the coupling is negligible, they should agree with some reasonable accuracy as the misalignments are common to both.

Interpretation of the Magnet Misalignments

Even if different lattice configurations give reasonably similar estimates of the magnet misalignments, they should not immediately be taken to be the real misalignments, because SVD is used to invert the response matrix with some limited subset of eigen vectors. However, the estimated misalignments are sufficient input to the orbit control system to create an orbit that allows beam circulation. In this sense, we call this estimate the "effective misalignment" of the storage ring corrector magnets.

EXAMPLE

Our immediate need was the commissioning of a new lattice configuration called LILA[1]. The main barrier to finding a functional steering set is the small vertical aperture clearance created by narrow gap chambers in several straight sections. Therefore, for this example we focus on the vertical plane.

There are 2 nominal lattices of the ALS storage ring: one with ν_x = 8.20 and the other with ν_y = 9.20 whereas ν_x = 14.25 for both cases. Figure 1 shows the COD caused by the vertical correctors with nominal settings, which are to cancel the uncorrected COD. Notice that these orbits are significantly different.

There are 36 bending and 78 quadrupole magnets along the ring. By using these 114 knobs in beam order, we calculated the response matrices of the vertical magnet misalignments. Figure 2 shows these estimates for 2 different kinds of lattice configurations. As they agree very well, they are likely meaningful as effective magnet misalignments.

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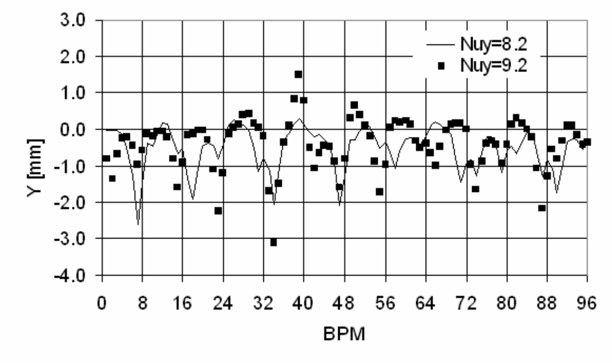

Figure 1: Vertical COD due to vertical correctors.

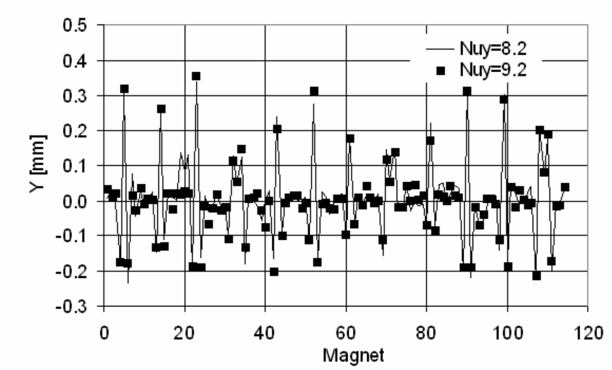

Figure 2: Effective vertical misalignments along the circumference.

The interpretation of this result is not trivial. Figure 3 shows the effective misalignments by sector. There is a clear pattern that the center bends (B2) are shifted up to about 0.3 mm upward and the quadrupoles on both of its sides (QFAs) are down about 0.2 mm, which are unlikely misalignments. A possible explanation could be the effect of strong sextupoles that are also used as correctors.

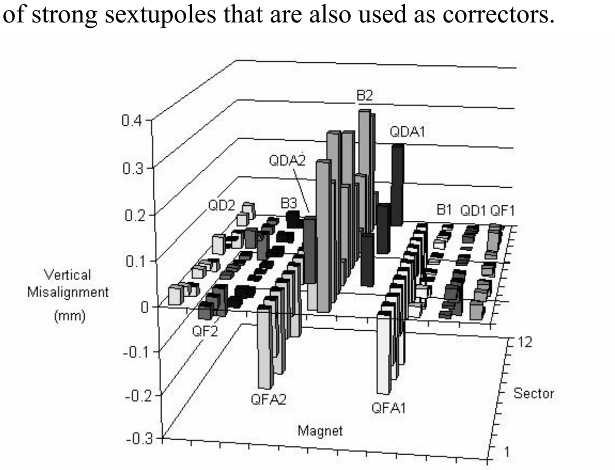

Figure 3: Effective vertical misalignments by sector.

Let us apply this result to LILA, a new lattice configuration with a completely different working point of ν_x = 8.39 and ν_y = 7.15, compared to the nominal lattice with ν_x = 14.25 and ν_y = 8.20/9.20. By using a model of the ideal linear lattice of LILA, we can calculate the uncorrected vertical COD of LILA, which is shown in Figure 4. Notice that it exceeds ± 5 mm at the sector 4 (BPM ~ 24) and the sector 11 (BPM ~ 88), where narrow gap chambers are installed. As the half heights of these chambers are less than 5 mm, the commissioning of the lattice is difficult without vertical orbit correction, which agrees with the trouble experienced at the beginning of its commissioning.

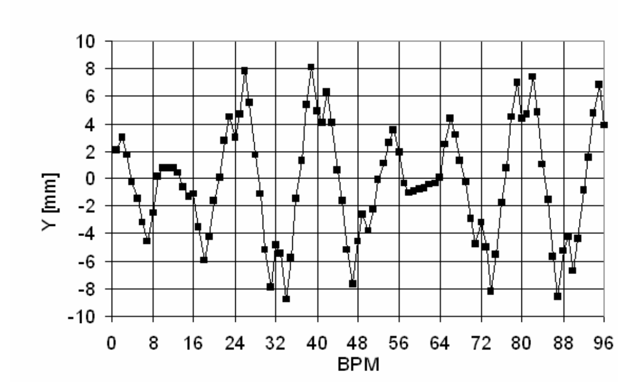

Figure 4: Uncorrected Vertical Orbit of LILA.

Once the vertical corrector settings were calculated and fine adjustments made around them, it ultimately became possible to store up to 45mA of beam with a lifetime of about 1.5 hours. As a comparison, the maximum beam stored before the vertical correction was 0.5mA with a lifetime of only about 1 second. The vertical orbit distortion after the correction was below ± 2mm peak to peak.

DISCUSSION

Our immediate need for this method was the commissioning of a new lattice configuration, LILA, and the technique worked well enough to store beam. However, if we want to estimate real misalignments, for example for physical realignment, the accuracy of the linear model must be iteratively improved by taking the estimate of the misalignments into account. More linear models with different optics will also be required to remove the ambiguities of the misalignments.

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REFERENCES

[1] W. Wan, et al, MPPE074, Particle Accelerator Conference, Knoxville, US, May 2005.