Application Software for Orbit Correction of SPring-8 Storage Ring

Hitoshi TANAKA, Schin DATÉ, Keiko KUMAGAI, Mitsuhiro MASAKI, Takemasa MASUDA, Takeshi NAKAMURA, Haruo OHKUMA, Jun-ichi OHNISHI, Takashi OHSHIMA, Taihei SHIMADA, Kouichi SOUTOME, Shiro TAKANO, Masaru TAKAO, Kouji TSUMAKI, and Noritaka KUMAGAI

Accelerator Division, SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan

Abstract

Application software for orbit correction of the SPring-8 storage ring has been developed. By using this software, closed orbit distortion (COD) of the storage ring could be reduced down to ~ 200 μm in a rms value.

1 Introduction

The storage ring is composed of 44 Chasman-Green cells and 4 straight cells with bending magnets removed, and its emittance is about 5 nmrad. Such a typical low emittance storage ring is generally sensitive to magnetic errors. Large COD was predicted and there was also some possibility that the injected beams cannot circulate in the ring. In such a case, it is necessary to correct the COD by analyzing beam trajectory data. In order to smoothly commission the storage ring under any condition, it is thus important to prepare an orbit correction system having not only the usual COD correction scheme but also a function to correct the COD by analyzing beam trajectory data.

2 Application Software for Orbit Correction

The composition of the developed application software for the orbit correction is shown in Fig. 1. Major components are loosely linked via the database. This distributed structure has an advantage on the modification of programs, which is frequently occurred during a commissioning period. In the storage ring, there are 288 beam position monitors (BPMs), 285 horizontal and 283 vertical steering magnets to control the COD less than 100 μm [1].

Machine parameters required for the operation are set by the operation control panels in a work memory field of the database, which is called a "current data set" [2]. The optics calculator is available for providing the orbit correction packages with optical parameters such as betatron functions and phase advances at all monitors and steering magnets. According to a choice of measurement-modes, COD or trajectory data are measured and stored in the database or in a data file by the BPM control panels. These data are used by three kinds of correction packages to calculate the strength of steering magnets. The strength can be set from each correction package directly by issuing the command [3] to the power supplies.

2.1 First turn steering package

This is used to correct the COD in the case where the COD exceeds the aperture of vacuum chamber. The COD is corrected by successively superimposing a single kick trajectory on the first turn trajectory [4,5]. Figure 2 schematically shows this correction sequence. The first turn steering (FTS) package provides following functions: (1) The FTS correction can be simulated by using an arbitrary steering magnet, changing the strength of the magnet, with help of a graphic system to display an expected result. (2) The least square method is available to calculate the strength of a selected steering magnet with an arbitrary set of monitors. (3) The successive correction is performed semi-automatically with a predefined set of combinations of monitors and a steering magnet.

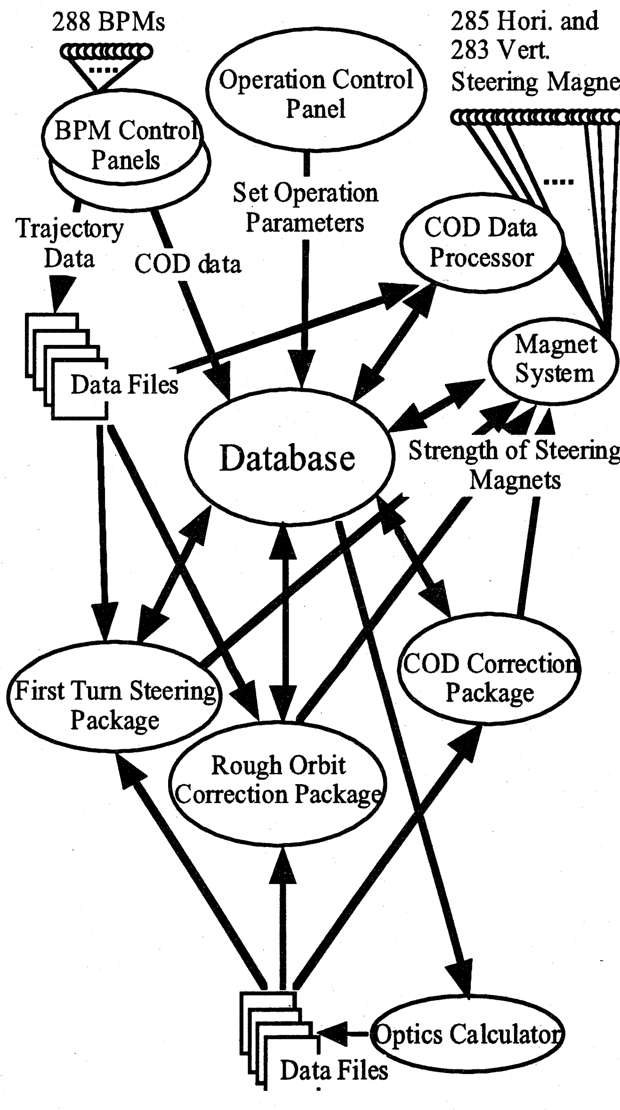

Fig. 1 Composition of orbit correction system.

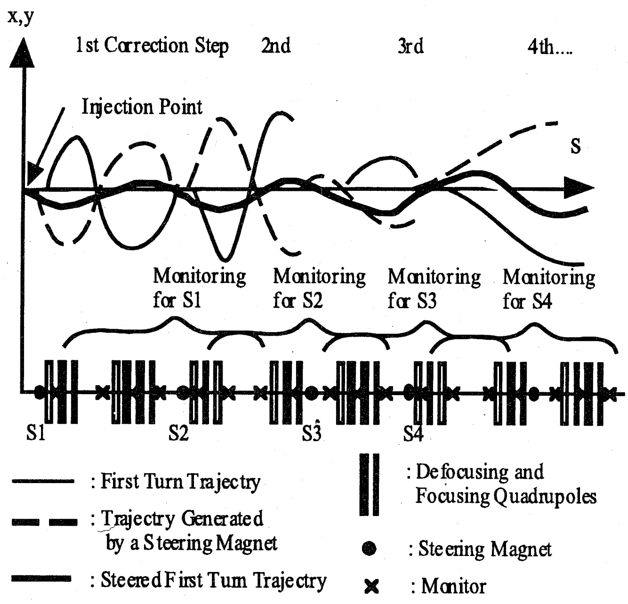

Fig. 2 FTS correction sequence

2.2 Rough orbit correction package

With the RF system turned off, the beams are lost within a few tens turns. Even in this case, the COD can be roughly estimated by averaging trajectories and can be corrected. For averaging, trajectories up to 128th turn can be used at most. The best corrector method [6], so called MICADO, is used to estimate the strength of steering magnets.

It should be noted that the orbit in dispersive sections shifts turn by turn owing to the radiation loss. The rough orbit correction (ROC) package therefore provides a function to correct this drift in trajectory data assuming that the energy loss per turn is constant and that the dispersion is linearly dependent on the energy shift of circulating beams.

The ROC package provides following functions besides the above dispersion correction: (1) Both the COD after the correction and orbit distortion generated by a determined set of steering magnets are shown in the same graph together with the COD before the correction. (2) The strength distribution of a determined set of steering magnets can be shown in a graph. (3) The rms values of the COD before and after the correction and the maximum strength used in the correction are displayed. (4) The maximum number of steering magnets to be used can be set for both horizontal and vertical COD corrections.

2.3 COD correction package

Once the beams are stored in the ring, the COD can be measured and corrected with usual COD correction methods.

At present, for the global COD correction, the best corrector method is used to keep the number of steering magnets small. It is important for the package to be equipped with functions of processing the COD data to support the correction. Our package provides following functions in addition to those provided for the ROC package except for the dispersion correction: (1) Arbitrary set of monitors can be masked from the panel and saved as a data file. (2) Power spectrum of the COD can be calculated up to a thousandth harmonic and shown in a graph. The high harmonics are necessary because of the low emittance optics where the phases do not advance in the sections with the BPMs but in bending magnets. (3) The COD can be filtered with arbitrary cut-off frequency less than a thousandth harmonic.

For the local correction, a single bump orbit generated by four steering magnets is used. This is mainly applied to tentatively adjust the orbit at insertion devices for the alignment of photon beam axis. A graphic system is available to select proper steering magnets.

2.4 COD data processor

This processor provides two functions. One is the addition and subtraction of two arbitrary data. Both COD and trajectory data are usable. The processed data can be stored in the database and also shown in a graph.

The other is the estimation of dispersion functions. By using two COD data each of which has the different beam energy, horizontal and vertical dispersion functions are estimated. Here, as a momentum compaction factor, a design value is used.

3 Results obtained in Storage Ring Beam Commissioning

At the beginning of beam commissioning of the storage ring, the first turn was completed and the beam was immediately stored with both sextupoles and RF system turned on [7]. Owing to this smooth commissioning, the COD package was mainly used to correct the orbit distortion. The FTS package was therefore never applied to the correction during the commissioning period. On the other hand, the ROC package was often used to correct the COD at the first stage of the commissioning. This is because the COD package initially had some bugs and a quality of COD data was not good. At present, the bugs has been fixed and the quality of the data has been improved to some extent.

Figure 3 shows the COD distributions before and after the correction. The rms values of the horizontal and vertical COD are respectively 1.7 and 2.4 mm, which have been reduced down to about 0.2 mm by the correction. Since lots of fictitious phase jumps are found at the sections where the phase can be regarded as a constant, this saturation seems to come from a monitor error.

In the correction, so far, coefficient matrices are calculated with the optical parameters which are slightly modified from design values to adjust betatron tunes to measured ones. Figure 4 shows the comparison between measured and expected rms values of the COD after the correction. A good agreement indicates the validity of the coefficients mentioned above as the first approximation used for a commissioning period. We are now developing a system to consistently estimate the distribution of all magnetic errors by measuring the response of a real ring. In future, optical parameters will be replaced by ones based on the measurement.

Figure 5 shows measured horizontal and vertical dispersion after the COD correction. The horizontal dispersion is well restored by the COD correction and this does not increase effective horizontal emittance at the straight sections for undulators. However, some correction of the vertical dispersion could be necessary for achieving a H-V coupling ratio of 1 %.

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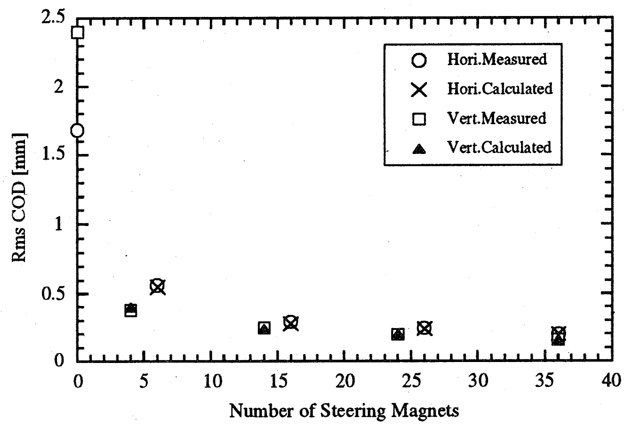

Fig. 4 Comparison between measured and expected rms values of the COD after the correction. The number of steering magnets represents the simple sum of the number used in each correction step.

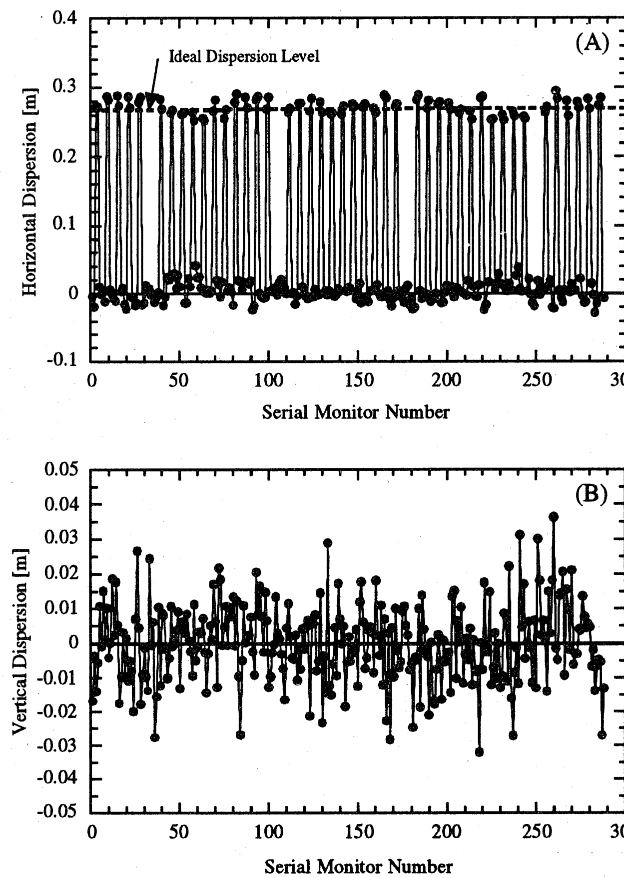

Fig. 5 Dispersion measured after the COD correction. The upper right symbols (A) and (B) denote respectively a horizontal and a vertical planes.

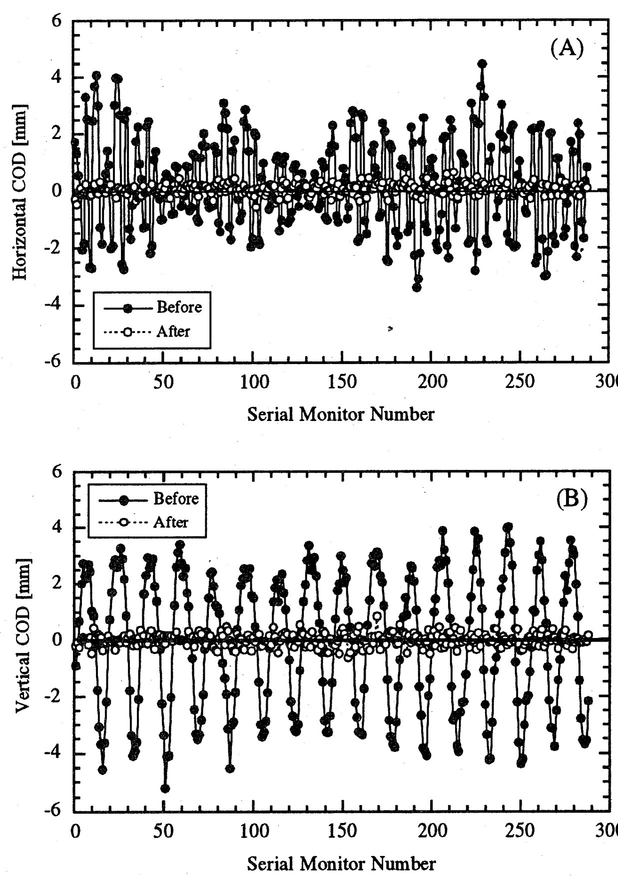

Fig. 3 COD before and after the correction. The upper right symbols (A) and (B) denote respectively a horizontal and a vertical planes.