ELSEVIER Nuclear Instruments and Methods in Physics Research A 467–468 (2001) 99–102

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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The SLS storage ring support and alignment systems

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Abstract

Storage rings of third generation synchrotron radiation facilities pose severe challenges for lowering the beam emittances and increasing the lifetimes, requiring thus increasing positioning and alignment precisions that must be preserved over long time spans. This work describes the SLS storage ring mechanical support, alignment and disturbances compensation systems that allow to meet these requirements. In particular, their design, the tests done on the respective prototypes and the applicability of the developed arrangement to beam-based alignment are addressed.

PACS: 29.20.Lq; 29.20.Dh; 07.85.Qe; 07.10.−h

Keywords: Storage ring; Support; Positioning; Alignment

1. Introduction

The main goal at SLS is to achieve a high quality source (brightness), which is mainly determined by electron beam quality (low emittance). This poses severe challenges for the stability and reproducibility of the stored beam. However, the room left for lattices optimisation is limited; precise magnets adjustment becomes therefore increasingly important to reach small emittances and reduce orbit distortions before switching on correctors [1]. To meet these requirements, provisions for accurate positioning and dynamic minimisation of ground motion and thermal effects have been foreseen during the storage ring design.

2. Configuration of the SLS storage ring support and alignment systems

A *girder* structure was designed as the *basic support unit of the storage ring elements* (Fig. 1). In total 48 girders are used, four in each of the 12 triple bend achromats (TBA). The upper part of the girders provides ground reference surfaces with a precision of $\pm 15\,\mu m$, onto which the magnets are laid and fixed; in this way a single pre-assembled object is obtained, not necessitating fiducialization of individual items.

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0168-9002/01/$ - see front matter
PII: S0168-9002(01)00246-7

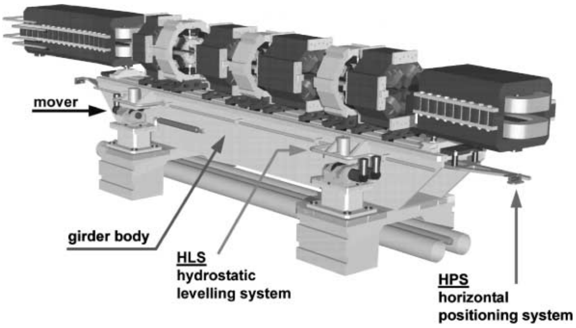

Fig. 1. The SLS storage ring support, alignment and disturbances compensation systems.

The dynamic alignment and disturbance compensation aims have been met by using eccentric cam-shaft drives (‘*movers*’—Fig. 2). These are based on a recent SLAC development [2], but provide increased load carrying capabilities, stiffness and motion ranges. The movers driving side includes a DC motor-worm gear assembly and a planetary gearbox; feedback is obtained via absolute rotary encoders mounted on the driven side, whose resolution was increased by in-house developed interpolation modules. The arrangement allows to obtain pseudo stepper motors with resolutions of 2 μm.

The requirement for monitoring the girders positioning stability is met by using the *hydrostatic levelling system* (*HLS*) and the *horizontal positioning system* (*HPS*).

The *HLS* consists of stainless steel pots (Fig. 3) connected by a half filled pipe around the ring, obtaining a single reference altimetric level; the working fluid is de-mineralised water. The sensing elements are capacitive proximity gauge-based. The resolution of the *HLS* is 2 μm in a $\pm$ 2.5 mm range, with the accuracy and repeatability better than 10 μm. On each girder are installed 4 pots to measure its heave, pitch and roll. The *HLS* system will have branches spreading to the insertion devices and front-ends; a possibility to connect beamline components is also envisaged.

The *HPS* monitors horizontal girder movements; it is constituted by pairs of lever arms under the girder surfaces equipped with encoders (Fig. 4). By extending the system, the relative

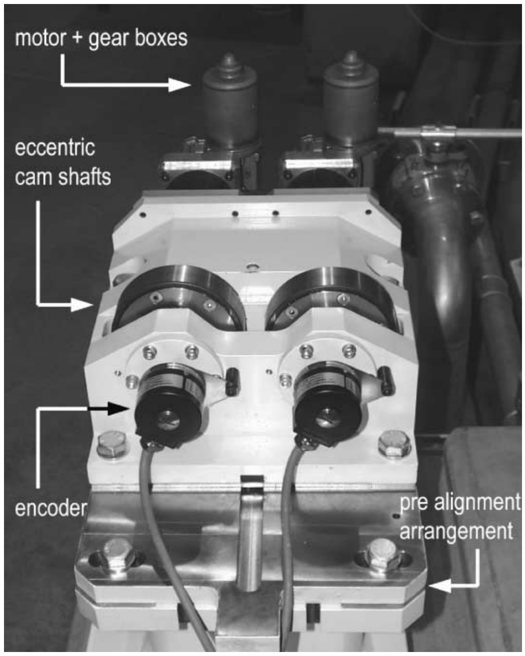

Fig. 2. Mover system.

Fig. 3. *HLS* pot.

horizontal displacements of adjacent girders can be correlated to artificially created reference poles at TBAs ends; any motion of individual girders

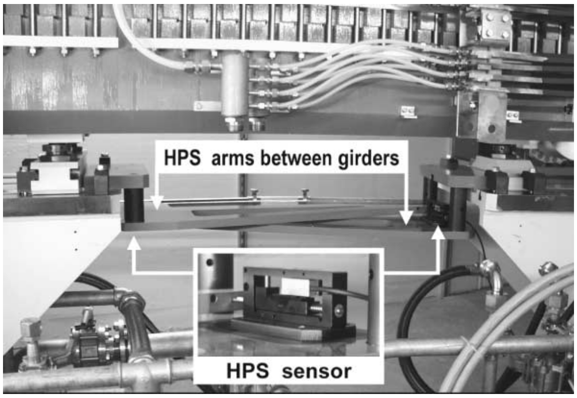

Fig. 4. *HPS* system.

can thus be traced back via a linear system of equations with the girder sways and yaws as the unknowns [3]. The used sensor is an absolute linear encoder having a 0.5 μm resolution and a ± 2.5 mm working range; an in-house developed counter module is employed to acquire the data [4].

3. Beam-based alignment

The storage ring beam trajectory will be measured by BPMs located between the magnets; encoders will monitor the positions of the BPMs with respect to adjacent quadrupoles. This data can be used to remotely align the girders via the described mover system, obtaining beam-based alignment. In fact, the girder mover system can be used like the corrector magnets to obtain closed orbit and coupling correction via the correction matrix.

Beam tracing simulations have shown that all static vertical closed orbit corrections can be covered by girder alignment; horizontally, a proper selection of girders to be re-positioned allows to reduce the corrector magnet strengths by a factor 4 (Fig. 5). This kind of alignment can thus allow to have an increased freedom in using the corrector strengths for the dynamic correction and local bump creation, or for machine studies [3].

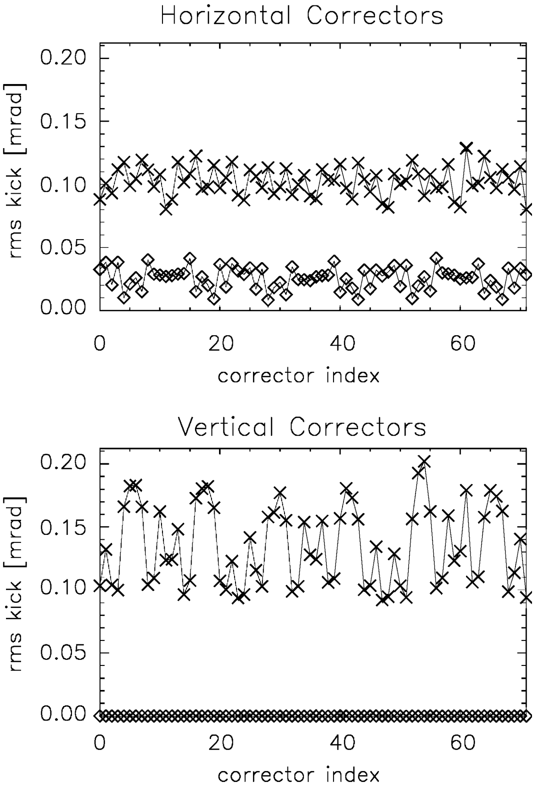

Fig. 5. RMS corrector magnet strengths before (X) and after (◇) closed orbit correction through girder alignment. 200 random misalignment seeds were generated and corrected. The random errors assumed partial train links over four girders with rms (2σ cut) displacement errors of 300 μm for the virtual girder joints, 100 μm for the joints play (errors in the HPS and HLS readings) and 50 μm for magnets and BPMs positioning tolerances relative to the girders surfaces [3].

4. Experimental assessment of systems performances

The straightness accuracy of the *girder reference surfaces*, assessed by using laser interferometry, proved to be within the tight tolerances.

Ground *vibrations* will displace the girder/magnet assemblies and generate closed orbit distortions, hindering the goal to reduce the rms beam jitter to 10% of the electron beam sigmas for frequencies below 100 Hz. Considering the emittance coupling and optics amplifications [5], this corresponds to mechanical vibration amplitudes below 0.2 μm vertically and 2 μm horizontally.

Measurements of the SLS site spectrum have shown that there are significant ground noises in the 5–40 Hz range; assessments on girder/magnet assemblies indicated that there are eigenfrequencies in the same range. However, it was evidenced that the transmissibility of the girder/magnet assembly is $\leqslant 10$ with the resulting amplitudes an order of magnitude lower than those which would produce significant perturbations.

The measured resolution and repeatability of a single *mover* was proven to be better than the specified $\pm 2\,\mu m$; the resolution of the whole girder is within $\pm$ 3–5 μm. The positioning repeatability of the system in the whole working range is better than $\pm 10\,\mu m$.

The *software* that allows the full operational control of the mover system has been optimised and tested proving its functionality. The simulated girder behaviour allowed to establish that combinations of misalignments restrain the common 5D working window to ± 1.4 mm and $\pm$ 1–1.5 mrad [3].

The measured repeatability of the *HLS* system mounted on a girder was proven to be better than $\pm 10\,\mu m$ for long range motions ($\geqslant 1$ mm), while for motions $\leqslant 100\,\mu m$ it is better than $\pm 3\,\mu m$. On a 100 m *HLS* piping network it was shown that even with extreme perturbations the settling times for the attainment of the needed precisions do not exceed $\sim \frac{1}{2}$ h, while the vibrations influence on the measurements is negligible.

Preliminary tests have been performed also on *HPS* prototypes mounted on girders. By using the laser interferometric measurements as a reference, it was established that the relative errors and repeatabilities are in the $\pm 1\,\mu m$ range, i.e. comparable to the resolution of the sensors.

5. Conclusions

The design of the SLS storage ring support, alignment and disturbances compensation systems has been optimised by thorough analytical, numerical and experimental assessments. All the available data indicate that the resulting arrangement creates the pre-conditions for on-line and even beam-based storage ring dynamic alignment. Hence, not only a significant reduction of the alignment and re-alignment time spans can be foreseen, providing a possibility for the maintenance of the storage ring location in space based on sensors rather than topographic instruments, but even an optimisation of the usage of the corrector magnets can be attained.

References

[1] A.F. Wrulich, Proc. PAC 99 (1999) 192.
[2] G. Bowden et al., SLAC-PUB-95-61326132 (1995).
[3] A. Streun, SLS-TME-TA-2000-0152 (2000).
[4] V. Schlott, PSI Sci. Rep. VII (1999) 19.
[5] M. Böge, PSI Sci. Rep. VII (1999) 15.