STANDARD SEXTUPOLE MAGNETS FOR NSLS-II SYNCHROTRON

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Abstract

Danfysik received the order to design, manufacture and test 169 Standard Sextupole Magnets for the NSLS-II synchrotron. Extraordinary tight tolerances were specified for the mechanical and magnetic properties. We present a re-optimized magnetic pole profile to make a more mechanically robust design, suitable for large-scale manufacture. Due to a well-controlled wire erosion process during the manufacturing stage, the mechanical tolerances were kept on the 10 micron level, even after assembly/disassembly cycles. A major challenge of the project was to verify the magnetic performance of the magnets. This was done using our in-house harmonic measurement bench. We present magnetic measurements of the magnet series, measured over more than 24 months, which show high stability, both in terms of magnetic roll angle, error field terms, and integrated strength.

INTRODUCTION

Danfysik has earlier supplied large series of laminated magnets and proven to be a reliable supplier of critical magnets for accelerator rings. For example, for the ELLETRA booster at Sincrotrone Trieste, Danfysik delivered dipoles quadrupoles, and sextupoles[1]. In this project, the specifications were tightened further.

MAGNETIC DESIGN

Magnetic Design

Compared to the reference magnet design, provided by NSLS-II, Danfysik re-optimized the magnetic pole profile to make a more mechanically robust design, suitable for large-scale manufacture.

As the magnet is not symmetric, there is a non-zero normal dipole built into the design.

The pole profile was optimized to minimize the 18-pole and the 30-pole. This was done by iterative pole chamfering and root chamfering

The optimization was carried out in OPERA 2D and 3D.

MAGNETIC MEASUREMENT SYSTEM

The magnets were measured using the Danfysik Multipole Measurement System, model 692, which is based on the ”harmonic coil method” in which a mechanically stable cylinder holding the main measuring coil is rotated inside the bore of the magnet.

The voltage is integrated using a Metrolab PDI 5025 integrator, with 2 channels.

The measuring coil is designed with a bucking coil, to achieve main harmonic bucking, as well as “main-1” bucking.

The radial measuring coil has a measuring radius of 30 mm.

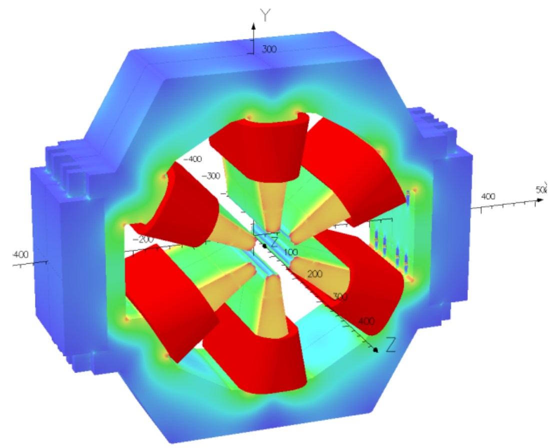

Figure 1: Full model of NSLS-II standard sextupole, generated using mirror planes. The field is shown up to 1.8 T.

PRODUCTION CHALLENGES

Due to the lack of production facilities, the coil and raw yoke production was subcontracted to Scanditronix.

As the magnet had to be taken apart to install the vacuum chamber, rigorous testing was performed on the first three ”First Article” magnets, to verify geometric reproducibility, upon assembly and disassembly. The mechanical reproducibility was found to be around 5 µm Furthemore, we found that the high level magnetic performance was preserved during these processes, as the magnets were remeasured between successive cycles. All procedures were carefully described, down to every detail to increase the accuracy of the assembly-disassembly step.

The magnet was designed with a removable top and bottom pole, to allow for insertion of the coil, around these poles.

During the series production stage, we inserted a standard shim of 76 µm under the top and bottom poles.

The coils were produced with a high content of alumina(> 50 %). This process proved to be quite challenging, with several trial tests needed before the coils were flawless

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MAGNETIC RESULTS

The test system was initially commissioned using a reference sextupole magnet provided to Danfysik by NSLS-II. This magnet had been measured at NSLS-II, and the data agreed with our system to a satisfactory degree.We found that, apart from the normal 10-pole, the field error terms agreed on the 1-unit level[2].

Apart from the general agreement with the data from NSLS-II, we were able to find excellent performance in roll angle stability, upon mounting the measuring coil assembly. This repeatability was found to be better than 0.1 mrad. Over the course of the measurement campaign, the roll angle was within ± 0.1 mrad. This is shown in Figure 2. The integrated strength for the magnet series is shown in Figure 3. The spread is 0.16 %.

Some of the magnets were remeasured at NSLS-II, upon arrival, and the agreement between the measurement systems was found to be good.

Concerning the reproducibility of the higher harmonics, upon successive measurements in the same setup, we found that each error field term reproduced within ±0.2 units, for the sextupole compensated coil.

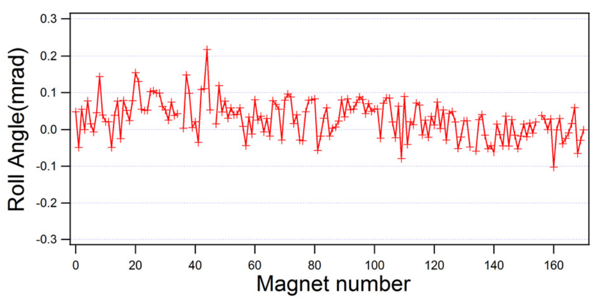

Figure 2: Roll angle stability, during the course of the measurement campaign.

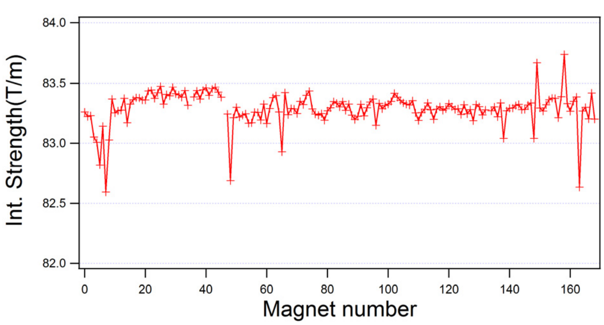

Figure 3: Integrated strength, during the source of the campaign.

Magnetic Shimming

The sextupole magnet is designed with a removable top and bottom pole, which allowed for shimming the normal dipole. It was our intention to only use the removable shim during the First Article production stage, where NSLS-II had to approve 3 magnets, before the series production could commence. However, Danfysik found that it was not possible to not settle on a single shim configuration in the prototyping stage, so therefore we decided to keep this flexibility for the series production stage as well. This proved to be a correct decision, as some of the magnets had to be re-shimmed during the series production stage, in order to meet the specifications, for the normal 10-pole and skew 8-pole.

During the course of the production campaign, the size of the shim varied by around 30 µm.

The shimming was performed to minimize the field errors at 100 A, which was very dependent on excitation level, as seen in Figure 4.

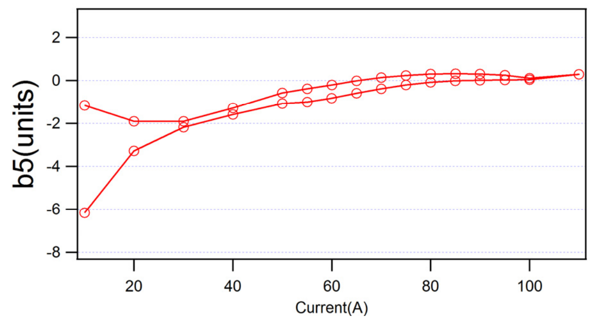

Figure 4: Normal 10-pole dependence on excitation current.

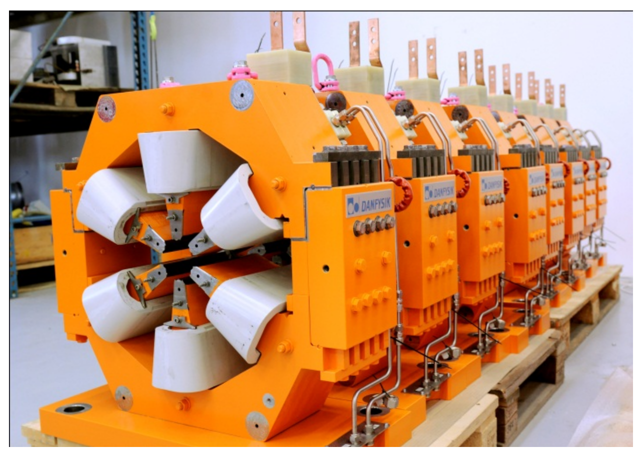

Figure 5: Completed magnets, prior to shipment to NSLS-II.

CONCLUSION

Danfysik has produced and tested 169 tightly specified magnets for NSLS-II. Due to solid engineering solutions, careful magnetic modeling, and excellent magnet measuring performance, Danfysik reached the target. Danfysik has shown its ability to adapt to ever-increasing customer demands for higher performing products.

REFERENCES

[1] http://www.elettra.trieste.it/
[2] A. Jain. Personal communications.