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GIRDERS FOR SOLEIL-II STORAGE RING

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Abstract

After two decades since its establishment, the SOLEIL Synchrotron facility needs to adapt to follow new scientific fields that have emerged since. After the Conceptual Design Report (CDR) phase for the facility Upgrade, the SOLEIL teams have been working for several months on the Technical Design Report (TDR). The "SOLEIL Upgrade" project is called "SOLEIL II" and is divided into several sub-projects. Among these sub-projects, one concerns storage ring Girders that will support all magnets of the new Lattice. These 86 Girders, each one supported by 2 plinths, must ensure an excellent degree of vibration stability. Before obtaining a final design for these Girders, a significant amount of study work has already been carried out (design, finite elements simulations, sub-assembly prototyping, dynamic measurements, tests, etc.). To validate the concepts, a fully equipped prototype girder was launched into manufacturing. In this contribution the preliminary studies and the ongoing investigations on SOLEIL II girder design will be presented.

INTRODUCTION

SOLEIL [1] teams have been working for several months on its Technical Design Report of "SOLEIL II" project that aims to study and install an accelerator with new performances. One sub-project concerns girders of storage ring that will support the magnets of the new Lattice. These girders must make it possible to achieve an excellent degree of vibration and thermal stability, including adjustment precision, with acceptable manufacturing costs. The difficulty is to find the best compromise between the level of specifications and the costs to achieve them. Figure 1 shows the previous magnets supports and the current philosophy. That will constitute a substantial budget saving.

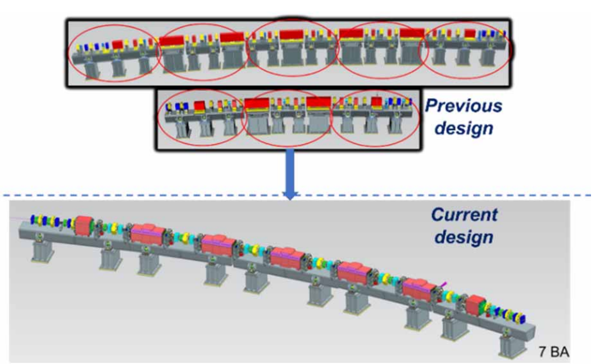

Figure 1: Previous and current magnets support situation (magnets in 7BA cell and 4BA cell of SOLEIL-II lattice.

Previously girders were supported by 3 plinths. Currently girders are supported by 2 plinths. Now the target defined by accelerator physicists for the 1st modal frequency is ≈ 40 Hz. After few iterations, we came up on four girder length families, with two assembling configurations, single or double dipole [2]. The high density of multipoles is a real challenge in terms of components integrating on girders [3].

Table 1 allows to compare previous and current magnets supporting philosophies. At the cost of a reduction of the 1st modal frequency target, the number of supports and plinths has been drastically reduced.

Table 1: Previous and Current Supporting Situations

	Previous	Current
Girders Nb.	98	86
Long dipole plinths Nb.	76	0
Standard plinths Nb.	236	172
First modal frequency Hz.	70	40

GIRDERS AND PLINTHS INTERFACE

Figure 2 shows the design of girder and plinth interface that allows to adjust and lock girder position. Adjustment principle consists in, a preload first applied by spring washers. Then the girder is aligned with adjusting elements using Nivell wedge and Push and pull screws. Finally, girder is locked by the spring washers, loaded at 45000 N.

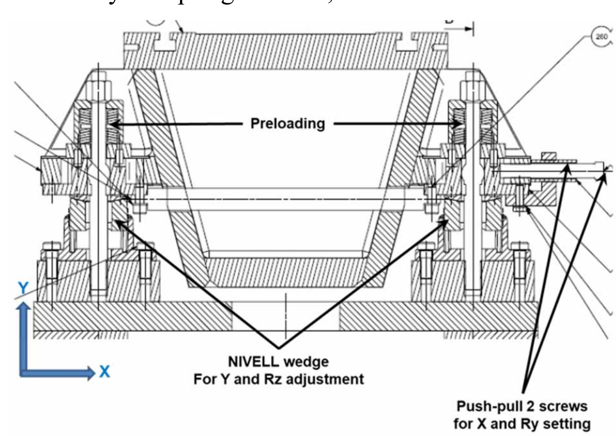

Figure 2: Girders positioning and locking system.

MODAL ANALYSIS

Current specification for the 1st modal frequency is 40 Hz minimum. FE simulations on both pessimistic configurations, regarding supported loads were carried out. In both case the 1st modal frequency is a transversal (X) bending mode of the plinths. Girder dynamic bending occurs from the 4th modal frequency at 105 Hz for single dipole

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configuration and 94 Hz for double dipole configuration. First modal frequency is 49 Hz for single dipole configuration, and 45 Hz for double dipole configuration, more than 40 Hz. Figure 3 shows dimensions and masses of pessimistic configurations. Long dipole mass is 850 Kg. Other magnets masses are a few tens of kg each one.

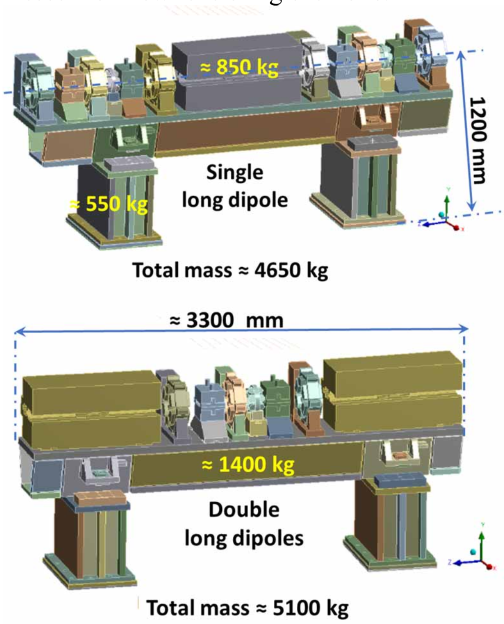

Figure 3: Both pessimistic configurations.

STATIC ANALYSIS

FE static analysis for both pessimistic configurations show a maximum displacement of the girder with single dipole of 0.025 mm. For the double dipole configuration, the maximum displacement of the girder is 0.03 mm.

In both case a maximum displacement of 0.01 mm can be reached with a compensation. It consists of machining the upper surface of girders (that supports magnets) at the same temperature conditions as the future tunnel and reproducing the same boundary conditions as the plinths. The future tunnel should be thermalized at 23 °C, compared to 21 °C currently, for economic reasons. An additional compensation consists in reproducing magnets load during machining of the upper surface. The theoretical maximum displacement could tend towards 0, with flatness tolerances close to 0.01 mm/m. This method would have a large impact on manufacturing cost and isn't currently justified.

FIRST PROTOTYPING AND TESTS

To validate design and check the FE simulation hypotheses mainly for modal analyses, we studied, provided, and installed a plinth prototype to carry out tests. Figure 4 shows the plinth in the testing area, manufactured by the company INGELIANCE, in France. Z defines the beam axis, Y the vertical axis, and X the transversal axis. A steel plate is grouted to the same concrete slab as current storage ring. Then the plinth is screwed onto this plate.

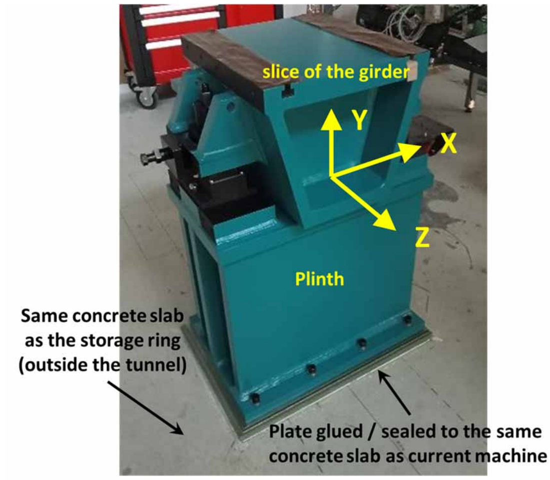

Figure 4: Plinth prototype in steel with a slice of girder.

In June 2022, vibration measurements were done. We observed eigen frequency in X and Z axis. In Y axis the plinth doesn't contribute much to the dynamic response. That will be controlled mostly by the flexibility of the girder (+3 m long) on its two plinths. On the Z axis we observed a bending mode at 55 Hz. On X axis we observed one twisting mode at 73 Hz and one bending mode at 99 Hz. From these values, we did an estimation of the bending frequency mode in X axis, for a loaded girder on two plinths. We considered a half of girder as shown on Fig. 5. 49 Hz is a value close to the results obtained in modal analysis. It's possibly an overestimated value because the flexibility of the plinth nor the lever arm of the magnets are considered. Still in X axis we extracted the displacement values of the ground and of the plinth. The estimated (transfer function) level of amplification for a loaded girder could be a difference of 15 nanometers between ground measurement and estimate values for a loaded girder.

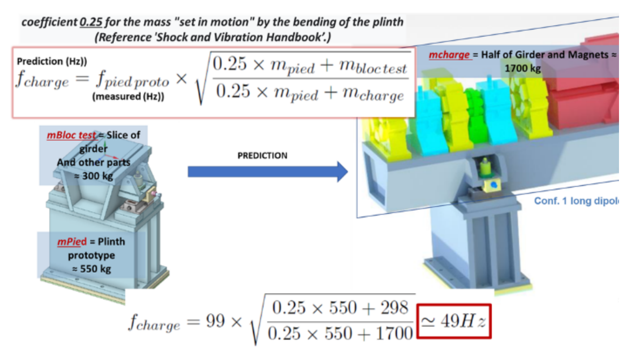

Figure 5: Prediction of bending frequency mode for a loaded girder with single dipole (X direction).

In June 2022, first alignment tests were carried out and showed that design seems to be a good basis for further studies. Adjustment under preload eliminates the problem of parasitic displacement. The fineness of fit is less than 1 µm in the Z-axis and a few µm in the other directions. Thermal stability also seems acceptable. In the area where the plinth prototype was installed, the temperatures varied between 23 °C and 23.5 °C, over 17 hours of measurements. Despite this, the thermal stability after adjustment

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was a few µm. Thermal regulation in the storage ring tunnel will be +/- 0.1 °C, so better than in the tests area.

Thanks to these tests, the design of adjustment system was improved. As shown in Fig. 6, we replaced spring washers by specific springs (steinel.com) that allow more loading precision, avoiding mounting mistakes. We changed materials for sliding surfaces, using bronze. A spherical reference for Z positioning of girders was added.

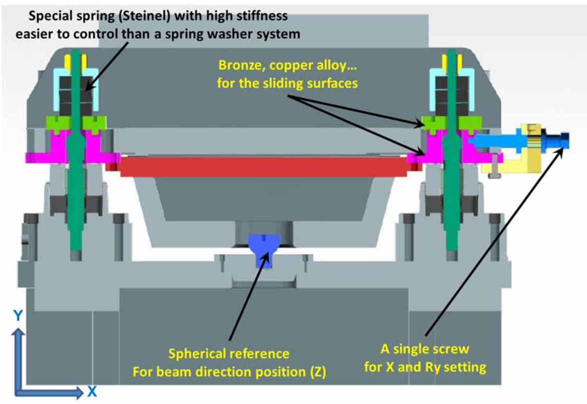

Figure 6: Design improvements.

GIRDER PROTOTYPE WITH DUMMY MAGNETS

With these encouraging results, thanks the plinth prototype, we decided to design and to provide a fully equipped girder prototype. The aim of this new prototype is to carry out as many full-scale tests and measurements as possible, for both pessimistic loading configurations. The goal is to validate the design and the processes. A single girder will allow to test both configurations alternately. Dummy magnets will have the same geometry, center of gravity and mass as the magnets currently being designed and/or prototyped.

Here is a non-exhaustive list of tests to carry out on girder prototype: alignment (precision and stability) tests; vibration stability and modal response measurements to estimate transfer functions and amplification levels; thermal stability measurements; loaded and not loaded girder deformation measurements; HLS system tests, study of motorization opportunity for installation procedure; impact studies of transporting of girder equipped on maintaining magnets alignment.

Figure 7 shows girder prototype and dummy magnets manufactured by NORTEMECANICA in Spain. Factory acceptance tests were done on October 17, 2023, with expected delivery at the end of October 2023. Installation is scheduled before the end of 2023. Tests and measurements will follow from the beginning of 2024.

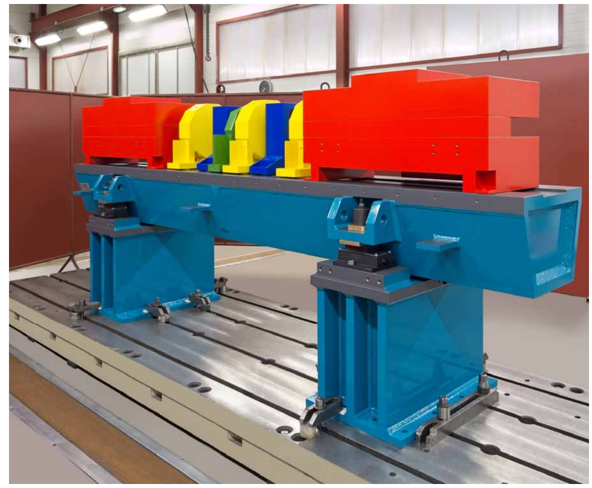

Figure 7: Manufacturing on progress.

CONCLUSION

Finding the best compromise between cost and performance is always a challenge. SOLEIL's upgrade lattice includes many distinctive zones, this fact increases the number of girder families. Some multipoles are quite narrow (~60 mm), these elements risk to have a lower natural frequency than the girders. The planning is very tight, lattice modifications can delay the design procedure. Factory and on-site acceptance tests will need to be rigorously followed and re-checked if needed because of very tight fabrication tolerances.

We continue the design procedure by carrying out integration studies of the girders in the tunnel of storage ring, considering front ends, building, interfacing with the magnets and with the vacuum chamber supports. We have also to think about logistics and installation process.

There is still a lot of work to be done to achieve our new research tool.

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