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HIGH RIGIDITY GIRDER SYSTEM FOR THE SIRIUS MACHINE

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Abstract

Sirius is a 4th generation synchrotron light source under construction in Brazil, with a bare emittance of 250 picometer rad, scheduled to have the first beam late this year. One of the most important aspects for this ultra-low emittance machine is the stability of the components, especially the magnets. This paper describes the main characteristics of the girder system, including the concrete pedestal, the levelling units, the girder itself, the clamping mechanism for the magnets and the measurements procedures. Each detail was considered in the design phase and the result is a high rigidity setup with a first horizontal mode close to 170 Hz.

INTRODUCTION

The Brazilian Synchrotron Light Laboratory – LNLS is currently installing the components of the new Brazilian light source (Sirius). This new machine will be a state-of-the-art synchrotron light source [1-2] with low emittance and capacity for 39 beamlines. First users are expected to 2019. For its proper operation, there are high demands in terms of stability of the storage ring components, especially the magnets. Their maximum vibration should not exceed 6 nm according to the specifications [3]. This tolerance implies that the whole building structure and the supports for the magnets should be designed accordingly.

When it comes to the decision as to where to install the storage ring magnets, the choice is usually to fix them on the slab, using intermediate support components such as bases, pedestals and girders. In most particle accelerators the solution is to fix concrete bases or metallic pedestals on the floor, followed by metallic girders that hold assemblies of magnets. Few studies propose girder-free magnet supports, notably [4].

To align the position of the components, levelling and positioning devices are used in-between pedestals and girders and in-between girders and magnets. For the Sirius supports, the concept of using metallic girders and concrete pedestals fixed to the slab is maintained. The main efforts were put into the design and manufacturing of the girders, although many innovations were applied to the concrete pedestals, the design of the levelling units and the fixation of the magnets on the girders. For the girder design, we built up on several girder designs, such as the Petra III [5], and optimized it in terms of rigidity.

One of the key issues for the Sirius building is its vibration characteristics, especially the special slab of the accelerators. Although this design and the civil construction details are of fundamental importance, a discussion about this is not within the scope of this paper. The intent of this work is to describe the main innovations and results related to the high rigidity girder system for Sirius, including design, manufacturing and tests.

SYSTEM DESIGN, MANUFACTURING AND TESTS

To maintain the displacement of the magnets within 6 nm, the vibrations coming from the ground must be attenuated. To achieve this, the vibration spectrum from the environment should not match the natural frequencies of the supporting structure. The goal is, therefore, design the supporting structure to maximize the natural frequency of its first modes of vibration. Also, the structure should provide a significative damping for the environmental vibrations. In terms of geometry of the girders, we performed a Topology Optimization starting from preliminary boundary conditions based mainly on dimensional constraints. Figure 1 shows the result of this study and the resulting geometry based on the study.

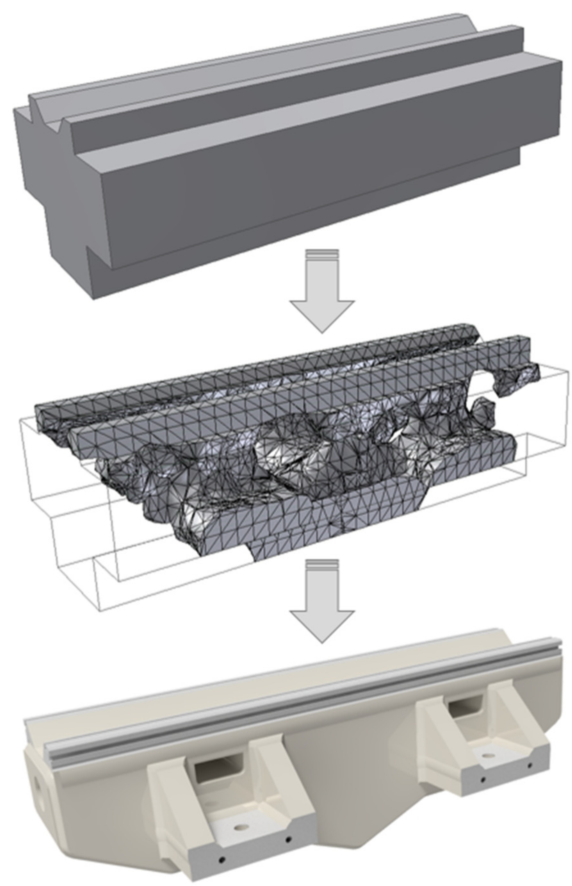

Figure 1: From the Topology Optimization to the final CAD model.

Finite Element Analyses – FEA shows that this “dolphin-shaped” design is indeed optimized in terms of vibration

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modes. In terms of material, two prototypes were tested. Experimental modal analysis was performed to compare a casting iron girder (ASTM A159 G1800H) versus a welded steel girder (ASTM A36). The measurements have shown that, besides the higher natural frequencies, the damping of the welded version was relatively better (see Table 1).

Table 1: Comparison Between Two Versions of Girders

Girder Version	**Natural frequency [Hz]**		**Damping ratio [%] Excitation (1 µm)**		**Damping ratio [%] Excitation (100 nm)**	
	1st mode	2nd mode	1st mode	2nd mode	1st mode	2nd mode
Cast Iron	286.9	573.3	0.16	0.14	0.20	0.14
A36 Steel	511.8	826.1	0.19	0.09	0.26	0.13

The concrete base was obtained by using state-of-the-art in concrete technology and differentiated techniques and tools. The process required a technological development including new manufacturing process, dimensional controls and results to reach the production of precast concrete. The initial requirements demanded by the Sirius project involved the development of an Ultra High Performance Concrete (UHPC) that must achieve a tangent elasticity modulus of 60 GPa and compressive strength above 100 MPa. The parts should be produced with a minimum dimensional precision of 2 mm in all verified dimensions, including flatness, parallelism and perpendicularity between the plan faces. The need for this unusual dimensional check in the current precast factories and processes required the use of technology and measurement equipment of use in the automotive and aeronautical industry – laser tracker.

The development of the concrete counted on techniques of packaging, use of several aggregates and modern chemical additives of concrete. The strength of the concrete was verified through compression test and its modulus of elasticity through a pulsed ultrasonic test. The forms, executed exclusively for the project, underwent dimensional validation in their execution, assembly and during the production process of the bases.

The resulting concrete achieved compressive strengths above 120 MPa and tangent elasticity modulus above 57 GPa. Several fixation methods were tested for the concrete bases on the special slab. The chosen solution is to grout the base to the floor using a high strength bi-component Epoxy resin. For levelling the girders, special levelling wedges were developed. Each device should have a maximum deformation of 0.016 mm when a 50 kN load is applied. This parameter was demonstrated experimentally for the prototypes and a 100 % inspection process was conducted for all 1000 units produced. Approximately 60 % of the levelling units had a maximum deformation below 0.010 mm for the applied load. Tests indicated that commercial units presented a three times larger deformation under the same load.

To increased stiffness, the magnets will be screwed directly on top of girders, using transversal and longitudinal adjustment devices only. This tolerance-based approach for assembly and alignment guarantees a better result in terms of vibration, both because the weak links represented by levelling devices below the magnets are absent and because this design allows the centre of mass from the assembly to be lowered. This compromise between stability and alignment issues demands high-quality magnets and girders in terms of geometrical and dimensional tolerances. Vibration measurements for a complete prototype setup show an actual result of 168 Hz for the first horizontal mode and 270 Hz for the first vertical mode (refer to Figure 2).

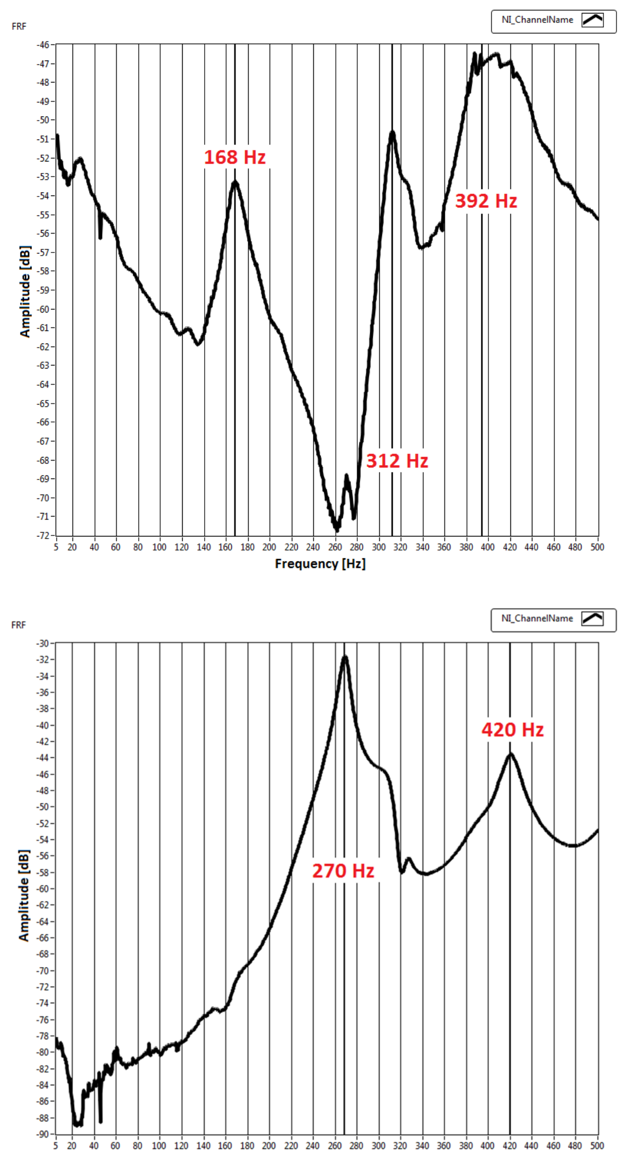

Figure 2: Experimental modal analysis of the complete assembly, results for the horizontal modes (top) and vertical modes (bottom).

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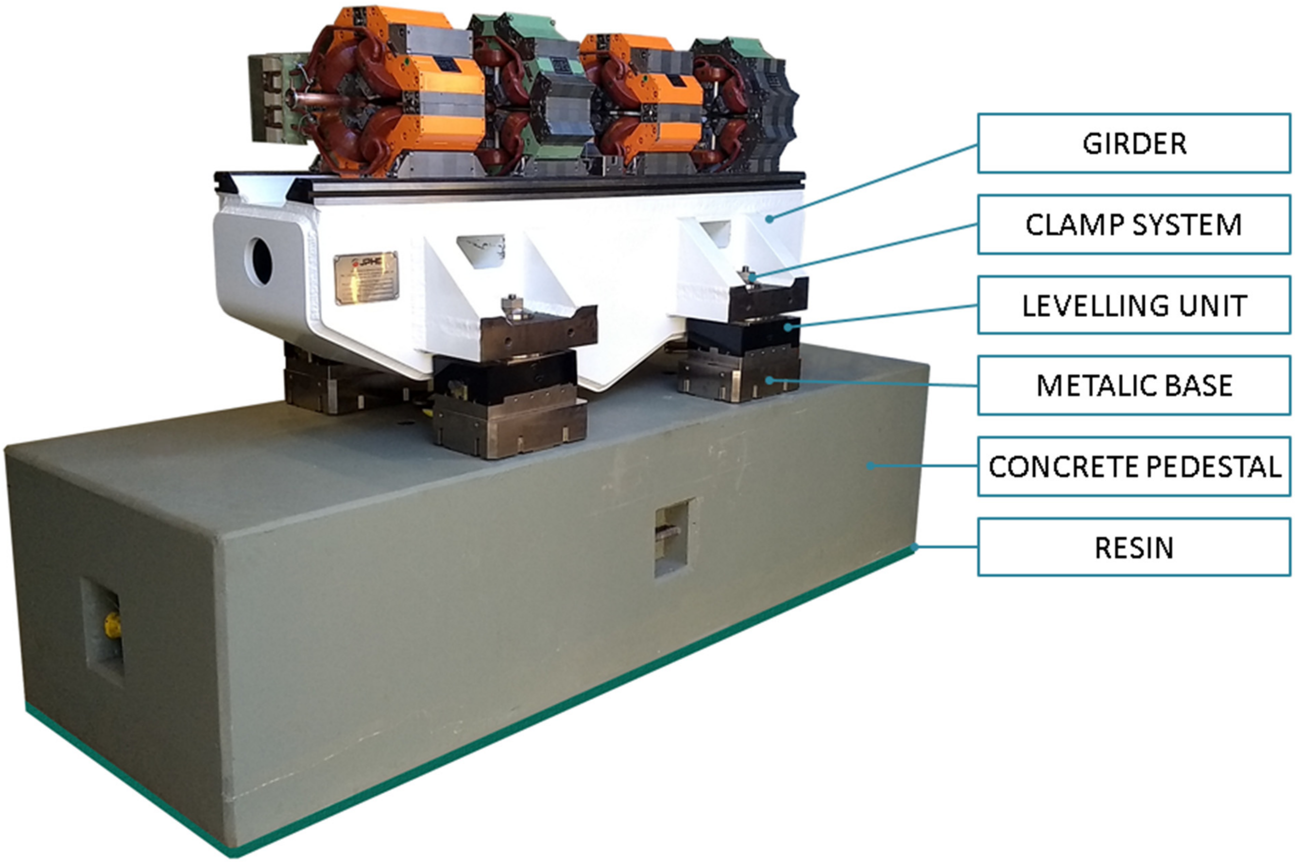

Figure 3: A complete assembly of the Sirius high rigidity girder system.

DISCUSSION AND CONCLUSIONS

The adopted vibration control is passive, that is, there is no active attenuation such as the use of piezo actuators studied for the TPS light source [6].

The so-called Sirius high rigidity girder system achieved natural frequencies outside the common and measured spectrum of vibration of the surrounding environment. The system has the potential to allow for a very stable electron beam, contributing to the success of the Sirius light source. The complete mechanical system can be seen in Figure 3.

We conclude that the Sirius magnets supporting system achieved the stiffness required for the good operation of the new light source, from the point-of-view of vibration stability. Moreover, the girder system presents natural frequencies results that stand-out from the current state-of-the-art. Reported girder systems resonances do not surpass the 120 Hz limit, including modern machines [5; 7]. This comparison is still valid if it is normalized for girder mass. The Sirius design utilizes smaller and lighter girders and magnets. This design decision contributes for the high natural frequencies, and represents another improvement in terms of design.

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REFERENCES

[1] Lin Liu, Natalia Milas, Afonso H. C. Mukai, Ximenes R. Resende, and Fernando H. de Sá, “The Sirius Project”,in *J. Synchrotron Rad.*, vol. 21, 2014, pp. 904–911.

[2] R.T. Neuenschwander, L. Liu, S.R. Marques, A.R.D. Ro-drigues, and R.M. Seraphim, “Engineering challenges of fu-ture light sources”, in *Proc. 6th International Particle Accel-erator Conference (IPAC’15)*, Richmond, Virginia, United States, May 2015, paper TUXC2.

[3] LNLS, `https://wiki-sirius.lnls.br/mediawiki/in-dex.php/Machine:Storage_Ring`

[4] S. Sharma, “A girder-free magnet support system design”, in *Proc. of MEDSI*, Barcelona, Spain, 2016, paper TUPE32.

[5] M. Schlösser, “The PETRA III Girder-Concept”, in *Proc. of the 9th International Workshop on Accelerator Alignment (IWAA)*, Menlo Park, California, United States, September 2006.

[6] T.C. Tseng *et al.*, “Preliminary active vibration elimination study of the TPS girder system”, in *Proc. of MEDSI16*, Bar-celona, Spain, 2016, paper MOPE11.

[7] W. Haijing *et al.*, “Overall design of magnet girder system for heps-tf”, in *Proc. of IPAC16*, Busan, Korea, 2016, paper WEPMR047.