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ELETTRA 2.0 –THE GIRDER SUPPORT DESIGN

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Abstract

Elettra will be upgraded between 2025 and 2026 and the storage ring lattice will be totally different to enhance the emittance and improve the coherence of the machine.

The storage ring design requires a stiff support system to reduce the impact of vibrations on the electron orbits, a high thermal stability as well as low static deformations. The magnets support system must be easy to transport, align and must be cost effective. In order to achieve these requirements, the magnets supports of each synchrotron cell are granite blocks long from 0.8 to 1.57 m and the girder alignment system consists of 3 main adjustment feet and 2 stiffeners. An optimization study was conducted defining the most effective location of the feet. Each magnet can be aligned on the girder by means of 3 levelling wedges that can be moved both manually and automatically by means of motorized actuators.

A FEA calculation was carried out to optimize the design in order to achieve a target stiffness and an experimental test was performed on a prototype girder in order to verify the numerical results.

INTRODUCTION

The new 6 Bending achromat lattice of Elettra 2.0 will considerably enhance the coherence of the storage ring. In-between each dipole a cell with a variable number of optical magnets will be supported by a girder, as shown in Fig.1. The storage ring will contain twelve identical sectors and each sector will have 8 multipoles girders and 6 dipoles girders. So, the storage ring magnets and the vacuum chambers rely on 168 girders [1].

In new lightsources like Elettra 2.0 the magnets require stringent mechanical alignment and stability [2,3]. Table 1 shows the alignment and stability specifications for Elettra 2.0 storage ring magnets. According to the physical requirements, the accuracy between magnets positioned on each girder should be less than 20 µm, between dipoles better than 50 µm and the accuracy between girders should be less than 50 µm.

Table 1: Elettra 2.0 Alignment and Stability Requirements

Magnets	**Alignment (µm)**			**Stability (nm)**	
	Δ X	**Δ Y**	**Δ Z**	**Δ X**	**Δ Y**
Quadrupoles Sextupoles	20	20	300	150	25
Dipoles	50	50	300	200	30
Girders	50	50	300	600	70

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GIRDER DESIGN

Girders are used to sustain magnets, vacuum chambers, BPMs and other instrumentations [4]. On girders top surface, each element must be positioned with high precision, relative to each other and to the storage ring absolute system: hence, each girder will be provided with fiducial marks referenced to its mechanical center.

In order to achieve a standard design and provide the most cost-effective solution, it has been decided to maintain the same girder shape, but different length. The girders consist of granite slabs long from 0.8 to 1.57 m, 0.6 m large and 0.3 m thick.

Granite was chosen for girders because of its reduced coefficient of thermal expansion, high stiffness and extremely good flatness that can be obtained at the top face.

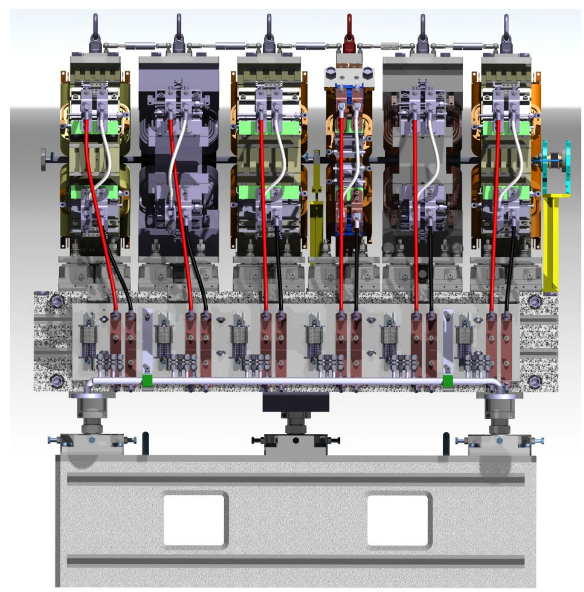

Figure 1: Elettra 2.0 girder design.

The girder positioning relies on three manual alignment systems with a spherical washer at its bottom to have the perfect isostatic constraint. The adjustment feet range is -/+15 mm in all the directions. Adjustment screws set transversal, longitudinal and yaw regulation, while the vertical, pitch and roll adjustment are actuated by M52 screws.

The dimensioning of the screws takes care about the static performance and the dynamic behavior of the system (in terms of vibrations). All the adjustments are independent and parasitic movements free.

Two further no tipping feet with spherical washers can be tightened after the alignment to increase the natural frequencies of roll and pitch and minimize static deflection of the magnet–girder system, but at the same time avoid rollover during the girder placement.

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Considered the Elettra 2.0 beam height of 1.3 m, a concrete pedestal will reduce the girder vertical dimensions, making the whole system stiffer.

Each girder carries about 1500 kg of magnets, bringing the payload, including the adjusting system, to a maximum of 2500 kg. The girder can be aligned quite fast and assures an easy transport, handling and installation can meet budget and schedule.

To reduce the onsite installation time, magnets assembly and alignment on the girder will be performed before the installation. For this purpose, dedicated installation teams will take care of the girders' preassembly, in a dedicated early assembly area.

The magnets must be fixed to the girder by means of a stiff system, avoiding vibration amplification but providing precise adjustment for the alignment of each magnet within the required tolerances.

By means of a motorized actuator, a baseplate can be precisely aligned along x axis, sliding on the granite top face, two pivots rigidly fixed to the girder avoid cross-talk. The positioning of the pivots is managed by means of a laser tracker. After reaching the final position, the base plate will be locked by T-nut to the girder. Three modified Airloc 505-KSKC wedge-mount levelling feet will be motorized and will be used to align the magnet along y, θ and ϕ (Fig. 2). At the end of the alignment, the system will be locked by threaded rods screwed to the base plate. LVDT sensors (Linear Variable Differential Transformer) will guarantee a feedback for the motorized system. In Table 2 a summary of the resolutions obtained with the motorized system at full step.

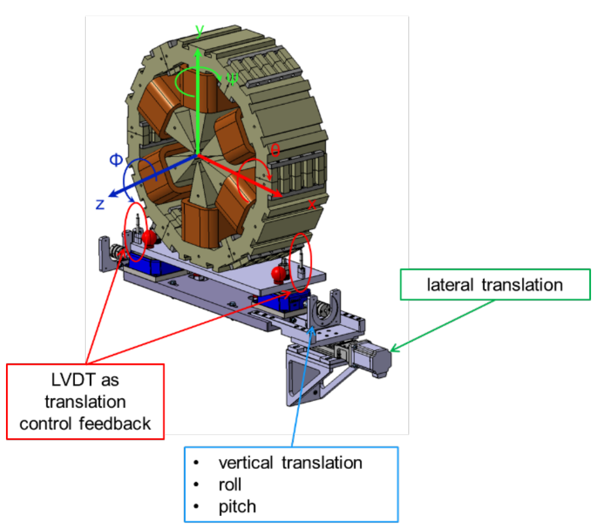

Figure 2: motorized system using Airloc 505-KSKC wedge-mount levelling feet.

After the magnets' pre-alignment, they will be fiducialized to the girder by survey reflectors. Every girder is provided with reference surfaces for the upper plane levelling and tolerated holes to allow the laser tracker survey.

For a precise alignment of the magnets the deflection of the girder must be static and repeatable, but it is certainly preferable that the gravity effect deflection is negligible. The measured flatness of the granite slab top surface is 20 µm.

Table 2: Full Step Magnets Alignment System Resolution

DOF	Resolution	Range
X	5 µm/step	+/-5 mm
Y	1,85 µm/step	+/-3 mm
Φ	0,005 µrad/step	+/-5 °

STATIC ANALYSIS

A static FEM analysis using the software ANSYS was performed on a complete structure with the aim to optimize the position of the supports and to minimize the deformation under girder and magnets own weight.

The maximum and minimum deflections of the magnets on the girder are 8.1 and 3.4 µm (Fig. 3). It means that the maximum vertical misalignment between the magnets due to the weights is 5 µm, which is far less than the design tolerance and the alignment system can easily compensate the static deflection of the girder.

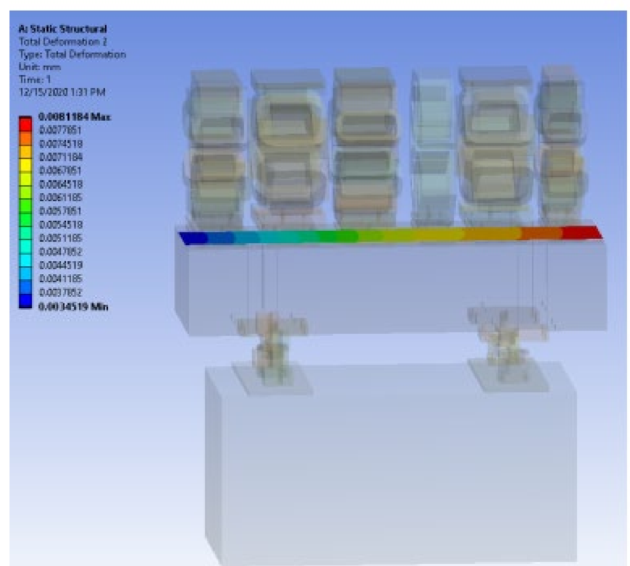

Figure 3: Girder–magnets assembly gravity deflections.

MODAL ANALYSIS

Vibrations of the girders lead to orbit deviations that can deteriorate the storage ring performance [5].

The system must allow a high-precision alignment of the magnets, but at the same time must be stiff and unresponsive to vibrations. The design aims to have an easy alignment solution that becomes stiff when the screws are locked to improve the vibration resistance. Furthermore, the slim geometry of the magnets leads to low frequency pitch modes, so a cardan joint shaft with adjustable length fixed between magnets will define a further constraint that improves the stiffness. To validate the girder design, a

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study of the dynamic characteristics of the system was carried out.

A modal analysis based on the linear vibration theory and finite element method has been carried out to optimize the design of the girder. The dynamic characteristics of the girder are crucial to avoid the resonance phenomena and decrease the vibratory displacements. [6,7]

The 3D model for the modal analysis includes the magnets, the granite slab and the adjustment systems. The finite element modal analysis of the magnet–girder assembly shows that lowest mode involving the girder is at 64.9 Hz.

Vibration amplitudes for frequencies far away from the resonances are very low and are not an issue for the system, because the amplification factor remains low.

The vibration sources are mainly the flow of the cooling water, air conditioning, power supplies and mains disturbances [5]. All these vibration sources are quite far from our modes, anyway we provided a provisional design for an auxiliary damping system with the aim to reduce the amplification related to that sources. The analysis showed that according to our constraints a granite girder is definitely stiffer than the steel made ones.

PROTOTYPE AND VIBRATION MEASURES

Some environmental measures were carried out in order to confirm that the ground vibrations at the Elettra site are weak, due to its geological conformation, so they won't be considered as an external source of vibration. It is essential to attenuate the displacement of the magnets due to forced vibrations: the natural frequencies of the supporting structure should be kept as far as possible from the vibration spectrum coming from external sources. This implies that the girder design must maximize the natural resonant frequencies of its first modes of vibration to avoid amplification of external low frequency vibrations.

A girder mock-up (Fig. 4) was mounted to validate the model by performing experimental vibration measurements. Further purposes for the prototype were the test of the alignment systems, the definition of the assembly and alignment procedures and a clear idea about spaces and the interfaces with other systems. In the prototype the girder is identical to the design, while the magnets are dummies with the same shape and weight as the real ones.

An Experimental Modal Analysis (EMA) was performed on prototype with magnet mockups for the identification of the natural frequencies of the system and the modal shapes. The obtained results were compared with the numerical model. In the girder 62 measuring points were identified and checked. In the measurements both the girder and a magnets were excited.

In the experimental measures, the first mode involving the girder has a frequency of 44 Hz, against 64.9 Hz of the simulation. The reason of this difference is supposed to be that we couldn't fix the alignment feet to the ground of the storage ring with permanent screws, so we couldn't realize the same constraint as set for the simulation. For future investigations, in order to have a better fitting between the simulation and the experimental data, the mock-up will be placed in a laboratory having a foundation equal to the storage ring and the same fixing constraints. Futher modes of the girder have frequencies definitely higher according to our measurement setup that is more cautelative than the real situation. This frequencies produce a smaller amplification factor.

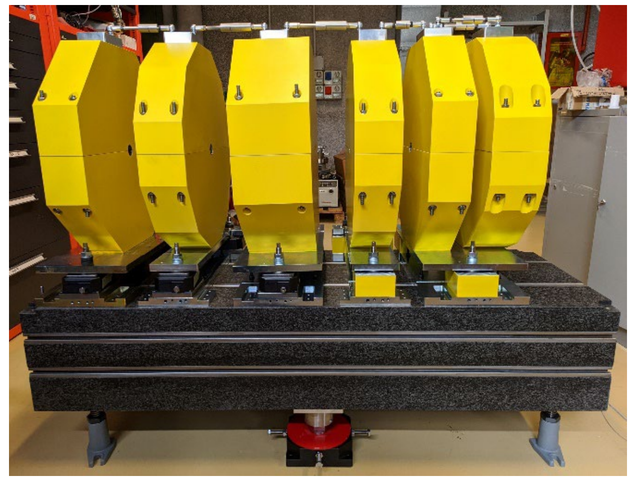

Figure 4: girder prototype.

CONCLUSIONS

The results of the test carried out on the prototype showed that the magnets supporting system achieved the stiffness required to reduce the impact of ambient and external sources of vibrations on the particle beam during operation of the future light source.

At the same time the girder offers a good thermal stability and satisfies the alignment system requirements.

Therefore, the prototype girder shows that the design meets the specifications required by the new storage ring.

The last step will be to improve the mock-up boundary conditions. The aim is to improve the correlation between the simulation model and the experimental one, but mostly to reproduce with more accuracy the installation condition in the storage ring.

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