Measurement of a Magnet Girder in MAXLab[*]

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Abstract

In this report, vibration measurements of a magnet girder in MAXLab, Lund, are reported[1]. The motivation was to provide information on the girder stability and its design. This is an example of a possible stability study of accelerator components which can, in turn, affect beam stability.

[1] In collaboration with CELLS-ALBA (Consorcio para la Construcción, Equipamiento y Explotación del Laboratorio de Luz Sincrotrón), http://www.cells.es

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1 Introduction

In high energy accelerators and synchrotron light sources, girders are used as means of support and mounting of the accelerator components as well as raising the components to the nominal beam height for expediting realignment.

However, a girder is another structural element, within accelerator components, which can affect the beam stability. If it is designed poorly, it may amplify ambient floor motion which could have adverse impact on the beam quality.

In this document, measurements of a magnet girder in MAXLab, Lund, are reported. It is foreseen that the girders of ALBA (Barcelona) will be based on the MAXLab girder design. The aim was to characterize the vibrations of this structure in vertical, transverse and longitudinal directions to the beam and to search for possible structural resonances in all directions.

A seismometer (Güralp CMG-6TD), with a precision of 0.04 nm/bit at 1 Hz for all three axes, [1] was used to take data on the girder and on the floor for the duration of around 2 hours in each case. Simultaneously, 2 vertical and 2 horizontal geophones (SENSOR SM-6) [2] were used to make similar measurements for a snapshot period of few minutes, Figures 1 & 2.

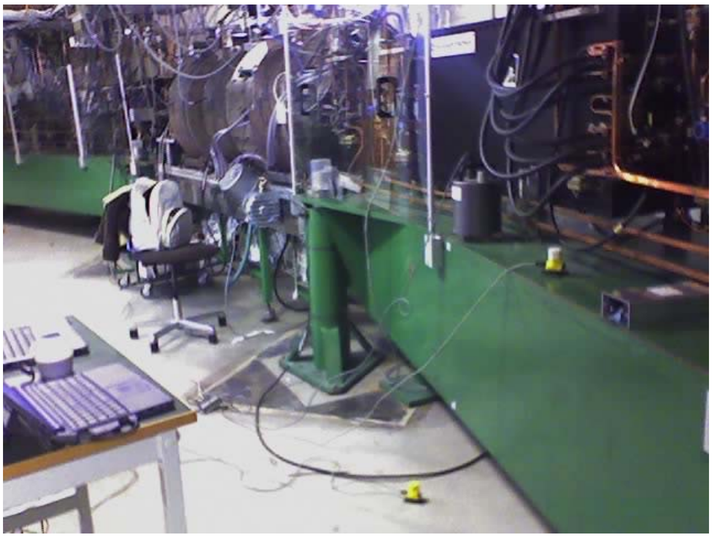

Figure 1: Partial view of a MAXLab girder. A Güralp CMG-6TD seismometer was placed on the girder for the vibration measurements. Simultaneously, two vertical and horizontal geophones repeated this measurement for a snapshot period of few minutes.

Figure 2: Measurement of the floor vibration near the girder with the seismometer and simultaneously, with both vertical and horizontal geophones

2 Measurements

Measurements were performed during the weekly shutdown period of around four hours, from 8:00-12:00 a.m., on Monday 13 February 2006. The seismometer was first placed on the girder and afterwards, it was moved to the floor. It was positioned such that the north direction, as indicated on the seismometer, was perpendicular to the beam pipe. The total measurement time in each case was around two hours and the final spectra were obtained by averaging over the one minute measurements in each case. Simultaneously, geophones (both horizontal and vertical) were used to take snapshot measurements of few minutes. Horizontal geophones were placed longitudinal to the beam pipe, and therefore, were used in comparison with the seismometer data in longitudinal (seismometer east) direction. The seismometer was then moved near a beam line for additional ground measurements, Figure 3.

Figure 3: Ground measurement near a beam line

Fast Fourier Transform (FFT), with no windowing, was performed to obtain average displacement and integrated Power Spectral Density (PSD) as explained in [3]. Figure 4 is a comparison of MAXLab average spectrum, in the vertical direction, with a reference site, Asse rock salt mine in Germany. Average root mean square (rms) calculated, at f > 1 Hz, in vertical direction, for MAXLab is 54 nm (Figure 4, right hand side), compared with 1 nm measured in Asse. In the horizontal directions (transverse and longitudinal to the beam direction), MAXLab average rms ground motion is around 22 nm.

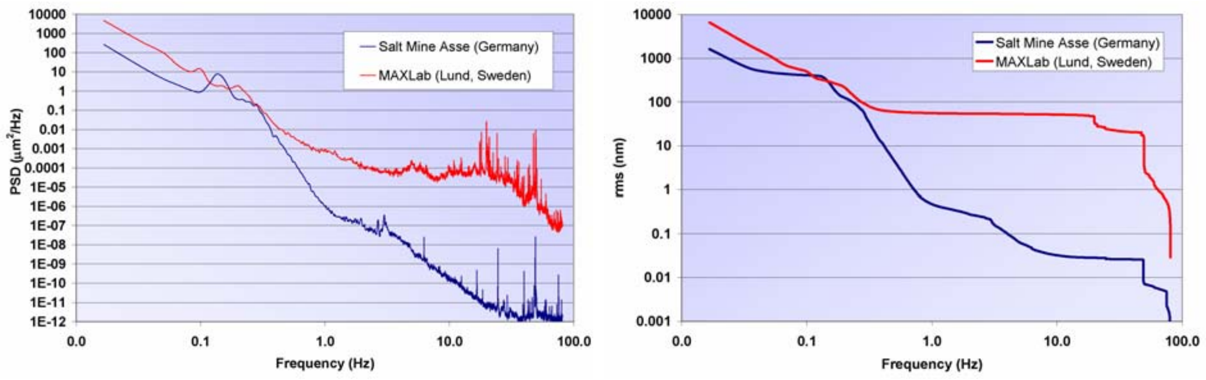

Figure 4: Average vertical displacement PSDs for MAXLab (red) as compared with a reference site (rock salt mine, Asse in Germany) shown in navy, on the left, and integrated average displacement PSDs for MAXLab, shown on the right

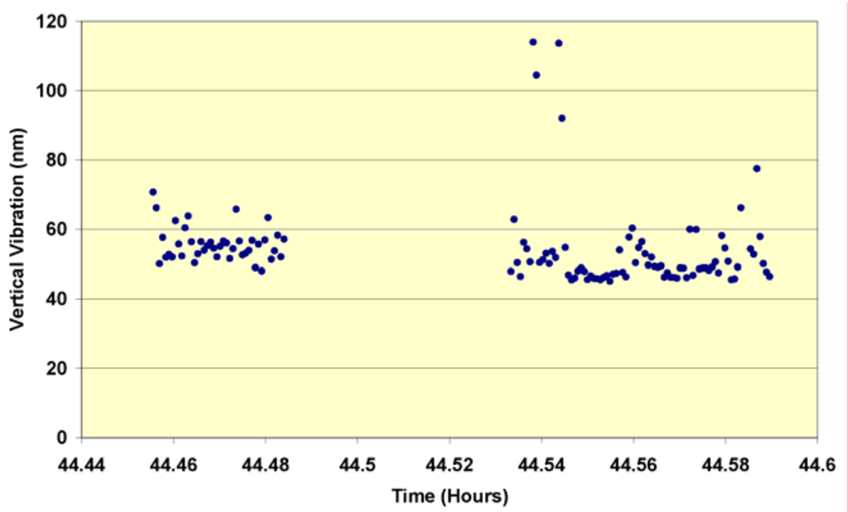

Figure 5: Root mean square of vertical ground motion at f >1 Hz

To gain a better picture on the ground vibration and 'cultural noise' situation in MAXLab, it is recommended to collect data for a longer time, including nights and weekend (quiet time) as well as daytime (noisier time). There is more information to be gained on correlation and coherence if two or more sensors are placed in different locations within one site. For definitions of correlation/coherence please refer to [4].

3 Results of Girder Measurements in MAXLab

Average PSD spectra for the ground, girder and the ratio of girder/ground, together with integrated average displacement PSDs, are shown in Figures 6, 7 & 8, for the seismometer data, in the vertical, transverse and longitudinal directions, to the beam pipe, respectively. Since only one seismometer was used to measure girder and ground vibrations separately, no coherence information on the signals was obtainable.

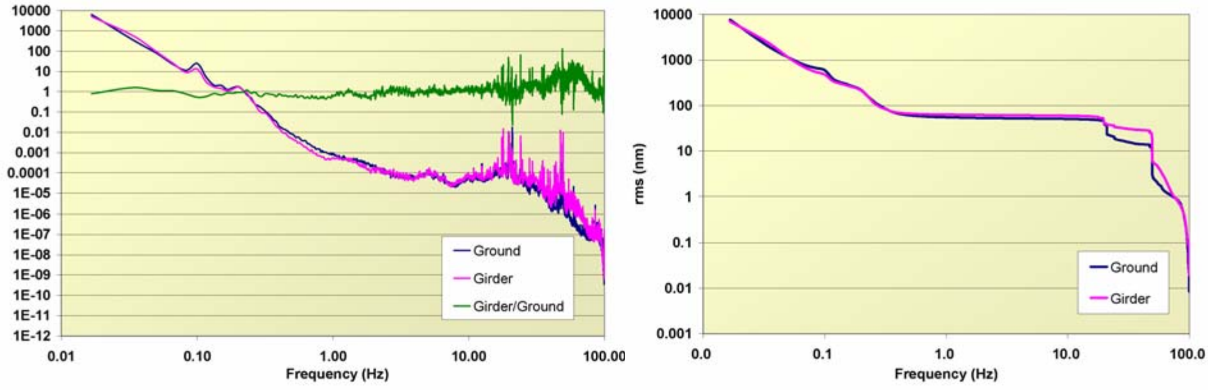

Figure 6: On the left panel, PSD spectra of girder (magenta) versus ground (navy) in the vertical direction, measured by the seismometer, are plotted. On the same plot, ratio of girder/ground, (green) is shown. On the right panel, their corresponding integrated average displacement PSDs are shown.

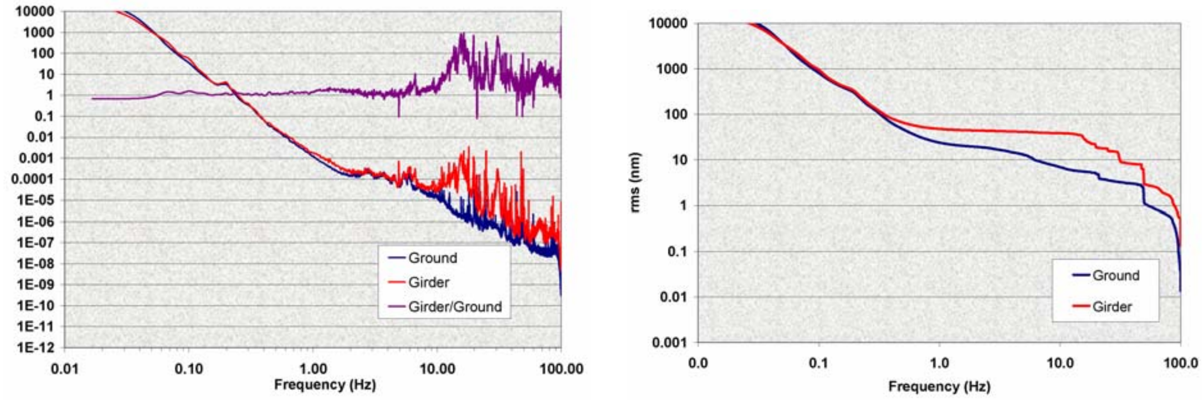

Figure 7: Same as Figure 6, this time in the transverse direction to the beam pipe

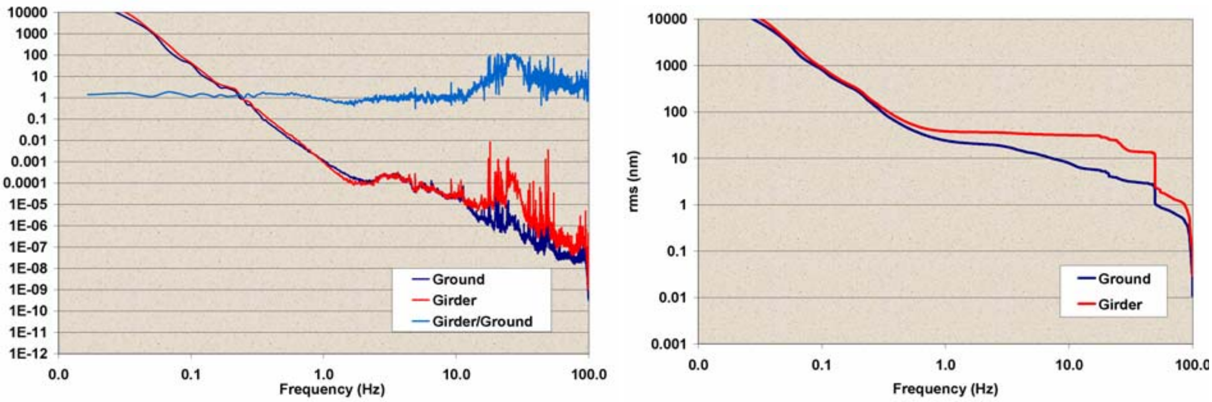

Figure 8: Same as Figure 6, this time in the longitudinal direction to the beam pipe

In the case of the seismometer data, in the vertical direction, the integrated PSD for ground at 1 Hz is 55 nm and for the girder, 63 nm. In the transverse (seismometer north) direction, the vibration at 1 Hz, for the ground is 24 nm and for the girder, 48 nm. In the longitudinal direction, the corresponding numbers are 24 nm and 38 nm for the ground and girder vibrations respectively.

In the vertical direction, the girder seems to be stable. This is evident from the ratio of PSD (girder)/PSD (ground), which at 1 Hz is about 1.2 (i.e. a 20% departure from the perfect 1:1 correspondence (Figure 6). The girder follows the ground vibration closely and no structural resonances are present in the vertical direction within the frequency range measured. However, as seen from Figures 7 and 8, the girder is less stable in the horizontal, both transverse and longitudinal to the beam pipe, directions. In the transverse direction, Figure 7, a resonance at ~15-16 Hz and another at ~28-30 Hz are visible. In the longitudinal direction (Figure 8) a resonance at ~28-30 Hz is seen which is also visible in the transverse direction. The ratio of integrated rms of girder/ground in the horizontal transverse direction is calculated to be ~2 at 1 Hz and in the horizontal longitudinal direction this ratio is ~1.6. Both vertical and longitudinal spectra have been re-measured via geophones for which coherence data is available.

Figures 9 & 10 are the geophone data taken simultaneously with the seismometer in vertical and horizontal directions and their corresponding coherence signals (Figures 12 & 13).

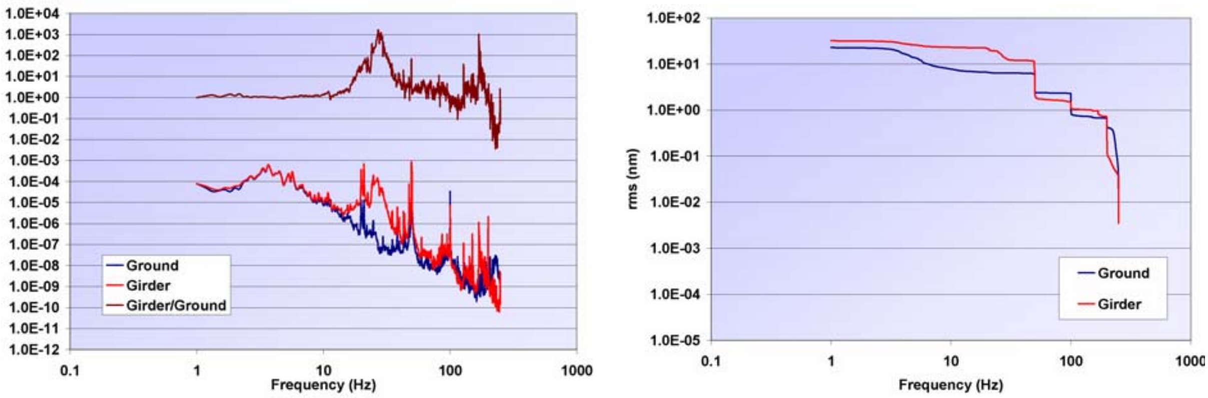

Figure 9: PSD spectra of girder (red) versus ground (navy), as measured simultaneously by the horizontal geophones, in the longitudinal direction to the beam pipe. On the same plot, PSD (girder)/PSD(ground) (brown) is shown

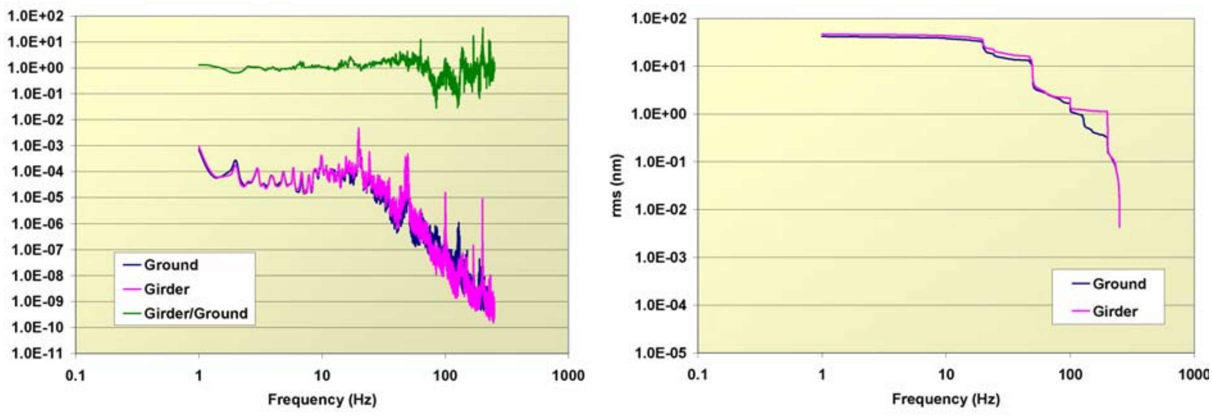

Figure 10: Same as Figure 9, this time in the vertical direction, using vertical geophones

In the horizontal direction, longitudinal to the beam pipe, the girder vibration, at 2 Hz [5], is ~ 31 nm compared to the floor vibration of 22 nm. In the vertical direction, these values are 47 nm for the girder and 42 nm for the floor. These numbers compare very well with the seismometer measurements.

Again, as seen from the seismometer data, the girder is stable in the vertical direction (Figure 10). However, in the horizontal direction, it exhibits a strong resonance at ~28-30 Hz as was also seen in the seismometer data, in the longitudinal direction to the beam pipe (Figure 8).
The corresponding ratio of girder/ground amplitude transfer functions are shown in Figure 11 on linear scale.

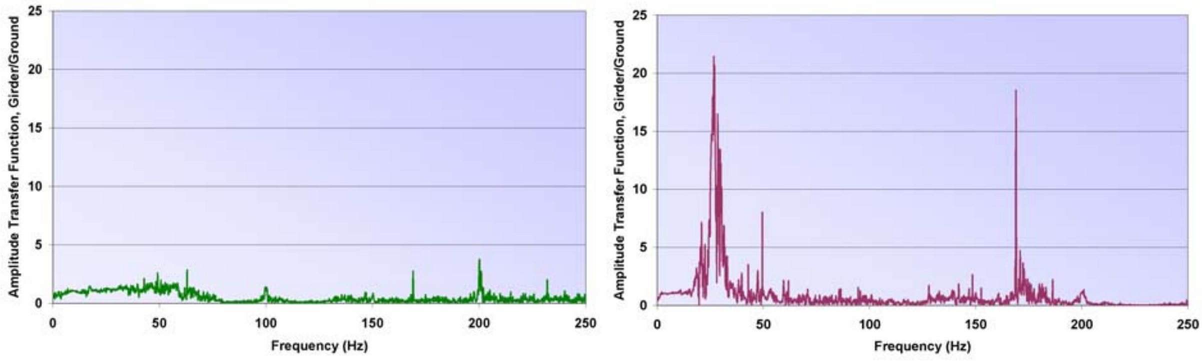

Figure 11: Ratio of girder/ground amplitude functions, as obtained from the geophone data, in vertical direction (left) and for horizontal direction, longitudinal to the beam pipe, (right)

The absence of any resonances in the vertical direction is evident. However, in the horizontal direction, the resonance at ~28-30 Hz is clearly visible. Coherence signal for the vertical direction is close to 1, i.e. the two signals from the vertical geophones are well correlated up to a frequency of ~55 Hz (Figure 12, left). In the horizontal direction, however, the two horizontal geophone signals are well correlated up to a frequency of ~15 Hz, with occasional good coherence thereafter (Figure 12, right). The signal seen at ~169 Hz in Figure 11 has poor coherence and therefore, may not be a structural resonance. However, the signal at ~28-30 Hz, has a good coherence of ~0.8.

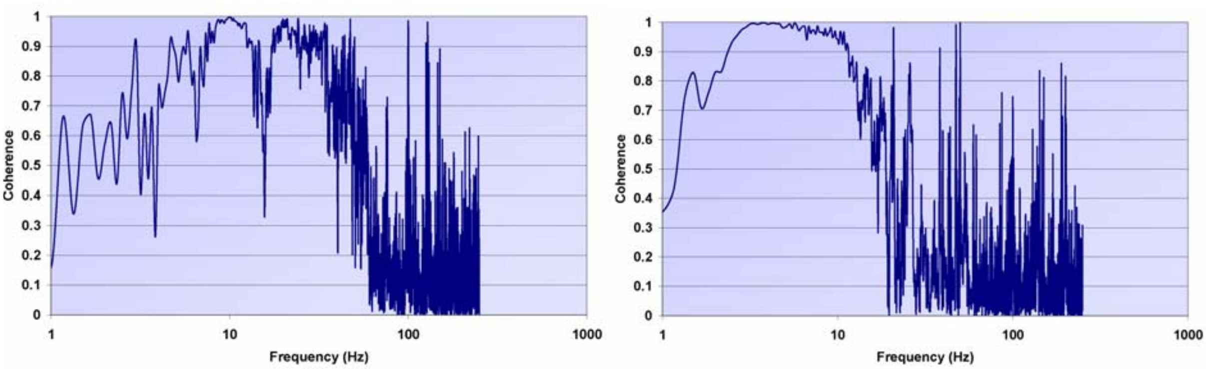

Figure 12: Coherence signal of two vertical geophones (left) and two horizontal geophones (right)

4 Conclusions

By looking at the coherence signals from the two simultaneous geophone measurements, PSDs, integrated rms ratios of girder/ground, and the data taken by the seismometers, one concludes that the girder seems to be stable in the vertical direction. However, it is rather unstable in both horizontal (longitudinal and transverse) directions. A resonance at ~28-30 Hz, in the longitudinal direction to the beam pipe, is seen in both seismometer and geophone data and the coherence data support that this signal is a 'true' resonance of the structure. In the case of the seismometer data, in the transverse direction to the beam pipe, an additional resonance is seen at ~15-16 Hz in addition to the resonance ~30 Hz already seen in the longitudinal direction. In general, structural resonances less than 50 Hz can affect beam stability/quality. Therefore, we recommend a more optimal design to be undertaken in order to either damp or push horizontal resonances to higher values, i.e. > 100 Hz.

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[4] D. Holder, "Basics of Site Vibration Measurements as Applied to Accelerator Design", Daresbury Laboratory, UK, AP-BU-rpt-001, Jan. 2000.

[5] SENSOR SM-6 geophones have a natural frequency (f_n) of 4.5 Hz and a nominal sensitivity of 28.8 V/m/s. A non-linear amplifier extends their frequency response and flattens it in the range 1.7 to 350 Hz. When we compare integrated rms motion, we therefore use a cut frequency of 2 Hz.