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VIBRATION MEASUREMENT & SIMULATION OF MAGNET & GIRDER IN SESAME*

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Abstract

SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) started operation in January 2017. During the design phase several FEA studies were performed to optimize the girder and the magnet design taking into account all the constraints such as the tight spacing between magnets, the vacuum chamber installation interactions with the magnets. In this paper the experimental and Numerical modal analysis are presented as well as the result comparison between the experimental and simulation work.

INTRODUCTION

Finite Element Analysis Using ANSYS were used during the design phase in order to calculate the Eigen Frequencies and to extract the mode shapes of the Girder-Magnets Assembly [1]. After that experimental modal analysis had been conducted at CERN vibration labs. The outcome results are then used to perform Model Tuning for the Girder-Magnet assembly FEA model used in the calculations of Eigen frequency and mode shape as well as the magnets PSD response to the ground vibration.

INITIAL FEA MODEL RESULTS

Initial Modal Analysis for the girder system design before modifications during manufacturing phase was performed using ANSYS workbench15 finite element analysis software. In which over 20 modes have been extracted. the lowest natural frequency found to be 22 Hz with a longitudinal bending shape (bending the around beam axis), as shown on Table 1. The second mode Eigen frequency was 23 Hz with a longitudinal bending shape as well, the 3rd mode related to the dipole magnet with a transversal shape (rotation around beam direction) and 45.4 Hz frequency, for the 4th mode the mode take a longitudinal bending shape with an Eigen frequency of 62.8 Hz related to the long quadrupoles magnets.

Table 1: Eigen Frequencies For The Initial Design

Mode	Freq.(Hz)	Shape
1	22	Sext Longitudinal Bending
2	23	SQ Longitudinal Bending
3	45.4	Dipole Transversal Rotation
4	62.8	LQ Longitudinal Bending

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PROTOTYPE EXPERIMENTAL MODAL ANALYSIS

In the following part of this paper the results of the experimental modal analysis performed by the Mechanical Measurement Lab of the EN -MME group at CERN to characterize the dynamical behaviour of the magnets and the girder impact of SESAME are described.

Test Setup

For measuring the dynamic response of the structure, five tri-axial accelerometers were used, two PCB Piezotronics 356A33 (sensitivity of 10 mV/g, frequency range from 2 Hz to 7 kHz and a mass of 5 grams) & two PCB Piezotronics 356B08 (sensitivity of 100 mV/g, frequency range from 0.5 Hz to 5 kHz and a mass of 50 grams. One PCB Piezotronics 356A15(sensitivity of 100 mV/g, frequency range from 2 Hz to 5 kHz and a mass of 10 grams).

In addition to the accelerometers, two impact hammers (PCB Piezotronics models 086D05 and 086D20) were used to excite the magnets and the girder respectively.

Measurement Positions

The measurement positions of the accelerometers were chosen in order to know the behaviour of the different parts of the structure. The measurements were carried out for four separate parts of the structure: the sextuple, the long and the short quadrupole and the girder as shown in Figure 1. The girder was not fixed to the floor during the measurements.

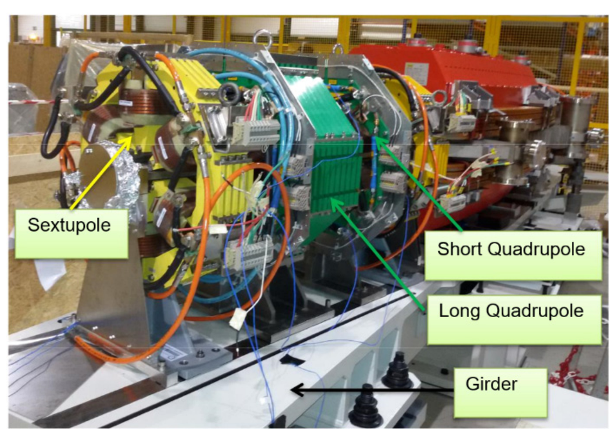

Figure1: Position of the accelerometers.

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The accelometers A1, A2, A3, A4, A5 were placed in such a way as to obtain the natural modes of the structures. Three accelometers were glued in the front side of the Sextuple. Two in the top in antisymmetric positions A1, A2 and one the A3 to the bottom. In the back side, A4 was placed in the top and A5 in the antisymmetric position in the bottom as shown in Figure 2. Similar positions are used the configuration of the acidometers in both Long and Short Quadrupole.

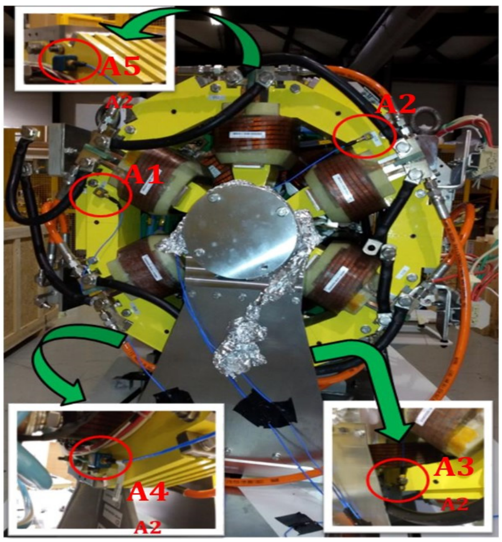

Figure 2: Positions of the accelerometers for the Sextuple.

Acquisition System

The acquisition system used was the MKII made by Müller-BBM. The MKII system is a real time spectrum analyzer and a compact data acquisition system. It contains 16 input channels with DSP (Digital Signal Processing) for each channel, with a sampling frequency rate up to 200 kHz. The dynamic resolution is 24 bits for ICP42 cards and 16 bits for ICP41 cards, and can be used in a range between 10 mV and 60 V.

The system is controlled by PAK® Software 5.6 SR4, which allows to control the hardware that measures the signal and allows different post-processing functions such as FFT (Fast Fourier Transform), PDS (Power Signal Density) and CPS (Cross Power Spectrum) to be carried out.

Post-Processing

In order to determine the mode shapes of the magnets and the girder it was necessary to create virtual structures with all points of measurement. During the post processing, each transfer function (magnitude, phase and direction) is associated with each point. The virtual geometry used for the experimental modal analysis is shown below in Figures 3 and 4.

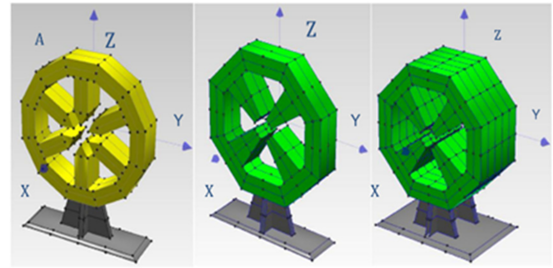

Figure 3: Simplified Model of the Multipoles.

ME'scopeVES® software V5.0 (Vibrant technology, Inc.) was used to obtain the modal parameters (modal frequencies, modal shapes) from the transfer functions obtained from PAK® Software. It allows graphical presentation of the test structure and animation of the motion.

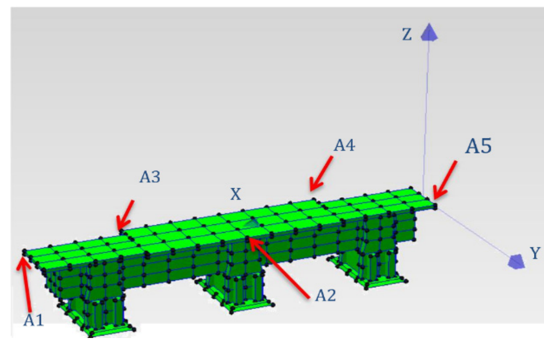

Figure 4: Simplified Model Girder.

Experimental Modal Analysis Results

After the acquisition of all transfer functions, the last step of the modal analysis is to extract the modal deformations using the FRF function obtained from the experiment. The first and most critical step of modal parameter estimation is to determine how many modes have been excited (and are therefore represented by resonance peaks) in a frequency band of a set of FRF measurements. Figure 5 shows a sample of FRF for the results of one of excitation points. The software has a choice of three different Mode Indicator functions; the Complex Mode Indicator Function was used. Table 2 presents the results.

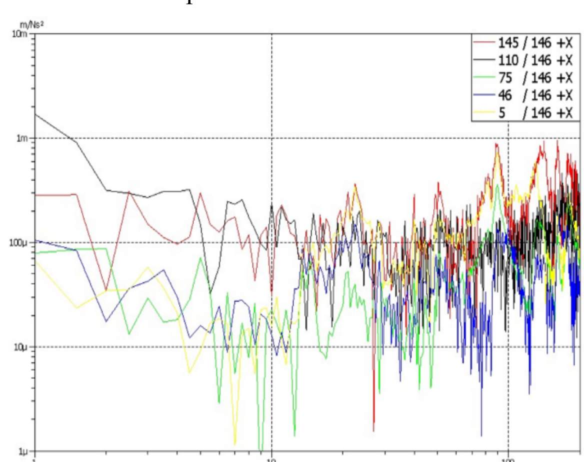

Figure 5: Sample FRF for the girder.

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Table 2: Experimental Modal Analysis Results

Model	Frequency [Hz]	Damping [%]	Description
Sextuple	13.4	0.83	1st longitudinal bending
	40.4	0.24	1st transverse bending
	41.4	0.29	2nd longitudinal bending
Short Quadrupole	15.4	0.87	1st longitudinal bending
Long Quadrupole	65.9	1.05	1st transverse bending
	86.4	1.25	2nd longitudinal bending
	28.8	0.94	1st longitudinal bending
	44.9	0.81	1st transverse bending
	51.0	1.42	transverse bending
Girder (with magnets)	14.2	1.23	rigid body (low frequency)
	40.8	0.29	1st torsional of the ends
	44.6	0.43	in-plane bending
	48.2	0.96	in-plane torsional mode

FEA MODEL TUNING

The FEA model (Figure 6) for the Modal Analysis have been tuned to using the mass and stiffness (Modules of Elasticity for the Girder and Magnets material) in order to get to an agreement with the experimental results. this step is necessary for further analysis such as PSD and to explore any modifications which may be applied to the system. The low frequency modes experimented by the sextuple and short quad magnets could be enhanced by some modifications on the magnets support and the clamping system between the magnets and the girder, the following Table 3 shows the FEA results after model tuning compared to the experimental Modal analysis results.

Table 3: FEA & Experimental Modal Analysis Results

Mode	FEA Freq. (Hz)	Experimental Freq. (Hz)	Shape
1	13.44	13.4	Sext Longitudinal Bending
2	15.92	15.4	SQ Longitudinal Bending
3	26.14	28.8	LQ Longitudinal Bending
4	62.8	42	LQ Longitudinal Bending

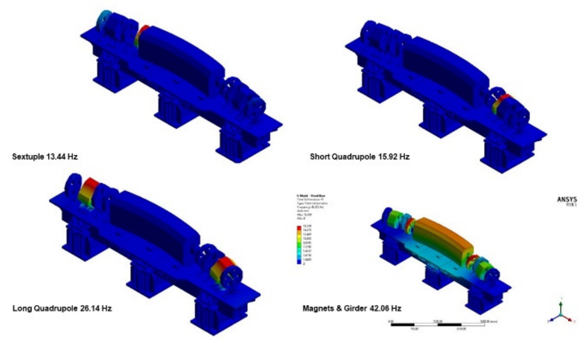

Figure 6: Girder & Magnets Assembly Mode Shapes.

CONCLUSION

The result obtained through the experimental measurements are lower than the ones obtain through FE calculations. the cause of the discrepancy is due to several reasons. one important cause is the clamping of the magnets on the girder which encountered major changes another reason the experimental modal analysis was performed without taking into account the actual fixation of the Girder-Magnets System to the Floor [2].

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