VIBRATIONAL STABILITY OF SRF ACCELERATOR TEST FACILITY AT FERMILAB*

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Abstract

Recently developed, the Superconducting Radio Frequency (SRF) Accelerator Test Facilities at Fermilab support the International Linear Collider (ILC), High Intensity Neutrino Source (HINS), a new high intensity injector (Project X) and other future machines. These facilities; Meson Detector Building (MDB) and New Muon Lab (NML) have very different foundations, structures, relative elevations with respect to grade level and surrounding soil composition. Also, there are differences in the operating equipment and their proximity to the primary machine. All the future machines have stringent operational stability requirements. The present study examines both near-field and ambient vibration in order to develop an understanding of the potential contribution of near-field sources (e.g. compressors, ultra-high and standard vacuum equipment, klystrons, modulators, utility fans and pumps) and distant noise sources to the overall system displacements. Facility vibration measurement results and methods of possible isolation from noise sources are presented and discussed.

INTRODUCTION

In anticipation of the Project X and HINS beamline operation, a study of vibration level was completed. Preliminary measurements indicate that vibration levels can be significant. Therefore, further study of these vibration levels and their sources is needed. Proper characterization of these motions in terms of frequency helps to identify their source. These motions are spectrally characterized in terms of root mean square (rms) displacement and Power Spectrum Density (PSD) velocity. In general, ground studies have been conducted at the Fermilab site over the past 15 years, monitoring vibration levels for various project including; Main Injector, Electron Cooling, Collider Experiments at CDF and D0 and large future colliders [1].

Extensive studies regarding existing cryomodule operation at DESY for the linac of the European X-Ray Free Electron Laser (XFEL) have been completed [2-4]. External ground vibration caused by technical (vacuum, HVAC, water and cryogenic systems) and cultural (staff activity) disturbances manifest fast motion of the focusing quadupole magnet resulting in pulse-to-pulse beam position jitter [4]. Recent stability criteria of 300 μm, considers the vertical quadrupole motion and limits it to 30 nm in a frequency range between 10 Hz to 100 Hz. Beam-based feedback through dipole corrector adjustment within the quadrupole package can correct for motion beneath 10 Hz [5].

* Operated by Fermi Research Alliance, LLC, under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy.
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The stability criterion for the Project X and HINS is still under consideration. For evaluation purposes the more stringent ILC stability criteria was considered in this paper for Project X. Cryomodule #1 (CM1) shown in Figures 1 and 2 was installed at NML with two future cryomodules, CM2 and CM3 to be built by Fermilab. Their basic construction is similar to the XFEL style cryomodule with differences in the blade tuner design and Fermilab style cavities. The focusing quad will be located in the center of each cryomodule with 4 cavities on each end.

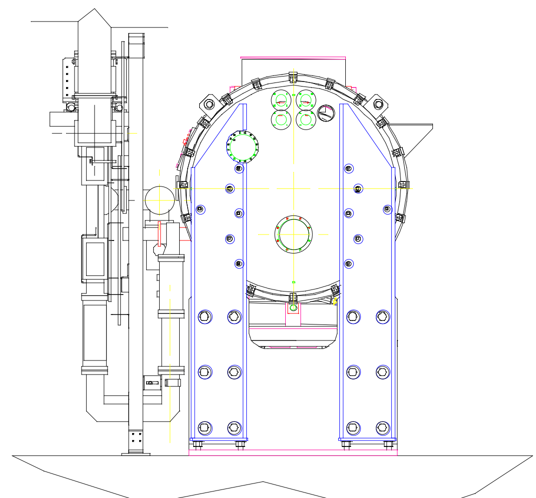

Figure 1: Upstream end view of CM1.

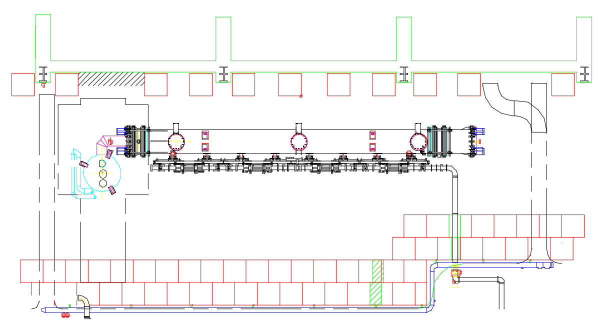

Figure 2: Plan view of CM1 at NML.

FACILITY CHARACTERIZATION

Development of the SRF areas comes with challenges regarding the existing infrastructure in terms of foundations, structural elements of each building and equipment. At grade level, NML is 226 m above mean sea level (AMSL) with the 0.94 m thick reinforced concrete slab, 5 m below. Constructed in 1983, the 74.8

m x 25.6 m footprint slab weighs 2.4e5 kg (without considering the weight of each wall). Over 2 kilometers away, MDB was built a decade earlier at grade level and still has many of its original utilities. The MDB foundation is 0.3 m thick with a 74.3 m x 46.9 m footprint, weighing over 2.9e5 kg. This structure is much different using a cast in place concert perimeter supporting a pretension steel roof.

Soil composition has an impact on the interaction of waves entering each structure. The pre construction soil composition samples for each facility were quite similar consisting of silty clay with trace sand and gravel from 3 to 8.2 m below grade, very stiff to hard clay with trace sand and gravel exists from 8.2 to 21 m deep and hard dolomitic limestone, green and gray shale partings at a 21 m depth.

Baseline Measurements

Inertial (moving coil) velocity sensors Geospace HS-1 (2 Hz) geophone [6] devices in tri-axial aluminum block sets were used with vertical Sercel Mark L4c seismometers [7]. Geospace GS-14-L9 geophones [6] were mounted on a supporting bracket above cavity number 3, 5 and 7 (one vertical and one horizontal) within CM1. These CM1 cavity geophones were enclosed within a cylindrical magnetic shield made of heat treated 1018 low carbon steel to protect the cavities from stray magnetic fields. A vertical Geospace GS-11-D geophone [6] and horizontal geophone SM6-HB from Sensor b.V [8] were attached on the quad, upstream. Cold calibration of these devices has been established at DESY [4]. All geophones were connected to six National Instruments (NI) NI-9233 4-channel, 24-bit ADC modules sampled at 5K/s, and the data was recorded to a laptop hard-drive.

Baseline measurements within each facility were completed during minimum cultural and technical noise activity. Figure 3 provides the reference integrated displacement for the vertical and transverse response (floor to quad) at NML. These values were considered quiescent, less than a micro meter (rms). Figure 4 depicts the associated reference velocity PSD vertical and transverse response for NML.

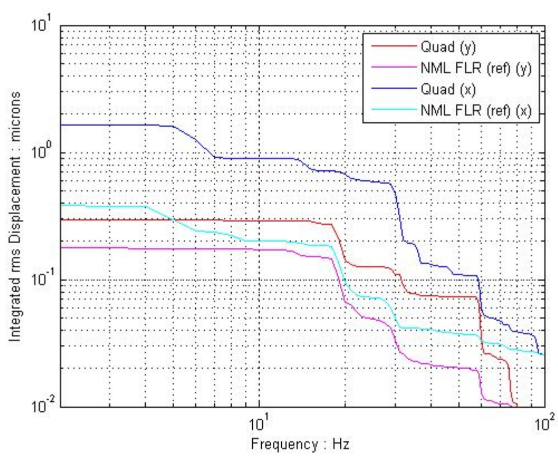

Figure 3: Integrated displacement baseline for NML.

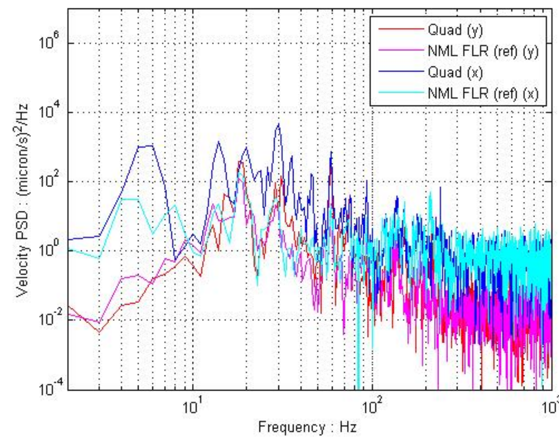

Figure 4: Velocity PSD baseline for NML.

The vertical, transverse and longitudinal integrated displacement reference within MDB is given in Figure 5 showing one magnitude higher vertical and transverse motion than NML on the micro meter level. Figure 6 depicts the vertical, transverse and longitudinal velocity PSD for MDB with respect to the HINS beamline.

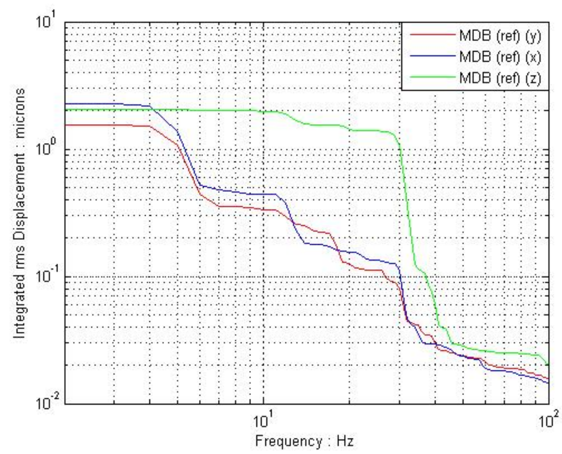

Figure 5: Integrated displacement baseline for MDB.

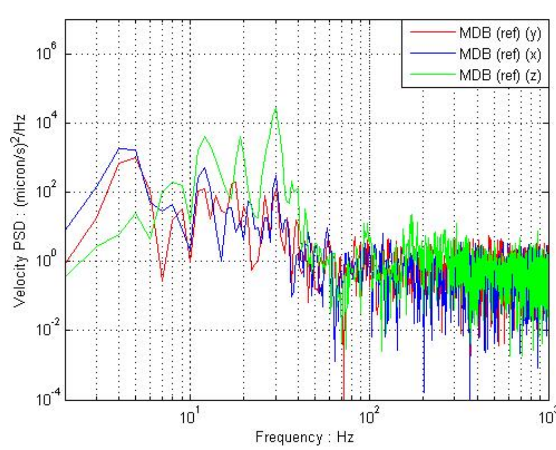

Figure 6: Velocity PSD baseline for MDB.

Rotational Equipment

Water systems and large volume vacuum pumping systems for support of the cryogenics are present in both buildings. Although the NML facility has similar type of rotating equipment, the MDB equipment is closer in proximity to the beamline. Necessary rotating equipment was defined as utility water pumps and HVAC air handling units to support computer facilities within NML. Utilities, low conductivity water (LCW) system, cryogenic equipment (wet and dry expansion engines) and compressors operate in a different area.

Table 1 provides a summary of operating equipment within each facility. The 30 and 60 Hz signature of this equipment is seen in both integrated displacement baselines. Documented site specific frequencies of 4.2, 9.2 and 13.2 Hz have been observed within the Fermilab site due to the Central Helium Liquefier (CHL) [9], located 1.5 kilometers from MDB and 2.4 kilometers from NML.

Table 1: Summary of MBD and NML equipment

Source	Rotational Motor Speed (rpm)	Excitation Frequency (Hz)
LCW Pump	3525 - 3550	58.5 – 59.2
Utility Water Chiller Unit	3550	59.2
Vacuum Pump	1725-1800	28.8 – 30.0
Chilled Water	1755	29.3
HVAC Unit Sump Pump	1750	29.2
Air Compressor	1725 - 1748	28.8 – 29.1

Cryogenic Equipment Commissioning

Figure 7 provides the vertical, transverse and longitudinal velocity PSD of combined Kinney pump, blower and Frick compressor during an operation study. A change in velocity PSD level with respect to the vertical NML reference was not observed. Therefore, energy was dissipated within the foundation well before reaching the cryomodule area, 100 m away.

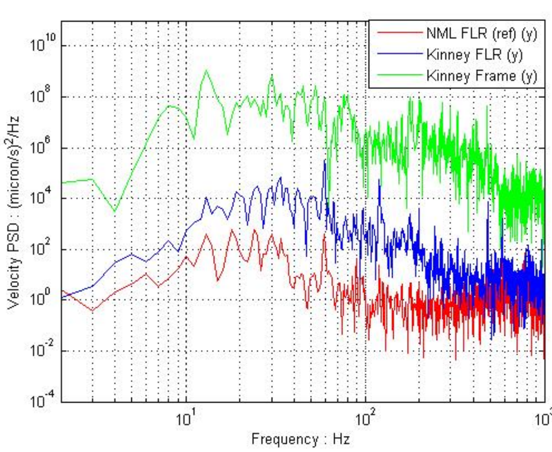

Figure 7: NML vertical PSD velocity Kinney test.

FUTURE WORK

Vibration due to cultural noise (above 1 Hz) was observed which is dependent on time, site location and elevation. Cultural noise sources (relevant between 10 and 100 Hz) are difficult to model, therefore daytime and nighttime measurements help to characterize this effect. Studies are needed to conservatively represent infrastructure and component installation activities.

It was difficult to isolate rotating equipment due to necessary operations within MDB. Baseline motion levels within MDB were high. As rotating equipment is evaluated, mechanical engineering efforts will be applied to decrease levels of vibration.

RF structures can manifest vibratory modes in response to power entering the cavity (or accelerating structure) and subsequently pulsate at a constant rep-rate [10]. Studies are planned which consider high power generating RF components such as klystrons and their modulators.

ACKNOWLEDGEMENTS

Thanks to Alex Chen, Jerry Leibfritz, Sergei Nagaitsev and Bob Webber and for their help regarding Project X and HINS. Special thanks to the SRF instrumentation team consisting of Ruben Carcagno, Fred Lewis, Darryl Orris, Yuriy Pischalnikov and Warren Schappert. Also thanks to the NML support staff Kermit Carlson, Chris Exline, Mike Kucera, Craig Rogers and Cryogenic Staff; Greg Johnson, Arkadiy Klebaner and Alex Martinez.

REFERENCES

[1] B. Baklakov et al., “Ground Vibration Measurements for Fermilab Future Collider Projects,” Phys. Review Special Topics – Accelerators and Beams, Vol. 1, (1998).
[2] R. Amirikas, A. Bertolini and W. Bialowons, “Vibration Stability Studies of a Superconducting Accelerating Module at Room Temperature,” PAC’07, (2007).
[3] R. Amirikas, A. Bertolini and W. Bialowons, “Vibration Stability Studies of a Superconducting Module at 2K,” PAC’07, (2007).
[4] R. Amirikas et al., “Vibration Stability Studies of a Type III+ XFEL/FLASH Superconducting Accelerating Module Operating at 2 K,” FEL’08, (August 2008).
[5] M.W. McGee, R. Doremus and C.R. Wands, “Mechanical Stability Study of Type IV Cryomodule (ILC Prototype),” PAC’07, (June 2007).
[6] http://geospace.com
[7] http://www.sercel.cm
[8] http://geophone.com
[9] C. Moore, ”Vibrational Analysis of Tevatron Quadrupoles,” Proc. IV Int. Workshop on Accel. Alignment, Tsukuba, Japan, KEK Proceeding 95-12, p.119, (1995).
[10] F. Asiri, F. Le Pimpec, A. Seryi, “Study of Near-Field Vibration Sources for the NLC Linac Components,” PAC’03, (2003).