Dynamic Response Analysis of The LBL Advanced Light Source Synchrotron Radiation Storage Ring*

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Abstract

This paper presents the dynamic response analysis of the photon source synchrotron radiation storage ring (Figure 1) excited by ground motion measured at the Lawrence Berkeley Laboratory advanced light source building site [1, 2]. The high spectral brilliance requirement the photon beams of the advanced light source storage ring specified displacement of the quadrupole focusing magnets in the order of 1 micron in vertical motion [2]. There are 19 magnets supported by a 430-inch steel box beam girder. The girder and all magnets are supported by the kinematic mount system normally used in optical equipment. The kinematic mount called a six-strut magnet support system is now considered as an alternative system for supporting SSC magnets in the Super Collider. The effectively designed and effectively operated six-strut support system is now successfully operated for the Advanced Light Source (ALS) accelerator at the Lawrence Berkeley Laboratory. This paper will present the method of analysis [3, 4, 5, 6] and results of the dynamic motion study at the center of the magnets under the most critical excitation source as recorded at the LBL site.

I. INTRODUCTION

Ground motion at the ALS site was measured from 4 to 100 Hz. The measured noise based upon 2% damping is about 0.1 microns. The significant mode of frequency for the storage ring is about 3 Hz and the damping coefficient is below 1%. Dynamic motion of the quadrupole focusing magnet (QF) is designed for a maximum 1 micron vertical motion limit to obtain photon beams with high spectral brilliance. This analysis predicts that the vertical motion of the quadrupole magnet should be below 0.8 microns based on an assumption that 0.5% damping composite is designed for the ALS storage ring system.

II. METHOD OF ANALYSIS AND MODELLING

The response spectra method [5], see Figure 2, is used as the computation technique in the present analysis [7,8,9,10]. Finite element method [6] is employed for the storage ring modeling. The actual spring constant for the six-strut system is experimentally determined. The strut spring constant has significant effect on the dynamic behavior of the storage ring structural system. An integrated finite model includes the steel girder, magnets, vacuum chamber and the six-strut supporting system. The ground motion is expressed as spectra [5] that is the envelope of all the individual responses from 0.5 Hz to 100 Hz. The spectra is applied at the floor slab level. The soil-structural interaction is included in the spectra as long as the location of the measurement of the ground motion is representative of strut's anchoring points and no major building is erected to influence the soil-structure interaction.

ALS STORAGE RING GIRDER FINITE ELEMENT MODEL FOR GROUND MOTION RESPONSE STUDY

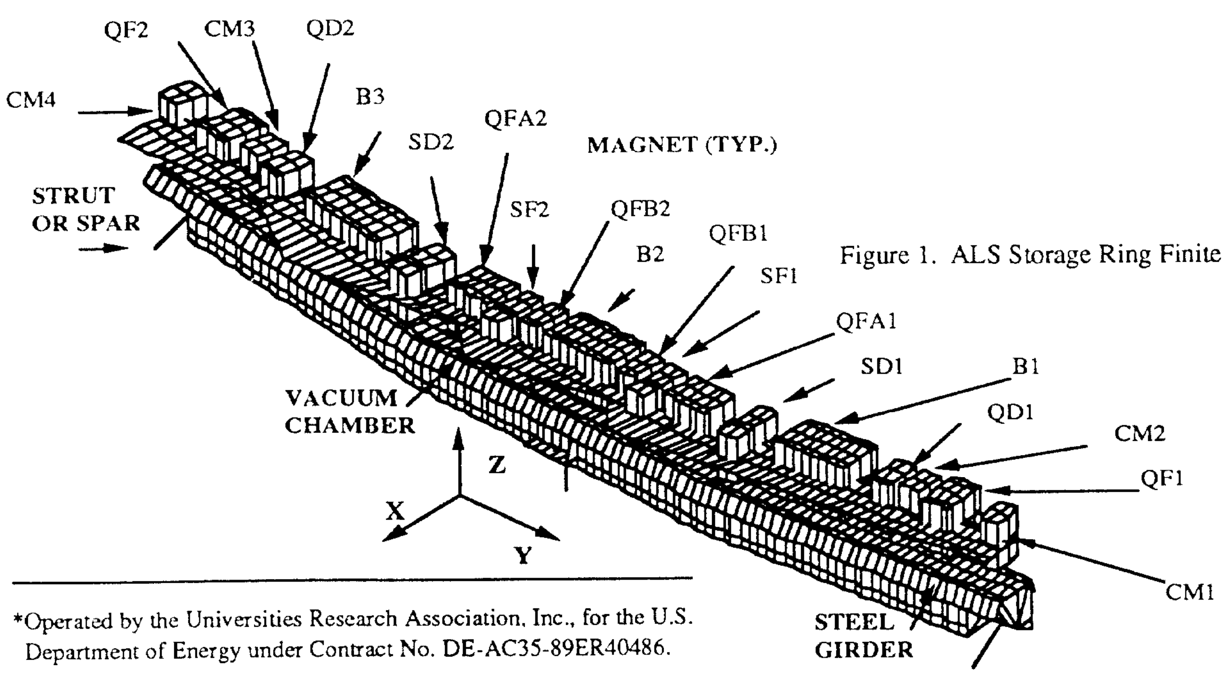

Figure 1. ALS Storage Ring Finite Element Model.

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The eigenvector and eigenvalue of the normal mode are first calculated. The modal spectra displacement, participation factors and effective mass are then evaluated for each mode. The modal dynamic motion is combined to give the maximum displacement response at the interested point. The method of modal sum [7, 8, 9,10] combination is based on the method of square root of the sum of the square for the non-closed spaced modes. For closed spaced modes, the algebraic sum method is used. The response spectrum is applied[10] at three directions, x, y, and z, independently.

III. GROUND AND SEISMIC MOTION

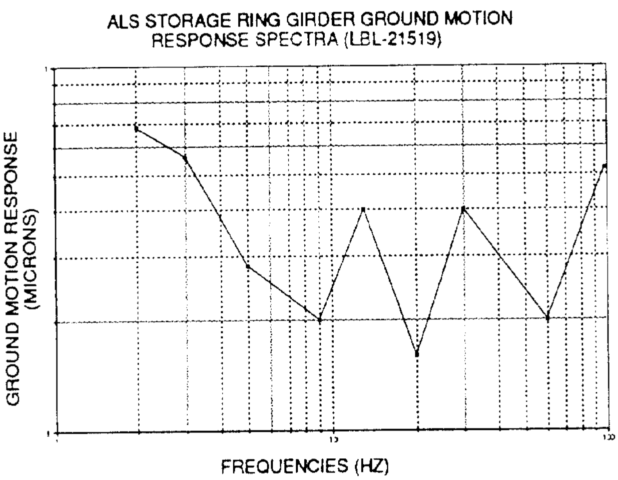

Figure 2. ALS Ground Motion Spectra.

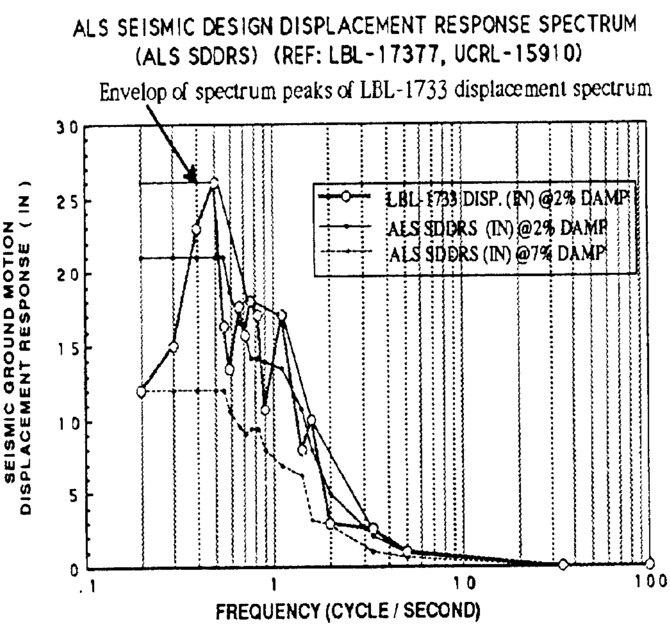

Figure 3. ALS Store Ring Magnet Vertical Displacement.

IV. RESULT OF DYNAMIC ANALYSIS

A three-dimensional model dynamic analysis is used to predict the actual response of the girder system from specified ground and earthquake motion as shown in Figures 2 and 3. The dynamic model includes correct mass point selection in each magnet to represent all significant modes. Coupled equipment masses and compliance are incorporated in the system mathematical model. The results of the finite element analysis are shown in Figure 4 for the maximum vertical deflection of each magnet in the ALS storage ring. The maximum vertical deflection for the focusing magnet is specified as 1.0 microns. The vertical deflection for the quadrupole magnet QF2 is 0.7 microns as shown in Figure 4. The ALS storage ring structural dynamic design appears to be successful. The design for controlling the ground motion response is based on selection of the boxed beam for maximum torsional rigidity for the steel girder, and arranging the six struts in the most effective position to limit the vertical response to the focusing magnets. The seismic dynamic design involves many structural components design including the welding, connection bolts, six strut system for each magnet, the plate, web, girder, and six- strut system for the storage ring.

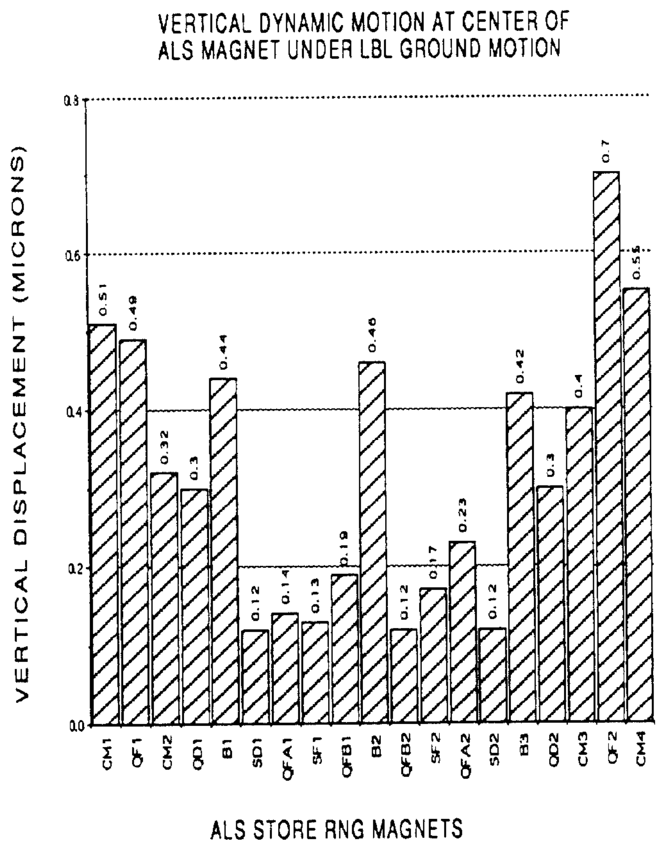

Figure 4. Vertical deflection of at Center of Magnet Subjected to Ground Motion Excitation.

The most critical structural component of the supporting system for the storage ring is the six strut that supporting the girder (Figure 5) because there are no redundant supports for the storage ring. The buckling loading capacity(Figure 6) for the strut is about three times larger than the seismic load and the seismic design of the ALS storage ring is therefore acceptable. An earthquake of 7.1 magnitude occurred at 100 miles from the ALS site in 1989 before the ALS storage ring structure is completed.

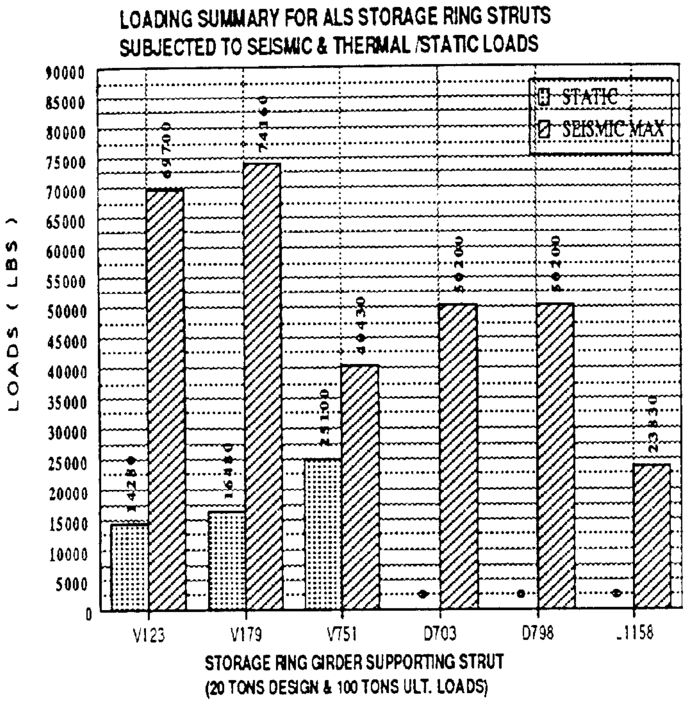

Figure 5. Total axial load for each of the six struts.

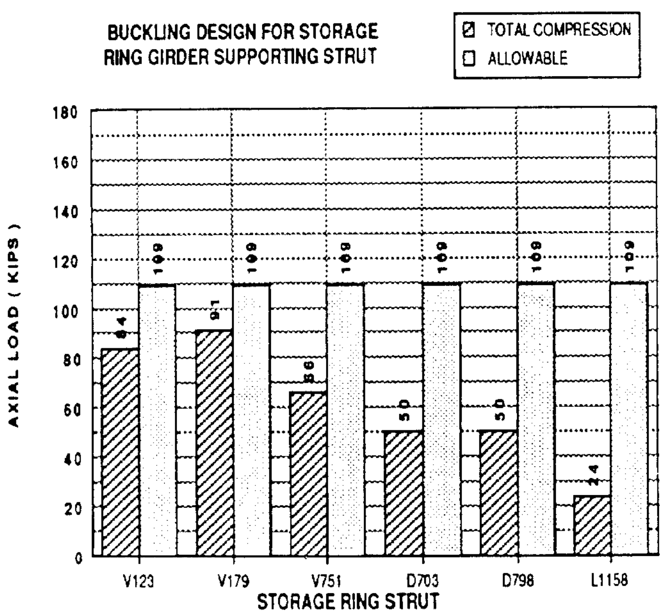

Figure 6. Comparison of seimic load and allowable buckling load on the six strut.

V. REFERENCES

[1] B. A. Bolt, "Strong Seismic Ground Motion for Design Purpose at the Lawrence Berkeley Laboratory," Report LBL-17377, July 1979, DOE Contract Number DE-AC03-76SF00098.

[2] M. A. Green et al., "Ground Motion Mrasurements at the LBL Light Source Site, the Bevatron and the SLAC," LBL Report-21519, 1086.

[3] K. K. Leung, M. S. Lin, et al., "Fast Flux Test Facility of Atomic Energy Commission Final Seismic Analysis Report," 1974.

[4] K. K. Leung, "Seismic Stresses of Piping Systems and Equipment on Heat Exchanger Supporting Structures," Section K-7/6, *Transactions of the 3rd Internatioan Conference*, 1975.

[5] N. C. Tsai, "Spectrum-Compatible Motions for Design Purposes," Journal of Engineering Mechanics Division, ASCE, Vol. 98, No. EM2 proceedings 8807, 1972.

[6] G. J. DeSalvo "ANSYS Engineering Analysis System," Swanson Analysis Systems Inc., Penn., U.S.A

[7] "Combination of Modes and Spatial Components in Seismic Response Analysis," USAEC Directorate of Regulatory Standards Regulatory Guide 1.92 , 1974.

[8] F. C. Nelson. "The Role of Closely Spaced Modes in the Seismic Response of Equipment and Structures," Proceedings of the U.S.National Conference on Earthquakes Engineer ing 1975, Ann Arbor.

[9] N. M. Newmark et al., "Earthquake Spectra and Design," Earthquake Engineering Research Institute, 1982.

[10] E. H. VanMark, "Structural Response to Earthquakes," *Seismic Risk and Engineering Decision*, Elsvier Scientific Publishing Co, Amsterdam Oxford, New York, 1976 (edited by C. Lomitz and E. Rosenblueth), pp. 287-337.

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