Orbit Distortion due to the Floor Displacement in the Light Source Building Under Climatic Thermal Stress

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Abstract

Diurnal orbit drift in the storage ring was found resulting from the floor displacement of the building distorted under climatic thermal stress. The building distortion was both simulated by using a computer model and measured with a leveling system. Both simulation and measurement gave a good evaluation of the floor displacement. The orbit drift calculated from the measured floor displacement agreed well with that actually measured with beam position monitors. In consequence, it was decided to insulate the roof, which made the building distortion much smaller and the orbit drift minimal.

I. INTRODUCTION

The Light Source Building distorted under climatic thermal stress was found mainly responsible for the diurnal aggravation of vertical closed orbit distortion (COD) in the storage ring. This was recognized first by the fact that COD measured at the beginning of a day was not conserved for the rest of the day, and at the same time by the fact that experimenters often found it difficult to keep track of synchrotron radiation photon beams coming from the storage ring to their stations.[1] Efforts were paid first to identify the origin of this cause, and second to reduce its effect on the storage ring. This report covers studies on the mechanism of building distortion and its correlation to the vertical orbit drift.

Building distortion was evaluated both by employing a model simulation based on the finite element method and by directly measuring the displacement of the ring floor with a hydrostatic leveling system (HLS).

Vertical orbit drift was then calculated by using both simulated and measured floor displacements along the ring and compared with the orbit drift actually measured with beam position monitors (BPM). The comparison was made both before and after the roof was insulated to reduce the thermal stress from the solar irradiation.

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II. EVALUATION OF FLOOR DISPLACEMENT

Figure 1 shows a plan view of the Light Source Building having two stories above and one below the ground to enclose an elliptical storage ring of which minor axis points almost the north. Location of some quadrupole magnets (quads) are shown as Q042-Q241.

To understand the mechanism of the floor displacement, a model simulation study was carried out assuming the building as a simple ellipse although the real building has an injection line. It was shown that the simulation produced about the order of floor displacements which would give the same amount of orbit drift as that observed with BPM. However, the shape of the observed orbit distortion could not be predicted well from the simulation results. This led us to actually measure the floor displacement and to see if such orbit drift can be obtained from the measured floor displacements. The floor displacement was measured at the location of quadrupole magnets.

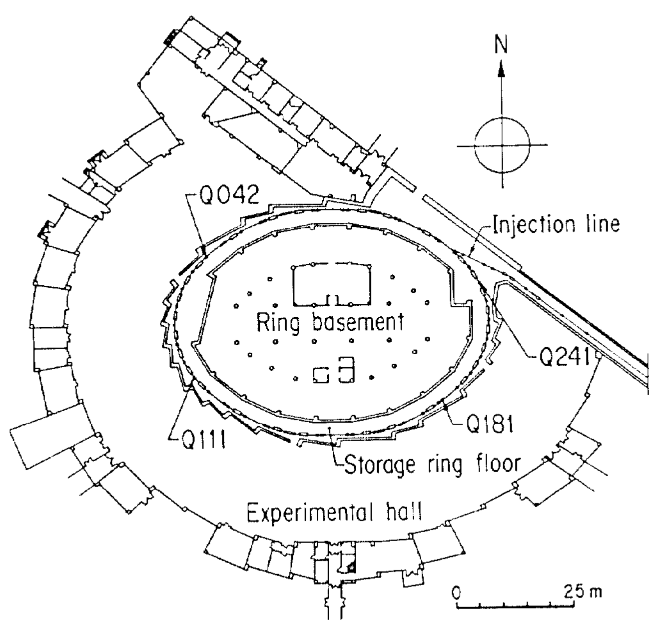

Fig. 1 Plan view of the Light Source Building.

A. Model simulation

The model structure used for the simulation analysis is shown in Fig. 2. The whole building shape was made elliptic with no injection region. Structural elements used in the modeling are the walls, columns, beams and piles of the real building. Symmetry of the ellipse is partially broken because the sizes and numbers of elements are different between the opposite ends of the major axis of the ellipse. The axis lies almost along the east-west direction. Simulated results are available on the mesh points.

The simulation program was supplied with data of temperatures measured both on the roof and in the surrounding atmosphere as a thermal stress loading. The building distortion was simulated both before and after insulation. The floor displacement was expressed as a relative value by choosing the mesh point at Q181 as reference. Simulation results are expressed both in the floor displacement versus time of day for each quad location and in the floor displacement versus distance along the ring for every hour of day.

In the top of Fig. 3, the simulated relative floor displacement along the ring is shown by a dotted line for the time of day at 15:00 before insulation. It is fundamentally symmetric but slightly different for its peak value at north and south points along the ring as the sun shines southerly. The west and east points differ because of the difference in column and wall strengths between them.

In the bottom of Fig. 3, the simulated floor displacement after insulation is shown by a dotted line. The difference in peaks between north and south or between east and west originates from the same cause as before insulation although the peak heights were greatly reduced compared to those before insulation.

B. Measurement of floor displacement

The displacement of the storage ring floor was measured by using a hydrostatic leveling system so designed to work as a water level of the size of the storage ring. Before a full-size leveling system was actually installed in the storage ring tunnel, the characteristics of this scheme was tested using a prototype system of three water tanks connected in series with water pipes.[2,3] The full-size system was composed of twelve tanks, each of which was located at the foot of a quad. Each tank has about 5 μm of measuring error.

As detailed description of the system was already reported,[2,3] only the results of the floor displacement measured with the system are given in Fig. 3 to be compared with the simulated results.

C. Comparison of simulation and measurement

Before insulation, both simulation and measurement of relative floor displacement agreed quite well in both magnitude and phase along the ring, except near the injection region. The reason for the exception can naturally be understood as the injection region was not included in the simulation model.

After insulation, both simulation and measurement gave about 1/3 of the floor displacement obtained before insulation and agreed with each other within the measuring limit of the HLS system. This proved that simulation can describe well the general tendency of the building distortion.

III. EVALUATION OF ORBIT DRIFT

Orbit drift was calculated by using the data of the floor displacement either simulated from the model or measured with the HLS, and compared with that measured with beam position monitors along the ring.

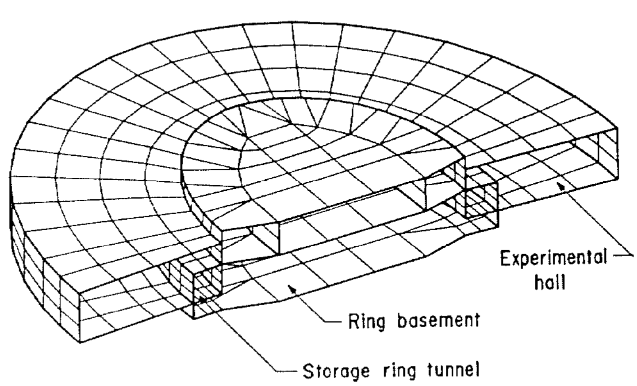

Fig. 2 Simulation model for the structure analysis.

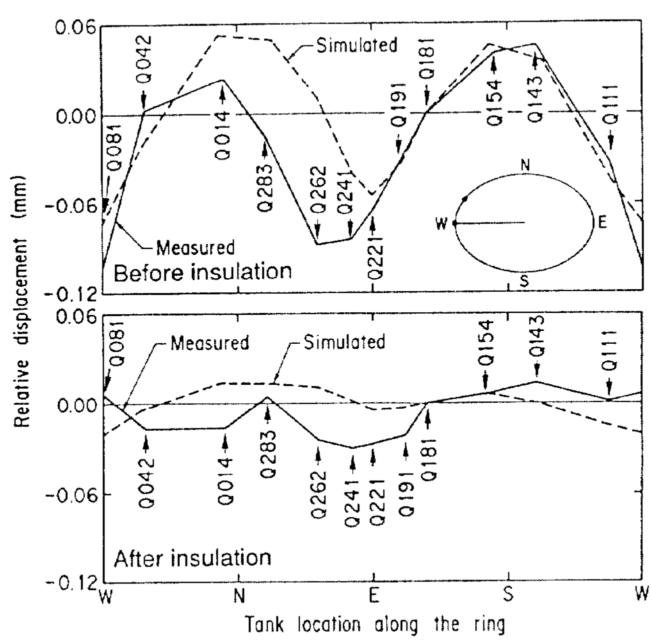

Fig. 3 Relative floor displacements both simulated and measured along the ring at 15:00 of one day before and after insulation.

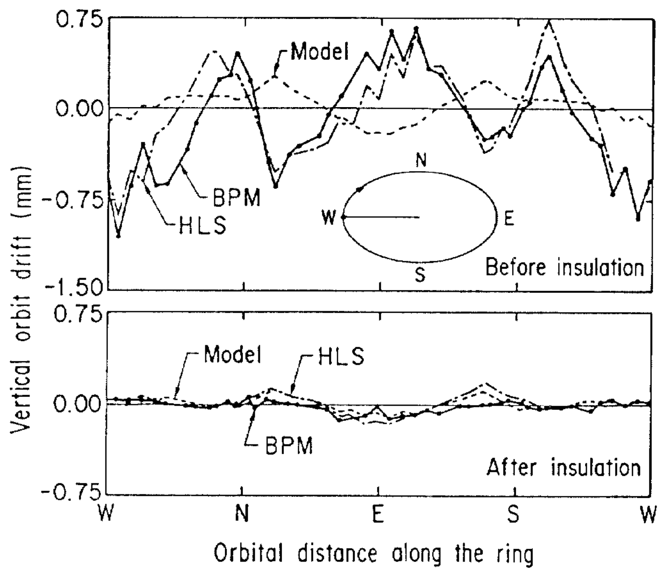

Fig. 4 Orbit drift measured with BPMs, calculated from the HLS measurement and model simulation.

A. Calculation and measurement of orbit drift.

Figure 4 shows the orbit drift calculated from the model simulation by a dotted line and that from the HLS measurement by a broken line. The amount of diurnal floor displacement was first obtained as a difference between floor levels measured at 6:00 and 16:00 and then given to the orbit calculation program.

The orbit drift directly measured with BPMs is also shown by a solid line with circles indicating where BPMs are located along the ring. The BPM system has about 7 μm rms of error for each BPM and the curve shown here is a difference between two COD data taken at 6:00 and 16:00. The error in the difference accordingly becomes about 10 μm.

B. Comparison of the three kinds of evaluation

Before insulation, both BPM and HLS results are in good agreement within the measurement errors. The results from the model simulation, however, do not agree with those from BPM and HLS; neither in magnitude nor in phase along the ring.

After insulation, all three results became close each other within the measurement errors. The orbit drift was reduced to 1/6 of that before insulation.

IV. DISCUSSIONS

The comparison made above shows that the building distortion was mainly responsible for the diurnal drift of the closed orbit.

Before insulation, the simple modeling expressed well the gross feature of the building distortion. The model suited well to express the magnitude but not the phase of the floor displacement because of the existence of the injection line. The roof behaved just as one single piece of an elliptical plate when irradiated by the sun and was the major factor of the floor displacement. The building was thus distorted quadratically with mode 2 along the ring, having peaks either at north and south or at west and east depending on what time of day it was observed. However, the vertical tune of the storage ring is close to 3 and the orbit calculation picks up selectively the component of mode 3. The orbit drift calculated from the results of the model therefore became smaller compared to that calculated from the HLS data.

After insulation, on the other hand, the major factor of distortion was shifted from the roof to other part of building such as walls and columns and induced more of other modes than only mode 2. This may be the reason why the measured orbit and the orbit calculated using either simulation or measurement of floor displacement became close each other.

V. SUMMARY

Diurnal drifting of the vertical closed orbit in the storage ring was quantitatively investigated by using a model simulation of the building distorted under climatic thermal stress and by employing a hydrostatic leveling system to measure the displacement of the storage ring floor. It was proved that building distortion was largely responsible for the diurnal orbit drift. After the building was insulated on the roof, the orbit drift was reduced to about 1/6 of that before insulation.

The model simulation proved to be a useful tool to analyze the building distortion in high precision and will be confidently used for designing a storage ring building. The orbit drift calculated from the HLS results of the vertical floor displacement was consistent with that calculated from the BPM results both before and after insulation. This report has dealt with the vertical floor displacement. The horizontal displacement is also of our current concern.

VI. ACKNOWLEDGMENTS

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VII. REFERENCES

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