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VIBRATION MONITORING AT TPS STORAGE RING*

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Abstract

In order to locate irregular vibrations caused by the installation of new equipment or malfunctioning of the machine, a vibration monitoring system was developed for the storage ring. Totally, 72 accelerometers and 10 velocity sensors were used to detect girder and ground vibrations, respectively. Continuous long-time observation results will be presented.

INTRODUCTION

For the low-emittance, high-brightness and high-stability Taiwan Photon Source (TPS), vibration issues have been studied. Before the TPS was constructed, D.J. Wang had recorded ground vibrations in 2006 at different locations across the NSRRC [1]. These measurements show that transverse vibrations were sometimes large than vertical vibrations for displacements at frequencies above 1.12 Hz but were almost the same above 3.5 Hz. However, we assume, that after more than ten years the situation is different now with significantly different environment. In recent years, the addition of vibration sources like the utility system, may have changed the vibration characteristic for the TPS. Since the utility equipment such as pumps, cooling water systems and air handling units (AHU) need to operate continuously over years, higher vibrations may get introduced when one component fails. In order to locate irregular additional vibrations caused by the installation of new equipment or the malfunction of the machine at the earliest time, we developed a vibration monitoring system to monitor the vibration status comprehensively and continuously.

Long-term girder and ground vibrations of the TPS storage ring were performed with the vibration monitoring system and we present in this paper observations of the vibration levels at various locations and variation of those vibrations with respect to day and night, work day and holiday.

EQUIPMENT AND METHODOLOGY

The TPS storage ring has a circumference of 518.4m composed of 24 Double-Bend Achromat lattice cells. Each TPS SR cell is composed of three magnet girders and the layout of 24 cells (R01～R24) of the TPS SR is shown in Fig.1. Accelerometers (PCB 393B31) were mounted on the first girder (G1) of each cell sensitive in three directions X, Y and Z, where X, Y and Z are the horizontal, vertical and longitudinal coordinates as shown in Fig.2. Tri-axial velocity sensors (Walesch MST-1031) were installed on the ground between G1 and G2 of each cell. However, there are only 10 velocity sensors installed in R01, R03, R05, R07, R09, R11, R13, R15, R17, and R21 due to the limited availability of equipment. Totally, 72 accelerometers and 10 velocity sensors were used to measure the vibration of girders and ground of the TPS storage ring, respectively. The sensors installed evenly in 24 cells of the TPS storage ring are connected to the corresponding DAQ devices (NI PXI-4496) which are installed in a PXI chassis in 24 control and instrument areas (CIA) on the second floor.

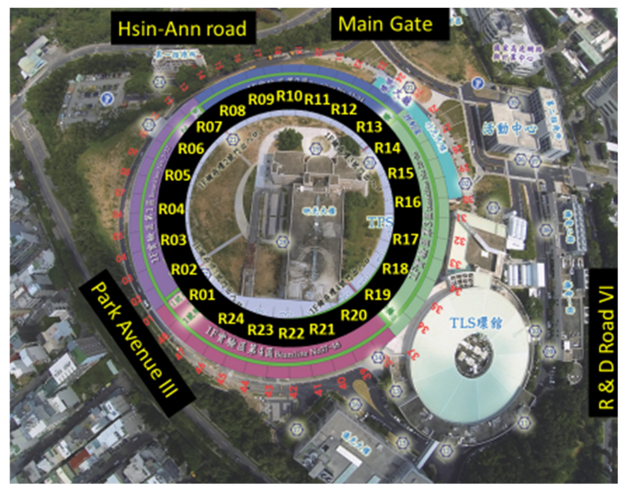

Figure 1: Layout of the 24 cells TPS storage ring on the NSRRC campus.

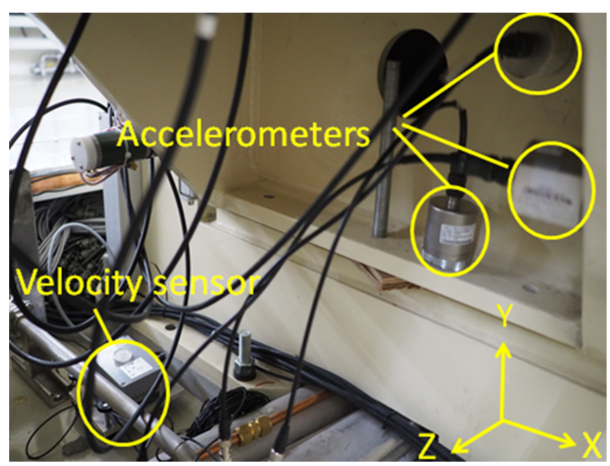

Figure 2: Vibration sensors are installed on the ground and girder of each TPS SR cell.

The Vibration signals were recorded, processed and analysed by a LabVIEW program with a sampling rate of 256Hz. We took 2048 data points for an FFT analysis to get the power spectrum density (PSD) [2]. The acceleration PSD and velocity PSD measured by accelerometers and velocity sensors are converted into displacement PSD by integration [3].

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In this article, we calculate the root-mean-square (rms) displacement from the PSD from 1 Hz to 100 Hz and from 4 Hz to 100 Hz [4]. To determine the storage ring cell in which the abnormal high vibration occurs, the displacement values of 24 cells in X, Y, Z are plotted in a bar chart [5] where a very high displacement is coloured as a red bar as shown in Fig.3.

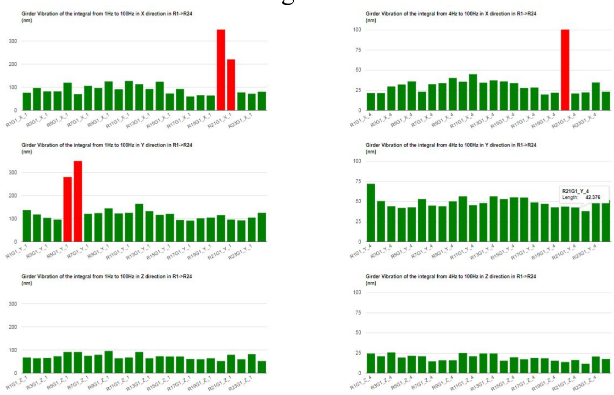

Figure 3: Integrated girders displacement of 24 cells in X, Y and Z.

For long-term observations, the historical integrated ground and girder displacement values [6] are shown in Fig.4. However, vibration spectra were not recorded due to limited hard disk space. The configuration of the vibration monitoring system is shown in Fig.5.

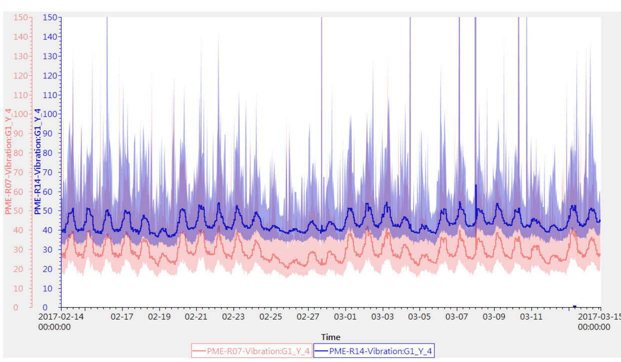

Figure 4: Monthly vertical displacement data (4-100Hz) of the girder in R07 and R14 in the CSS browser.

For further statistical analysis, we downloaded one month of the integrated displacement values from the CSS database collected during February 14th to March 14th, 2017. In order to compare the vibration levels between day and night, we separate a day into daytime and nighttime. Daytime is defined from 8:00 A.M. to 5:00 P.M. Nighttime is defined from 0:00 A.M. to 8:00 A.M. and from 5:00 P.M. to 0:00 A.M. The data were classified and the statistics were obtained with the Scilab program. Differences between vibration displacements and their mean value being more than 140 nm for frequencies above one Hz and being more than 35 nm above four Hz were filtered out, thus eliminating extreme values which may influence the mean value.

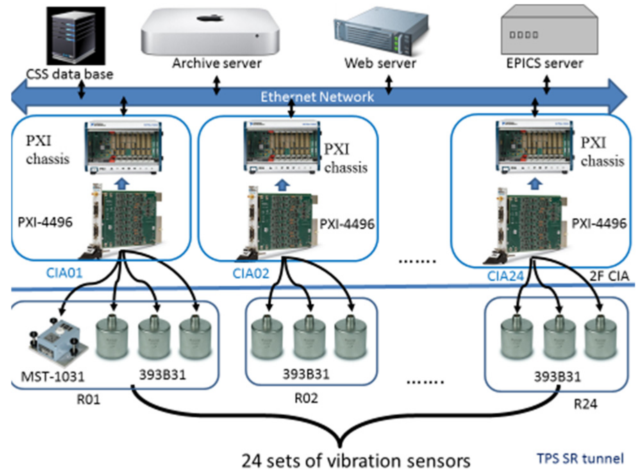

Figure 5: Configuration of the vibration monitoring system.

MEASUREMENT RESULTS

Vibration at Different Location of TPS SR

The integrated displacement observed at different locations of the TPS SR was individually averaged from February 14th to March 14th and the averaged values are plotted as a line chart as shown in Fig.6. We can find all the vertical vibrations measured at R05~R13 were higher than 130 nm above one Hz during daytime. By inference, the locations from R05 to R13 with higher vibrations were near the heavy traffic Hsin-Ann road during rush hours. The vertical vibrations of R14 were higher than 40 nm above four Hz during daytime. One of the sources we speculate is related to the nearby AHU, and the related research is still in progress.

Vibration with Respect to Time

For legibility, the individual vibrations measured for the ground and girders at R01~R24 are averaged to be one data in one direction. The daily integrated RMS displacement of that with respect to day and night in X, Y and Z directions are plotted from February 14th to March 14th in Fig. 7. In addition, the holidays are coloured red; the work days are coloured blue; the make-up workday (February 18th) is coloured green.

As a further simplification, the average monthly integrated displacement of ground and girder in the X, Y, and Z directions during day and night are shown in Table 1 and Table 2.

The measurement results are summarized as following:

- The girder vibrations are a little higher than that of the ground in all directions and the amplification is about 1.01~1.17.
- The vibration of both ground and girders in the vertical direction is much higher than that in the horizontal and longitudinal direction; the vibration in the horizontal direction is a little higher than that in the longitudinal direction.

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- The mean value of vibration during daytime is 7~14 nm higher than that at nighttime above one Hz and 1~5 nm higher than that during nighttime above four Hz.
- The mean value of vertical vibrations measured during a work day was about 40 nm during daytime. On the other hand, the mean value measured on a holiday was about 30 nm during daytime.

Table 1: Average Monthly Displacement of TPS SR (1-100 Hz)

Ground	**X**	**Y**	**Z**
Day	92.8	114.1	92.8
Night	83.9	100.5	85.1
Girder	**X**	**Y**	**Z**
Day	106.9	125.5	104.1
Night	98.5	113.0	96.6
			(unit: nm)

Table 2: Average Monthly Displacement of TPS SR (4-100 Hz)

Ground	**X**	**Y**	**Z**
Day	20.2	36.2	16.8
Night	17.3	31.8	15.1
Girder	**X**	**Y**	**Z**
Day	22.9	37.3	17.2
Night	20.1	33.3	15.2
			(unit: nm)

CURRENT STATUS

The vibration monitoring system of TPS storage ring was developed. Moreover, the long-time continuously and overall measurement results were presented. Although the system was not in service due to the incompatibility of the PXI vibration module in Linux OS, the historical measured data of this system will also be useful references.

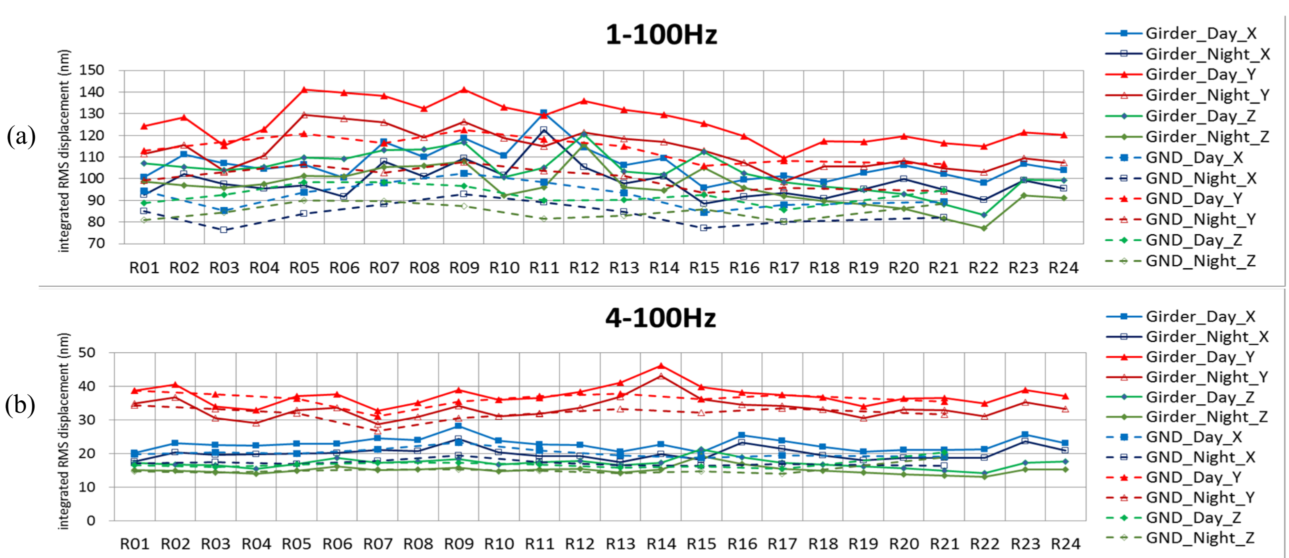

Figure 6: Integrated displacement of ground and girder in TPS SR R01~R24 in X, Y, Z (a) 1-100 Hz. (b) 4-100 Hz.

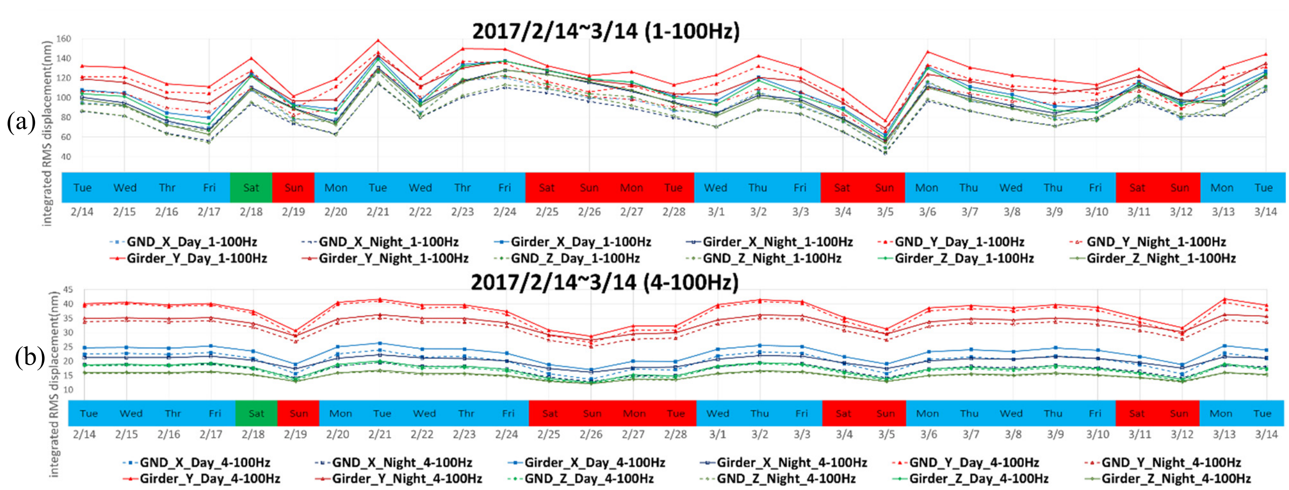

Figure 7: Averaged daily integrated displacement of TPS SR ground and girder from 2/14 ~ 3/14 (a) 1-100 Hz, (b) 4-100 Hz.

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