

THE DATA ACQUISITION SYSTEM ON VIBRATION EVALUATION AND PREDICTIVE MAINTENANCE FOR COOLING WATER PUMPS SYSTEM IN TPS*

Yung-Hui Liu[†], Yen-Ching Chung,
National Synchrotron Radiation Research Center, Hsinchu, Taiwan

Abstract

This paper evaluates the vibration condition of the cooling water pump system at the Taiwan Photon Source (TPS). The utility systems have been operating continuously since TPS commenced operations in 2014. Predictive maintenance based on vibration levels and spectrum analysis has become increasingly important, particularly for water pump systems that must run without interruption. A vibration monitoring system was initially implemented in 2017 and subsequently upgraded in 2023. Through vibration testing conducted over several months and years, issues such as component abrasion and misalignment were identified in the cooling water pumps. The recorded data revealed irregular increases in vibration levels, exceeding the ISO 10816 standard. Spectrum analysis provided detailed insight into the condition of the pump systems. Based on these evaluations, necessary repairs and maintenance were carried out. Regular vibration inspections and daily data acquisition enabled the utility systems to prevent malfunctions for periods exceeding one month. The data acquisition system for vibration analysis allowed sufficient lead time for predictive maintenance, helping to prevent unexpected shutdowns.

INTRODUCTION

The utility systems at the TPS have been operating continuously for several years. Key rotating machinery—including motors, pumps, chillers, and air handling units (AHUs)—must run without interruption to ensure the stable operation of the synchrotron accelerator. As such, vibration inspection has become a critical component of the facility's preventive maintenance strategy [1]. In 2004, Argonne National Laboratory (ANL) conducted studies on mechanical vibration control systems and defined specifications for rotating machinery in accelerator facilities [2]. Later, in 2007, Taiwan Light Source (TLS) investigated water-induced vibrations and vibration propagation through piping systems [3]. The ISO 10816 standard, which was developed for in-situ vibration measurements, provides guidelines for evaluating industrial machinery with power ratings above 15 kW and rotational speeds between 120 and 15,000 rpm [4].

Based on operational experience at TLS, the same vibration amplitude criteria and spectrum characteristics were applied to TPS utility systems. Initial measurements revealed that deionized water (DIW) pump systems exhibited higher vibration amplitudes, often exceeding ISO

10816 thresholds [5]. A rapid increase in vibration levels over a short period indicated mechanical failure in the CU DIW system. This issue was traced to a broken inertial pad, which was subsequently replaced with a more robust one. Continuous vibration monitoring enabled early detection—more than a month before failure occurred—allowing for timely maintenance [6]. In 2017, the cooling water pump system exhibited vibration velocities exceeding 7.2 mm/s. As a result, the motor and pump were disassembled, the bearings were replaced and realignment was performed [7]. To ensure accurate diagnosis and analysis, ISO 18436-2 Category II outlines the training, experience, and examination requirements for personnel conducting condition monitoring using vibration analysis [8].

DATA ACQUISITION SYSTEM

The original Phoenix GM3 data acquisition system for the TPS water pump system, developed by Prowave Engineering Corporation, was upgraded to the Phoenix GM4 model in 2023. The system utilizes an 80-channel signal acquisition unit, powered by the PW 747 DAQ module. It offers a bandwidth of 20 kHz and a sampling rate of 51.2 kS/s, with a 24-bit resolution. Data transmission is carried out via Ethernet.

The vibration monitoring system was implemented on various subsystems, including the deionized water pumps, the first and second-stage ice water pumps, the heat pump and chiller, as well as the hot and cold water pump systems. Vibration sensors were mounted in the horizontal direction on the motor side and at a 45-degree angle in the vertical direction on the pump side, as illustrated in Fig. 1 for the cooling water pump configuration. All 80 channels of data are transmitted to a PC server, where the original vibration acceleration waveforms are stored as raw data for further analysis.

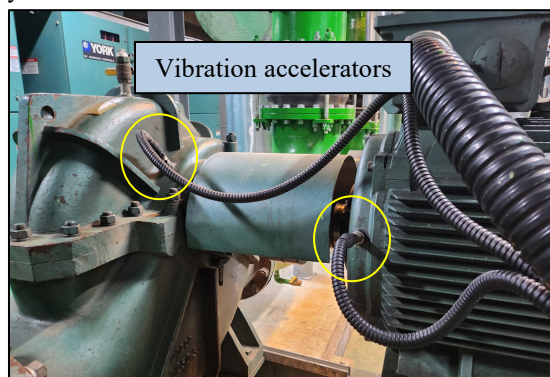


Figure 1: Sensor mounting locations on the motor and pump sides of the CWP-1 cooling water pump system.

* Work supported by National Synchrotron Radiation Research Center

† iris@nsrc.org.tw

INTERNATIONAL VIBRATION STANDARDS - ISO 10816

The ISO 10816 vibration standard, initially released in 1995 and revised in 2009, provides guidelines for evaluating vibration severity in situ for industrial machinery with power ratings above 15 kW and rotational speeds between 120 and 1,500 rpm. For machines operating above 600 rpm, the applicable vibration measurement frequency range is 10 to 1,000 Hz.

The cooling water pump systems at TPS operate at a full power output of 110 kW, with a maximum rotational speed of 1,750 rpm and a flow rate of 954.5 m³/h. The motor provides a lift head of 29 meters to supply cooling water to the cooling tower. The pump systems are installed on flexible foundations with damping spring supports to reduce vibration transmission.

According to ISO 10816, if the vibration velocity amplitude measured at any non-rotating point exceeds 11.2 mm/s (r.m.s.), it indicates potential damage to the system. Vibration levels in the range of 7.1 to 11.2 mm/s should be considered a warning zone, and long-term operation under these conditions is not recommended.

VCAT-II INTERMEDIATE VIBRATION ANALYST ISO 18436-2 CATEGORY II

ISO 18436-2 Category II defines the training, relevant experience, and examination requirements for personnel involved in condition monitoring and machine diagnostics using vibration analysis (VA). Certification or a declaration of conformity to ISO 18436-2:2014, in accordance with ISO 18436-1, serves as formal recognition that an individual is qualified to perform vibration measurements and analysis for machinery condition monitoring and diagnostics using various types of vibration measurement equipment.

The author obtained VCAT-II certification in 2023 and applied the corresponding methodologies to analyze vibration spectra, thereby assessing and verifying the operational condition of the system.

VIBRATION MEASUREMENT RESULTS

The Phoenix GM4 data acquisition system continuously recorded raw vibration data on a daily basis and enabled frequency spectrum analysis. This system effectively tracked vibration trends and variations at specific measurement points. Depending on operational requirements, both acceleration and velocity data across different frequency bands were recorded. There are four cooling water pump (CWP) systems at TPS responsible for supplying cooling water to the cooling tower. At any given time, two of the four units were switched to operate.

CWP-1 Cooling Water Pump System

The first cooling water pump system (CWP-1) provides cooling water to the cooling tower. For past several years, its operating frequency was fixed at 50 Hz, consistent with the electrical supply frequency. Despite multiple mainte-

nance and repair efforts, the vibration level consistently exceeded 15 mm/s. According to ISO 10816-3, this level indicates potential mechanical damage and unsuitability for continuous operation. Further spectrum analysis revealed that the dominant vibration component occurred at the 1X frequency, suggesting unbalance. As outlined in ISO 18436-2 Category II, such unbalance could be attributed to factors including mass imbalance or structural looseness.

Figure 2 presents vibration data for CWP-1 over the past year. When the operating frequency was increased from 50 Hz to 55 Hz, the vibration level significantly decreased—from over 15 mm/s to below 6.0 mm/s. Conversely, reverting the frequency back to 50 Hz caused the vibration level to rise again. In both cases, the 1X frequency remained the dominant component in the vibration spectrum, indicating a resonant condition near 50 Hz. For a four-pole motor, this corresponds to a mechanical resonance around 25 Hz.

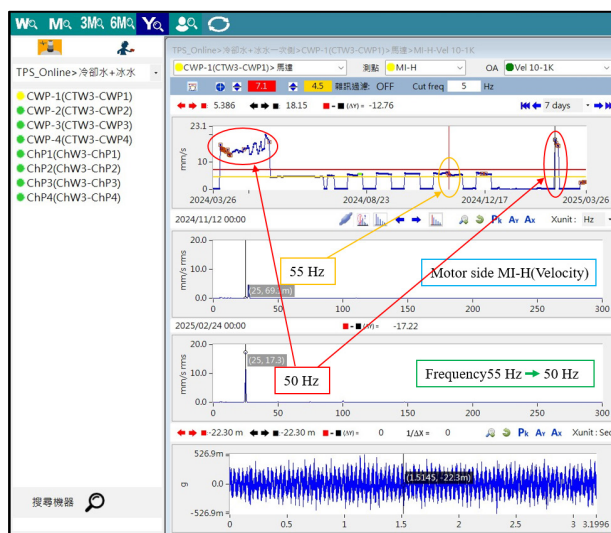


Figure 2: Vibration data of the CWP-1 system over the past year, measured in the horizontal direction on the motor side.

Improvement Resonance for CWP-1

Spectrum analysis revealed that resonance in the CWP-1 system significantly contributed to elevated vibration levels, affecting the overall system performance. Prolonged high-level vibrations can reduce the lifespan of the bearings on both the pump and motor sides. In addition, long-term operation under resonant conditions compromises the structural stability of the entire system. To address this issue, the primary improvement strategy focused on reinforcing the structure and shifting the system's natural frequency away from the excitation frequency (i.e., increasing the resonance frequency).

Figure 3 illustrates the structural reinforcements implemented for the CWP-1 system. The cooling water pump is mounted on a T-shaped concrete foundation, which contains several structurally weak points—particularly between the motor and pump sides, as well as between the inlet and outlet pipelines. To enhance structural integrity

and vibration isolation, several pieces of high-stiffness rubber were inserted between the foundation and the ground. These rubber elements were strategically positioned: on both sides of the vibration-damping springs, in the central section of the base, and along its edges. The addition of these rubber elements not only reduces vibration transmission to the ground but also reinforces the overall stiffness of the foundation, thereby shifting the resonance frequency and mitigating the adverse effects of resonance.



Figure 3: Strengthened structure of the CWP-1 system, with hard rubber installed between the concrete basement and the ground.

Improvement Results for CWP-1

Figure 4 presents the results following the structural reinforcement of the CWP-1 system. After implementing the improvements, the vibration level at 50 Hz operation was significantly reduced—from 17.3 mm/s to 2.6 mm/s. This indicates a substantial decrease in the 1X frequency component, which had previously dominated the vibration spectrum. Even when the system operates near the resonance frequency (approximately 25 Hz), the overall vibration level remains below 4.5 mm/s. This falls well within the acceptable range defined by ISO 10816-3, indicating that the system now operates safely and reliably across various operating frequencies. The current vibration performance demonstrates that the CWP-1 system has reached a

stable operational condition, with resonance effects effectively mitigated through structural enhancement.

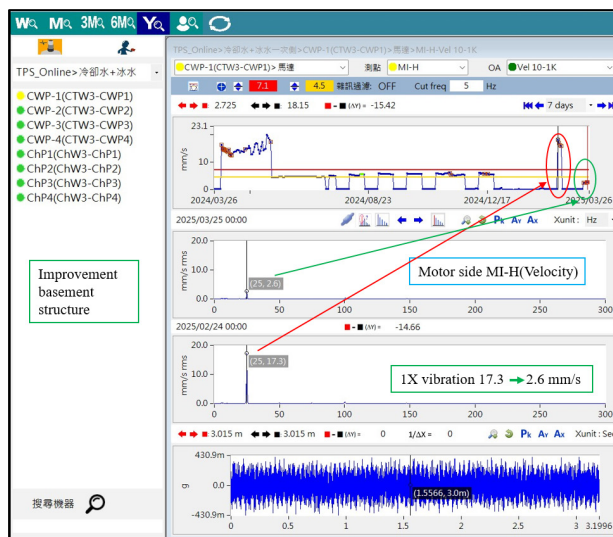


Figure 4: Vibration improvement results for the CWP-1 system after structural reinforcement.

CONCLUSIONS AND DISCUSSIONS

The vibration monitoring and inspection system for the cooling water pump systems has been in operation for several years. Long-term observations indicate that operating frequency significantly influences both vibration levels and spectral characteristics. The measurement results provide critical insights into the condition of the system, allowing operators to determine whether the equipment is functioning properly. Furthermore, the system offers sufficient lead time for predictive maintenance, enabling proactive intervention before failures occur. Although notable improvements have been achieved—particularly for the CWP-1 system—some issues persist in the ice water pumps and other deionized and cooling water pump systems. Overall, the integration of regular vibration inspections and daily data acquisition plays a key role in maintaining system stability and preventing unexpected malfunctions in the utility systems.

REFERENCES

- [1] J. P. Den Hartog, *Mechanical Vibrations*, Dover Publications, 1985.
- [2] W. Zander, "Mechanical Vibration Controls," Sec. 15071, Department of Energy, Argonne National Laboratory, Argonne, Illinois, 2004.
- [3] Y. H. Liu *et al.*, "Vibration Evaluation for Utility Instruments and Water Piping System in TLS," in *Proc. APAC'07*, Indore, India, Jan.-Feb. 2007, paper THPMA093, pp. 776-778.
- [4] ISO 20816-3:2022, *Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 3*, International Organization for Standardization, 2022.
- [5] Y. H. Liu *et al.*, "Vibration Evaluation for Deionized Water Pumps in TPS," in *Proc. IPAC'16*, Busan, Korea, May 2016, pp. 3731-3733.

doi:10.18429/JACoW-IPAC2016-THPMY033

- [6] Y. H. Liu *et al.*, "The Data Acquisition System and Inspection Equipment on Vibration Evaluation for Deionized and Cooling Water Pumps in TPS," in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 3568-3570.
[doi:10.18429/JACoW-IPAC2017-WEPVA128](https://doi.org/10.18429/JACoW-IPAC2017-WEPVA128)
- [7] Y. H. Liu *et al.*, "The Data Acquisition on Vibration Evaluation for Ice Water Pump Systems in TPS," in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 3757-3759.
[doi:10.18429/JACoW-IPAC2018-THPAL051](https://doi.org/10.18429/JACoW-IPAC2018-THPAL051)
- [8] ISO 18436-2:2014, *Condition Monitoring and Diagnostics of Machines – Requirements for Qualification and Assessment of Personnel – Part 2: Vibration Condition Monitoring and Diagnostics*, International Organization for Standardization, 2014.