ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-MOPTY028

INTRODUCTION TO BINP HLS TO MEASURE VERTICAL CHANGES ON PAL-XFEL BUILDINGS AND GROUND*

Hyojin Choi†, Kwang Won Seo, Kyehwan Gil, Seung Hwan Kim, Heung-Sik Kang
Department of Accelerator, PAL-XFEL, Pohang, Korea

Abstract

PAL-XFEL is being installed and will be completed by December of 2015 so that users can be supported beginning in 2016. PAL-XFEL equipment should continuously maintain the bunch beam parameter. To this end, PAL-XFEL equipment has to be kept precisely aligned. As a part of the process for installing PAL-XFEL, a surface geodetic network and the installation of a tunnel measurement network inside buildings is in preparation; additionally, the fiducialization of major equipment is underway. After PAL-XFEL equipment is optimized and aligned, if the ground and buildings go through vertical changes during operation, misalignment of equipment's will cause errors in the electron beam trajectory, which will lead to changes to the beam parameter. For continuous and systemic measurement of vertical changes in buildings and to monitor ground subsidence (sinks) and uplift, the BINP Ultrasonic-type Hydrostatic Levelling System (HLS) is to be installed and operated in all sections of PAL-XFEL for linear accelerator, undulator and beam line. This study will introduce the operation principle, design concept and advantages (self-calibration) of BINP ULS Sensor, and will outline its installation plan and operation plan.

INTRODUCTION

During the construction of the Egypt Pyramids between 2600 and 2480 B.C., water was poured into an animal's gut in order to measure the hydrostatic level and strings were used to measure the wire position in the survey and alignment process. The Hydrostatic Levelling System (HLS) and Wire Position System (WPS) are still in use to format the horizontal axis in construction. The position of an object was measured by the human eye in the past, but these days it is measured by an electrical sensor and the data are analysed by computer - thanks to the advances in electronic equipment [1]. Recent advances in laser technology have made surveying an area of several tens of μm possible by using laser tracker [2]. But in cases where changes of the horizontal axis are measured continuously long-time, HLS and WPS, which are more precision (<1μm) then laser tracker, should be used.

HISTORY OF HLS USED ON THE ACCELERATOR

The HLS was developed by the Alignment and Geodesy (ALGE) group at the European Synchrotron Radiation Facility (ESRF) for long term monitoring and control of rapid realignment of the Storage Ring machine. The concept of the non-contact capacitive sensor developed at the ESRF for the monitoring of level differences in the ESRF storage ring has been considerably improved upon by the company FOGALE-Nanotech. ESRF announced the results of twelve years of experience in HLS operation and measurement [3]. Various types of HLS Sensors, including capacitive and ultrasonic sensors, have been developed and used. European Council for Nuclear Research (CERN) announced the results of the comprehensive testing of HLS Sensor and WPS Sensor in many forms [4]. The status and useful information about HLS and WPS used by many research institutes around the world is available at CLIC Pre-Alignment Workshop and International Workshop on Accelerator Alignment (IWAA).

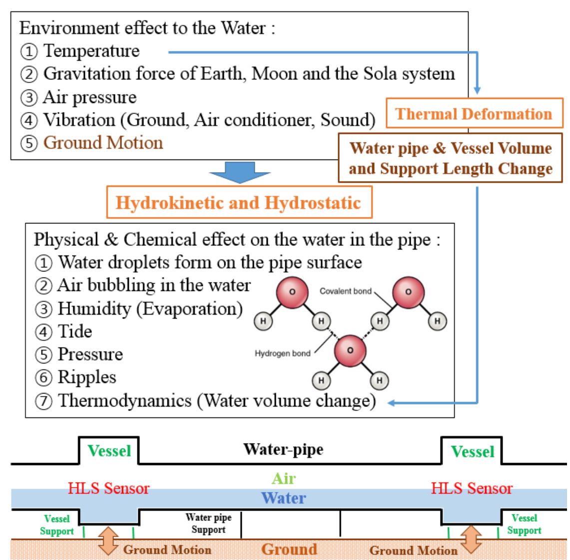

Figure 1: The surrounding environment influencing HLS.

HLS REFERENCE: WATER PIPE

The most important thing about HLS is the water pipe which provides the measurement reference. As shown in Figure 1, water within the water pipe should have good fluidity even with changes in the surrounding environment such as changes in temperature and pressure in order to maintain the constant level of water in the water pipe. It's the only way to calculate the floor deformation accurately using the measurement of all HLS Vessel floors. In terms of the fluid behaviour, after investigating studies about the way of calculating the water pipe diameter which is most appropriate for the length of full-filled and half-filled water pipes and the consequential stabilization time of water oscillation, the

*Work supported by Ministry of the Science, ICT and Future Planning
†choihyo@postech.ac.kr

ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-MOPTY028

half-filled water pipe was found to be measured accurately [5,6]. Some studies even show a comparison between the thermal deformation of the material of the water pipe according to changes in temperature and changes in water volume [7]. To minimize the effects of thermal deformation, the length of the HLS sensor support should be shortened. The large-diameter PAL-XFEL should be used in order to provide the smooth flow and consistent level of water in the water pipe as shown in Figure 2.

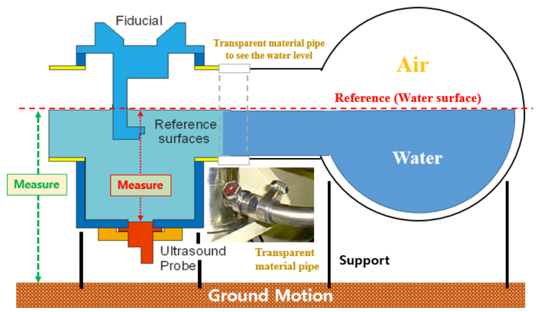

Figure 2: Half-filled water pipe.

HLS DATA MEASUREMENT AND ANALYSIS

To detect any errors generated in the installation process of HLS equipment ($\Delta H_{install}$) and resulting differences in floor height (ΔH_{floor}), the absolute height of all HLS installed by laser tracker should be measured and all measurements of HLS sensor should be calibrated in a HLS data acquisition computer as shown in Figure 3. Such a measurement of absolute values should be performed once or twice a year because it takes long time.

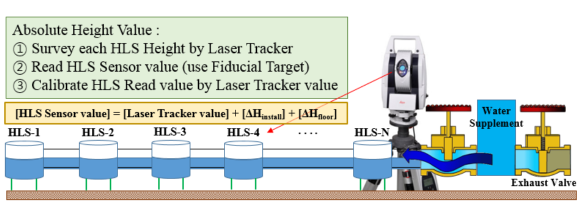

Figure 3: HLS absolute calibration.

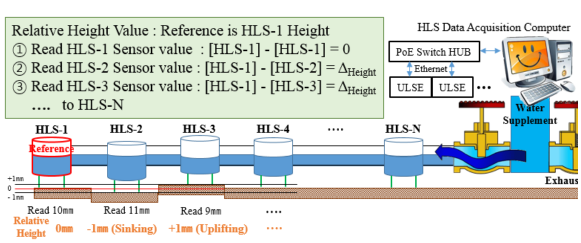

Figure 4: HLS relative measurement (methods for routine measurement and displaying values).

After the calibration of all HLS errors through absolute value measurement, all HLS measurements should be expressed in relative values based on a reference HLS measurement value as shown in Figure 4. The level of water in the water pipe continually changes due to changes in the surrounding environment and the HLS reference measurement also changes due to ground motion. Changes in the ground motion of the reference HLS measurement should be measured once or twice a monthly by the laser tracker and calibrated by HLS data acquisition computer.

HLS measurements include information such as ground level and various noise components affected by the environment (refer to Figure 1). The accurate ground change can be understood when the various noise components are reduced by analysis program. Figure 5 shows an example of long term measurements of the SPring-8 and the results of decomposition by the computer program, BAYTAP-G (Bayesian Tidal Analysis Program). This program is a method for tidal analysis proposed by Ishiguro based on the concept of Bayesian statistical modelling, Akaike's Bayesian Information Criterion (ABIC). BAYTAP-G decomposes the input data into (a) a tidal part, (b) a temperature part, (c) an irregular part, (d) a drift part under the assumption that the drift is smooth. The analysis model is obtained by maximizing the posterior distribution of the parameters. For the given data ABIC is used to select the optimum values of the hyper-parameters of the prior distribution and combination of parameters [6,8].

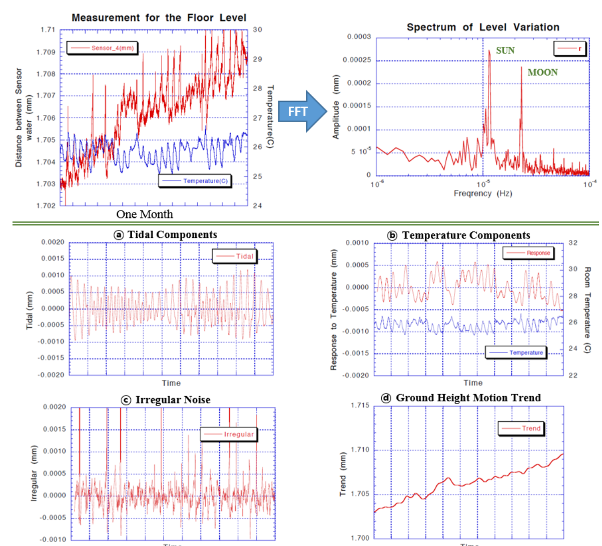

Figure 5: BAYTAP-G Analysis of SPring-8.

BINP HLS ULTRA SONIC (ULS) SENSOR

In the United States at 1914, R.A. Fessenden developed a moving coil transducer and succeeded in detecting an iceberg a mile away. After Paul Langevin succeeded in detecting a submarine 1500m away using the vacuum tube amplifier in France at 1918, Sound Navigation and Ranging (SONAR) began to be used widely. Aided by increased understanding of the characteristics of sound wave medium and development of sensor and electronics during two world wars, it is widely used for medical ultrasound testing and non-destructive testing.

Deutsches Elektronen Synchrotron (DESY) conducted In-situ experiments to develop the Ultrasound sensor for

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HLS in 2001 and the basic design concept of Ultrasound sensor for HLS was built based on the result of the experiments [9]. The structure of ultrasonic pulse hydrostatic level sensor developed by Budker Institute of Nuclear Physics (BINP) is described in Figure 6. The sound reflector made of invar metal that has a low thermal deformation acts as an absolute ruler at an interval of 7.5mm and self-calibrates the differences of water density due to the changes in temperature (sound speed) and electrical properties of the transducer. The composition and operating principles of ULS Electronics developed by BINP and its results of field tests are described in more detail in related papers [10-12].

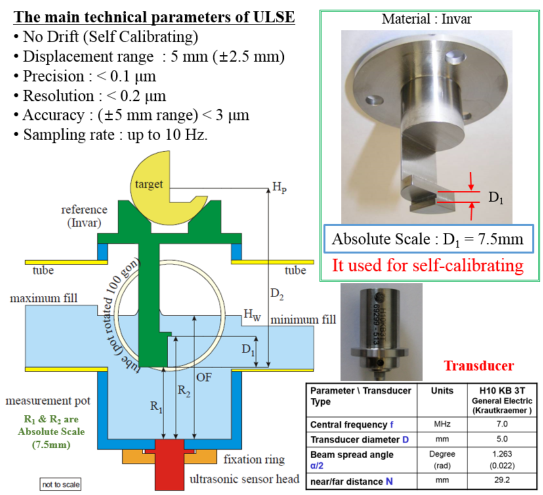

Figure 6: BINP Ultra sonic (ULS) sensor.

BINP HLS TEST ON PAL-XFEL

Figure 7 shows the method of using BINP HLS and the result of testing ULSE 2 sets which was borrowed from BINP to learn about the operation. The tidal effect of the sun and moon could not be confirmed because of the changes in surrounding temperature (2.2 degrees). The tidal effect can be seen in HLS when the influence of surrounding temperature is less than the tidal effect.

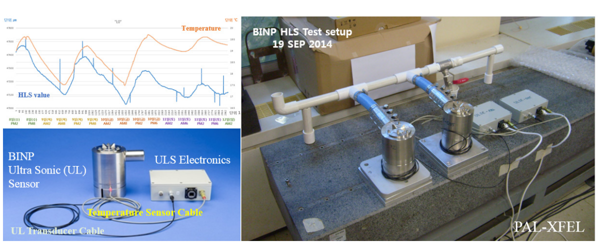

Figure 7: BINP ULSE Test on PAL-XFEL.

HLS INSTALLATION AND OPERATION

Figure 8 shows the geography, building of PAL-XFEL and the installation location for HLS. The purpose of installing HLS is to measure and record the floor deformation according to the vertical change of buildings and grounds (subsidence and uplift) in a systematic and organized way and align the PAL-XFEL quickly [13]. HLS and WPS will be installed in the undulator section to weigh them.

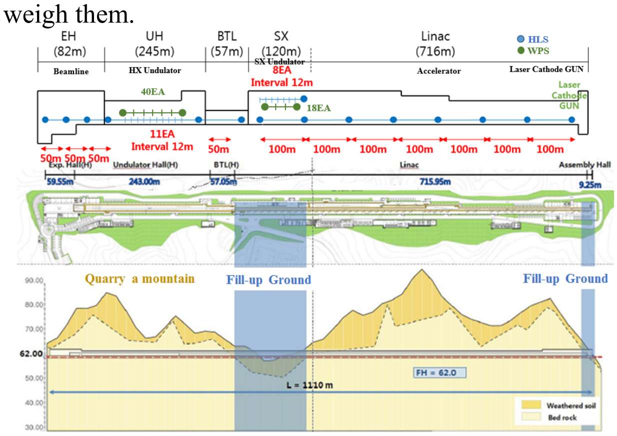

Figure 8: The geography of PAL-XFEL and the installation location for HLS.

ACKNOWLEDGMENT

Thanks to Dr. A.G. Chupyra and Dr. M.N. Kondaurov of BINP for their technical support and cooperation on testing BINP HLS in PAL-XFEL.

REFERENCES

[1] R. Ruland, “Some Alignment Considerations for the Next Linear Collider”, Proc. of IWAA 1995, p. VI/451, Tsukuba, Japan, SLAC-PUB-7060 (1995).
[2] R. Staiger, “Push the Button – or Does the Art of Measurement Still Exist?”, Proc. of FIG Working Week 2009, PS 3, Eilat, Israel (2009); http://www.fig.net/pub/fig2009/index.htm
[3] D. Martin, et al., “The European Synchrotron Radiation Facility Hydrostatic Leveling System – Twelve Years Experience with a Large Scale Hydrostatic Leveling System”, Proc. of IWAA 2002, p. 308, Spring-8, Japan, (2002).
[4] A. Herty, et al., “Intercomparison Tests with HLS and WPS”, Proc. of IWAA 2010, DESY, Hamburg, Germany (2010).
[5] C. Zhang, et al., “Primary Hydrokinetics Study and Experiment on the Hydrostatic Leveling System”, Proc. of IWAA 2002, p. 2978, Spring-8, Japan, (2002).
[6] C. Zhang, et al., “From the HLS Measurement for Ground Movement at the Spring-8”, Proc. of IWAA 2004, Geneva, Switzerland (2004).
[7] S. Singatulin et al., “A High Precision Double Tubed Hydrostatic Leveling System for Accelerator Alignment Applications”, FR005, Proc. of IWAA 2006, SLAC, Palo Alto, CA, USA (2006).
[8] S. Takeda, et al., “Slow Drift and Frequency Spectra on Ground Motion”, Proc. of IWAA 1990, p. IV/225, DESY, Hamburg, Germany (1990).
[9] M. Schlösser, et al., “High Precision Survey and Alignment of Large Linear Colliders – Vertical Alignment”, Proc. of IWAA 2002, p. 343, Spring-8, Japan, (2002).
[10] A.G. Chupyra, et al., “The Ultrasonic Level Sensors for Precise Alignment of Particle Accelerators and Storage Rings”, FR004, Proc. of IWAA 2006, SLAC, USA (2006).
[11] A.G. Chupyra, et al., “BINP Capacitive and Ultrasonic Hydrostatic Level Sensors”, Proc. of IWAA 2008, TU015, KEK, Tsukuba (2008).

ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-MOPTY028

[12] J. Volk, et al., "Hydrostatic level sensors as high precision ground motion instrumentation for Tevatron and other energy frontier accelerators", Journal of Instrumentation 2012
[13] H. Kimura, et al., "A Floor Deformation of SACLA Building", presentation given at Proc. of IWAA 2014, IHEP, Beijing, China (2014).