ANALYSIS OF TIDAL EFFECTS ON MEASUREMENT ACCURACY OF HLS*

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Abstract

HLS (Hydrostatic Levelling System) is mainly used in survey and high-accuracy alignment in particle accelerator. Monitoring the earth tides is primarily introduced in this paper. Based on the earth tide theory and the ocean load effects on the planet earth, the tidal effects on a hydrostatic leveling system are analyzed. Finally, the local ground deformation is obtained, and the current research establishes a foundation for the further study.

INTRODUCTION

Hydrostatic leveling system follows the principle that the liquid (deionized water or purified water) in the HLS are always looking for equipotential surface, which uses connected reservoirs of water to determine the relative elevation difference at the locations of HLS [1]. Figure 1 shows the structure of the sensor, Fig 2 briefly represents the measuring principle of HLS, h1, h2 means the data collected from each sensor.

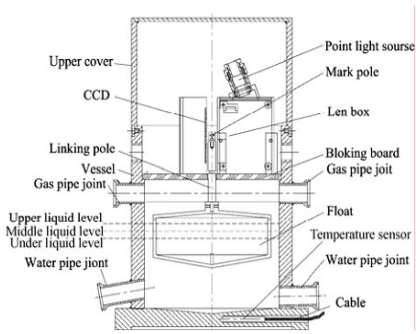

Figure 1: Structure of the sensor.

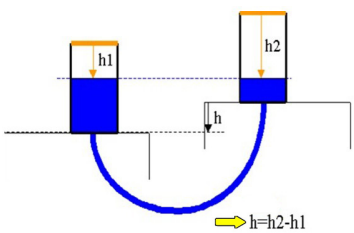

Figure 2: Measuring principle of HLS.

With the progress of science and technology, especially in high-accuracy alignment measurement (micron dimension), the tidal effects and other effects on HLS readings can not be ignored.

HLS has been widely applied Due to the advantages of HLS, especially in European Center for Nuclear Research (CERN), ESRF, DESY, Fermilab, BEPC II and Shanghai Synchrotron Radiation Facility[2, 3, 4, 5, 6, 7]. In addition, HLS also plays an important role in the construction of long span bridges, high-rise buildings, hydropower stations.

HLS INSTALLATION AND THE VALIDATION OF THE TIDAL EFFECTS

Firstly, a relatively good installation site for HLS is necessary. Based on many factors, the cave of a local seismostation is chosen for the test. The temperature and humidity there is stable, beyond that low noise surroundings there is very attractive. The cave is showed as fig 3.

Figure 3: Field installation.

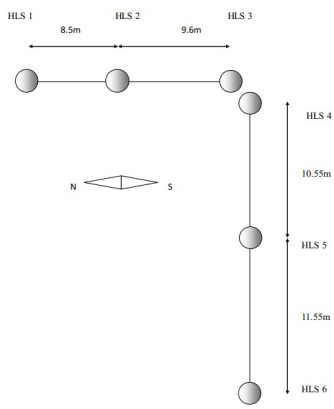

Figure 4: Installation schematic plot.

Six HLS sensors are installed as fig 4 shows. After finishing the installation, we got the primary two months' readings of HLS.

The effects on HLS readings, as a general rule, would be composed of the tilt tide, ocean loading tide (only in offshore area) and residual perturbations. With the progress of science and technology, especially in high-precision alignment in particle accelerator, the effects mentioned above on measurement accuracy of HLS can not be ignored.

The tide effect have two components, the crust tide or the crust tilt tide which effect on the height; and the equipotential tide which applied to the water in the HLS.

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The two components can be modeled together with the Eterna software. Generally the load effects on HLS are oceanic load tide, atmospheric load and hydrological load, Jingxian is about 400KM from the nearest coast, and the water in the HLS is sealed and isotonic, so the load effects can be ignored. Thus the main effects on HLS would be tidal effects and diurnal temperature on ground and instrument. The temperature effects on HLS readings can be reflected in figure 5. Due to the different expansion coefficient between the plastic (water pipe) and stainless steel (Stainless steel sensor housing), the height of the water in HLS increased with temperature decreases.

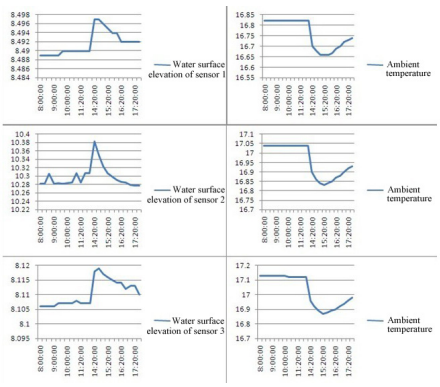

Figure 5: Temperature effects on HLS readings.

Raw data are shown in figure 6. These results show the difference in two sensors 22.1 m apart from mid-November 2012 until mid-December 2012. Pre-processing has been applied to the raw HLS signal mainly for temperature compensation by using empirical equation [8], so the residual data show the ground tilt, and the tidal motion with a 11.6 hour period and 23.1 hour period are visible in Figure 7. Fast Fourier Transformation shows the tidal peaks. Thus the influence of the tides on HLS is verified by using frequency analysis on the signals of HLS.

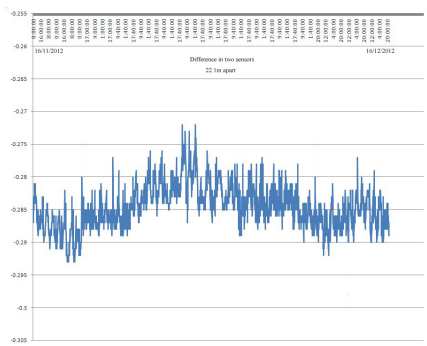

Figure 6: Difference in two sensors 22.1 m apart.

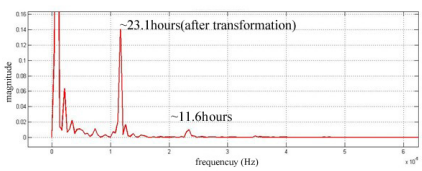

Figure 7: FFT of the difference in two sensors 22.1 m apart.

HARMONIC ANALYSIS

The tidal effects on the region where the HLS are installed can be simulated by using the software ETERNA recommended by ICET.

Firstly, harmonic analysis of the tilt tidal observations based on the readings of HLS is of great importance. Then high-accuracy local tilt tide model and parameters are obtained. In order to represent the local tide briefly, modeling of local tilt tide (east-west segment) is chosen for example. Figure 8 represent the local tilt tide model from 10/11/2012 to 25/1/2013, figure 9 shows the relative elevation changes only caused by tilt tide between the two sites. Figure 10 shows residual signal after tidal correction to the HLS signal which stands for the height difference change between the two sites, figure 11 represent the local ground deformation.

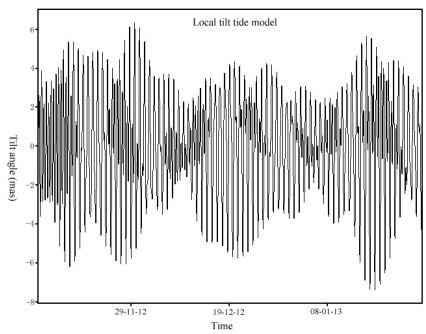

Figure 8: Modeling of local tilt tide (east-west segment).

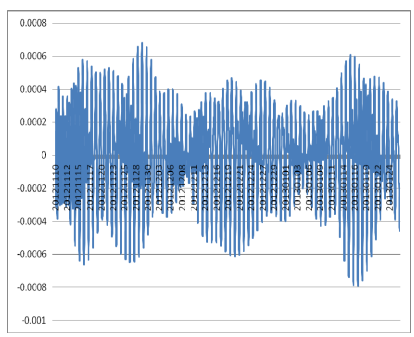

Figure 9: Relative elevation changes between the two sites.

CONCLUSION

After tidal correction， the residual signal can be considered to be the ground deformation. But after an FFT analysis of the residual signal, there is still periodic signal as figure 12 shows.

The local ground deformation (shown in Figure 11) can be attributed in part to some other phenomena which haven't been addressed, even which could involve alignment errors. These might include periodic ground movements other than tidal effects (such as thermal effects) or local water heating (even diurnal temperature on ground and instrument), specific response of the water in HLS, cavity effects and so on.

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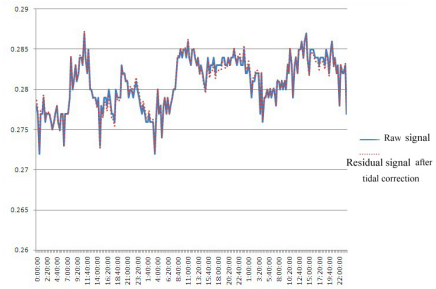

Figure 10: Residual signal after tidal correction.

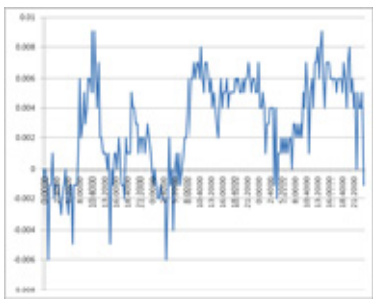

Figure 11: Local ground deformation.

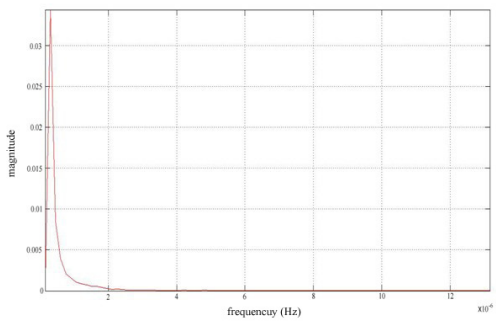

Figure 12: FFT for residual signal.

In addition to those probability mentioned above, it is worth noting that in the process of preprocessing the raw data. The relevant empirical formula is particularly used for temperature compensation, it is possible that the real effects of temperature on the readings of HLS is not removed completely, instead, partial tidal signals have been filtered out when using this approach. Besides, with using Eterna to do harmonic analysis, preliminary analysis is based on data from HLS just lasts for about 2 months, it would be somehow flawed to predict the local tilt tide without long term tidal constituents(S_a, S_{sa}, M_m, M_f waves...). So further harmonic analysis will be done in the future using data for about one year or more.

In the future, more research has to be done to improve the reliability of such analysis with using Eterna.

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REFERENCES

[1] HE Xiaoye, XU Shaofeng, WANG Peng. Preliminary study on the influence of the tides of planet earth on hydrostatic leveling system [J], Nuclear Techniques,2012, 35(6):405-408.

[2] Roux D., Alignment and Geodesy for the ESRF project, Proceedings of the First International Workshop on Accelerator Alignment, July 31-August 2, 1989, Stanford Linear Accelerator Center, Stanford University.

[3] Martin D, Roux D., Real Time Altimetric Control By A Hydrostatic Levelling System, Second International Workshop On Accelerator Alignment, September 10-12, 1990.

[4] Martin D, Alignment at the ESRF, Third European Particle Accelerator Conference: Berlin, 24-28 March, 1992.

[5] Martin D., Deformation Movements Observed at the European Synchrotron Radiation Facility, Proceedings of The 22nd Advanced ICFA Beam Dynamics Workshop on Ground Motion in Future Accelerators, SLAC, USA.November,2000.

[6] HE Xiaoye. Latest Developments and Applications of Hydrostatic Levelling System.2010.

[7] M. Jones et al., Latest Results from the CLIC Geodetic Studies, International Workshop on Accelerator Alignment, Proceedings of the 11st International Workshop on Accelerator Alignment, Hamburg ,2010.

[8] HE Xiaoye et al., Analysis of influence of pressure and temperature on HLS, Nuclear Techniques,2006,29(5):321-325.

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