DEVELOPMENT OF NEW HYDROSTATIC LEVELLING EQUIPMENT FOR LARGE NEXT GENERATION ACCELERATOR

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Abstract

The Hydrostatic Levelling Systems (HLS) are installed and commissioned in many laboratories, in order to attain severe requirements of the vertical alignment on the accelerator components. We have developed a new type of HLS for the large future accelerator. The important designing points as followings:

(1) Application of the half filled water level sensor instead of the usual full filled level sensor,
(2) Introduction of the capacitive sensor being supported by an invar rod to decrease the temperature influence,
(3) Adaptation of adjacent signal conditioner to the capacitive sensor, including A/D converter and a digital signal transmission system.

These three points are very important factors to apply the levelling system to large next generation accelerator in order to obtain good temperature stability and being free from the environmental electronic noises. Typical resolution of the equipment is 0.05 micron-meters and its signal to noise ratio is better than ten times comparing usual HLS.

1 INTRODUCTION

HLS is one of the useful equipments for the pre-alignment or re-alignment of the accelerator components. Almost all of the levelling systems use water to provide an absolute elevation reference for measuring distance between the equipotential surface of the water and the surface of the sensor. Some other liquid, such as mercury and silicon oil, however, are used in another application of levelling system [1]. Mercury is used to get the easy floating method for the leveller. Although the thermal expansion coefficient of silicon oil is about five times larger than water, they use silicon oil to avoid corrosion or fungus and moss gathering in water. After using distilled and deionised water more than ten years for the elevation reference, we can say that there is no problem for application of water to the reference.

Usually, the vessel of the water is made by quartz glass to eliminate the levelling error by the thermal expansion and contraction of the vessel. It gives us mechanically fragile problem, then they make the vessel using stainless steel. The present new sensor's vessel is composed by hydro-carbonate material. This material and water have similar thermal expansion coefficient, that is, we can expect to decrease the incidental error to the environmental temperature. Application of the half filled water level sensing method, instead of the usual full filled type, increases reliability of the observed data [2].

In the geological application of HLS, they use combination of an float and LVDT or eddy current sensor to detect the ground distortion, at least in Japan. These combinations give us, however, severe problem about the temperature dependent error signal, if we use them in the accelerator tunnel. Non-contact capacitive sensor or light reflection detector [3] are preferable sensor for the detection of equipotential surface on the application of the accelerator.

2 DESIGN OF NEW HLS

The general requirements for the new HLS are summarized in Table 1. Condensation of the vaporized water on the surface of the capacitive sensor becomes one of the error sources of the measured value. We adopt an integrated heater and its controller to control the temperature of the saturated vapour pressure.

Table 1: Technical Requirement Data

Measuring method	Non-contact capacitive displacement measuring system
Measuring range	± 2 mm
Offset distance	1 mm (between sensor surface and the highest water surface)
Non-linearity	$\pm\ 10\mu m$
Resolution	$\pm\ 0.1\mu m$
Target	Distilled and deionised water
Output signal	Digital, CAN bus
Maximum data rate	5 messages/sec
Connector	9 poles D-sub

The principle of the capacitive distance measurement is based on the parallel plate capacitor, as shown in Fig. 1 with a simple equivalent circuit. Constant AC current I flows through the capacitor, that is the sensor, the amplitude of the AC voltage V at the sensor becomes,

$V = \dfrac{Id}{\omega\varepsilon A}$: where ω is frequency of AC current; ε is dielectric constant of the air; A is the sensor plate area and d the gap. If the electric field were perpendicular to the water surface by cooperative effect of the guard ring being set on the sensor surface, the sensor electrode and the opposite water surface form a two electrodes of the capacitor. Carefully considering the above equation, critical error sources for the value of V are tilt of the sensor plate and adsorption of water vapour onto the sensor plate. But in our case with large offset gap, we can ignore the effect of the tilt. The value of ε depends on the partial pressures of the materials between the sensor plate and the water surface. According to L. Essen and K. D. Froome, we can estimate the effect of the partial pressure of the materials. In practice larger changes than this estimation are reported about the adsorption of the vapour on to the sensor [4].

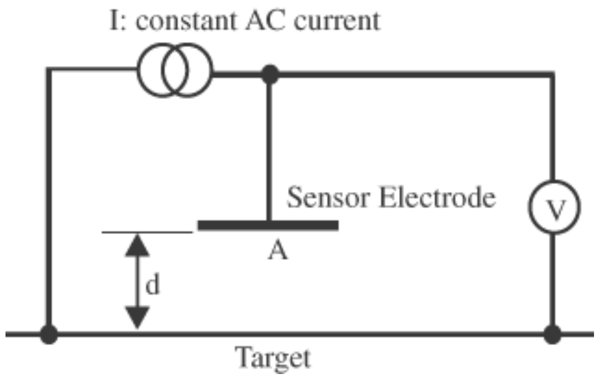

Figure 1: Equivalent circuit description for measurement principle.

Fig. 2 shows a schematic description of the present new HLS. The surface of the capacitive sensor is protected by anti-vapour absorbing material and the top surface attached by a heating circuit. In order to avoid the change of sensor position by environmental temperature, an invar rod supports the sensor plate.

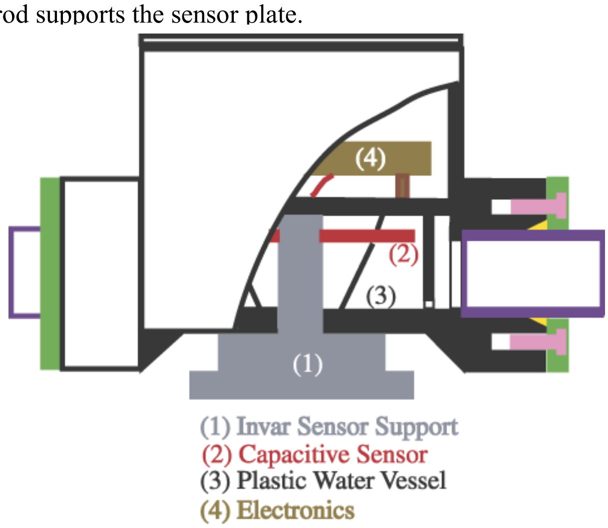

Figure 2: Schematic description of the new HLS.

The water vessel has special inner walls working as a breakwater. The walls of inlet/outlet side of the vessel have small openings and the both sides have trapezoid windows as shown in Fig. 2. This structure of the vessel is very effective to prevent the direct touching of the surges for the sensor plate. Separated upper side of the vessel is equipped by the electronics. The electronics is composed by circuit boards of V detection, 24bit A/D converter, MSC1210 of Burr-Brown Products, and the CAN controller with Philips SJA-1000. DC 24 volts power is supplied through 9-pin D-sub connector's reserved pins, the pin No. 9 for +24V and the pin No. 5 for power GND. CAN specification is found in the ISO11898/11519 being originally developed for use in automobiles and now used in industrial field bus systems. CAN is adaptable to the accelerator field because of similarities such as low cost, the ability to function in a difficult electrical environment and real time capability.

3 TEST RESULTS

The first test of the present HLS gave us a few problems about the resolution related to the noise and the long-term drift of the data. The resolution as shown in Fig. 3, is a little worse than the designed one.

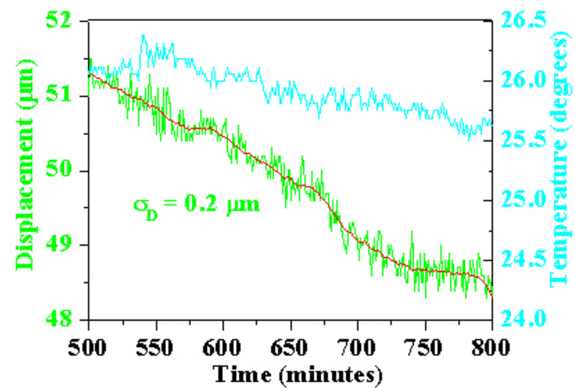

Figure 3: Resolution obtained by the first test.

An improvement on the V detection circuit gives better resolution than the designed one, as $0.05\mu m$ or more. The second problem was more serious. This problem has been cleared by reproduction of the sensor plate with careful coating method for anti-diffusing water vapour.

Noise issues

We have experiences of degradation of SN ratio for usual analogue signal transmitting method as an example shown in Fig. 4, though the signal was transferred using shielded twisted pair lines. In this case, the HLS was set

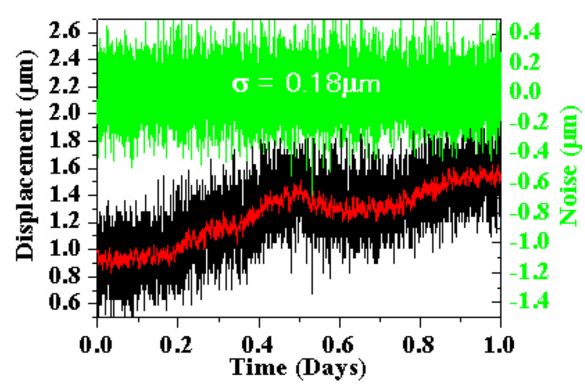

Figure 4: The signal observed in the EM noisy place; cable length is 50m and HLS made by FOGALE.

in the high EM noisy place and the root mean square [rms] noise width becomes $0.18\mu m$.

We have also checked the SN ratio in the quiet place of EM noise using the same experimental set-up. The observed rms noise width becomes $0.02\mu m$ as shown in Fig. 5. The rms noise for this case shown in Fig. 5 gives a contrasting result with that of Fig.4, though the cable length was longer than the above bad case. These two results indicate clearly that wide range voltage analogue signal transmission is easily interfered with the external EM noise along the transmission line, even if the twisted pair lines are applied.

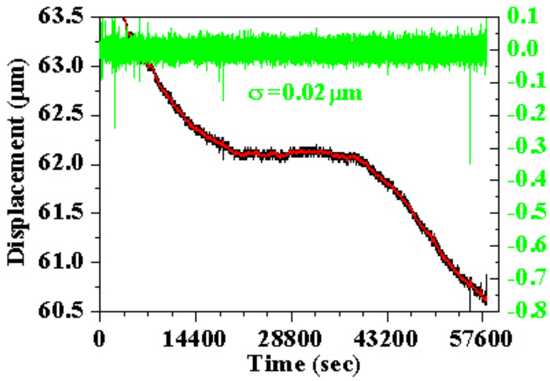

Figure 5: Observation in the quiet EM noise place; cable length 100m and HLS made by FOGALE.

Digitisation Effect for Noise Figure

On the present HLS, the analogue signal from the capacitive sensor is digitised using ADC and converted to serial CAN signals at the very near place of the sensor to obtain the best SN ratio. In this situation, we have to take care in setting the electronic parts on the circuit board in order to avoid the digitising noises. At first test of the HLS, we found a slightly high noisy result as shown in Fig. 3, comparing the designed resolution. As mentioned above, the source of the noise was depending on the V detection circuit and a little change of the circuit gave large reduction of the noise as shown in Fig. 6. Fig. 6 shows one of the measuring results of the new HLS.

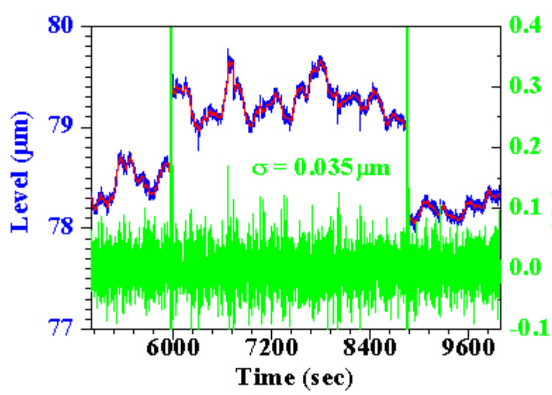

Figure 6: The signal observed in the EM noisy place; C-band klystron is operated at the very near place: Cable length is 60m and HLS made by Micro-Epsilon.

In spite of the high EM noise environment being incidental to the operation of C-band klystron and its modulator near the test station of HLS, the obtained rms noise width is very small as $0.035\mu m$ as shown in Fig. 6. This figure includes also about $1\mu m$ step change by adding 0.1 cc drops of water and extracting the same volume of the water. Fig. 6 shows some waving signals instead of a straight line, though the amplitude is small. These phenomena may correspond to the ground motion noise in KEK site. Although we have much information of the ground motion in KEK site and this site shows very large *ATL* value [5], this waving slow ground motion is new information. We are going to study this ground motion in detail using the present HLS.

SUMMARY

We have designed and produced the new HLS as the following concepts to obtain the low temperature drift and low noise system:

- Introduction of the half filled water level sensor instead of the usual full filled level sensor.
- Introduction of the capacitive sensor being supported by an invar rod to decrease the environmental temperature influence.
- Integration of the related circuit board into the very near place for the capacitive sensor.

Typical resolution of the New HLS is less than 0.05 micron-meters. Better resolution will be possible after the improvement for EM noise shielding around the vessel.

Our next progress is to be clear the waving ground motion and to check the temperature dependence of the HLS doing long term observations.

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