SYSTEM OF GEODETIC MEASUREMENTS FOR LIA-20.

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Abstract

The system of geodetic measurements for accelerator LIA-20 is presented in this paper. The system consists of two subsystems. The first one is hydrostatic level system and the second one is system with the stretched wire. The system of geodetic measurements controls vertical and horizontal shifts of the accelerating structures, and also their inclinations in the longitudinal and cross directions.

INTRODUCTION

LIA-20 is a new accelerator for radiography which is now under development and construction. It consists of the injector and a number of accelerating modules placed on girders. Total length of the accelerator is about 70 meters. The accelerator is designed to provide a electron beam with energy up to 20 MeV, current 2 kA and lateral size of beam less than 1 mm. The last condition requires a careful alignment of the accelerator's elements and further monitoring of their positions. It is necessary to control change of the accelerating module's position less than 0,1 mm on height and less than 1 milliradian on angle. System for geodetic measurements is developed for this purpose.

The system consists of two subsystems. The first one is hydrostatic level system and the second one is system with the stretched wire. The system of geodetic measurements controls vertical and horizontal shifts of the accelerating structures, their inclinations in the cross directions and its rotation angle around the longitudinal axis (Fig.1).

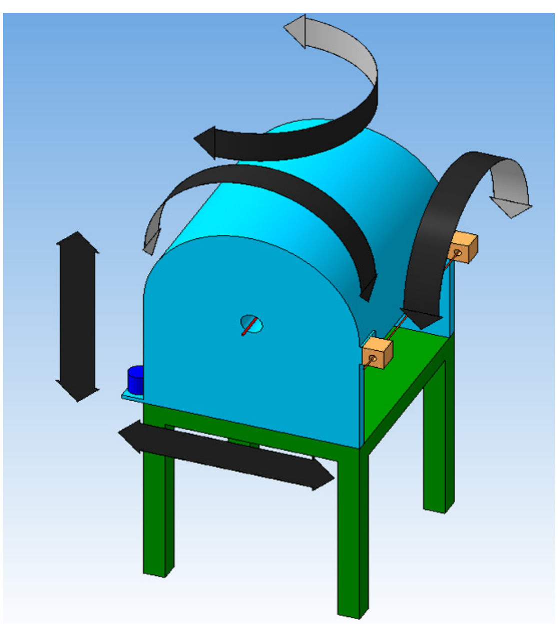

Figure 1: Movement types measured by the system.

HYDROSTATIC LEVEL SYSTEM

General Description

Hydrostatic level system is based on principle of communicating vessels. All water level measuring sensors are linked to its neighbours by a system of tubes. So the principle is based on the equilibrium of the pressure of liquid in communicating vessels (see Fig. 2).

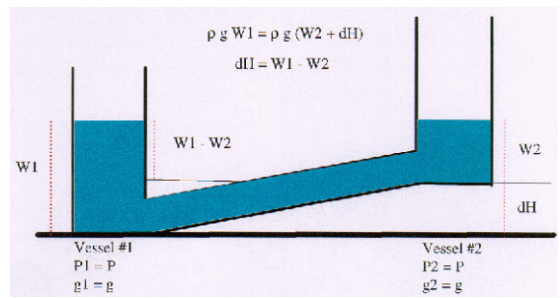

Figure 2: The principle of communicating vessels.

Ultrasonic level sensor

Ultrasonic Level Sensor (ULS) is designed to work into the hydrostatic level system for monitoring of vertical position of the accelerating modules. The resolution of the ULS is 0.2 μm and the accuracy is 5 μm in measurement range of 5 mm.

A pulse-echo method is used in ULS for water level measurements. The ultrasonic hydro-location is well known and widely distributed method of distance measurements for many applications. One of precise methods was described by Markus Schlösser and Andreas Herty [1]. Their idea is to locate not only the water surface in a vessel, but also two addition surfaces with calibrated distance between them (D1) and at the calibrated distance to alignment reference target (D2), see Fig. 3.

The pulse-echo ultrasonic measurements can determine the location of free water surface in a vessel or location of reflective surface into water by accurately measuring the time required for a short ultrasonic pulse generated by a transducer to travel through a thickness of water, reflect from the free water surface or from the reflective surface, and be returned to the transducer. The two-way transit time measured is divided by two to account for the down-and-back travel path and multiplied by the velocity of sound in the test material.

$$d = v \cdot t / 2 \qquad (1)$$

Here ***d*** is the distance from the surface of transducer to the reflective surface or to free water surface, ***v*** is the

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velocity of sound waves in water, and ***t*** is the measured round-trip transit time.

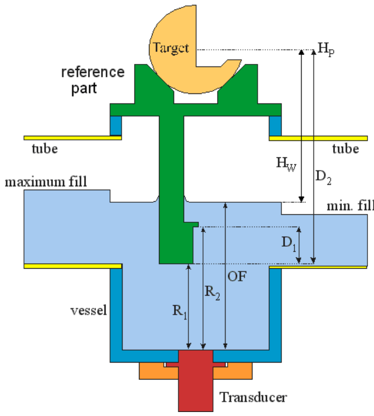

Figure 3: Principle of organizing the reference surfaces at the ultrasonic sensor.

Usually it is necessary to determine vertical distance between the free water surface and centre of alignment ball (Hw). It is easy to do by next formula:

$$H_W = D_2 - D_1 * \frac{t_{OF} - t_{R_1}}{t_{R_2} - t_{R_1}} \quad (2)$$

Here D_1 and D_2 are linear dimensions of the reference part. They can be measured with high accuracy after their fabrication. So ULS has self-calibrating capability and as result there is a possibility to make measurements of absolute water level position with high accuracy. Because of self-calibrating capability one can eliminate any electronics drifts.

On each girder it will be installed three Ultrasonic Level Sensors (ULS).For the placement of the sensors on the girders special brackets will be used. All sensors will be connected into the hydrostatic level system with pipes half-filled with water.

Fig.4 presents general view of the ULS installed on prototype of the girder. ULS has special nest for a 1.5 inch ball to provide alignment survey.

Figure 4: The general view of the ULS installation.

ULS electronics

The ULS electronics is located in separate module of Euromechanics 1U size. One module encloses electronics for three ULS sensors. The goal of the ULS electronics is to measure time intervals and to transfer them to the operating computer for calculation of actual accelerator module's positions.

Experimental Results

Test results of the ULS sensitivity are presented on Fig.5. For two sensors connected in hydrostatic level system test with dosed addition of water has been carried out. As result level steps of about 0.5µm were performed which were measured by the sensors (curves L1 and L2 on Fig.5). In calculated level difference signal there are only noise and spikes at moments of water addition.

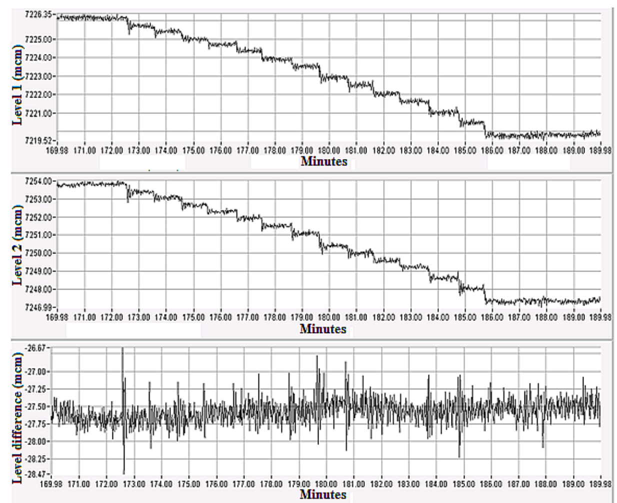

Figure 5: Test of the ULS sensitivity.

STRETCHED WIRE SYSTEM

General Description

Stretched wire system consists of stretched wire, wire position monitors and electronics. 150 m long stretched wire is passed through 140 wire position monitors attached with the accelerating modules and transportation line magnets. One end of the wire is loaded with a weight of 50 kG via roller installed in special girder (Fig.6).

Figure 6: Load at the stretched wire end.

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The wire is made of aramid thread (Fig.7). This material is able to withstand the load approximately the same as steel.

Figure 7: Stretched wire material.

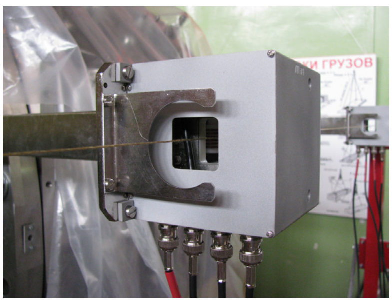

Figure 8: Wire position monitor on the acceleration module.

But its weight in 5 times less than steel. As a result wire sag in the middle of the 150 m long wire is only ~50 mm. 1 MHz sinusoidal current of 20-40 mA goes through the wire.

Two wire position monitors are attached to each acceleration module (Fig.8). Wire positions measurement relatively of these monitors gives us not only position of the acceleration module but its inclination angles in the cross directions and its rotation angle around the longitudinal axis.

Wire Position Monitor

The wire position monitor (WPM) consists of body, 4 coils located in horizontal and vertical planes and 4 BNC connectors (Fig.9).

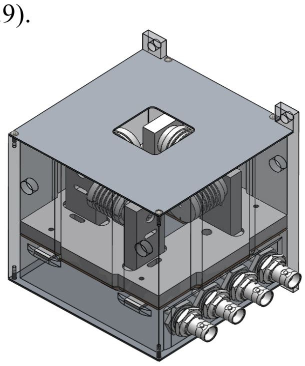

Figure 9: Wire position monitor.

An amplitude of 1 MHz signal induced in the coil ends is proportional to distance between the coil and stretched wire. After measurement of four coil voltages V_i then wire position is calculated with formulae:

$$X = K_{X0}\frac{V_1 - V_3}{V_1 + V_3}, \qquad Y = K_{Y0}\frac{V_2 - V_4}{V_2 + V_4},$$

where K_{X0}, K_{Y0} are WPM geometric coefficients.

Wire Position Electronics

Functional diagram of the wire position electronics is represented in Fig.10.

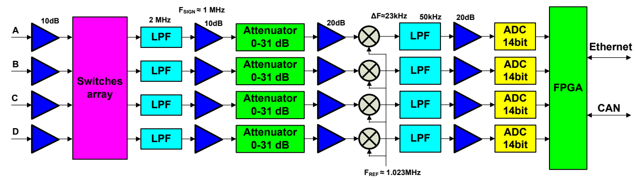

Figure 10: Functional diagram of the WPM electronics.

Electronics for one WPM consists of Switches array, 4 identical signal processing channels, FPGA Cyclone-3 of Altera firm, Ethernet interface and CAN interface. Use of the Switches array allows us to eliminate measurement error caused by inequality of the channels transmission coefficients.

Experimental Results

Two WPMs were installed on the accelerating module prototype. Continuous wire position measurements had been performed during a few days. Some results of these measurements are represented in Fig.11.

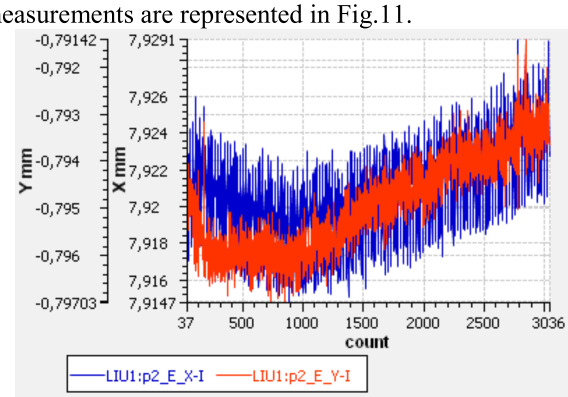

Figure 11: Results of continuous wire position measurements during ~1 hour.

An achieved resolution of the wire position measurements is about 1 micron.

SUMMARY

At present prototype of the accelerating module with installed on it hydrostatic level sensors and wire position monitors is successfully tested in BINP. The system demonstrates required accuracy parameters.

REFERENCES

[1] M. Shlösser, A. Herty, “High precision accelerator alignment of large linear colliders – vertical alignment”. Proceedings of the 7th IWAA, Spring-8, 2002.

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