DYNAMIC PROPERTIES MEASUREMENT OF THE HYDROLEVELLING SYSTEM HOLMES

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Abstract

The hydrolevelling system HOLMES (Hydrostatic Optoelectronic Levelling MEasuring System) is used for the height differences of the Nuclotron accelerator magnets monitoring since 1998 year. In the paper are given the system operation principles, sensor description, measured data evaluation, results presentation and filing. Included are also results of the dynamic properties of the system measurements.

1. INTRODUCTION

Reaching the designed accelerator parameters is directly dependent on the prompt observation and measurement of its magnet system, beginning with the spatial position of the magnets installed in the ring. Since the commissioning of the Nuclotron in 1993, the research in the field of experimental nuclear physics, as well as the investigation of the accelerator characteristics, has been carried out. One of the most important tasks to be accomplished in the nearest future is to achieve a project intensity and high-efficiency extraction of the beam from the accelerator ring. To do this, several parameters of the accelerator should be obtained and controlled, especially those related to its magnet system. Particularly, the requirements to the magnet position were determined from the restriction on the form of the beam closed orbit amplitude, the distortion of which must not exceed ±3 mm in the horizontal plane and ±2 mm in the vertical one. In this case, the tolerable errors in arranging and maintaining the position of the structure magnets should be within ±0.4 mm for the dipoles and ±0.15 mm for the quadrupoles. While assembling the accelerator ring in 1990-1992, such requirements were fulfilled with some insignificant deviations. Since then, measurements of the magnet position have not been carried out, though such information is required, both at present and in future, for analysing the beam dynamics and losses during the accelerating cycle and beam extraction.

Since the most probable position changes of the accelerator ring are in the vertical plane (which may be caused by temperature, seasonal and other fluctuations of the accelerator base), a vertical position measuring system with distributed intelligence for the Nuclotron magnets has been designed and manufactured at the Institute of Measurement Science of the Slovak Academy of Sciences in collaboration with the Laboratory of High Energies, JINR.

The measuring system uses the method of hydrostatic levelling [1] based on the well-known hydromechanical properties of liquids in connected vessels. Such a stationary measuring system allows a operational measurement of the accelerator ring geometry in the vertical direction.

2. THE MEASURING SYSTEM

A block-diagram of the optoelectronic system for hydrostatic levelling is shown in Fig. 1.

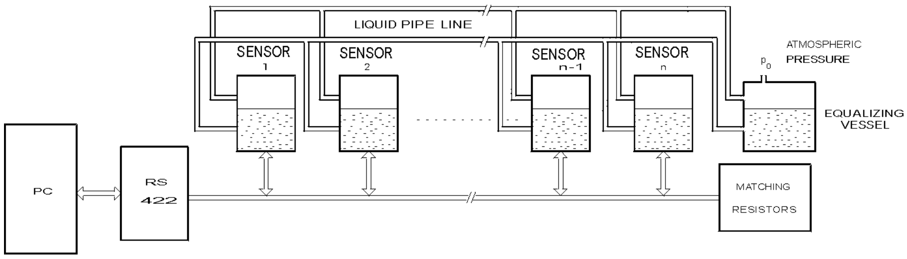

Fig. 1. A block-diagram of hydrolevelling system.

The hydrolevelling sensor vessels, interconnected by a liquid pipeline, make up a system of joint vessels. This system can be added by an equalising vessel as a hydrostatic liquid stock. In hydraulic system is used low viscosity silicon oil. To ensure an equal air pressure above the liquid levels, all the sensor vessels are also interconnected by an air pipeline, which is connected with atmospheric pressure only at one place.

Output data from each sensor and command data from the central computer are transferred by a pair of twisted wires with matching resistors according to RS 422 standard. For data communication, the IEC 870.5 protocol standard, is used. The system contains 24 sensors, located on the Nuclotron magnets.

3. THE OPTOELECTRONIC SENSOR FOR HYDROSTATIC LEVELLING

There exists a large number of methods for liquid level position measurement [1]. For this purpose, the optoelectronic method, developed at the Institute of Measurement Science of the Slovak Academy of Sciences in Bratislava, was used for this system.

The optoelectronic hydrolevelling sensor (Fig. 2) consists of a flat window cell (as one vessel in the system of connected vessels), an optoelectronic system for liquid level measurement, a thermometer and an electronic circuitry with measuring, storing and communication functions.

In the optical part of the sensor, a beam of parallel rays from the light source created by a light emitting diode with a collimator, passes through the vessel, and the transmitted rays are imaged onto a CCD line sensor by a relay optical system. Only rays in the meniscus region do not pass through this optical system due to reflection or refraction at the air-liquid boundary. The effect of meniscus can be considered as a non-transparent strip illuminated by a collimated beam of light. The resulting illumination, registered on the CCD sensor, has a U-form intensity profile. The lower part of the meniscus (lower part of U-form intensity profile), represents a liquid level position or a liquid column height in the sensor vessel. For exact determination of level position a special algorithm is used. A more comprehensive description of the sensor measuring principle is given in [2].

The electronic part of the liquid level sensor generates control pulses sequences necessary for the

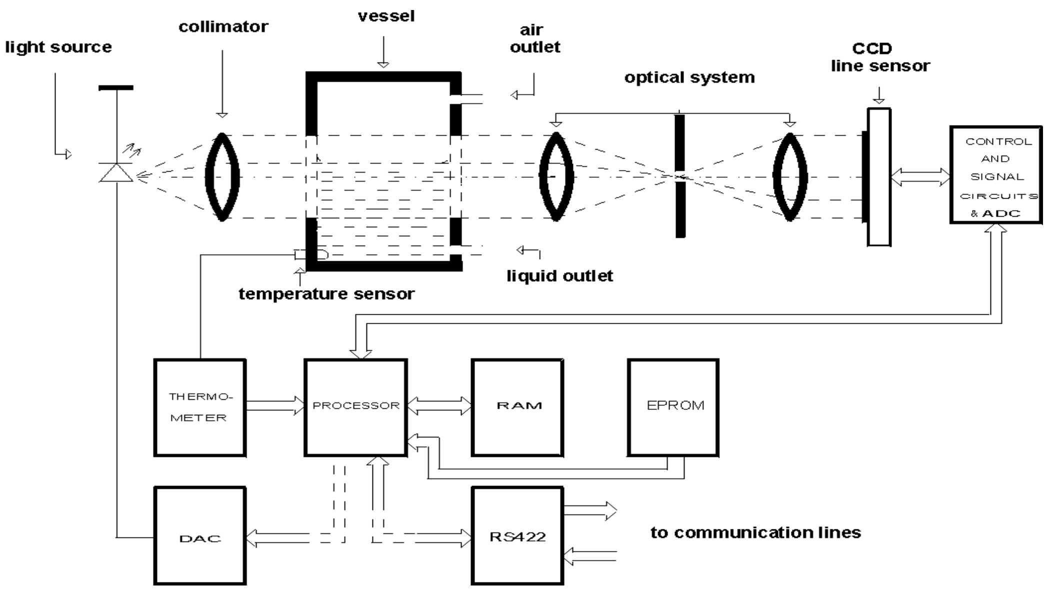

Fig.2. Liquid level optoelectronic sensor lay-out.

CCD chip operation, amplifies and forms a CCD output signal and converts it to the digital form. The resulting illumination profile for one measuring cycle is also stored in a local RAM. The hydrostatic levelling sensor has also a precise semiconductor thermometer integrated with a processing electronic circuit. Data transfer by serial communication lines to a central personal computer of the system is an important function of the electronic part.

The used CCD chip has 1648 photoactive elements with a distance of approximately 14 μm between the elements centres and a summary length of approx. 23 mm. As the magnification of the optical system is 1.00, the summary measuring range is ± 10 mm. The resolution using mentioned algorithm is better than 1 μm.

All the hydrolevelling sensor electronic circuits are controlled by a microcontroller. Outgoing data transfer to the central personal computer is controlled by a special microcontroller according to the RS 422 standard.

Low viscosity silicon oil is used in the described hydrostatic levelling system as a working liquid with outstanding stability of its properties.

4. THE SENSORS CALIBRATION METHOD AND SOME CALIBRATION RESULTS

The most complex calibration method of hydrolevelling sensors is of course adjustment and precise measurement of the sensors height difference (as minimum pair of them) by a suitable method and measuring the sensors height differences with hydrolevelling system itself in the hydrostatic equilibrium. In this case are included into calibration process also influence of measuring vessel imperfections and influence of hydrostatic liquid. The disadvantage of this method is its laboriousness, slowness and impossibility to use it in installed sensors. All other calibration methods have always simulation character, e.g. in calibration process the measuring vessel with liquid is not used. The optical effect of missing liquid meniscus is substituted in this case by the nontransparent rod or strip of equal vertical dimension, or by the optical grid with known geometry of etched strips.

The "grid method" seems to be the most suitable for fast measurements of sensors linearity in alignment process and also for the check of installed sensors. The measured object is the lithographic grid with grid constant 1mm ± 0.1μm and line/space ratio 1:1 in special holder, located instead of vessel. For one sensor with 9,6 kBd communication speed lasts the measurement and data evaluation about 6 s.

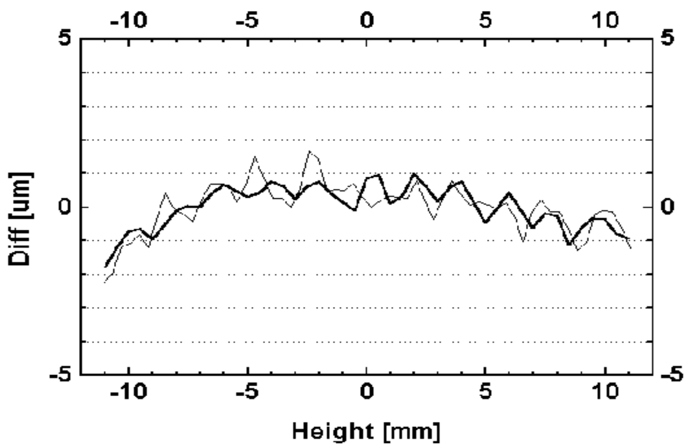

Fig. 3. The nonlinearity of sensor 01 (- after alignment , -- 1 year after installation).

In the Fig. 3 are shown nonlinearities for one of sensors measured in alignment procedure and one year after sensor installation. The sensor nonlinearity is better than ± 2μm in measuring range ± 10 mm.

5. SYSTEM DYNAMIC PROPERTIES MEASUREMENTS

One of calibration and testing procedures of the system was also its dynamic properties measurement. The system consist of 24 sensors located on 250 m accelerator circle. Unfortunately the hydraulic part of system did not create an closed circle, but it was in one place broken. The measuring procedure was as follows: after 4 mm lifting of sensor 24, was measured in 10 minute intervals height differences of all sensors in relation to first one.

Measured data in are shown Fig.4. For better understanding and visualisation of the liquid transient process in Fig. 5 are showed differences from steady values of individual sensors elevations.

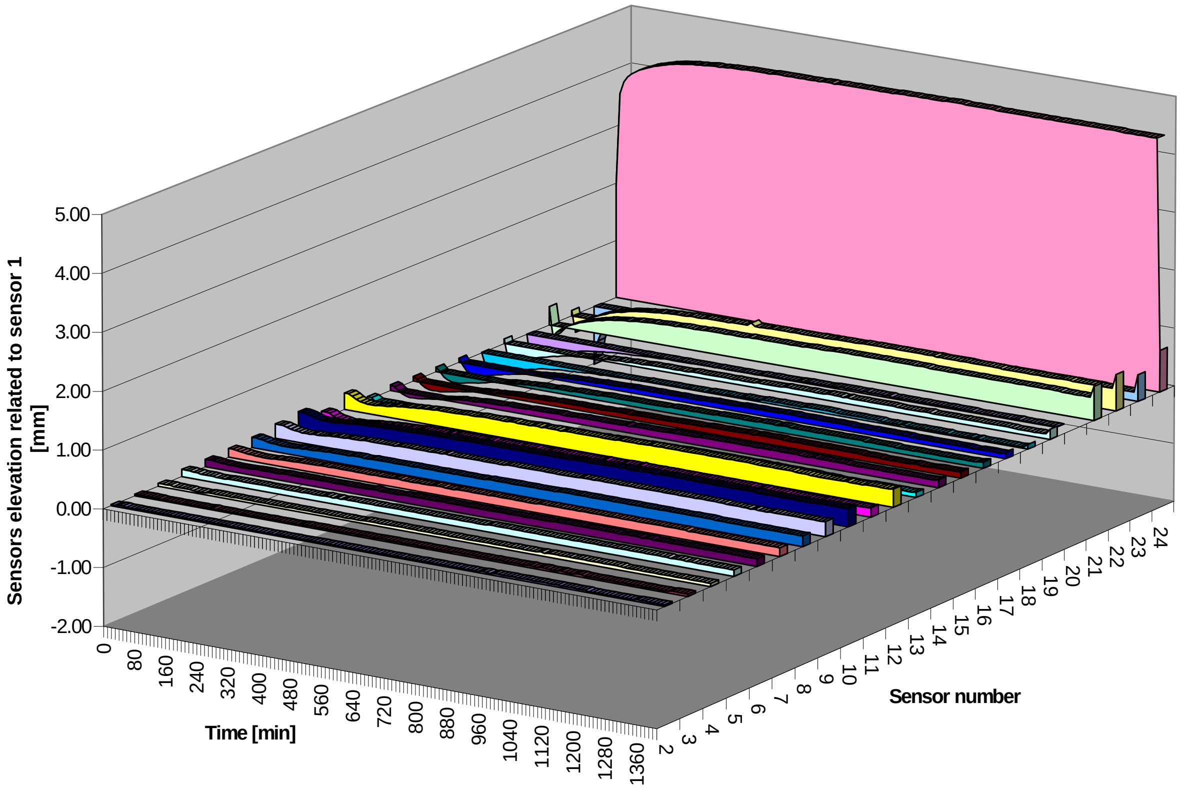

Fig.4. Sensors elevations related to sensor 1 after 4 mm lifting of sensor 24.

In this picture is good visible a spreading of the hydraulic wave in system. From these elevation time dependencies is possible to determine for each sensor the transient time. For example in sensor 24 is this time for 0,1 mm accuracy about 90 min. and for 0,01 mm accuracy about 150 min. Measurement of above mentioned dependencies was done at temperature 12 °C.

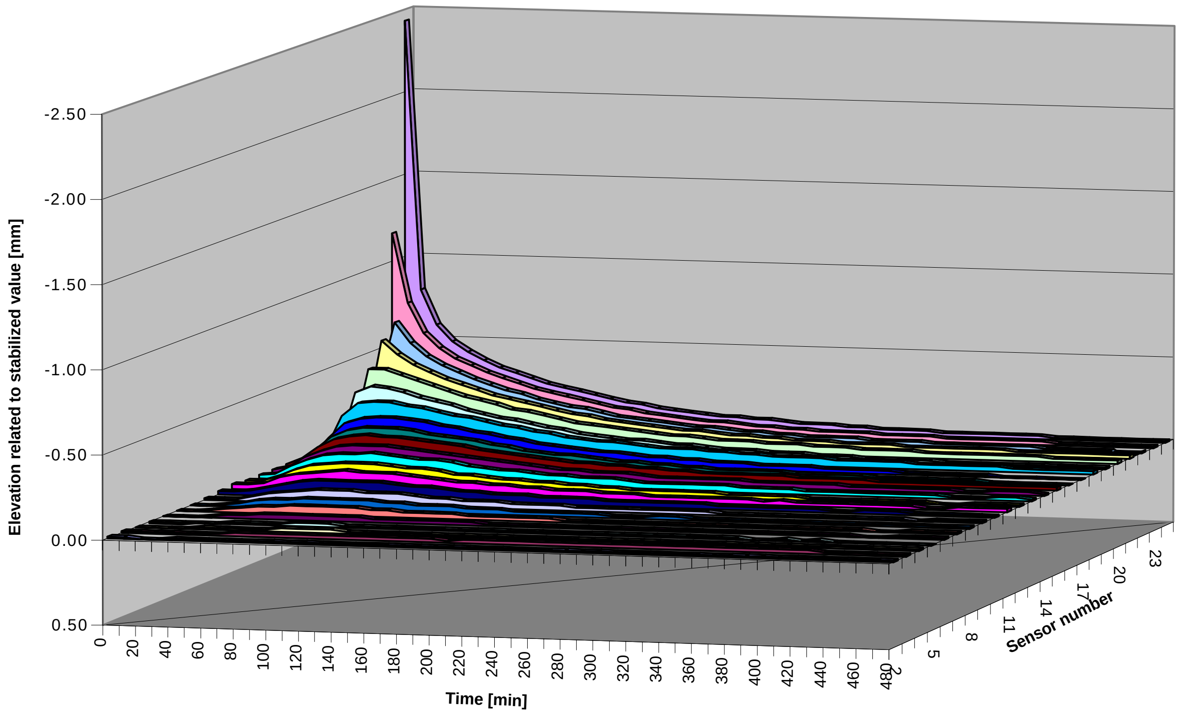

Fig. 5. Sensors elevation related to sensor 1 and stabilised value of sensors .

6. CONCLUSION

The described in this paper stationary measuring hydrolevelling system fully meets all requirements for operative, eventually continuous, completely automated measurements of the precise vertical position of the Nuclotron accelerator function elements.

In hydrostatic levelling systems, different temperatures of the sensors and hydraulic circuits can lower the resulting measuring precision. In Nuclotron hydrolevelling system, the temperature influence is minimised by measuring the sensor temperature and correcting the measured data and also the pipe lines for liquid are installed in order to minimise a temperature influence.

The software means of the described system allow a user friendly different modes of simultaneous measurement of a large number of point elevations, variety of data acquisition, processing, result presentation and filing.

7. REFERENCES

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