Conference Paper

Automated System for Measuring Geometric Parameters of Graphite Masonry and Measuring Deviations of Technological Channels from the Vertical of the Channel Reactor EGP-6

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Abstract

The system solves the problem of controlling the curvature and the diameter of the cells of the graphite masonry of the EGP-6 reactors in two mutually perpendicular planes during the routine preventive and overhaul repairs.

Diameter control is carried out by means of 4 sensors of displacement of the resistor type fixed on the sensor probe block. Each of the sensors is mechanically connected to the roller, which is in direct contact with the channel wall. Diameter measurement uses data from sensors connected to two opposite rollers.

Curvature control is performed using an ultrasonic inclinometer filled with liquid, which is located in the tail part of the probe. The inclinometer is designed for measuring angles of inclination in 2 mutually perpendicular planes. The data from the inclinometer is transmitted via the interface to an analog-to-digital converter, which is located in the measuring unit and is designed to convert the interface to USB.

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1. The problem to be solved

Diagnostics of graphite blocks and technological channels by measuring deviations of technological channels from the vertical, as well as monitoring the state of the structural materials of the core of the channel reactors, is a very important task at the NPP. The state of the structural materials largely depends on the safe operation of the nuclear reactor.

Under the influence of radiation exposure and temperature, the physical properties of metal and graphite change during the long-term operation of the channel nuclear reactor. The ducts undergo deformation. The diameter of the channels increases. The swelling of graphite under the action of irradiation leads to a decrease in the diameter

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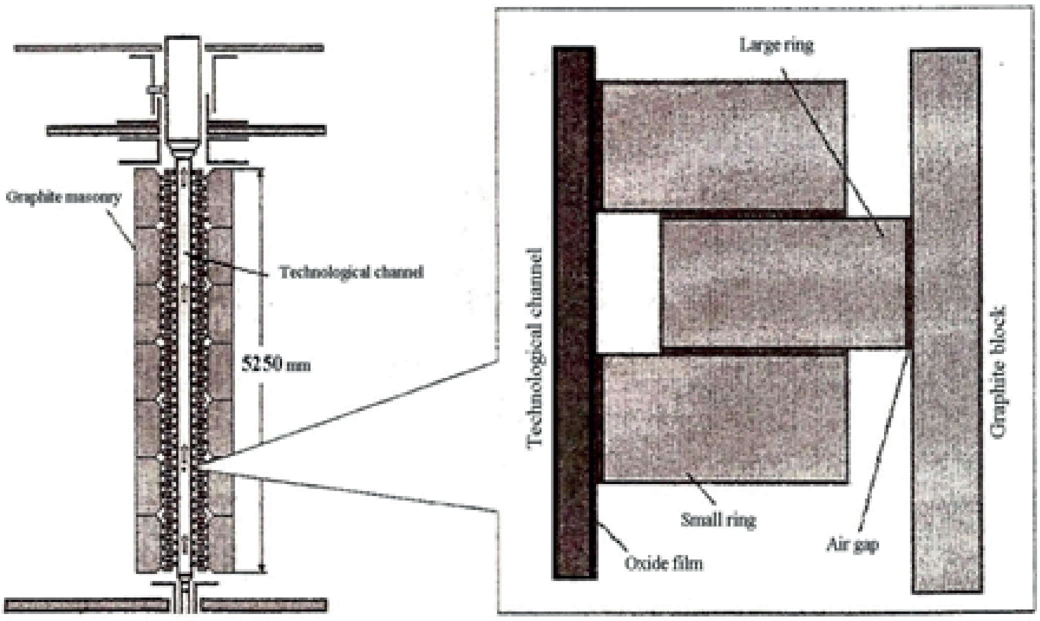

Figure 1: Scheme of the technological system "channel-graphite".

of the graphite cell. As a result, the gap between the channel and the graphite cell decreases until the channel is fully compressed and jammed.

The monitoring system solves this problem, controlling the curvature and the diameter of the cells of the graphite masonry of the EGP-6 reactors in two mutually perpendicular planes, in the course of carrying out preventive and capital repairs.

2. Object of study

The technological channels of the reactor are placed in a graphite masonry. The masonry of the reactor has a cylindrical shape with a diameter of 6 m and a height of 5.25 m. It is composed of individual graphite and in the upper part of cast-iron blocks of square section. The central part of the graphite masonry with a diameter of 4.1 m and a height of 3 m, which is the active zone of the reactor, consists of 333 vertical columns with holes of 88.6 mm in diameter along the entire height, which accommodate 273 working channels and 60 CPS channels. The masonry of the reactor is enclosed in a cylindrical hermetic casing. The cell diameter of the graphite masonry of the EGP-6 reactor is 85 - 95 mm. Between the channel and the walls of the graphite cell spring graphite rings are placed split. One part of rings adjoins the channel walls (small rings) and the other to the walls of the graphite cell (large rings) (Figure 1). As a result, a gap is created to allow the channel to be shifted within certain limits [2].

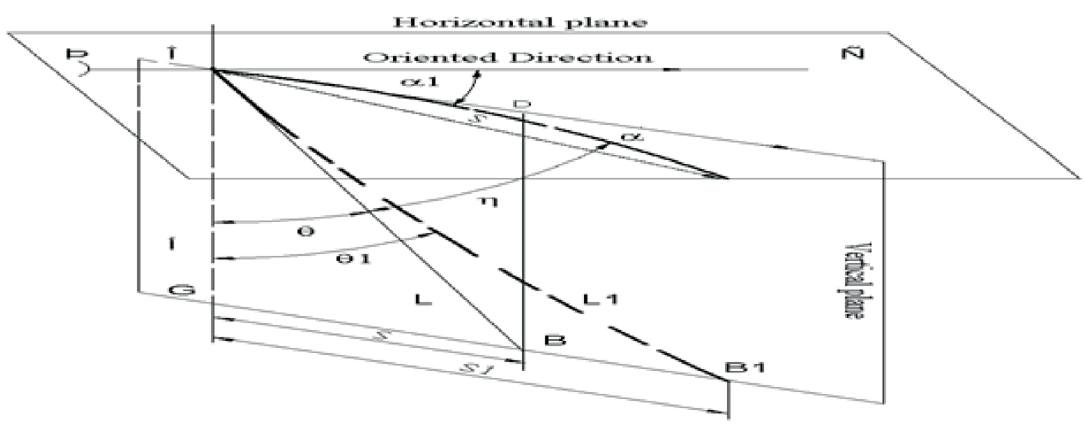

Figure 2: Elements defining spatial axial position of the process channel.

3. Technique for measuring the angle of deflection of the technological channel

The spatial position of the path of the technological channel is determined by the angle of inclination (zenith angle), the azimuth angle, the distance from the zero mark of the channel to the point of measurement of the angles (Figure 2). The angle of inclination η is the angle between the TC axis or the tangent to it and the horizontal, and the zenith angles Θ, $\Theta 1$ - are the angles between the same axis or the tangent to it and the vertical. The sum of these angles is always 90°, and they lie in a vertical plane, called zenith or apsidal. Based on this technique, the curvature of the technological channel was calculated [4].

For the experimental confirmation of the theory, a piezoelectric ultrasonic transducer of the angle of inclination was used, made in the form of a glass with liquid and an ultrasonic sensor in the form of a block of ultrasonic sensors. The instruments were filled with water and transformer oil. To study their behavior in measuring devices, experimental measurements were made. In the course of the measurements, information was used on the goniometers, and it was fully used for experimental confirmation of the theory [5].

The signal from the ultrasonic sensor (or inclinometer) was transmitted to the ultrasonic flaw detector "UD2-12", the analog signal with "UD2-12" was transmitted to an analog-to-digital converter, the digital signal was transmitted to a computer on which the program "PicoScope" plotted diagrams (Figure 3), at which the arrival time of the signal could determine the angle of inclination.

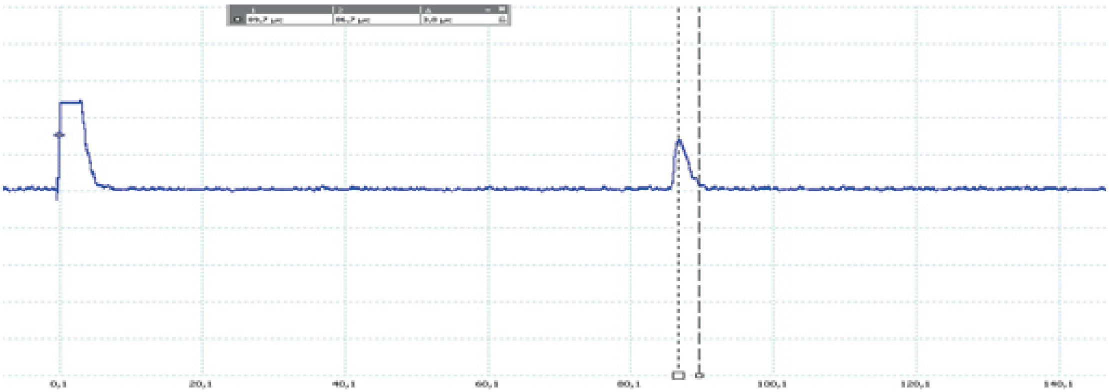

Figure 3: Diagrams obtained from the ”PicoScope” program.

The following angles were measured: the sensitivity angle of the sensors, the maximum angle of inclination. Angle of sensitivity was measured during vibration as well. An experiment was also carried out with liquid poured into the sensors.

In the course of the work done with the ultrasonic sensor and inclinometer, it was found that for diagnostics of the graphite masonry of the EGP-6 reactor and for the diagnostics of other reactor installations, it is appropriate to use transformer oil as a liquid filled in diagnostic equipment. Due to its viscosity, and hence the resistance to vibration generated by the operation of the reactor, there will be less interference in the signal from the diagnostic equipment, which makes control difficult. As a result, it is preferable to use transformer oil.

4. Automated system

The automated control system consists of functionally completed blocks, communication between which is carried out through detachable connections. The probe with sensor blocks is equipped with upper and lower centering wheels. The lower an inclinometer centering wheels are connected to the linear displacement sensors. In the upper part of the probe is located. The probe through the swivel joint is fixed to the ”boom” of the crane beam (Figure 4).

To the probe, through communication lines, the electronic block of registration and information processing is connected. The electronic unit for recording and processing information is connected to a computer.

Diameter control is carried out by means of 4 sensors of displacement of the resistor type fixed on the sensor probe block. Each of the sensors is mechanically connected to the roller, which is in direct contact with the channel wall. Diameter measurement uses data from sensors connected to two opposite rollers.

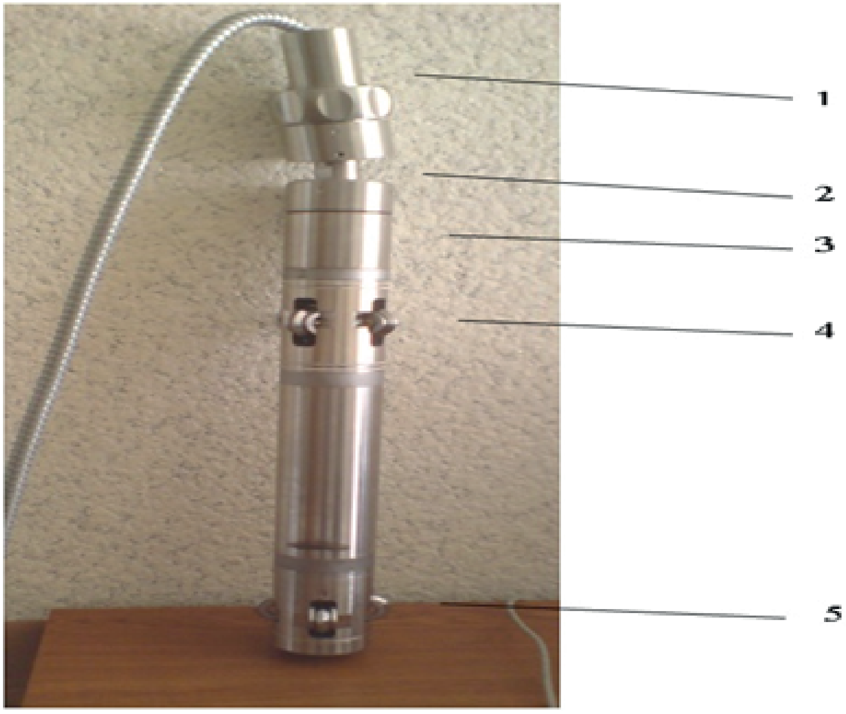

Figure 4: Probe with sensor blocks. 1 - fixation block to the "rod", 2 - articulated joint, 3-section inclinometer, 4 - upper centering wheels, 5-bottom centering wheels

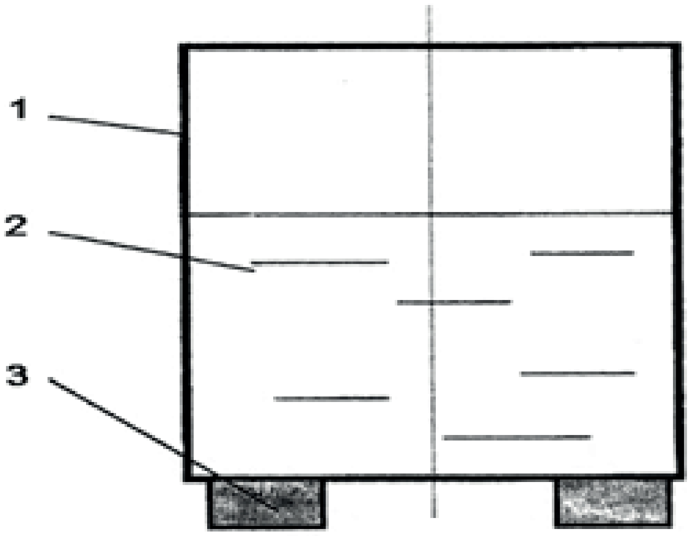

Figure 5: Ultrasonic inclinometer filled with liquid. 1-body, 2-liquid, 3-piezoelements

Curvature control is performed using an ultrasonic inclinometer filled with liquid (Figure 5), which is located in the tail part of the probe. The inclinometer is designed for measuring angles of inclination in 2 mutually perpendicular planes. The data from the inclinometer is transmitted via the interface to an analog-to-digital converter, which is located in the measuring unit and is designed to convert the interface to USB.

To carry out work to control the geometric parameters of the cells of the graphite masonry, the probe that is part of the system must be moved along the axis of the cells of the graphite masonry by means of a rod suspended from the crane beam or by a launching device [1]. The control of the parameters of the cells of the graphite masonry is carried out with contact method, without using of liquid. The software provides the processing of information for controlling the parameters of the cells of the graphite masonry (diameter and curvature). Input of data goes in a dialogue with the operator through the video terminal of the computer. The result of the input is the system data file: a file that is input information for the program for reading and adjusting data.

5. System error

The total positioning error will be composed of the sum of the errors of the frequency drives, the cable, the chain drive, the analog-digital converter unit and the controller, the centering devices, and is:

$$\delta = 0.01 + 1 + 5 + 2 + 0.00001 + 0.001 = \pm 11.01101\%$$

The total error of the obtained measurements will be composed of the positioning error and the error of the electronic processing and it will be equal to:

$$\Delta_{\text{total}} = 11.01101 + 1.5 + 2 = 13.51101\%$$

This error can be taken into account when obtaining data on the basis of which it is possible to talk about the diameter of the technological channel, its curvature related to the vertical.

6. Conclusion

In this project, an automated system for measuring geometric parameters of graphite masonry and measuring deviations of technological channels from the vertical of EGP-6 reactors was developed. The automated system allows increasing the safety of nuclear power plants by measuring the geometric parameters of the graphite masonry and the deviations of the technological channels. Thanks to the diagnostics of the canal and masonry, NPP personnel will have a clear understanding of the state of the core, minimally exposing themselves to irradiation.

The project presents the results of experimental studies that were carried out at the stand with the help of experimental equipment (ultrasonic sensor, inclinometer, flaw detector "UD2-12", analog-digital converter, computer, optical quadrant, calipers). The behavior of transformer oil and water in diagnostic equipment was studied. Measuring the angles of the position of the sensors relative to sea level, conclusions are drawn regarding their behavior in the technological channel.

The project describes the main devices necessary for automation of the system, their brief characteristics. For the devices used, errors are calculated that are acceptable for measuring the parameters of the technological channel and graphite masonry. The cost of creating the system is calculated.

Based on the fact that the system measures the geometric parameters of the graphite masonry and the deviation of the technological channels, it is a diagnostic system for ensuring the safe operation of the unit.

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