1.13.5. INTEGRATED CONTROL OF THE BASE METAL AND WELDED JOINTS OF NPP EQUIPMENT AND POWER UNIT PIPELINES

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By now, the service life of the majority of Ukrainian NPP power units has exceeded the half of the term specified by the initial project, and by 2025 it will be exhausted for the power units now in service. Nevertheless, the world experience shows that the extension of the service of operating NPP in excess of the design lifetime (30 years) is one of the most efficient ways of recoupment of capital investments in nuclear power engineering. The analysis of merits and demerits of various inspection and diagnostic techniques employed in nuclear power engineering indicates that only an all-round approach with the use of different ways and methods can provide an exact information on the real condition of the equipment and pipeline metal, enabling one to elaborate science-based guidelines for both the safe operation of power units and the extension of the design life.

The aim of the present work is to develop the methods of integrated diagnostic monitoring of the equipment and pipeline metal after its continuous service for substantiating the operational capability of the metal both during the designated period of service and on extension of the latter.

Magnetic properties of metals correlate with the stress-strain state arising in the unit components while in service. The methods of coercimetry [1] and magnetic memory of metals [2] have been used in this work. The coercive force was measured with the help of a magnetic structurescope, while a specialized magnetometric device IKN-1M-3 was used to measure the self-magnetic field distribution and to determine the zones of stress concentration (ZSC) (the magnetic memory technique). The coercive force is connected with actual working stresses and with damage accumulation in the metal, which determine the remaining life of the structure. The physical processes of damage accumulation under fatigue manifest themselves first of all in the increased coercive force at stress concentration points. Compared to other techniques, the magnetic methods (magnetic memory and coercimetry technique) of metals have the following advantages:

– they require no metal surface scraping or any other surface preparation;

– being related to rapid test methods in the labor intensity of control, the magnetic methods provide a 100% examination of the equipment and pipeline metal.

The main task of the magnetic-diagnostic analysis at the unit under test is to detect the most dangerous sections and junctions, which are characterized by the zones of stress concentration being the sources of damage development. Integrated studies have been made to determine the mechanism of crack formation and development in the zone of "hot" collector welding to the steam-generator shell (welded joints No. 111). The mechanism is demonstrated to be corrosion under stress. The testing techniques based on magnetic methods (coercimetry and magnetic memory) have been developed for diagnostic analysis of the strain-stress state of weld seams No. 111. Over the last six years regular magnetic measurements have been made on the weld seams and in the weld-affected zone of welded joints No. 111. On the strength of the diagnostic analysis, science-based recommendations are developed for further service life of weld seams No. 111. A variety of experiments have been performed to control the influence of service conditions on the failure of the metal of quick-closing cut-off valve piping in the turbine section of NPP power units, and also of other pipelines subjected to erosion-and-corrosion wear. The magnetic methods are efficiently used for the diagnostic analysis of the strain-stress state of the WWER-1000 reactor vessel.

A new method has been developed for testing the mechanical properties and the structure of the equipment-and-pipeline metal by means of the microsample technique. The technique is aimed at obtaining the maximum body of information on the mechanical properties, the structure-phase changes in the metal when in service, and also at estimating the remaining life without causing damage to the integrity and strength of the NPP equipment and pipelines. The mechanical inspection of the base metal and welded joints of the NPP equipment and pipelines with the use of microsamples provides the information on:

– tensile properties (ultimate strength, yield point, elongation per unit length, contraction ratio);
– impact toughness;
– fracture mode of the samples tested (fractography);
– microstructural and structural-phase changes in the course of service (metallography, electron microscopy, internal friction);
– hardness and microhardness;
– condition of the grain boundaries responsible for the processes of metal embrittlement.

Among the merits of the microsample technique we mention the following:

– templates for sampling are cut out without violation of structural integrity and strength of the equipment and pipelines;
– *in-situ* method is used to determine the mechanical properties;
– mechanical tests are carried out at the required temperature;
– integrated analysis of mechanical properties and structural-phase changes in the metal is carried out.

The main distinctive feature of the microsample technique is the fact that the sample tests are made with destructive methods, while this testing technique is nondestructive for both the equipment and the pipelines.

Conclusions:

1. The most "critical" parts of the base metal and welded joints have been determined for the NPP equipment and pipelines, which call for constant control, as in the course of reactor operation there may arise and develop the processes of discontinuity flaw formation.
2. The analysis of the present results has revealed that after a prolonged service the metal of the main circulation line shows a tendency to embrittlement.
3. Taking into account the urgency of the issue, the authors consider it necessary to continue the investigations aimed at finding and estimating new informative parameters of nondestructive magnetic testing methods, especially, the method of metal magnetic memory.

References:

1. **DSTU 2954-94** Steel. Magnetic inspection methods. (In Russian).
2. **DSTU 4857:2007** Welded joints of the equipment and structures. The method of metal magnetic memory. General requirements. (In Ukrainian).