1.12.2. DEVELOPMENT OF ELECTROMAGNETIC FLAW DETECTION METHODS BASED ON SOLUTION OF INVERSE PROBLEMS DURING TESTING OF NUCLEAR POWER PLANT EQUIPMENT

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Presently, scientific researches in the field of evaluation of operability of nuclear power plants (NPP) equipment taking into account its wear and detected defects become the priority ones. It is easy to explain, because most part of equipment in nuclear power industry has worked out already its design service life and the problem whether to replace it or to continue operation is especially acute. In order to examine the process of destruction of a metal article with defects presented in it, numerical method of finite elements is applied for analysis of stressed-strained state in the zone of defects of various configuration and for evaluation of destruction criterion. As a result, remaining service life of the defective article is calculated. Apparently, that the more accurate is data on defect parameters, the more reliable is the forecast of service life.

Electromagnetic testing methods are extremely important for diagnostics of critical state of nuclear power plants equipment. However, application of traditional technologies for testing of the metal state provides satisfactorily results from the point of view of flaw detectability only, which can be explained by certain successes in improvement of experimental and measuring equipment. At the same time, possibilities of these technologies with regard to determination of defect parameters using data obtained from respective sensors are much more modest. Dimensions, position in article, orientation, shape, as well as type (stress-corrosion cracks, pitting, spots) are used as frequently required defect parameters. All these parameters are very important, since they impose significant influence on the operational reliability of an article.

In order to resolve the inverse problem of electromagnetic testing, i.e. problem of reconstruction of defect parameters by sensor signals, methods is mostly spread that implies the plotting of calibration characteristics, when individual values of parameters extracted from experimental data are compared with values taken from the set of standard signals obtained from known defects. Every calibration curve is obtained if one of the defect parameters varies, while other ones remain unchangeable and adopts known specific values. Generally speaking, methods based on the plotting of calibration curves are valid only when the defect shape is known in advance.

With growth of computational resources, an improved approaches to the solution of inverse problems of electromagnetic testing were elaborated. These algorithms can be divided into two major groups depending on the basic strategy they use during solution.

Methods based on the mathematical model taking into account the physics of phenomenon laid down in the testing method and activating respective mathematical model in the process of solution search are referred to the first group. Approach consisting in iterative solution of direct problem by numerical method with constant updating of coordinates of digitalization network nodes or re-determination of material in small areas seems to be prospective one. Purpose of this iterative method is to find distribution of material across the material area that would provide obtaining of a signal in the direct model coinciding with experimental signal of a sensor. Selection of mathematical model for signal evaluation is of extreme importance, since it influences directly on the quality of obtained result. Good result can be guaranteed only by models with least simplifications in the description of phenomenon physics, although considerable computational resources can be required

in this case. Primarily, models based on the finite elements method are referred to such numerical models. Computational costs of this method of numerical solution of mathematical physics problems can be reduced significantly by selection of efficient methods of calculations arrangement. In MEI (TU), by means of this method, problem of reconstruction of parameters of cracks in NPP feedwater pipe was resolved and pipe surface profile in the field of weld seam was evaluated.

In second group of approaches to solution of inverse problems, procedure of experimental data inversion is stated as a problem of image recognition and, in this case, signal is identified as a representative of one of the classes related to the defects of known type. Use of the formed in advance data bank containing respective signals from defects of all types is a distinctive feature of methods based on the classification or image recognition algorithms. This set of signals is referred to so called training sample, which is used for training of some automatic system with recognition algorithm laid down in its operation principle.

Classification procedure consists of two steps. First step is extraction of attributes, i.e. determination of some characteristic parameters of diagnostic signal carrying discriminatory information. Second step consists in the operation of classification and parameterization of attribute vector.

Attribute vector is found by analysis of measurement results. Attribute extraction procedure is arranged with the purpose to provide invariance being the most important aspect of signal classification systems. In practice, nondestructive testing is carried out in constantly varying experimental conditions like probe characteristics (for example, under influence of temperature), varying scanning speed, application of various frequencies, varying (local) values of conductivity and magnetic permittivity of test object, instability of amplification coefficient of measuring instrument, variations of gap, etc. But, the main purpose consists in elaboration of signal processing algorithm that would make it possible to compensate signal variation in the result of varied instable conditions of the experiment performance. Such processing schemes are of most importance for successful functioning of the signal classification system in general providing insensitivity to inevitable influences of external conditions, where real diagnostic signal is obtained in.

For the last decade, during solution of inverse problems of electromagnetic testing of NPP equipment (heat-exchanger tubes of NPP steam generators with reactor installations VVEP-440 and VVEP-1000, reactor fuel elements) in MEI (TU), prospective technology of data analysis is applied successfully, which is based on the application of artificial neural networks. Ability to be trained on examples and to generalize the obtained information, noise immunity and inherent parallelism of architecture is their distinctive feature. All above mentioned makes neural network approach to be extremely attractive for solution of such complex problems as defect classification and parameterization in conditions of noise, as well as incomplete and contradictory data. In practice, neural networks are used for creation of automated systems for processing experimental diagnostic information serving as an intellectual assistants for high-qualification experts , when large volume data has to be analyzed in order to take a decision.

Elaborated automated classifier of defects by the results of eddy-current testing of heat-exchanger tubes of NPP steam generators has passed successfully acceptance and pilot industrial tests in the mode of operational testing. Moreover, classifier has demonstrated the number of serious advantages as compared with the standard testing system (Harmonic-AIDA) (in respect of accuracy of detected defect depth evaluation, possibility to evaluate the axial length of defects, as well as to operate in automatic mode).