1.13.7. EFFICIENCY OF APPLICATION OF ACOUSTIC-EMISSION TESTING METHOD FOR RISK EVALUATION DURING EXPERT EXAMINATION OF INDUSTRIAL SAFETY OF EQUIPMENT OF PETROCHEMICAL PRODUCTION FACILITIES

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Under [1], the main task of risk analysis consists in provision of answers to the following three main questions:

– What bad things can occur? (Identifications of hazards);
– How often it can occur? (Analysis of frequency);
– What are possible consequences? (Analysis of consequences).

From the point of view of a specialist in non-destructive testing (NDT), purpose of examination consists in detection and identification of defects in metal and welded joints at a hazardous production unit (HPU). In opinion of an expert on industrial safety (IS), performance of examination is aimed to evaluation of the HPU operability and calculation of its remaining service life. Therefore, risk analysis from the point of view of NDT specialist and IS expert can be related with solution of first two from three above indicated problems, and namely:

– "identification of hazards", i.e. detection of hazardous defects and identification of their type;

– "analysis of frequency", i.e. probability analysis of the frequency of detection of hazardous defects.

Third problem – "analysis of consequences", i.e. consequences of incident, accident, failure, malfunction at HPU is not within the competence of NDT specialist or IS experts and is not the purpose of the given paper.

Mathematical models of reliability theory – probability analysis of risks (PAR) widely applied in nuclear power and other industry branches are used in the paper.

It is known that every operational cycle in the event of prolonged functioning ends with failure. For obviousness and simplification of solution of task set in the paper, failures caused by defects are considered. Under Griffith's crack theory and mechanics of destruction, fragile cracks, i.e. cracks achieving critical size L_{cr} can be such defects. For metals, it corresponds with exhaustion of plasticity and achievement of critical coefficient of stress intensity at the top of crack:

$$K_{IC} = f(L_{cr}).$$

Presently, acoustic-emission (AE) method is the only one, which makes it possible to record and analyze jumps of cracks of pre-critical (preceding formation of fragile crack) and critical length.

Therefore, it was of interest to study efficiency of the new acoustic-emission (AE) testing method for evaluation of risk during expert examination of industrial safety of petrochemical production equipment. Furthermore, unlike to other NDT methods, this method allows detection of developing defects and evaluation their hazard. It makes it possible to predict the term of HPU further operation basing on experimental data on developing potentially hazardous defects with application of modern reliability theories.

In practice, function of time distribution density of sudden system failures is accepted to be exponential:

$$f(t) = \lambda \exp(-\lambda t),$$

where parameter λ represents the average number of failures per time unit and features the scale of distribution.

Faultlessness or reliability of equipment is the characteristic of its technical efficiency E, i.e. its ability to fulfill the tasks set.

In the event of various equipment operation modes (cycles), generalized index of technical equipment efficiency is combined from products of reliability Pi and specific efficiency index Ei for every operation mode:

$$E = \sum_{1}^{n} PiEi .$$

Probability of faultless operation in the presence in metal of sequential link of defects like cracks with each of them able to result in failure is the lowest and is defined by the product of probabilities:

$$P = p_1, p_2, \ldots, p_n .$$

It is the most dangerous option of the events development.

Probability of faultless operation in the presence of cracks forming bunches in the form of two, three, etc. cracks is defined as:

$$P = \sum_{n} pi - \sum\left(\prod p_1 p_2\right) + \sum_{n}\left(\prod p_1 p_2 p_3\right) + \ldots,$$

where first item is the sum of faultless operation probabilities in the presence of cracks that do not interact and do not form bunches; second item is the sum of paired products of faultless operation probabilities for the bunch of two cracks; third item is the same as second one for the bunch of three cracks, etc.

AE sources are identified by means of normative criteria established by the Rules [2] and governing 4 classes of hazard. Critical crack corresponds with the highest IV hazard class of AE source. Under Rules [2], such emergency situation is inadmissible, because it corresponds with the HPU complete failure with all ensuing consequences.

Therefore, it is reasonable to calculate time until the first crack jump or the first failure T_1. When there are several individual operable states for any HPU, values T_i and p_i are calculated by solution of the system of equation of the following type:

$$-p_0(0) = -\lambda_{01} T_0 + \lambda_{10} T_i ;$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$-p_k(0) = -\lambda_{(k-1)} T_{k-1} - (\lambda_{k(k-1)} T_i + \lambda_{(k+1)}\, T_{k+1} ;$$

$$-p_n(0) = -\lambda_{(n-1)} T_{k-1},$$

where $p_0(0) = 1, p_i(0) = 0$.

Average time until the first failure T_{av} is equal to the sum of values of average operation time for every one of n individual operable states T_i:

$$T_{sr} = \sum_{i}^{k} T_i \ .$$

Knowing relationship between the hazard class of AE source and parameter λ, it is possible to predict the time until the first failure and to evaluate subsequently the remaining service life of HPU.

In the present paper, an attempt of experimental calculation of remaining service life of chemical reactors under data obtained by means of SAEK acoustic emission instrument is made. Instrument distinguishes by high sensitivity to displacements (more than 10^9 V/m), small dimensions (300×200 mm); it has 32 channels and is operated by PC. High sensitivity makes it possible to extend the base of statistical data and, correspondingly, to increase trustworthiness of results of their processing. Analysis and post-processing of AE signals are carried out basing on initial digitalized signals without loss of valid information.

Obtained results have shown possibility and efficiency of application of acoustic-emission testing method for evaluation of risk during expert examination of industrial safety of petrochemical production equipment.

References:

1. **RD 08-120-96** “Methodological guidelines on performance of risk analysis of hazardous industrial facilities”.

2. **PB-03-593-03** “Rules of arrangement and performance of acoustic-emission testing of vessels, equipment, boilers and technological pipelines”.