Application of AE method in nuclear power industry

The acoustic emission method, which is widely used in oil and gas industry in Russia, is not applied widespread for nondestructive testing in nuclear industry.

The new potentialities of this method, which have been recently opened up, allow us to hope for its implementation at nuclear power plants.

At present we have obtained the results and tested the potentialities of the acoustic emission method for the following applications:

- Material degradation monitoring;
- Corrosion rate measurement;
- Detection of zones of stress-strain state;
- Integral thickness gauging measurements (at an area between sensors);
- Leak detection.

Integral thickness gauging measurements

We have developed and tested the procedure for determining the monitored object wall thinning as a result of material degradation. This procedure is based on the standard acoustic emission system. The measurement process consists of the pulse signal radiation (emitted by the acoustic emission or ultrasonic transducer or Su-Nilsen imitator) and the reception of this signal by the acoustic emission transducer located at a specified distance from the source. After that the time-frequency conversion of the received signal oscillograph record is carried out. Then the Lamb wave propagation modes (as a rule, A_0 and S_0) are selected on the obtained spectrogram, and their numeric parameters are determined. These parameters allow us to determine (with high accuracy) the averaged thickness of the wall between the source and the receiver.

We have conducted a series of experiments on the gas pipelines with a wall thickness of 10-17 mm and a diameter of 1020-1220 mm, with isolation and without isolation, as well as on the spherical gasholder with a wall thickness of 40 mm. It has been found that the wall measuring error does not exceed 1-3%. It has been detected that the minimum distance between the source and the receiver with all above-mentioned thicknesses is 1 m, and the maximum distance may reach 10-12 m with isolation and 50 m without isolation. The experiments also have shown that welded joints do not affect the measurement process.

At present we are investigating the effect of wall thickness irregularity, presence of isolation, liquid in the pipe, and pipe curvature on wall thickness determination accuracy. In addition we are developing the ways for further method automation. Among other options, the best transducer configuration is being selected, and the process of determination of the dispersion curves parameters is being fully automated.

Corrosion rate measurement

We have developed, tested, and patented the method for determining the penetration depth and rate of pitch (pit) corrosion penetration by analyzing the acoustic emission data. This method is based on the fact that the signal propagates in thin-walled object in the form of Lamb wave propagation modes combination, and a low-frequency A_0-mode dominates in the signal when the corrosion propagation depth is small, but with an increase of the corrosion propagation depth a higher-frequency S_0-mode dominates in the signal. The ratio of A_0 to S_0 modes is calculated by application of the spectral analysis or wavelet transformation. Next the corrosion propagation depth is determined by the above-mentioned ratio, and the estimation of corrosion propagation rate is made by this process behavior.

In the series of experiments with the samples made of carbon steel with a thickness of 5 mm and the sulfuric acid solution the corrosion propagation depth has correlated well with the ratio of low-frequency (30÷200kHz) component energy to high-frequency (300-500kHz) component energy of the signal.

In addition we have found that the oxide film destruction on the metal surface is also accompanied by the radiation of high-frequency acoustic emission signals.

The detection of developing defects (fractures, welded joints defects, corrosion) makes the acoustic emission method attractive for application in the nuclear industry along with conventional usage in other branches of industry.

The personnel stay time in high-radiation areas is an important factor taking into account the special requirements specified for carrying out nondestructive testing at nuclear power stations. A new architecture of acoustic emission devices (series connection of channels) has been developed. It allows reducing the personnel stay time in dangerous areas by 40%.

Taking into consideration complicated design features of the reactor facilities and a large labor content in case of the execution of ultrasonic testing in the design mode, a new approach has been proposed. This approach consists in performing (during shutdowns) first of all the monitoring with application of the acoustic emission method, and the monitoring with application of the ultrasonic testing method only at the detected dangerous areas.

The positive operation experience of many years is confirmed at the petroleum chemistry and oil refining facilities. We consider the application of the acoustic emission method as an integrated part of the integrated diagnostic monitoring systems to be a very promising way.

At the present time the acoustic emission method has been already applied in the nuclear industry of France, USA, Hungary, Czechia, and Ukraine.

The application of the acoustic emission method in nuclear power industry when carrying out inspections and monitoring is based on the normative document approved by the Rostechnadzor.