ACOUSTIC EMISSION METHOD OF TECHNICAL DIAGNOSIS
OF POWER PLANTS

V. N. Byrin

Theoretical and experimental investigations of acoustic emission (AE) — the process of emission and propagation of sound waves in solids during their fracture — began in our country in the first half of the twentieth century. However, the first significant reports about the applied value of AE for purposes of technical diagnosis were published only in 1976 [1-3]. In the first years of its development, the method of technical diagnosis based on AE served as an "exotic" method and to a greater degree had a promotional character. At the same time, its possibilities, leading to a marked reduction of the downtime of equipment and material expenditures on its operation, reduction of the failure rate, and possibility of servicing with respect to its actual condition, attracted considerable scientific forces to the development of the AE method. Thanks to the efforts of scientists the acoustic emission method began to rapidly increase the number of its advocates and to find wide use. Whereas at the start of the 1980s it found use as an additional nondestructive testing (NT) method accompanying other NT methods, at present it already serves as an independent technical diagnostic method.


As is known, processes of continuous rupture and restoration of interatomic bonds occur in unloaded solids, and these processes are equiprobable. If a load is applied to the solid, the probability of rupture of the bonds begins to exceed the probability of their restoration. The excess of the probability of rupture over the probability of restoration is greater, the higher the applied load. Consequently, the longevity of the integrity of a solid (its time to failure) is less, the greater the load applied to it. These arguments are based on the kinetic theory of strength, according to which the life of a solid which is under the effect of a constant external load and temperature is determined by S. N. Zhurkov's known formula

$$\tau = \tau_0 \exp \left\{ \frac{U_0 - \gamma \sigma}{kT} \right\}$$

where $\gamma$ is the time to failure after loading; $\tau_0$ is the period of thermal oscillations of atoms ($10^{-13}$ sec); $U_0$ is the fracture initiation energy; $\gamma$ is the coefficient of reduction of the initial potential barrier by the applied stress $\sigma$; $k$ is the Boltzmann constant; $T$ is absolute temperature.

The applied load leads to a probabilistic process of development of micro- and macrocracks and, as a result, to fracture of the solid. Cracking is accompanied by the emission of AE signals, by analyzing which we can check the condition of the material under stress, determining its closeness to failure. Not giving the analytical derivation and final expression of the time dependence of the number of AE signals of the loaded structure, we will show only the qualitative graphic dependence depicted in Fig. 1. It shows the "life curves" of the object being tested under various static stresses $\sigma_1$ and $\sigma_2$ and same temperature. The start of exponential increase of the number of AE signals corresponds to the formation and increase of the main crack.

The effect of a high test pressure on the life of equipment subjected to such testing is seen, in particular, from Fig. 1. If some object operates under a static stress $\sigma_1$ and its life curve corresponds to type 1 and the life corresponds to time $t_1$, then during operation under conditions of static stress $\sigma_2$ ($\sigma_2 > \sigma_1$) the life curve will have form 2, and the life will corre...
spond to time $t_2$. Let after time $t_1$ of an object being under stress $\sigma_1$ a stress $\sigma_2$ be created for the purpose of testing and be kept constant for time $\Delta t_1$, after which the stress is reduced to $\sigma_1$. For simplicity of the arguments, since only the qualitative picture is being considered in the given case, we will consider that the processes of an increase and decrease of stresses occur instantaneously.

When the process of accumulation of microfractures occurred according to curve 1, after time $t_1$ these accumulations corresponded to point A of the life curve, i.e., to point M on the axis of the ordinates. An increase of stress to $\sigma_2$ converts the object to the accumulation of microfractures in it according to a law corresponding to curve 2, starting from point B, i.e., from the state of the number of microfractures already accumulated under stress $\sigma_1$. During the test time $\Delta t_1$ the state of the objects will move from point B to point C of curve 2, the number of microfractures will increase and will correspond to point K on the axis of the ordinates. A decrease of the stress to $\sigma_1$ at the end of the tests will return the object to life curve 1, but no longer to point A but to point D, to which corresponds the number of microfractures K. Thus, the tests will shorten the life of the object by time $\Delta t_2$.

In technical diagnosis of equipment by the AE method it is preferable to use multichannel diagnostic apparatus. The arrangement of the transducers of several channels at various points of the equipment being tested makes it possible not only to record the AE signals but also to determine the coordinates of the sources of their emission from the difference of the times the signals reach the various transducers.

The absence of AE signals indicates the absence of the development of flaws even in their presence. Recording of signals indicates the presence of developing flaws, establishes the places of their development, and makes it possible to assess from the repetition rate and character of the signals the degree of danger, to calculate the remaining life.

Many types of acoustic emission diagnostic apparatus have presently been created in Russia and abroad. In 1996, in accordance with the order of the joint-stock company (JSC) Lenenergo (Leningrad Regional Power Administration) the JSC KONTES designed and produced the first batch of Resurs-2M diagnostic complexes. These complexes correspond to the current level of development of acoustic emission apparatus and are superior to foreign analogues in a number of parameters.

It should be noted that one of the important virtues of technical diagnosis by the AE method is the fact that the diagnosis can be made with the equipment operating, without removing it from the direct purpose of its functioning.

Works on estimating the remaining life by associates of KONTES were carried out successfully at enterprises in St. Petersburg and Novgorod, Kaliningrad and Togliatti, Novorossiisk and Vladivostok, Neman and Petropavlovsk-Kamchatskii, Dzerzhinsk and Dorogobuzh, and a number of other cities.

The end result of carrying out each of the works is the determination of the remaining life of the equipment under the specified operating conditions and issuance of recommendations on the operating parameters, if the actual remaining life is almost exhausted. The detection of equipment whose life with respect to the actual conditions is virtually exhausted makes it possible to avoid the occurrence of emergency situations, some of which can lead to disastrous consequences. Just in the past several months more than a dozen objects were detected by the AE method during their inspection by workers of KONTES, which made it possible to prevent failures.

As a result of the inspection the compressed-air receiver at the JSC Neman Cement and Concrete Plant was taken out of operation; the prefailure state of the condensers of the JSC Volkhov Refrigeration Plant, the air tightness of which was disturbed several weeks after making the diagnosis, was determined. On objects of the JSC Black Sea Oil Trunk Pipeline in Novorossiisk several multilayer metal expansion joints with diameters of 500 and 1000 mm whose life was close to zero were found, and further operation of one of the 500-mm-diameter joints was considered impermissible. Also there, on a 1000-mm-diameter oil pipeline laid along a pier for loading tankers, a 50-m-long section with a remaining life of 5-6 months was detected, which will make it possible to replace the defective section in good time, without allowing accidental pollution of the sea water.

Since AE signals are caused not only by fracture of solids but also by such physical processes as friction, outflow of liquid and gas, boiling, cavitation, electric arc, and a number of others, the limits of applicability of the AE method for technical diagnosis are expanded considerably. They are not limited to pipelines, cylinders, vessels, and other structures operating under static and low-cycle loads. Thus, in 1995 on the grounds of the JSC Leningrad Metals Plant (LMZ) (St. Petersburg) specialists of KONTES demonstrated the possibility of determining the presence and location of a crack in the rotor of a steam turbine for the example of the high-pressure rotor of the K-800-240 turbine at the Surgut state regional power station.