4.2.10. UTILIZATION OF NATURAL OSCILLATIONS FREQUENCIES “NOF” IN NON-DESTRUCTIVE TESTING OF PHYSICAL MECHANICAL PROPERTIES OF MATERIALS AND PRODUCTS

Kovarskaya E.Z., Moskovenko I.B., LLC “ZVUK”, St.-Petersburg, Russia

The subject of this report is dedicated to the possibility of using natural oscillation frequencies (NOF) of products and specially prepared samples to assess physical and mechanical properties of different types of materials, primarily non-metal materials with high attenuation of acoustic waves, for which the use of traditional methods of ultrasonic testing is difficult or even impossible. In the first place, these are products made from ceramics, polymers and composite materials, and also products with the surface, impeding the penetration of ultrasonic vibrations, such as cast iron castings.

It is known that in general terms, the relationship of products’ NOF at a propagation speed of acoustic waves in the material from which they are made, can be presented as:

$$f_i = F_i C_l, \tag{1}$$

f_i – frequency of natural oscillations of a certain type (i); F_i – shape factor that depends on the shape and size of products, Poisson's ratio, as well as on the type of the excited oscillations i; $C_l = \sqrt{E/\rho}$ – the reduced speed of propagation of acoustic waves (as defined by the Governmental standard 25961–83 and Governmental standard R 52710–2007) – velocity of propagation of elastic waves in an infinitely long rod made of the same material as the material of an object under testing; E – Young’s modulus; ρ – product’s material density.

The expression (1) implies that for the same shape and size of products, the frequency f_i, corresponding to a particular vibration mode, characterizes the reference speed of propagation of acoustic waves C_l. This parameter is the elastic constant of the product’s material associated with the Young's modulus, density, strength, porosity, hardness and other physical and mechanical properties of the material, as well as the presence of defects or rupture of the material’s structure.

On the other hand, the same values of speed C_l the frequency f_i may change in case of changes in the form factor of F_i, which can be caused by a change in the geometric dimensions and the presence and impact of major defects as well. Thus, in any case the change in frequency f_i of definite modes of vibration indicates either changes in the physical and mechanical properties of a product’s material, or the presence of defects. Herewith the deterioration of physical and mechanical properties of a material (reduction of durability, hardness, etc.), and presence of defects usually result in a decrease of NOF value.

Formula (1) also implies that it is possible to separate the influence of physical and mechanical properties of the material of a product under testing and its geometry on the NOF values, wherefore the ratio of frequencies of natural oscillations of two different modes of “i” and “k” must be considered, which does not depend on the speed C_l and determined only by geometrical factors, including the presence of defects:

$$\frac{f_i}{f_k} = \frac{F_i}{F_k}. \tag{2}$$

With the same geometrical dimensions the clause (2) actually describes the change in the NOF spectrum of a product in case of defects. To implement the method based on measuring the NOF, it is necessary to develop special methods of testing in order to ensure reliable emission of corresponding selected testing types (modes) of oscillations from NOF spectrum, eliminating the impact on the results of shape and size of products and samples.

For practical implementation of the method natural frequencies meters are used (NFM), they utilize the method of free oscillations excited in the product by a blow, and also the method of forced oscillations (resonance method). The most widely used in industry for solving practical problems are NFM produced by LLC “ZVUK” and NPP “INTERPRIBOR” (Russia) and the company “J.W. LEMMENS N.V.” (Belgium).

Main spheres of application of the method for the purpose of solving effect-oriented tasks:

– testing of grinding tools for all types of ligaments, including shaped (profiled with grooves) cut-off wheels of any diameter, as well as small-sized tools with a diameter of 8 mm or less, for determination of physical and mechanical properties which can not be determined by means of traditional methods hardness testing;
– testing of refractory products;
– testing of carbon and graphite products;
– testing of cast iron blanks of different grades;
– testing of products made from high-strength ceramics and synthetic superhard materials;
– testing of natural frequencies of turbine blades;
– elastic constants identification (elastic modulus, Poisson's ratio, etc.) of products of various shapes and materials.

Presently, the testing method based on measuring NOF, begins to find application also for solving tasks of flaw detection of different types of castings, products used in rail transport (railway wheels and axles, trolley system suspension fittings, side frames of freight wagons) and for condition testing of power lines wooden poles etc.