PRESENT STATE AND SOME PROSPECTS FOR ELECTRIC NONDESTRUCTIVE EVALUATION DEVELOPMENT

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INTRODUCTION

The industrial processes of the laminated nonmetallic structures and components production provide an urgent need for the nondestructive evaluation (NDE) of their physical properties, especially referred to an interface layer in composite structures. It presents a number of challenges concerning to

- the materials making technology inspection,
- the manufacturing technology control,
- the nondestructive inspection technology integrated in main manufacturing stages of a product making with a predetermined quality.

Each of them, as a particular problem, is an interrelated scientific and technological task today. The last of them deals with a nonuniqueness choice of its solution in the terms [illegible] quality prediction of the permanent joint properties, for example. It is important that some making technologies of various permanent laminated joints refer mainly to such advanced industrial branches as the aerospace and nuclear engineering where a full-size nondestructive inspection of the products quality and their long-term reliability prediction is not only necessary scientific or technological progress factor, but as for the sake of safety one. In this connection it is rather interesting to mark that the whole summary content to the paper [1], devoted to the role of testing in the development of advanced materials, is put into the single phrase: "There can be no advanced materials without the ability to test them".

Qualitative indices and interface position in a bilamellar permanent joint such as a bearing composite construction and its protective nonmetallic coating may be identified through the various penetrating physical fields supply at an inspection zone having some material property gradients on density, thermal and electric conductivity or dielectric permittivity. Two last physical characteristics are essential at their nonzero gradients highlighting by the electric field effects measurement. The dielectric measurement methods are similar to some electric NDE ones because there are few common features. The first of them lies in the fact that a low-value current measuring is needed and the second one is referred to the methods reducing errors caused by contact conditions. In practice, these limitations present a major stumbling-block in attaining the reproducible and admissible test data [2]. The corresponding nondestructive methods and sensors are enough various in their application. This statement may be illustrated by a selective reviews analysis given in its sketch. The possibility to use the electric field supplied to the glass-reinforced laminates testing has been pointed and compared with other nondestructive testing methods in a review paper [3]. Another appreciation of the electric field to be used as a nondestructive testing tool has been also reported in works [4, 5]. The report [6] contains some papers review and analysis in the scope of 155 bibliographical denominations. More detailed description of electric testing methods has been given as some adduced recommendations on a resolving capability improvement for transducers operating in the range of (10 - 80) MHz. As for superhigh frequency gauges, operating in the range of (26 – 40) GHz, they were referred there by works of the British Aircraft Corp., S. Petersburg's Electrical Engineering Univ. (former LETI) and other research groups. A specific review [7] concerns to the electric method diversification as well. It already contains information about a dielectric spectrometry and electrostatic charge decay methods. The feasibility to use the pulsewise electric field, especially at the combined testing of nonmetallic structures, has been also pointed in a review paper [8].

A comprehensive study of these contributions brings some arguments in favour of the electrical methods status revision taking into account as follows:

- reviewed works, as a rule, are related to well mastered techniques and many workings out, having a limited gain or access to practice, are obviously excluded from them;
- physical experimental methods, being known as a base of the nonmetallic material properties investigation, are not yet embraced by the electric NDE practice.

The perspective electric methods may be conventionally subdivided into three groups as the test electrifying, dielectric spectrometry and electric field distribution sensing.

TEST ELECTRIFYING

The high-voltage test electrifying is well known to be a proper process [9, 10] which can highlight some inhomogeneities in the imperfect dielectrics. The test electrifying is usually performed by the high-voltage ionization of an air gap between a corotron electrode and one of surfaces of a planar nonmetallic structure, being subjected to the test, while its opposite surface can be locally recognized as the zero equipotential of the supplied electric field. The process model deals with the absorption currents and corresponding space charge accumulation or its decay at the boundary interfaces in the imperfect dielectric medium. So that, in any case a change of the nonmetallic structure internal state may be detected either by some deviations in the potential decay pattern on the test zone surface or through the local absorption currents integrated during the test electrifying [11-13].

The alternative is to use a test-pulse electrifying. In this case, the locally initiated transient polarization current is the dominating component of the integral response [14, 15].

An advantage of the electric NDE based on the high-voltage test electrifying is its contactless. It allows to inspect some nonmetallic objects having rotational symmetry, for example. One of the disadvantages consists in that the deep layer defects detection is hampered. Another problem is a complexity of mathematical models taking into account the charge carriers transport through the nonmetallic structure under the strong electric field intensity.

DIELECTRIC SPECTROMETRY

The dielectric spectrometry using a measuring cell with the uniform testing electric field applied to the composite sample is well known [16-18]. Electric field interactions with some composite structures may be characterized by various relaxation mechanisms which depend on a microstructure state or its transitions during a production stage of the composite structure or its ageing.

The polarization–depolarization process control and responses sampling are realized through the special interface unit connecting the measuring cell with a computer. An evaluation of some complex permittivity changes can be obtained with their high accuracy by the transient current integration combined with following Fourier transform and Havriliak-Negami four-parametric representation usage. This method acceptability under unilateral access conditions has been also confirmed [18, 19]. However, such kind of the dielectric spectrometry implementation demands some new approaches that could help to solve three problems as

- to improve the signal-to-noise ratio,
- to stabilize the coplanar electrode contact conditions,
- to develop a method for the integral effects modeling at the nonuniform electric field conditions.

ELECTRIC FIELD DISTRIBUTION SENSING

The gas-discharge defectoscopic probe can be recognized as the simplest device [20] using an electric intensity redistribution effect for a detection of disbonds or other inhomogeneities in some nonmetallic composite structures. The main parts of such probe are the optically transparent high voltage electrode, special metal-fiber protector and a discharge space. The interelectrode equivalent gap may be presented here by the composite structure under test, the metal-fiber protector and the discharge space which can provide a visual evaluation of the electric flow distribution owing to ion-emissive processes. The facility of this probe is obviously the unsatisfactory one.

If the electromagnetic wave length in a dielectrical low-loss laminate gets comparable with its thickness then other principles of the electric field distribution sensing, based on the registration of effects of an interference, dispersion or absorption, can be used. The corresponding NDE techniques are very various (see, for example a work [21]). One of them is based on the complex reflection coefficient of the material being tested in a wide frequency band with a subsequent inverse Fourier transformation into a time domain [22]. Analysis of the obtained time dependence of the reflection coefficient permits to evaluate the bilamelar structure parameters nondestructively, at least.

Another approach to the same NDE problem solution is the quasi-stationary electric field distribution sensing [23, 24]. The mathematical modeling of quasi-stationary nonuniform electric fields in the piecewise dielectrics is to be improved for this NDE further development.

CONCLUSION

Three groups of the admissible nondestructive evaluation methods are briefly characterized. Their common feature is the decreased influence of contact conditions on the nondestructive evaluation data. Another feature consists in overt imperfections of the electric nondestructive evaluation fundamentals.

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