INVESTIGATION OF FAILURE OF COMPOSITE MATERIALS BY THE METHOD OF DEFORMATION LUMINESCENCE IN A BROAD VELOCITY RANGE OF LOADING

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The article presents a way of investigating failure of materials with the aid of the method of deformation luminescence (DL) and describes the results of tests with specimens of laminated glass reinforced plastic with reinforcing structure (02; ±60) and (±30; 902) in static and dynamic tension. Diagrams are plotted of the change of intensity of DL and stress \(\sigma_{11}\) vs. time at a speed of impact 0.5 and 1 m/sec, and also under static loading at the rate of 3 mm/min. It is shown that static and dynamic tension of laminated glass reinforced plastic is accompanied by DL expressing the jumpwise nature of step-by-step failure of the material.

The method of deformation luminescence (DL) is a comparatively new method of investigating the process of failure, mainly of crystals [1, 2], polymer materials [3, 4], and some composites [5]. The luminescence occurring when various materials are loaded is directly connected with the very primary acts of failure. It was established that luminescence is due to several microprocesses: motion of dislocations in the structure of a crystal, the nucleation of new dislocations [6], the relaxation of free radicals after rupture of bonds [7, 8], electrization of surfaces when cracks develop [4, 9], when an increasing electric field induces local gas-discharge phenomena in the space between the surfaces, etc.

Modern photodetectors FEU receive a photon flux almost without inertia and at high speed. When an FEU is used, temporal resolution of optical radiation attains \(10^{-9}\) sec, for special photodetectors it lies in the picosecond range of time. Almost instantly DL provides information on processes of failure in materials when they are loaded, and it can solve many problems of micromechanics.

The material for the investigation was laminated glass reinforced plastic with reinforcement structure (02; ±60) and (±30; 902), based on glass fiber VMPS 6-7 and epoxy binder.

Fig. 1. Block diagram of the apparatus for recording deformation luminescence: FEU (photodetector); S) light shutter; CS) current supply; K) signal amplifier; D) discriminator; F) frequency meter (counter); A) amplifier; DAC) digital-to-analog converters; R) recorder.

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Fig. 2. Arrangement for the recording and processing of the results of deformation luminescence in dynamic tests of materials:
1) piezoelectric dynamometer; 2) loading device with specimen; 3) synchronizing pulse; 4, 6) amplifier; 5) current supply unit for FEU; 7) graphic display; 8, 13) recorder 4604; 9) perforator; 10) display; 11) alpha-numerical printer; 12) dataplotter.

The specimens were cut out of blank sheets in the form of a double shovel with 7·0.5 mm of the working part for the structure (02; ±0) in static experiments. For dynamic investigations the specimens with the structure (02; ±0) had the dimensions 7.5·1.9 mm; with the structure (±30; 902) it was 7.5·8.0 mm.

In static tests the specimens were loaded on a specially devised installation at the rate of 3 mm/min. During loading we registered the dependences DL vs. time and force vs. time. Force vs. time was recorded on a recorder N 306 which recorded signals received from a dynamometer connected to a tensometric bridge and a tensoamplifier TDA-3.

To measure the intensity of the DL we used the method of photon count. Figure 1 presents the block diagram of the measuring apparatus: The specimens were placed in a light-tight chamber. The housing of the photodetector FEU, cooled by running water +15°C warm, was placed as near as possible to the specimen. Between the chamber and the housing there was the electromechanical light shutter S. The output pulses of the FEU were amplified by the pulse amplifier K. Separation and standardization of the amplified photoelectronic pulses was effected by the integral discriminator. The pulses were counted by the electronically counting frequency meter F type 43-38. This method was described in greater detail in [10, 1].

Dynamic tension of the specimens was effected on a rotary impact tester RSO with a massive disk which was rotated by an electric motor. The rotary speed of the disk was checked by a tachodynamo connected to the shaft of the disk. The specimens were loaded with the aid of a striker situated in a recess of the disk and held in place by a pawl of the striker. When the required loading speed of the specimen had been attained, an electromagnet was switched on which released the pawl of the striker while the disk rotated.

In the experiments we measured the dependences of DL vs. time and of force vs. time. As sensor of DL we used a specially selected low-noise FEU-79 whose signal was transmitted to the input of a compatible amplifier, and then to the input of the recording apparatus. To prevent extraneous light from reaching the space of rupture of the specimen, we covered the rotary impact tester on the outside with light-tight material. Prior to each experiment we checked the dark noise of the FEU; this ensured that there was no extraneous light in the course of the experiment.

To record the force vs. time we used a piezoelectric dynamometer [12] mounted in series with the specimen on a fixed rigid frame. The piezoelectric crystal was lead zirconate-titanate (TsTS-19) in the form a cylinder with 8 mm diameter, 5 mm high. The signal from the piezoelectric sensor was transmitted to the input of a highly resistive (10^{11} \, \Omega) preamplifier, and then to the input of the recording apparatus.

Under dynamic kinds of loading of composite materials the process of rupture of the specimen occurs in the microsecond range of time. In such cases the method of photon count cannot be used because there is a probability of superposition of single-electron pulses, which substantially distorts the kinetics of failure of the specimen. For dynamic tests we used the method of measuring the mean current on the output of the FEU, oscillographing the signal in time. The time constant of integration of the signal \tau in the anodic circuit is...