A DYNAMIC METHOD OF ARRESTING CRACKS

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A number of methods of static crack arrest and prevention of crack growth exist [1-13]. These are chiefly theoretical, however, and have not obtained wide usage in practice, since fracture of various materials takes place suddenly, as a rule after a time interval measured in tens and hundreds of microseconds. From our point of view, the basic role in preventing fracture must belong to simple computers, capable of determining the beginning of fracture, its trend, and its rate for timely insertion of a crack arrester.

In the present paper we have described an electronic logic device for predicting rate of fracture and dynamic crack arrest (Fig. 1) and have experimentally investigated the operation of the device and evaluated the possibility of dynamic crack arrest. The device, for time intervals reckoned in microseconds, determines the instant that fracture begins and, according to the rate of fracture, gives the signal for inserting a crack arrester in the path of the advancing crack. For dynamic control of the crack it is convenient to use stress waves, produced by an explosive charge.

In the present work, microchanges of PETN (pentaerythritol tetranitrate) were used, placed in holes 3 mm in diameter. The detonator (a droplet of lead azide) was set off by means of a strong current discharge of a condenser, $C_1$ (Fig. 2), initiated by a high-voltage pulse (10 kV) that was supplied from an amplifier at one of the dischargers $D$. The tests were made on a UP-8 universal press.

A plate of Plexiglas $150 \times 150 \times 3$ was subjected to static tension (15 kg/cm$^2$). The stress concentrator was a marginal notch.

The specimen was fractured by a sharp blow on a steel knife in the marginal notch of the plate. In this connection it was inadvisable to use an acoustic method of recording the fracture. The pickups were thin copper wires 0.05 mm in diameter, attached to the specimen with epoxy (without plasticizer), set 5 cm apart.

![Fig. 1. Circuit diagram of electronic logic device for three (a) and n (b) points.](image-url)
The process of crack propagation was recorded by a motion-picture camera (SKS-1M) (Fig. 3), set at an angle of 45° to the surface of the specimen. An illuminator was set at the same angle, permitting strong illuminating power of the optical system. The motion-picture camera was operated through a magnifying glass at a rate of 5000 frames per second, and the results made it possible to gain a general picture of the nature of crack propagation up to and after interaction between the crack and the stress waves.

In order to synchronize operation of the camera for maximum rotations with the fracture process in the specimen, a special relay scheme was used (Fig. 4), operating in the following manner. By pressing the button switch (BS) the relay 1PR and the normally open contacts 1PR2 are switched in, connecting the power circuit to the time relay TR. The camera begins to operate at the same time. After one second the intermittent contacts of the time relay TR2 are switched into the 2PR relay, which initiates fracture by a sharp blow on the knife. After one more second the contact of time relay TR3 disconnects the entire power system, and the setup is returned to the initial state.

The operating principle of the electronic logic device involves a comparison of the actual rate of crack growth with the maximum probable rate for a given type of material and construction, determined experimentally. The resolving power of the logic device is given by the number of stages in the circuit. A device consisting of n stages (set Fig. 1b) operates in the following manner. An advancing crack, rupturing the first pickup, starts up the electronic time relay (FIZ). Duration of the pulse of the relay $T_{tr}$ corresponds to the minimum time of crack propagation between the first and succeeding pickups, i.e., the maximum rate of fracture. If the crack moves at maximum rate, after the time $T_{tr}$ all pickups will be ruptured and the logic device will insert the crack arrester with minimum delay $T_{m} \lambda$, preventing operation of all the intermediate stages.

The indicated system permits us to regulate the thresholds of the interval of rate deviation from the maximum within wide limits by changing the positions of the pickups. Thus, with uniform spacing of n pickups, if $v_{cr} \leq v_{max}/n$, the crack arrester is inserted with a delay of $nT_{m} \lambda$. The time delay is increased from the n-th to the first stage. By means of the device it is possible to test any material within a wide range of rate changes.

Fig. 2. Electrical scheme for setting off microcharges of explosives: com) computer; A) amplifier; D1, D2, D3) controlled dischargers.

Fig. 3. Testing scheme: 1) specimen; 2) motion-picture camera, SKS-1M; 3) illumination source; 4) condensing lens.

Fig. 4. Synchronization scheme.

Fig. 5. Form of pulse created by explosive charge.