A NEW METHOD FOR THE DETECTION OF CRACK FORMATION IN GLASS USING THE ELECTRIC EMISSION

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A novel technique for detecting crack formation and propagation, based upon electric emission, is described. It is shown that a correlation between electric emission and fracture exists for glass, ceramics and concrete. Experiments on crack detection in glass slabs are performed at quasistatic and dynamic loadings, and the results are discussed.

INTRODUCTION

The method for detecting the onset of crack propagation in materials described here uses transient electric fields accompanying the crack formation (electric emission). In order to detect these fields, two electrodes are positioned in the vicinity of the expected crack. The electric field generates a potential difference between the electrodes which is amplified and recorded. The electrodes together with a preamplifier form the crack gauge unit.

FUNDAMENTALS OF ELECTRIC EMISSION

The electric emission is caused by several different processes described in papers by Dickinson et al. (see, e.g. (1,2,3)) leading to the concept of "fracto-emission". Fracto-emission is the emission of electrons, photons, ions and molecules caused by the rupture of materials. Because of their small mean free path in air, these particles can only be directly detected in high vacuum. Fresh fracture surfaces may carry such a large number of electric charges (4) that gaseous discharges in the crack tip can occur. This process is accompanied by the emission of electromagnetic radiation and has been demonstrated in (5) for the case of MgO-crystals.

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With the measuring technique presented in our paper the rapidly changing fields of moving electric charges during a fracture process can be detected showing the correlation in time between the electric emission signal and fracture.

DETECTION OF ELECTRIC EMISSION AT CRACK START IN GLASS

The aim of the first investigations was to prove the correlation between electric emission and the formation of cracks. Therefore, a method for crack initiation had to be used which avoided perturbations of the electric emission measurements by interfering external fields and friction processes. The initiation of cracks in glass by local thermic loading has shown up to be an appropriate method, particularly because it is possible to optically observe the crack propagation.

Experimental Set-Up

In order to determine the direction of crack propagation, both surfaces of 10 mm thick glass plates were provided with very thin v-notches. Then a hot ceramic tile was brought into contact with the glass plate in such a manner that the plate was heated up in the vicinity of the notches by the small side of the tile. After a certain time, the mechanical stress caused by the temperature gradient initiated the propagation of a crack. The length of the crack could be influenced by variation of length and position of the contact area between the ceramic tile and the glass plate.

The experimental set-up is schematically shown in Figure 1. Two coaxial electric emission gauges are positioned at different heights in front of the glass plate in distance of a few millimeters from its surface. The middle axis of the upper gauge is oriented to the edge of the glass plate. In order to trigger the measuring equipment, a laser beam is directed to the front surface of the glass plate and crosses the plate in the height of the upper gauge. When the crack is initiated the light is partially reflected at the newly created surfaces. The resulting sudden drop of the transmitted light intensity is measured by means of a photo diode. A second laser beam crosses the glass plate in the height of the lower gauge to record the time of the passing crack tip.

Experimental Results

Figure 2a shows the electric signals and Figure 2b the signals from the photo diodes of an experiment. A comparison of the two types of signals shows that electric emission and the change in light intensity occur simultaneously. That underlines the thesis that crack initiation and propagation are accompanied by transient electric field emission.

ELECTRIC EMISSION DURING CRACK FORMATION IN DYNAMICALLY LOADED GLASS SLABS

The experimental configuration for the dynamic loading of glass specimen is shown in Figure 3. A projectile impinges upon the edge of the glass slab (size of the glass specimen 100 x 100 x 10 mm), which is precracked by thermic loading.

The projectile is fired against the glass slab in such a way, that only the part of the specimen above the initial crack is loaded by the shock wave. An electric emission gauge is positioned in front of the initial crack tip to record an elongation of the crack or the formation of a crack field. The impact and fracture process are simultaneously observed by means of a 24-spark high speed camera of the Cranz-Schardin type.

Two photographs cut of a series of nineteen, taken in one experiment, are shown in Figure 4. The photograph on the left side shows the glass plate before impact. The thick black stripe on the left side (impact side) is the image of the notch on the surface of the plate. The fine dark line below the notch represents the precrack. The photograph on the right side shows the specimen 8 μs after impact. Beside the black area at the left edge of the plate caused by the damage in front of the impact side, a bundle of cracks can be recognized, starting from the initial crack tip. The corresponding electric emission signal of this process is plotted in the lower part of Figure 5. In addition, this Figure shows the signals of a photo diode which controls the sequences of the sparks from the high speed camera. Each minimum of this curve gives the time of one photograph. The series of photographs show that the fracture propagation from the crack tip begins at about the exposure time of photograph number 13. This experiment again demonstrates that the beginning of the crack propagation is accompanied by an electric emission signal.

ELECTRIC EMISSION IN OTHER MATERIALS

The occurence of electric emission during rupture was furthermore observed with Al_2O_3 ceramics and even with such an inhomogeneous material like concrete. The ceramics and concrete specimen were loaded in a 3-point bending test, as schematically shown in Figure 6. In these experiments the measuring instruments were triggered by the negative edge of the signal from a piezoelectric force gauge, which indicates the rupture of the specimen. The electric emission gauge was positioned in front of the lower edge of the specimen where the crack starts. Examples of measurements with ceramics and concrete are shown in Figures 7 and 8.

SUMMARY

With the investigations reported here the correlation between electric emission and the initiation and propagation of fracture is demonstrated for the materials glass, ceramics and concrete under quasi-static and dynamic loading conditons. In opposition to other methods for crack detection (for example measurement of acoustic and magnetic emission, material strain or electrical resistance) a direct contact between the tested materials and the gauge is not required. The method is applicable to metallic and non-metallic materials.

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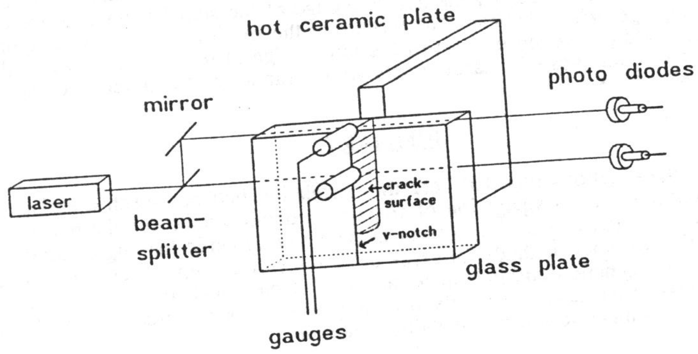

Figure 1 Experimental configuration for the detection of electric emission in glass

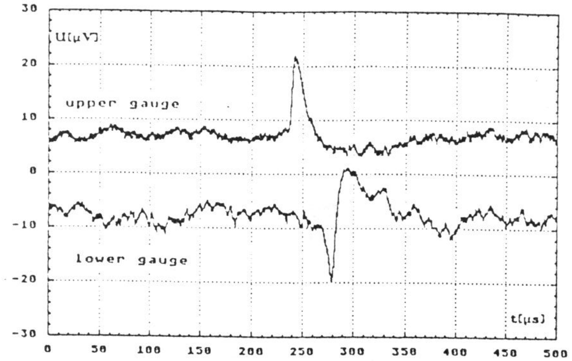

Figure 2a Electric emission signals versus time

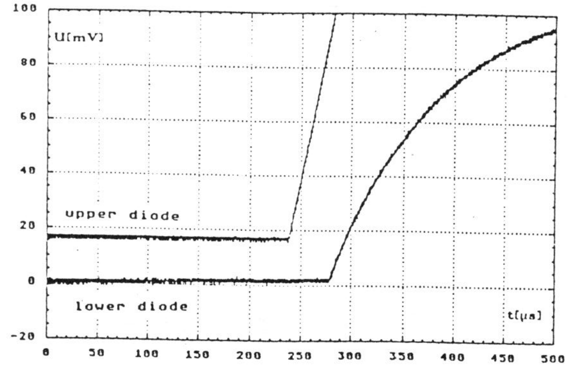

Figure 2b Voltages registered at the photo diodes versus time

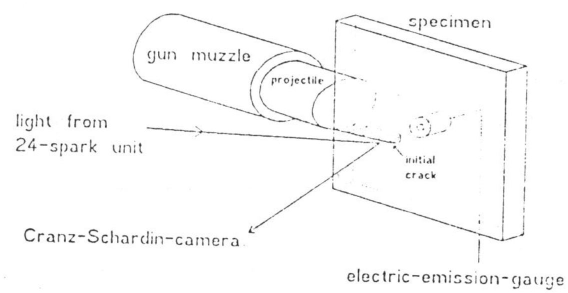

Figure 3 Experimental set-up for dynamic loading and simultaneous electric emission measurement

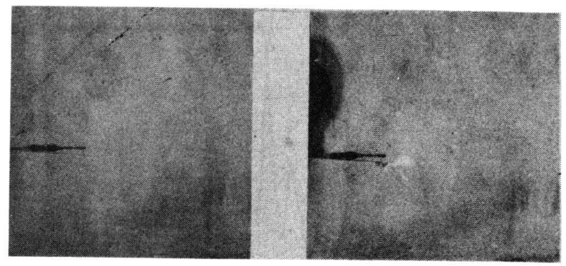

Figure 4 Photographs of the specimen before (left side) and after impact (right side)

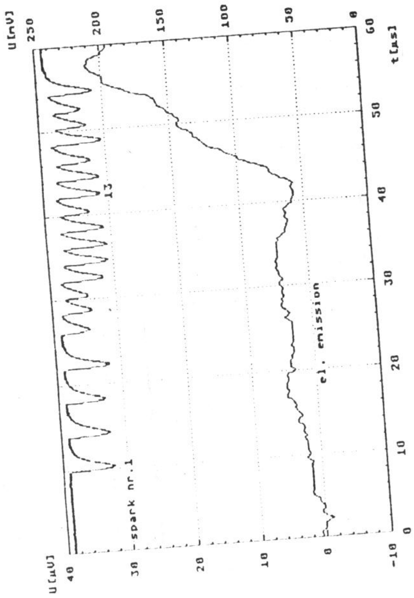

Figure 5 Electric emission and spark signals

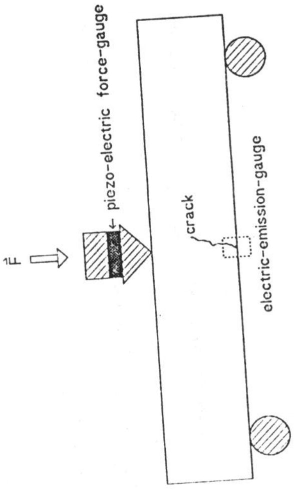

Figure 6 Three-point bending arrangement for testing ceramics and concrete specimen

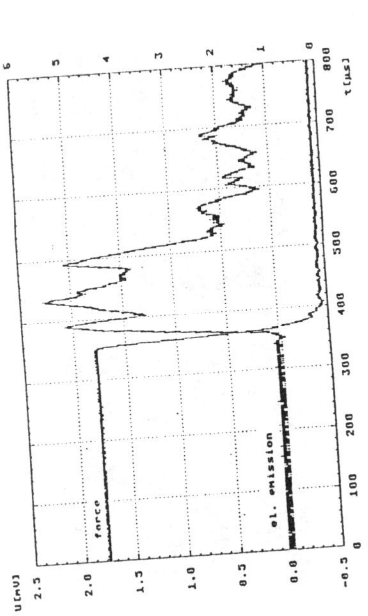

Figure 7 Electric emission and force time plot during rupture of a thin ceramic tile

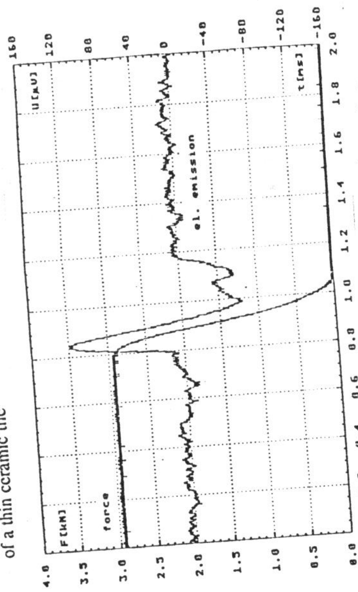

Figure 8 Electric emission and force time plot during rupture of a concrete specimen