Evaluation of an ultrasonic field effect on Pyrex compression fracture

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The effect of an ultrasonic field (23 kHz) on surface fracture topography of Pyrex cylindrical samples tested under compression has been studied. The stress to fracture the sample under an ultrasonic field was lower. The classically observed patterns in brittle fracture were found. Direct measurements of the surface roughness by profilometry showing that the Rq roughness is less in the tests with ultrasound suggest that the ultrasonic fields can affect the crack propagation dynamics improving the fracture process.

Keywords: Fracture, ultrasonic essays.

Introduction

The fracture of brittle materials is a natural phenomenon that can be described and modeled by fractal geometry [1,2]. The linear elastic theory [3] predicts a crack propagation velocity near to the Rayleigh speed in the sample, value pretty far from the experimental data. Such a behavior appears because in the classical uniaxial tension experiments the direction of cracks propagation is normal to the applied loads, producing a dynamical instability in the sample that creates the observed breaking patterns. In this way, over 90% of the energy feeding to the tip of a crack can be consumed by subsurface instability. The cracks would produces an extensive branching pattern, which makes it unable to accelerate up to the high velocities predicted by classic theories of dynamic fracture [4–7]. When the roughness patterns observed on the fracture surfaces show some spatial regularity, it is said that they are self-similars or self-affines [1]. These effects are also present in the case of compressive test because Poisson coupling produces lateral stresses even in a sample under compressive loads. Because the fracture phenomenon is associated to the sound emission could be accepted that a high-power acoustic field can interacts with the crack propagation dynamics modifying its motion [3, 8]. The aim of this work is to evaluate the effect of an ultrasonic field (23 kHz) on fracture surface topography of Pyrex samples tested under compression loads.

Experimental setup

The experiments were carried out with an hidraulic press in which the compression tip is an ultrasonic transducer, in this way the samples can be tested under stress field with and without ultrasonic activation with the same geometry. The system can be excited at 23 kHz with ultrasound power up to 500 watts. The samples were Pyrex (Borosilicate) cylindrical samples 16 mm length and 8 mm diameter. The compression stresses and the ultrasonic field were applied in a direction parallel to the axis of the sample. The samples break at a compression load between 1500 to 2000 Psi, afterwards, the same experiment with an acoustic power of 50 watts were added to the compression loads was done. The surface surface topography were recorded with a CCD camera and the surface roughnesses were measured through contact profilometry obtaining the profile lengths “L” and Rq roughnesses.

Results and discussion

Figure 1 shows the fracture surface of samples tested under compression with and without application an ultrasonic field. In the Fig.1a patterns called “River Line”, “Bands” and “Grooves” can be observed [9]. Also in Fig.1b “Mirror-Mist-Hackle” regions are observed [9,10]. In the figure 1b can be identified:

a) changes in the appearance of the fracture surface associated with an increment of the surface roughness,

b) the transitions among the three regions, not sharp but progressive as is shown in the Fig.3, and

c) the changes in the roughness are associated with changes in the crack lenght [10].

In the Fig.1b, the patterns are formed or nucleated like a series of spaced steps that emerge progressively to form large steps. The average fracture surface remains parallel to the
axis bar but is covered with radial steps that increase in height and number as the crack expands. This behavior is not observed in the fracture surfaces obtained without ultrasound (Fig. 1a). It is also observed in the Fig.1b (x20) that the steps spacing is similar, this suggests that potential location distribution is closer than necessary to accommodate the twisting forces [10].

The roughness of the fracture surface, apparent in all observation scales revealed that the Rq(L) roughness, depends on the length scale of measurement profile (L), indicating that there is a strong statistical factor in its determination. This phenomena of growing roughness is associated with an accelerating crack Thus, the instability in the crack tip increases producing the observed pattern.

Figure 2 show the fractal dimension of the fracture surface profile. The slope values were D=1.29 (without ultrasound) and D=1.08 (with ultrasound). Since the relationship obtained is approximately linear, the following laws of the roughness can be applied:

1) The roughness profile exhibits self-similarity (Fig.4) and self-affinity (Fig.3) [1].

2) The roughness degree grows as D grows (D=1 for straight profile).

The previously specified phenomena take place because the high stress and great energy liberated produce large micro-mechanic activity in the crack tip and a progressive increment in the fracture surface roughness.

**Conclusion**

The compression stresses in the tests with ultrasound (~1000 Psi) were lower than those used in the tests without ultrasound (~1500-2000 Psi). In the tests without ultrasound the following fracture patterns were found: River Lines, Grooves and Bands [9], while in ultrasound presence the observed patterns were the "Mirror-Mist-Hackle" regions [9,10]. Direct measurements of the surface roughness by means of contact profilometry showed that the roughness is lower in the tests with ultrasound. The roughness profiles obtained in the tests with and without ultrasound showed the existence of certain self-similarity and self-affinity respectively [1]. Because its propagation is less unstable the cracks produced under ultrasonic field have bigger acceleration capacity, producing a fracture surface less rough than those produced only under compression. Thus, the ultrasonic fields can affect the crack propagation dynamics affecting mainly on: its motion and the fracture surface topography. Consequently its improves the fracture process.
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