Journal of the Mechanics and Physics of Solids 59 (2011) 1338–1354

Contents lists available at ScienceDirect

Journal of the Mechanics and Physics of Solids

journal homepage: www.elsevier.com/locate/jmps

An ESPI experimental study on the phenomenon of fracture in glass. Is it brittle or plastic?

Daniele Ferretti [a], Marco Rossi [b], Gianni Royer-Carfagni [a,*]

[a] Department of Civil-Environmental Engineering and Architecture, University of Parma, Viale G.P. Usberti 181/A, I 43100 Parma, Italy
[b] Department of Civil Engineering, University of Pisa, Via Diotisalvi 2, I 56126 Pisa, Italy

ARTICLE INFO

Article history:
Received 22 July 2010
Received in revised form
24 March 2011
Accepted 3 April 2011
Available online 16 April 2011

Keywords:
Electronic speckle pattern interferometry (ESPI)
Crack opening displacement (COD)
Glass
Porous plasticity
Cohesive crack

ABSTRACT

The crack opening displacement (COD) in annealed soda-lime (float) glass has been measured with an electronic speckle pattern interferometry (ESPI) apparatus using coherent laser light. Specimens, naturally pre-cracked with a particular technique, were loaded under strain-driven bending until crack propagated; at regular intervals loading was paused to let the crack reach subcritical equilibrium and the COD measured. By using a post-processing algorithm comparing four images lighted with phase-shifted laser beams, surface displacements could be measured at a resolution of 0.01 μm.

Glass transparency has allowed to see through that the propagating crack front is not sharp but curved, jagged and merged in an opaque neighborhood. Numerical simulations show that the measured CODs cannot be reproduced if cohesive *surface* forces *à la* Barenblatt–Dugdale bridge the crack lips; instead a plastic-like region must form in a *bulk* neighborhood of the tip, where inelastic strains are associated with volume increase rather than deviatoric distortion. For this, a Gurson–Tvergaard model of porous plasticity, accounting for the formation of microvoids/microcracks, has been found more efficient than classical von Mises plasticity. This study confirms the formation at the crack tip of a process zone, whose occurrence in brittle materials like glass is still a subject of controversy.

1. Introduction

Glass is more and more used as a prestigious construction material in luxury architecture mainly because of its aesthetic appeal due to its transparency but, apart from this, it presents other exceptional properties like chemical durability, intrinsic hardness, high compression strength and high melting point. However, its intrinsic brittleness may render its structural use quite questionable and annihilate the other good characteristics. But is glass really brittle? There is a growing, though not yet universal, belief that *plastic*[1] phenomena may occur right at the crack tip, albeit at a length scale far below that of a ductile metal. Since for this class of materials the chief problem in design is the containment of potential fracturing to guard against catastrophic collapse, a better understanding of the mechanism, rather than the mechanics, of fracture appears of importance, in particular to determine which properties should be optimized to prevent or at least mitigate the crack propagation. This kind of problems is also shared by other brittle materials like ceramics, which are frequently used for mechanical components of high-tech devices.

* Corresponding author. Tel.: +39 0 521 905917; fax: +39 0 521 903924.
E-mail address: gianni.royer@unipr.it (G. Royer-Carfagni).

[1] Here the term "plastic" may be somewhat improper, but it can be used to mention any type of inelastic irreversible dissipative deformation.

0022-5096/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jmps.2011.04.008