Experimental techniques for design of impact-resistant material

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Introduction

Some polymers are not only transparent and lightweight, but also impact and ballistic resistant. Designing and preparing such polymeric materials with a high impact-resistant performance is of importance to e.g. aviation, military and windscreen applications.

Objective

Damage mechanisms under high amplitude impulsive loading are related to the induced stress waves, thermal effects and to the material composition and properties at all scale levels.

The aim of this work is to develop a technique to enable the optimization of polymer material composition design. Damage control under impulse loading is the challenge.

Main tasks are to develop a high rate loading device for compression and tension tests at meso-level and to study the dynamic response mechanisms of polymers.

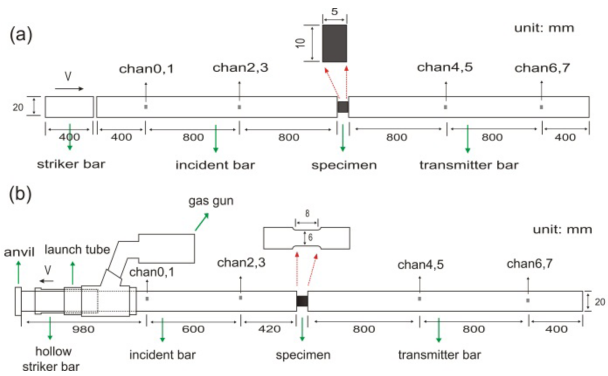

Figure 1 Scheme of Split Hopkinson bar: (a) compression; (b) tension.

Methodology

Split Hopkinson bar (SHB) setups for dynamic compression and tension tests have been built at TU Delft, which consist of a gas gun, a striker bar, an incident bar, a transmitter bar, and a high-frequency data acquisition system. The set-ups and dimensions are given in Figure 1. To calculate the stress, strain and strain rate in the specimen and derive the mechanical properties, the following equations are used [1] :

$$\sigma(t) = \frac{EA_B}{A_S}\varepsilon_T(t), \qquad \varepsilon(t) = -\frac{2C_0}{L}\int \varepsilon_R(t)dt, \qquad \frac{\partial\varepsilon}{\partial t} = -\frac{2C_0\varepsilon_R(t)}{L}.$$

Results

A typical set of incident, reflected, and transmitted signals recorded by a digital oscilloscope with a sampling rate of 2.5 MHz is shown in Figure 2. The strain rates in these tests on CF 75 polymer are 1993/s and 976/s for the compression and tension test, respectively.

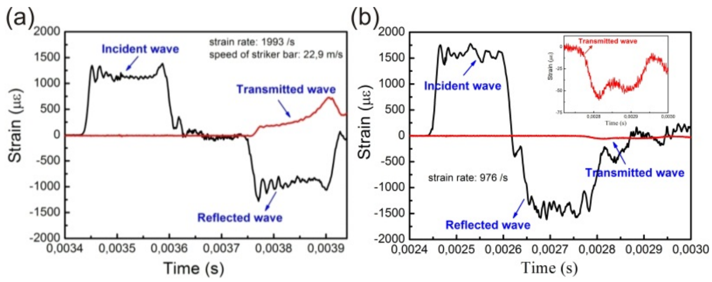

Figure 2 Typical incident, reflected, and transmitted signals recorded from the SHB experiment: (a) compression; (b) tension.

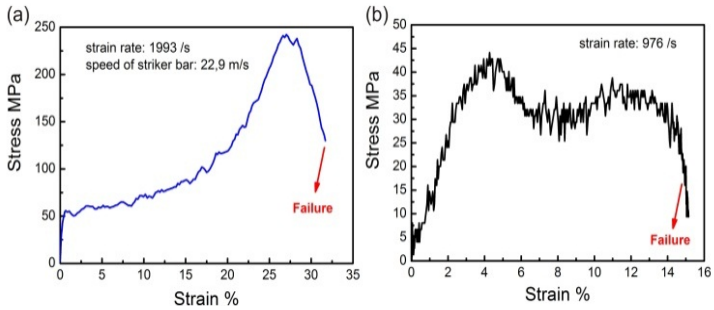

Figure 3 SHB test on CF 75 polymer: (a) compression at strain rate of 1993/s; (b) tension at strain rate of 976/s.

Figure 3 depicts the derived stress-strain curves from the dynamic compression and tension tests. They show the dynamic mechanical properties of a CF 75 polymer at the given strain rates.

In post-test analyses, formation mechanisms of micro crazes and cracks at the main crack tip are studied by a SEM to demonstrate the fracture toughness, as shown in Figure 4.

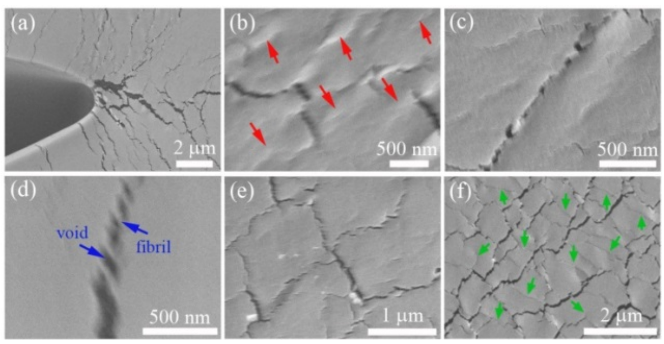

Figure 4 Fracture toughness origin: (a) micro crazes and cracks at the main crack tip; (b) nucleus of craze; (c) embryo of craze; (d) mature craze with voids and fibrils; (e) circular disc pattern; (f) micro cracks formation.

Conclusions

SHB setups are built for dynamic compression and tension tests; the dynamic mechanical response of CF 75 polymer is characterized; and a detailed study to the origin of the fracture toughness is carried out.

[1] Kolsky H. *Proceedings of the Physical Society.* Section B, 62, 676-700, 1949.