Available online at www.sciencedirect.com
ScienceDirect
Defence Technology 10 (2014) 154–160
www.elsevier.com/locate/dt

Research on the fracture behavior of PBX under static tension

Hu GUO*, Jing-run LUO, Ping-an SHI, Jian-guo XU

Institute of Systems Engineering, China Academy of Engineering Physics, Mianyang 621900, China

Received 26 February 2014; revised 24 April 2014; accepted 26 May 2014
Available online 5 June 2014

Abstract

The fracture behavior of polymer-bonded explosive (PBX) seriously affects the safety and reliability of weapon system. The effects of interface debonding and initial meso-damage on the fracture behavior of PBX under quasi-static tension are studied using numerical method. A two-dimensional representative volume element (RVE) is established based on Voronoi model in which the component contents could be regulated and the particles are randomly distributed. A nonlinear damage model of polymer matrix relative to matrix depth between particles is constructed. The results show that the simulated strain-stress relation is coincident with experiment data. It is found that interface debonding leads to the nucleation and propagation of meso-cracks, and a main crack approximately perpendicular to the loading direction is generated finally. The interface debonding tends to occur in the interface perpendicular to the loading direction. There seems to be a phenomenon that strain softening and hardening alternatively appear around peak stress of stress and strain curve. It is shown that the initial damages of intragranular and interfacial cracks both decrease the modulus and failure stress, and the main crack tends to propagate toward the initial meso-cracks.

Keywords: Polymer bonded explosive; Initial damage; Fracture behavior; Voronoi model; Interface debonding

1. Introduction

Polymer bonded explosive (PBX) is a heterogenous explosive consisting of a mixture of crystalline particles and polymer binders. This kind of explosive is pressed from molding powder and could be classified by different components and their contents. In weapon system, PBX with some structure is always an important part, and the initiation is the main function of PBX structure. In order to insure the safety and reliability of weapon system during storage, transportation and use, PBX structure must provide sufficient mechanical property [1]. PBX is a highly filled composite material comprised of more than 90% of crystals (by volume), which brings challenges to study its mechanical behavior. In general, the modulus of the binder is 10^5 times lower than that of the crystalline particles, resulting in the mechanical behavior of PBX being heavily influenced by the properties of the binder. The mechanical response of PBX is known to be with very low tensile strength relative to its compressive strength, which makes PBX structure one of the weakest parts in weapon system. With the improvement of weapon safety assessment requirements, the research on fracture behavior of PBX is becoming more and more important.

It is an effective approach to study the fracture behavior of PBX by establishing a microscopic model, especially for the study of fracture mechanism. The establishment of microscopic model is difficult since the crystalline particles possess irregular shapes and different sizes. Biswajit Banerjee [2] proposed a recursive cells method (RCM), in which the representative cell is divided into many sub units, and calculated by stepwise iteration method. The effective elastic modulus of PBX was calculated through this method. This

* Corresponding author.
E-mail address: guohu@mail.ustc.edu.cn (H. GUO).
Peer review under responsibility of China Ordnance Society

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.dt.2014.05.010
2214-9147/

method could exhibits the high filling of crystals, nevertheless, the irregularity of shapes and random sizes could not be characterized. Li Jun-ling [3] established a microscopic model of PBX disc specimen using discrete element method (DEM), and simulated the failure process of PBX disc under diametral compression. DEM is more favorable than FEM in the simulation of fracture behavior, but costs more memory and time. Wu Yan-qing [4] built a microscopic model based on Voronoi model, and simulated the interfacial debonding of particles using a viscoelastic constitutive model, but the microscopic model was not periodic.

In this paper, we shall construct a two-dimensional representative volume element (RVE) based on Voronoi model in which the component contents could be regulated and particles are randomly distributed. A nonlinear damage model of polymer matrix relative to matrix depth between particles is employed. Through finite element method, the fracture behavior of PBX under quasi-static tension is simulated and the effects of initial damages are studied.

2. Finite element implementation

2.1. Representative volume element establishment

The original concept of Voronoi model is from the domain of computing geometry. Since the concept of Voronoi model was proposed by Dirichlet in 1850 [5], Voronoi model has been applied to a few areas. It is well used to simulate the process of crystallization.

The ultimate principle of Voronoi model is to seek the nearest domain S_i of reference point P_i. Voronoi model with two and six reference points are shown in Fig. 1. In computing geometry, the construction of two-dimensional Voronoi diagram could be described with a formula. If there is a point set P with n reference points in a plane, namely $P = \{P_1, P_2, \ldots, P_n\}$, the domain S_i could be defined by the formula below

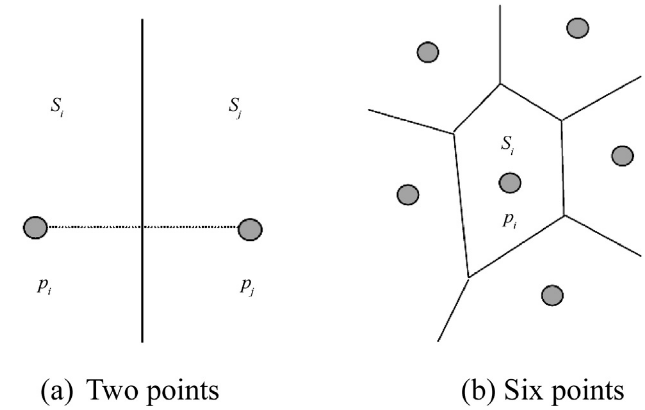

Fig. 1. Schematic diagram of Voronoi model with different amounts of reference points.

$$S_i = \bigcap_{i \neq j} H(P_i, P_j), \quad i,j = 1, 2, \ldots, n$$

where $H(P_i, P_j)$ is a plane domain about reference points P_i and P_j, every point in this domain is nearer to P_i but to P_j.

As described above, S_i denotes a half plane for $n = 2$, S_i denotes the intersection of $n-1$ half planes for $n \geq 3$, and S_i denotes a convex polygon with $n-1$ edges for $n \geq 4$. If the reference point set is determined, the corresponding Voronoi diagram is definite [6], so the Voronoi diagram could be controlled by the corresponding reference points. In this paper, a Voronoi model which is periodic and random was constructed by controlling the reference points. As shown in Fig. 2, a plane box A is given in the size of $3L \times 3L$, where L is a scalar. Box A is divided into 9 sub-boxes, each of which is $L \times L$. The sub-box in the middle is sub-box B. First, the reference points are seeded in sub-box B randomly, and then they are copied into the other 8 sub-boxes. The distance between two points in sub-box B is controlled by a parameter η in case a quite small polygon cell is generated. The polygon cell with small size has little effect on simulation

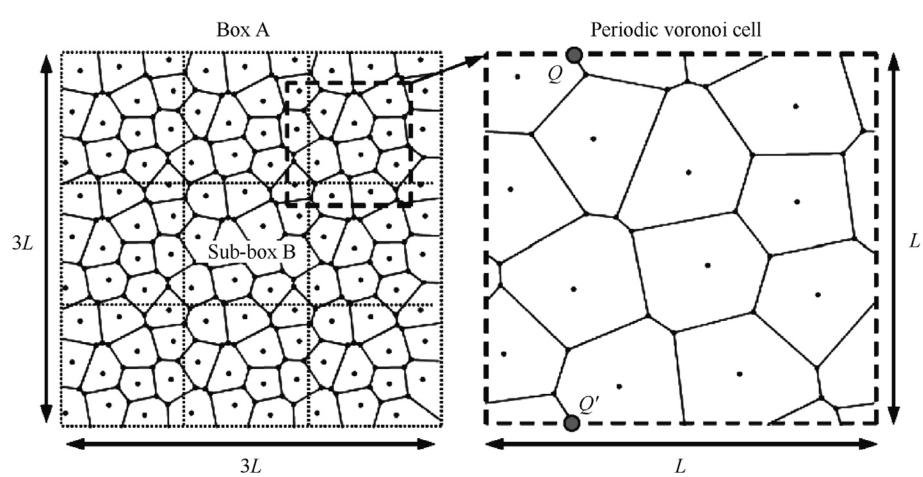

Fig. 2. A periodic Voronoi cell derived by controlling the points.