Reproduction of 3-D wing-crack using 3-D discrete element method, Esys_Particle

Wang, Y[(1)] and Mora, P[(1)]

(1) ESSCC, The University of Queensland, Brisbane, Australia
ph. +61-07-33464095 ; fax +61-07-33464134 ; email wangyc@esscc.uq.edu.au

Wing cracks are frequently observed in uni-axial compression of brittle materials with a pre-existed crack. It is found that tensile cracks nucleate at the tips of the flaw, grow in a stable manner with increasing of compression, then tend to align with the direction of axial loads. Here stable means that with the increase of loads, cracks grows lowly, without causing abrupt overall fracture of the sample. Wing crack extension is thought as a possible mechanism for splitting along the loading axis of brittle. In fact, wing crack extensions are so widely observed that we think a reliable numerical model should be able to reproduce the basic features of such phenomenon. In the previous 2-D study, we investigated what basic mechanisms a Discrete Element Model should have in order to reproduce the realistic wing crack extension, a widely observed phenomenon in uni-axial compression of brittle material with pre-existed crack. Using our Discrete Element Model Esys_Particle (previously called the Lattice Solid Model), we study how cracks propagate when different force-displacement laws are emplyed. Our results suggest that the basic features of crack propagation observed in laboratories can not be reproduced at the following circumstances: 1) When only normal forces between two bonded particles exists and particle rotation is prohibited; 2) Normal and shear stiffnesses are present and particle rotation is prohibited; 3) Normal, shear stiffnesses and particle rotation are present and bending (rolling) stiffness is absent. Only when normal, shear and bending stiffness exist and particle rotation is permitted, is it possible to reproduce laboratory tests. This study suggests that shear stiffness cannot be neglected in particle-based models of fracture. Single particle rotation and rolling resistance must also be included due to their important roles in reproducing phenomena observed in laboratory tests. Neglecting these important mechanisms results in inaccurate transmission of forces and torques between particles, especially when stress concentration appears due to local fracture. Consequently if these mechanisms are neglected, the exact crack paths can not be reproduced accurately. In the 3-D case, however, A.V. Dyskins laboratory tests demonstrated that 3-D crack growth in compression was qualitatively different from the 2-D case. Unlike 2-D cracking, there were intrinsic limits on 3-D growth of wing crack produced by a single pre-existing crack. The crack extension stops at certain length. This limitation was related to the wrapping (curing) of emerging wings around the initial crack. In the current numerical study, we extend our study and try to reproduce this important phenomenon by running 3-D simulation using Esys_Particle. An oblique pre-existed circular crack is made by removing the bonds in the crack area and uni-axial compression is applied to the sample. The simulation successfully reproduced the basic features of the laboratory tests. On one hand, this gives the further validation of our model, such as the failure criterion for the bond, the input parameters, on the other hand, this study provides a preliminary understanding fracture extension in the brittle materials.