Computer Generation of Sphere Packing for Discrete Element Analysis in LS-DYNA

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Abstract

The constructive algorithms for sphere packing are based on the pure geometrical computation. They are very efficient and robust for building very large sphere packings with millions of spheres in a few minutes. A constructive algorithm has been developed in LS-DYNA for arbitrary 3D geometries with the size distribution control. The brief introduction of the algorithm is presented in this paper. The procedures and some generated sphere packings are also presented to demonstrate its application for the discrete element analysis by using LS-DYNA.

Sphere Packing and Applications

Currently the sphere packing engine has been integrated into the latest version of LS-PREPOST, supporting multiple platforms. A bounded volume is required for the engine to start the packing process. A bonded volume can be specified by its surface mesh of 3-node or 4-node shell elements, as one part shown in Fig. 1. A sample packing of 907 spheres is generated within the cube as a demonstration in Fig. 2. Another example is a hollow cylinder which is a double-connected volume. The surface mesh needs to be created for both outer and inner surfaces, as shown in Fig. 4. A packing of 474 thousand spheres is shown in Fig. 5. The current version of the packing engine is single thread and generates about 8 thousand spheres per second, running on a regular desktop computer.

The discrete element method in LS-DYNA is still under development for coupling with other mesh-based and particle-based methods, including FEM, ALE, and Particle Methods. The DEM itself can be also used for simulating the solid mechanics through "Bonds" between neighboring spheres. A benchmark example has been solved for a pre-notched thin rectangular plate with 100mm by 40mm under tension load. Three models are created with the sphere sizes of 1mm, 0.5mm, and 0.25mm respectively. For a viscous material, the numerical results show that the crack starts to grow at 27µs and breaks the plate at a same steady growth rate, along the center line. Figs. 6-8 show the crack propagation processes. For a brittle material, a high-speed tension load has been applied at the top and bottom edges, and the fragmentation of the plate is shown in Fig.9.

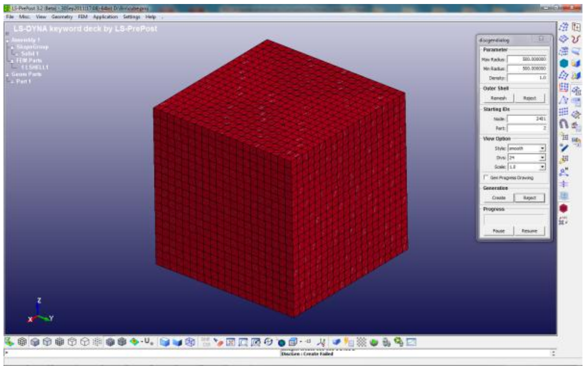

Fig. 1 A cube with a surface mesh

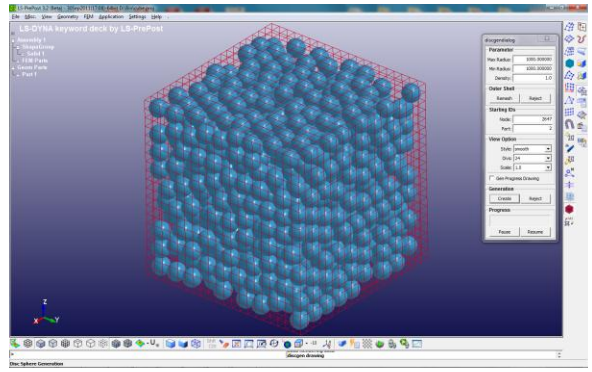

Fig. 2 907 spheres generated within the cube

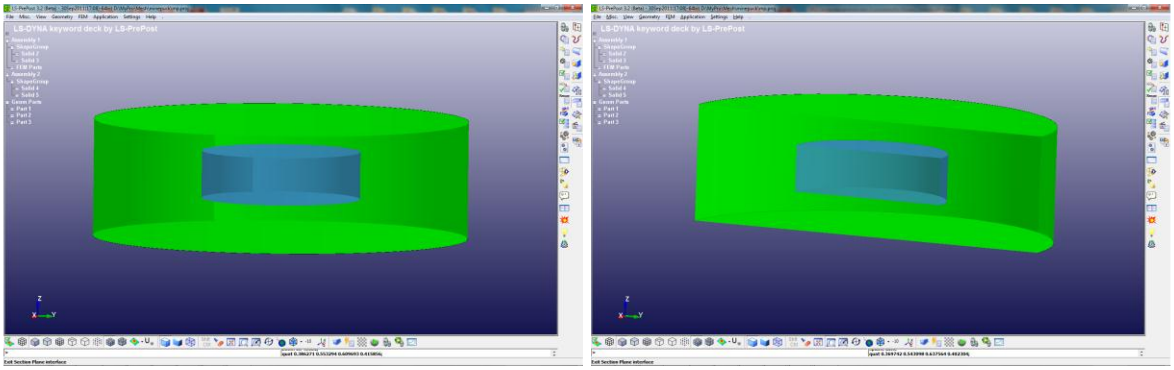

Fig. 3 a hollow cylinder

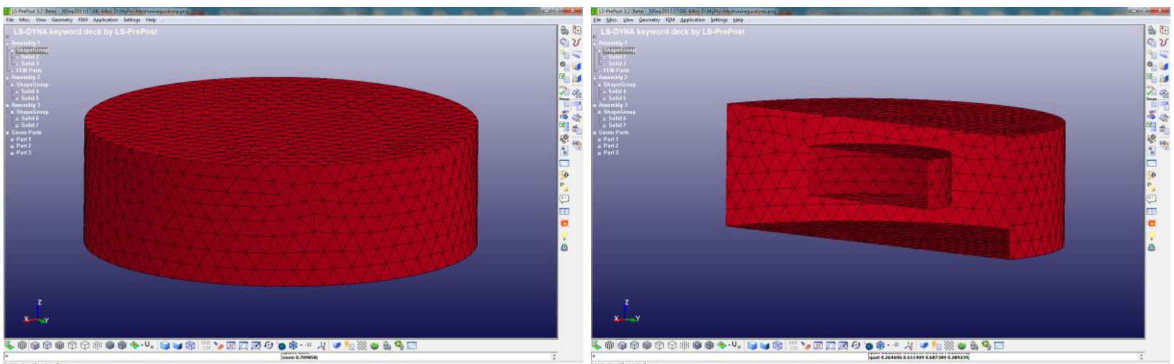

Fig. 4 The triangularized surface of a hollow cylinder

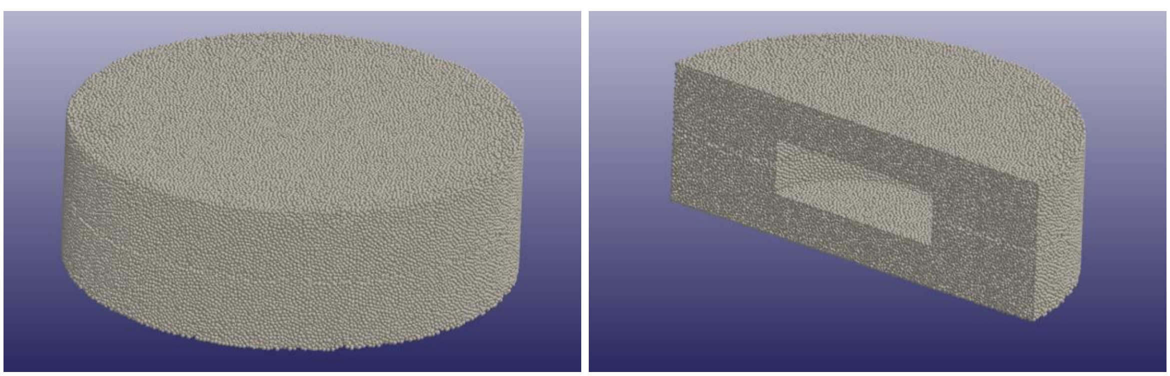

Fig. 5 A packing of 474,562 spheres generated within a hollow cylinder

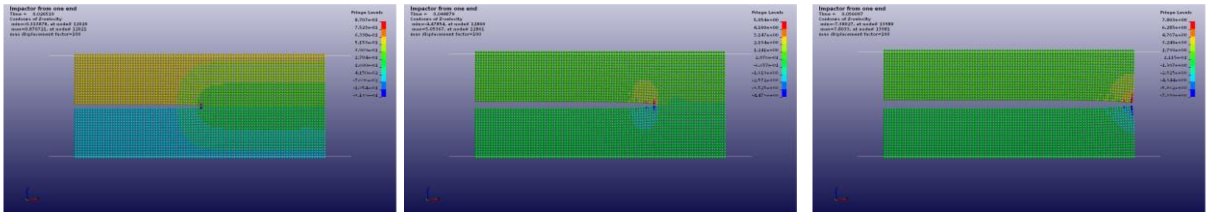

Fig. 6 Crack propagation of a pre-notched thin rectangular plate (a sphere diameter of 1mm)

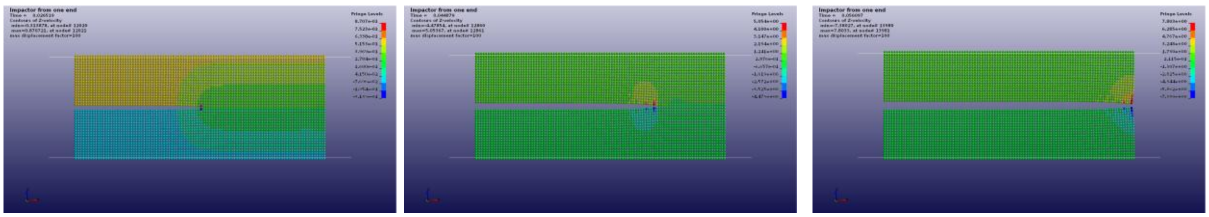

Fig. 7 Crack propagation of a pre-notched thin rectangular plate (a sphere diameter of 0.5mm)

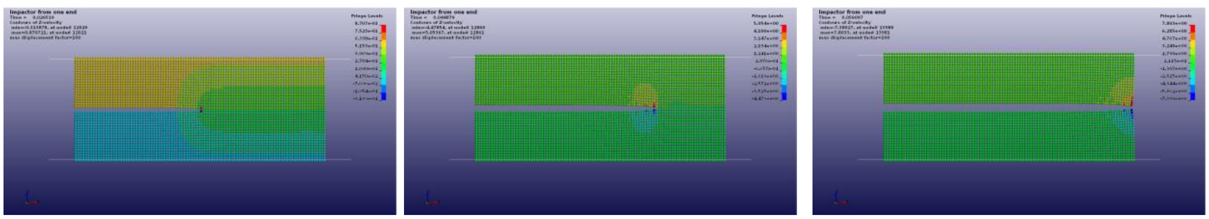

Fig. 8 Crack propagation of a pre-notched thin rectangular plate (a sphere diameter of 0.25mm)

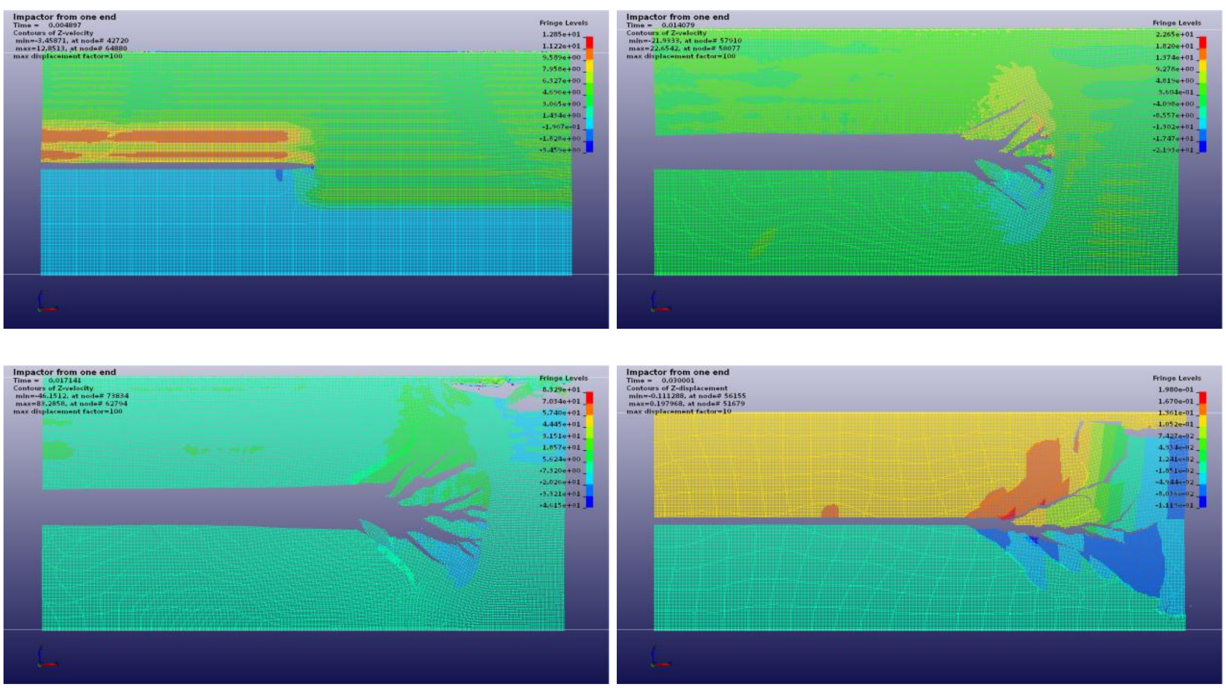

Fig. 9 Fragmentation of a pre-notched thin rectangular plate under high-speed tension (a sphere diameter of 0.25mm)