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An elastoplastic contact model for spherical discrete elements

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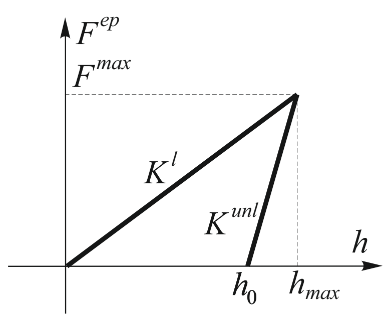
In the discrete element method, it is assumed that the material is represented as a large collection of rigid particles interacting with one another by contact forces. In principle, the particles can be of arbitrary shape, however, due to their numerical efficiency spherical particles have gained great popularity in different DEM applications.

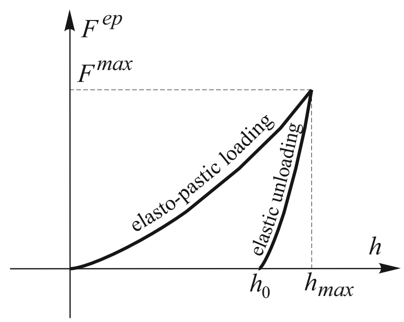
The quality of the results in the DEM depends to a large extent on the interparticle contact model. The contact model for the DEM analysis should account for different physical effects in the interparticle contact and at the same time it must be relatively simple to allow an efficient solution. Different interaction models can be assumed for the contact in the normal and tangential direction [1, 2].

The normal contact, which be considered in the present work, is very often modelled assuming an elastic linear or Hertzian force–displacement relationship. In many applications, however, particle deformation due to contact cannot be treated as purely elastic. Because of the contact force concentration, yielding at the contact zone between two spheres made from ductile materials, e.g. metals, may occur at a relatively low loading [3]. In such cases, a partial irreversibility of interparticle penetration should be included in the contact model in the DEM. An issue of great importance in the elastoplastic contact models is the choice of a suitable unloading model.

Two models taking into account plastic effects will be investigated in the present work: (i) the Walton–Braun model with the linear loading and unloading, (ii) the Storåkers model with a nonlinear relationship for the loading combined with the Hertzian elastic unloading. The force–displacement relationships for these models are shown in Figures 1a and 1b, respectively. The performance of the analytical models has been verified using experimental and numerical data. The laboratory tests have consisted in compression of steel balls between two parallel flat plates (Figure 2a). The same problem has been simulated using the finite element method. It has been shown that the interaction between the



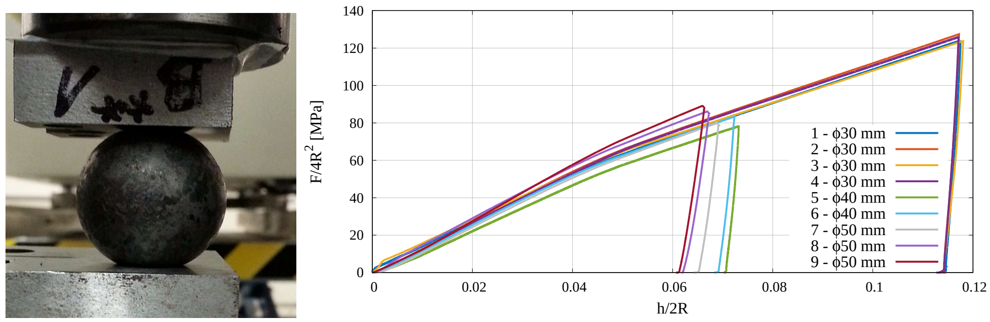
(a)



(b)

Figure 1: Force–displacement contact relationships for loading and unloading: (a) Walton–Braun model, (b) Storakers model with the elastic Hertzian unloading.

spheres subjected to a contact pressure inducing a plastic deformation can be approximated by a linear relationship in quite a large range of elastoplastic deformation (Figure 2b). Similarly, the linear model has been shown to be suitable for the unloading. Thus, it has been demonstrated that the Walton–Braun type model with a linear loading and unloading is an efficient and accurate model for the elastoplastic contact in the discrete element method using spherical particles (Figure 3).



(a) (b)

Figure 2: Compression of a ball between two plates: (a) experimental set-up, (b) scaled force–displacement curves for the loading and unloading for the balls of different diameters

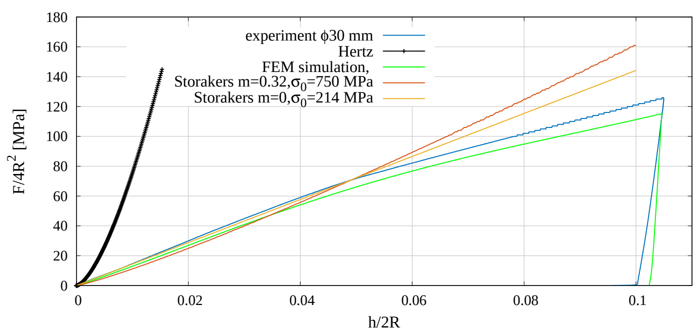


Figure 3: Comparison of the scaled analytical force–displacement curves with experimental and numerical results

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