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Influence of Domain Decomposition Method on the solution of a simple granular test via the N.S.C.D

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Non Smooth Contact Dynamics (NSCD) [1] has shown its efficiency in the simulation of granular media. Since the number of particles and contacts increases or/and the shape of discrete elements becomes more complex, numerical tools need to be improved to keep a reasonable CPU computation time. A first step in this direction has been performed in [2] by the parallelization of the NSCD contact solver. A second step consists in introducing a domain decomposition method adapted to the diffuse non-regularity of granular media. The aim of this presentation is to validate decomposition domain simulations of granular media, as regards of physical key points, on an academic test.

1) A domain decomposition strategy

One particularity of the spatial repartition of granular system consists in choosing the type of objects which constitute interface. Concerning a discrete structure, two classical partitioning are : (i) to distribute interactions (or links) among sub-structures, (ii) to distribute grains among sub-structures. Consequently, interface is defined as split grains (i) or links (ii).

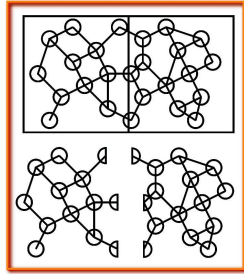


Figure 1 : A decomposition strategy of a collection of rigid bodies.

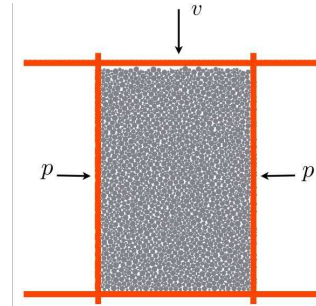


Figure 2 : Geometry and boundary condition of a simple test.

The nonsmoothness comes from interactions, thus it is convenient to distribute those interactions among sub-structures. Therefore the problem becomes a classical NSCD scheme for all domains separately, combined with a gluing step of split interface grains. This last step uses Lagrange multipliers associated to a zero velocity jump between the parts of interface grains [3].

2) Granular reference test

Biaxial simulations have been used since few years by various authors to understand many fundamentals aspects of granular rheology. Thus, we propose to use this reference geometry to test the robustness of our methodology with respect to granular physics. We prepare geometrically a dense packing composed with discs in a confined box. To avoid long range ordering a small size polydispersity is introduced. The lateral walls are then replaced by a chain of discs in order to mimic a membrane; see Fig. 2. A confined pressure p and a constant velocity v_y is applied to the lateral walls and on the upper wall, respectively. Friction between particles is fixed to 0.5. We are interested here to the quasi-static behavior so that p and v_y are chosen such as the inertial parameter I was small, where $I = \frac{\dot{\gamma}}{y} \sqrt{\frac{m}{p}}$ [4]. The simulations are performed to a cumulative vertical strain $\epsilon_1 \sim 25\%$. This simulation is repeated three times varying the number and

the shape of sub-domains from 1 (corresponding to the reference simulations) to 4. The results are compared in terms of macroscopic shear strength as well as microscopic force and fabric anisotropy. The shear strength of granular media is calculated from the stress tensor defined by $\sigma_{ij} = n_c \langle f_i^c l_j^c \rangle$, where n_c is the number of contacts per unit volume and the average runs over the contact c with contact force f^c and branch vector l^c (joining the centers of the two contacting particles) [5]. The mean pressure is defined by $p = (\sigma_1 + \sigma_2)/2$ and the deviatoric stress by $q = (\sigma_1 - \sigma_2)/2$, where $\sigma_1 > \sigma_2$ are the principal stress values. The shear strength is simply given by q/p .

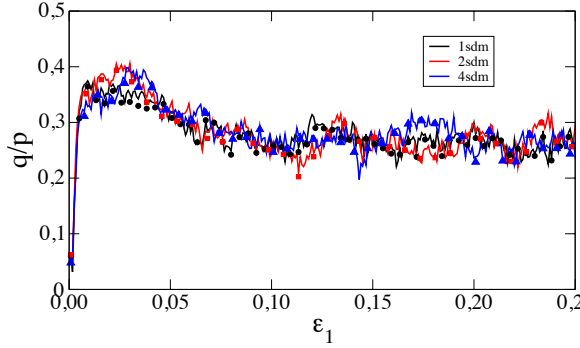


Figure 3 : Normalized shear strength as a function of ϵ_1 for each decomposition (plain line) together with analytical fit proposed by Eq. (1) (symbols)

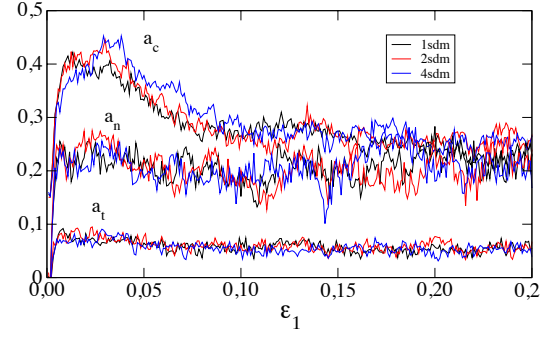


Figure 4 : Variation of the anisotropy as a function of ϵ_1 for each decomposition.

Figure 3 shows the variation of q/p as a function of ϵ_1 for all sub-domains tested. During shear, the shear stress jumps initially to a high value before decreasing to a nearly constant value in the steady state. All curves join nicely on the same curve. From the expression of the stress tensor, it can be shown that the shear stress reflects the packing structure and force transmission via a simple relation [6]:

$$\frac{q}{p} = 0.5(a_c + a_n + a_t) \quad (1)$$

where a_c , a_n and a_t are the anisotropies of the different angular distributions as a function of contact orientation θ : contact orientations $P_n(\theta)$, normal forces $\langle f_n \rangle(\theta)$ and tangential forces $\langle f_t \rangle(\theta)$, respectively. Much more details related the physical meaning of these parameters which describes the granular microstructure can be found in [7]. Figure 4 plots anisotropies parameters as a function of ϵ_1 for all sub-domains tested. All the curves join also nicely on the same curve, and thus, the prediction given by equation (1) run also using domain decomposition method.

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