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Kinematic fields in 2D granular media

M. TOLOMEO^a, G. COMBE^b, V. RICHEFEU^c

UJF-Grenoble 1, Grenoble-INP, CNRS UMR 5521, 3SR Lab., B.P. 53, 38041 Grenoble Cedex 09, France

a. mathias.tolomeo@3sr-grenoble.fr

b. gael.combe@3sr-grenoble.fr

c. vincent.richefeu@3sr-grenoble.fr

Résumé :

On étudie ici le comportement mécanique d'un milieu granulaire modèle constitué de rouleaux de Schneebeli en bois (hêtre). Constitués de 2000 grains, les assemblages granulaires sont contraints isotropiquement par palier de 20 kPa jusqu'à une valeur de 200 kPa. En cours d'essai, les échantillons (50 cm X 50 cm) sont photographiés. Les images ont une définition de 80 MPixels. Par le biais de mesures de champs cinématiques reposant sur la technique de la corrélation d'image numérique, il est possible de mesurer le rapprochement des grains en contact suite à l'augmentation de la pression de confinement. Une analyse statistique de ces rapprochements montre une similitude étroite avec la statistique des forces de contact classiquement observées en DEM, aussi bien pour les « rapprochements » petits (forces faibles) que pour les « rapprochements » grands (forces fortes).

Mots clefs: milieu granulaire 2D; étude expérimentale, compression isotrope; CIN; analyse statistique des forces de contact.

Abstract

We study here the mechanical behaviour of a granular medium made of Schneebeli's wooden rods (ash wood). Made of 2000 grains, the granular assemblies are isotropically loaded from 20 kPa to 200 kPa by steps of 20 kPa. Photos of the samples (50 cm X 50 cm) were shot by means of a 80 MPixels digital camera. Using the technique of Digital Image Correlation, the full kinematics of grains is assessed. Hence, the distance of grains of contact (called hereafter "overlay distance") is measured during the loading. A statistical analysis of the intergranular overlay distance shows same features as the ones classically observed for intergranular contact forces in DEM, for both ranges of values: small overlay and strong overlay distances.

Key words: 2D granular materials; experimental isotropic compressions; DIC; PDF of contact forces.

1 Résumé étendu

We present an experimental study on the statistics of interparticle distances in quasi-static biaxial tests on an analogous granular material (Schneebeli rods). A software called TRACKER has been used to process images of the granular assembly taken by an 80 M pixels digital camera. This software makes use of a Particle Image Technique (PIT), derived from the Digital Image Correlation (DIC), in order to measure in-plane kinematic fields of the assembly, i.e. grains displacements and rotations. In particular, we focused on the relative displacement of couple of “neighbour” grains that can either be in contact or not. Thanks to the high resolution of the images, as well as to the accuracy of such measurements – as already proven by [1] – it was possible to measure the evolution of a parameter, referred to as “overlay distance”, which is defined as the difference between the distance from one grain’s mass centre to the other one’s and the sum of the radii of the two grains, and to perform a reliable statistical analysis of it.

One of the main outcomes of this statistical analysis is that it allows us to underline similarities between the overlay distance and the contact force, which is typically used to describe the behaviour of a granular material at the grain scale. Only normal forces were taken into account, as the overlaying was assumed to take place along the direction of the branch vector connecting the two mass centres. As it can be seen in Fig. 1, the shape of the Probability Distribution Function of overlay distances recalls the shape of the same distribution for normal contact forces, as in [3] (Fig. 2), showing a clear agreement with a power law decay for values lower than the mean, and with an exponential law for values higher than the mean.

Other analyses on the overlay distance were performed, finally proving, consistently with the previous findings, that the considered parameter is strongly related to the contact force between grains and thus it can be used to describe the microscopic behaviour of a granular material. Among these, two need a particular mention: the determination of a macroscopic continuum-equivalent stress tensor - Weber’s formulation – and the detection of force chains. The first one was carried out by assuming a linear dependence between the interparticle gap and the contact force, as confirmed by experimental tests on a single couple of grains; the stress tensor obtained in this way was found to be qualitatively similar to the macroscopic one imposed by the machine. The force chains, detected by plotting maps of the evolution of the interparticle gap throughout a test, were essentially found to correspond to the major principal stress direction.

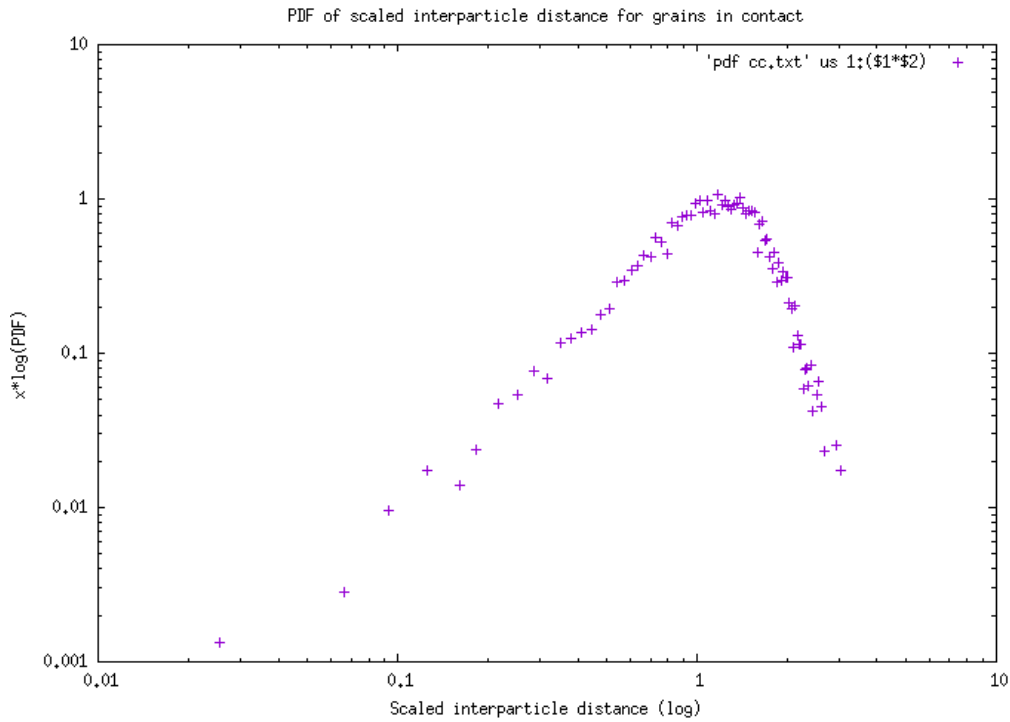
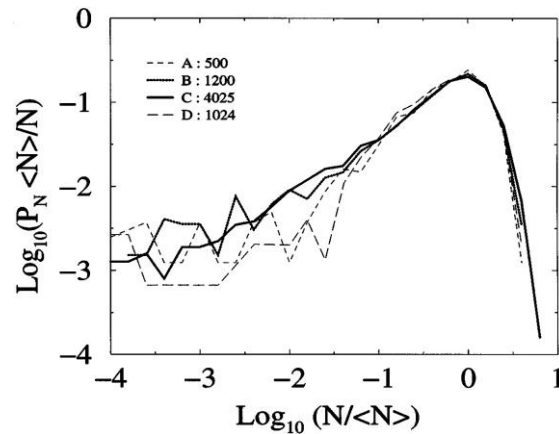


Figure 1: log-log plot of the probability distribution of overlay distances

Figure 2: Log-log plot of the probability distributions of normalized normal forces $N/\langle N \rangle$ [3]

References

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