Coupling multibody system and granular dynamics

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Achievements

We are able to simulate a granular media interacting with mechanical device (2D & 3D). The simulations are able to capture granular phenomena such as the fluidization and its direct consequences on the mechanical device.

Applications, motivations

Analyzing the **tamping process** of railway tracks, allowing a better knowledge of the forces in the tamping machine and the consequences in the ballast.

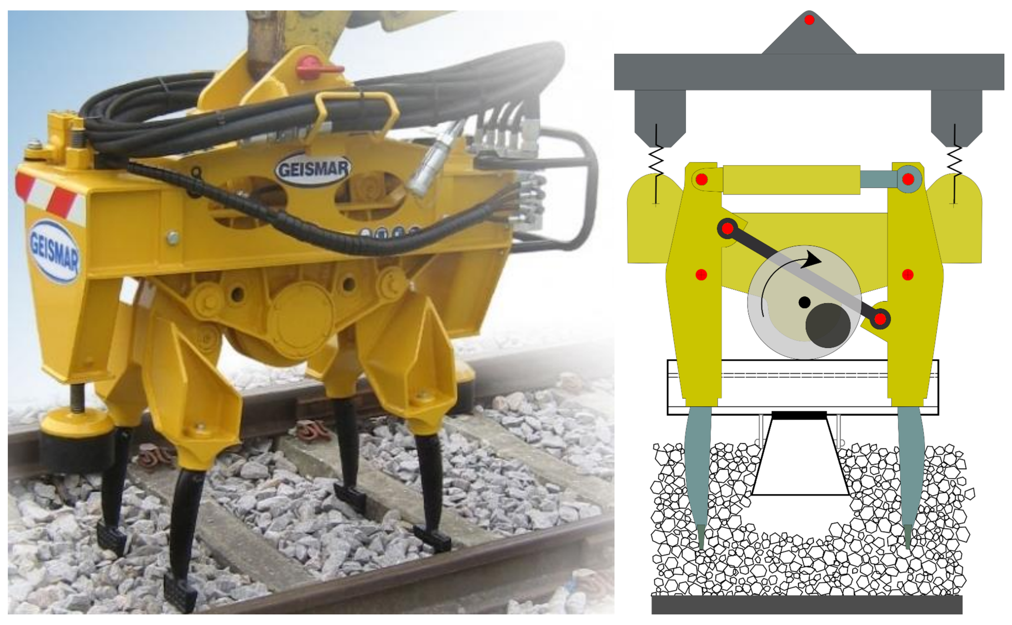

Fig.1 Tamping machine, the real from Geismar and the model. A tamping machine put the ballast in vibration to go inside, then the stones are squeezed by the machine.

Quarries facilities request energy-intensive processes such as stone crushing, stone screening. Better comprehension of the interaction between the machines and the stones can lead to energy savings.

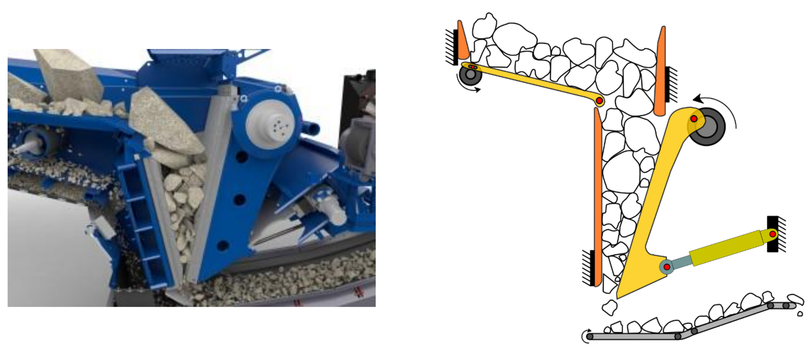

Fig.2 Crushing process heavy machine submitted to heavy constraints and possible grains locking in silos.

Stone, grains transportation by trains or truck can be analyzed to reduce payload motion while driving leading to more security.

Fig.3 Truck lying on its side following a loss of control maybe caused by the payload.

2D Benchmark

Goals, validate

- The numerical methodology
- The robustness of the integration

Design

- A four bar mechanism with a telescopic bar
- Blends a frame filled with particles
- The frame is excited by a hydraulic cylinder at different frequencies
- The photo-elasticity allows to observe the force chains between particles

Numerical results

The force needed by the mechanism to blend the granular decreases while the granular is at rest, lightly vibrated and finally in a fluidized state. Numerical simulations allow one to see how the **force chains** tend to prevent the motion of the mechanism.

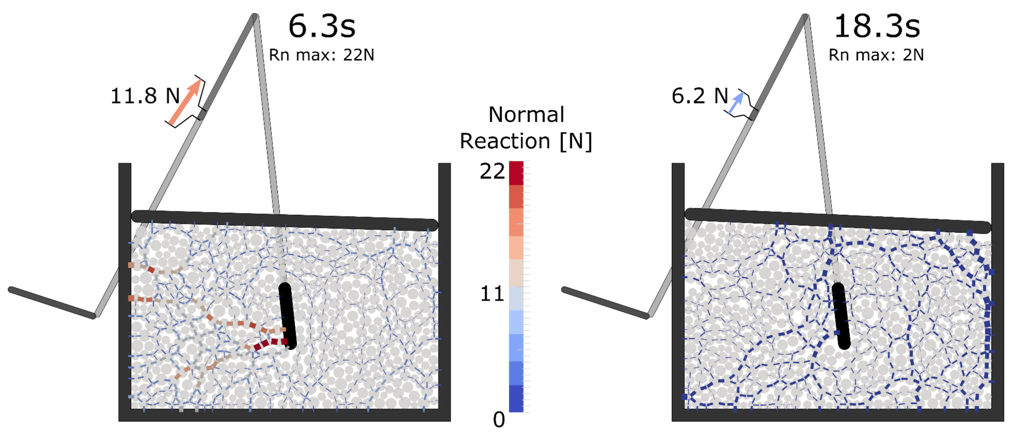

Fig.4 Force chains: higher force interaction causes higher forces in the mechanism for a similar configuration (here granular media is not vibrated).

Another image of the force transmitted from the granular media to the mechanical device is the **compression of the telescopic bar**. A lower cohesion of the granular media is reflected by lower mechanical loads on the telescopic bar.

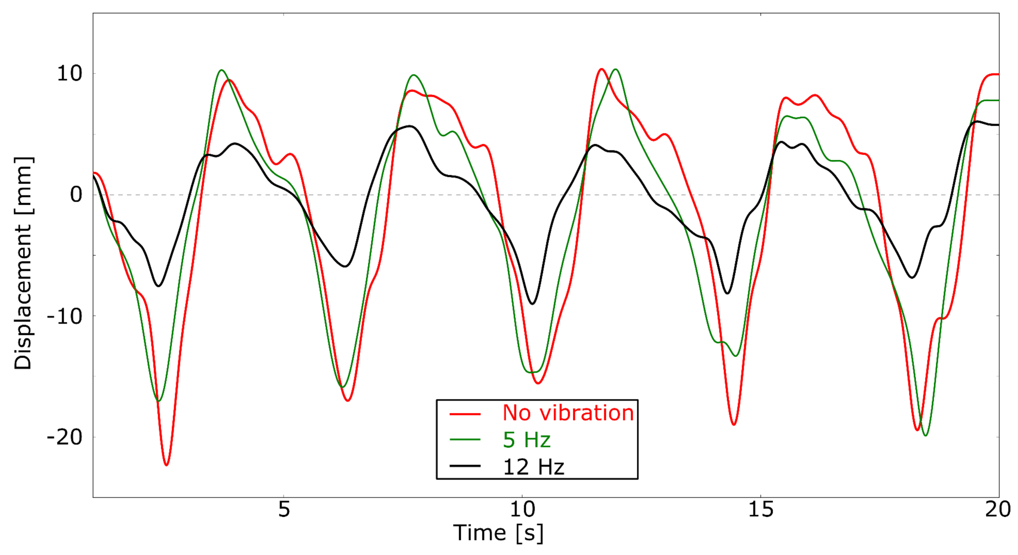

Fig.5 Elongation of the telescopic bar for different granular excitations. Lowest amplitude at highest frequency (in black); Highest amplitude with no vibration (in red).

Experimental bench

A test bench is being manufactured in order to validate the numerical method coupling mechanisms and granular media. It consists of the below 2D-benchmark for which the telescopic bar displacement will be recorded (and serve as comparison measure).

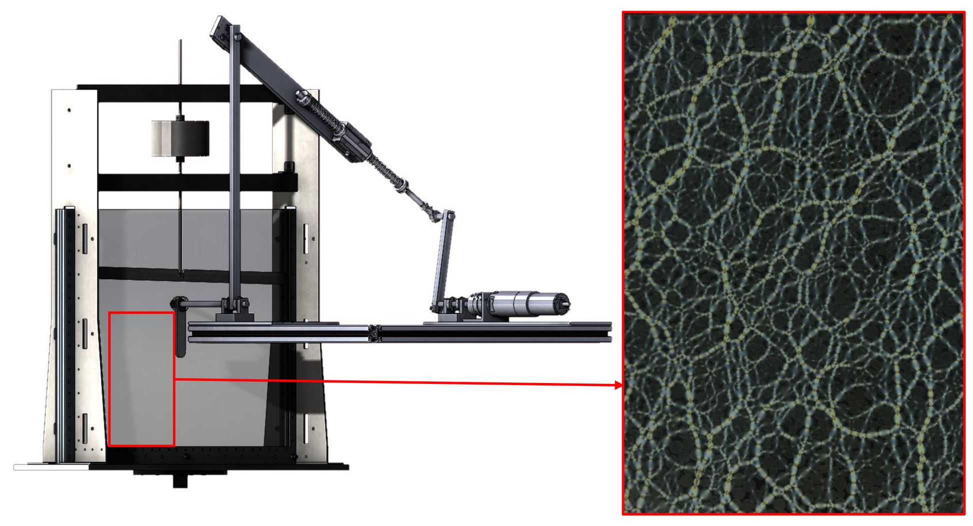

Fig.8 CAD of prototype currently being build and a **photoelastic analysis** highlighting the force network between particles, here for a biaxial compression test (courtesy of J. Barés, Univ. Montpellier, France)

The force network and the apparition of jamming in the granular media will be tracked using photoelastic analysis.

Numerical methods

Nonsmooth contact dynamics method[2]

- Contact: Non-smooth frictional
- Time stepping: almost Moreau and Jean
- Solver: Non-linear Gauss-Seidel procedure for mechanism and grains together

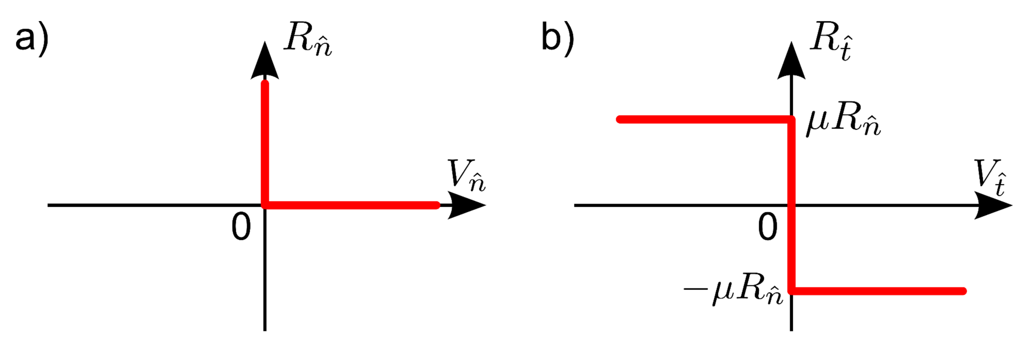

Fig.9 Contact force a) Signorini's condition in normal direction b) Coulomb's condition in tangential direction

Mechanical device modelling

- Formalism: rigid multibody system
- Coordinates: relative coordinate system (reduce the number of joints constraints)
- Bilateral constraints: solved by the coordinate partitioning method[1]

Sources

1. J. Samin, P. Fisette, Symbolic modeling of multibody systems, Springer, 2003.
2. M. Jean, Computer Methods in Applied Mechanics and Engineering 177, 235 (1999)

Implementation

LMGC90[1] solves the dynamics of the granular media. and contact problem dynamics

Robotran[2] solves the dynamics of the mechanisms.

1. N. Docquier, A. Poncelet, P. Fisette, Computer Methods in Applied Mechanics and Engineering 4, 199 (2013)
2. F. Dubois, R. Mozul, "Lmgc90", in CSMA2013, 11e colloque national en calcul des structures, May 13-17, Giens, France 2013

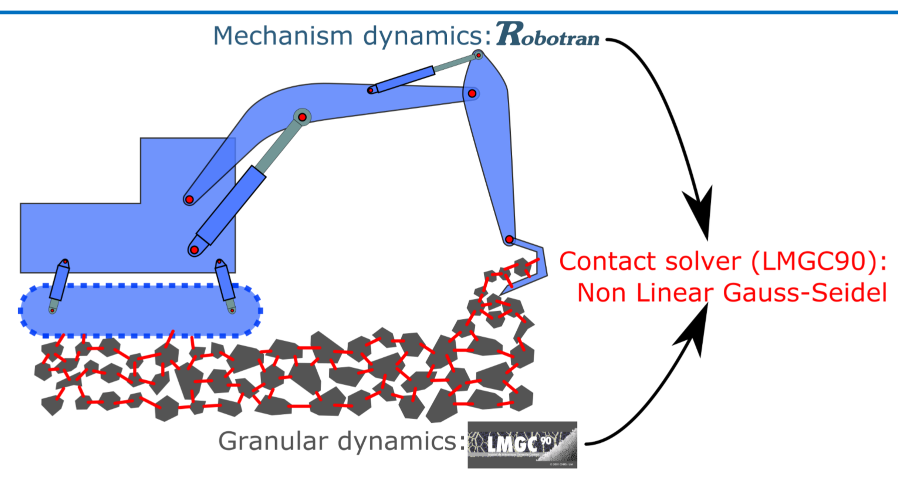

Fig.6 The contact solver take into account for granular dynamics and mechanism dynamics

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