Coupled simulation of multibody systems and granular media using the non-smooth contact dynamic approach

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Abstract

Coupling multibody systems formalisms with other fields of engineering is still a challenge for enlarging their scope of applications. In particular, numerous problems involve a dynamic interaction between an articulated system and a granular material such as the dynamics of a vehicle on a sandy soil or the handling of agricultural products, aggregate or ore. During the last decades, much research effort led to the development of *discrete element methods* that enable to consider each particle of such a media (see Ref. [1] for instance). Several approaches exist to manage the contact between particles which is a key issue in such techniques.

In this context, the present work aims at coupling models of multibody systems and granular media using the Non-Smooth Contact Dynamics method (NSCD) proposed by Moreau and Jean (Ref. [2]). This method relies on a time-stepping strategy which, as opposed to even-driven methods, does not synchronize its time step with each contact event. It imposes to solve geometric and dynamic contact equations for the whole media at each time step. Following this approach, the equations of motion are formulated in terms of differential measures and impulses and not at the acceleration level, both for the multi-body system and particles. The strategy we adopted relies on the following points.

- The contact constraints are formulated at the velocity level which may be more favourable for the stability of the scheme. However, it may induce a drift-off effect which must be controlled with the time step size so as to remain acceptable for capturing the collective behaviour of the granular media. A solution for solving this problem using the GGL approach is proposed in Ref. [3].
- The contribution of impacts and contacts is split from the smooth motion, i.e. the motion in absence of contacts.
- At each iteration of each time step, the smooth motion is first computed using a classical numerical integrator such as a θ-schema or the generalized-α method.
- The contact constraints are then solved using a non-linear Gauss-Seidel algorithm which may be slower than other techniques but more robust, especially for three-dimensional problems with complex geometries and specific contact laws.
- The bilateral constraints resulting from the articulated system are solved during the integration of the smooth motion. For instance, if relative coordinates are used, constraints arising from kinematic loops can be eliminated using the coordinate partitioning technique (see Ref. [4] for details).

From the implementation point of view, the equations of the multibody system are generated in the symbolic form by the Robotran software (Ref. [4]), including the bilateral constraints and their Jacobian. Those equations are coupled to the LMGC90 software (Ref. [5]) which manages the dynamics of the set of particles and solves the contact problem.

This approach was applied for analysing the tamping process of railway tracks. This maintenance action consists in correcting the track geometry by compacting the ballast under the sleepers. A vibration imposed on the tamping tools induces a "semi-viscous" state in the ballast which enhances the process.

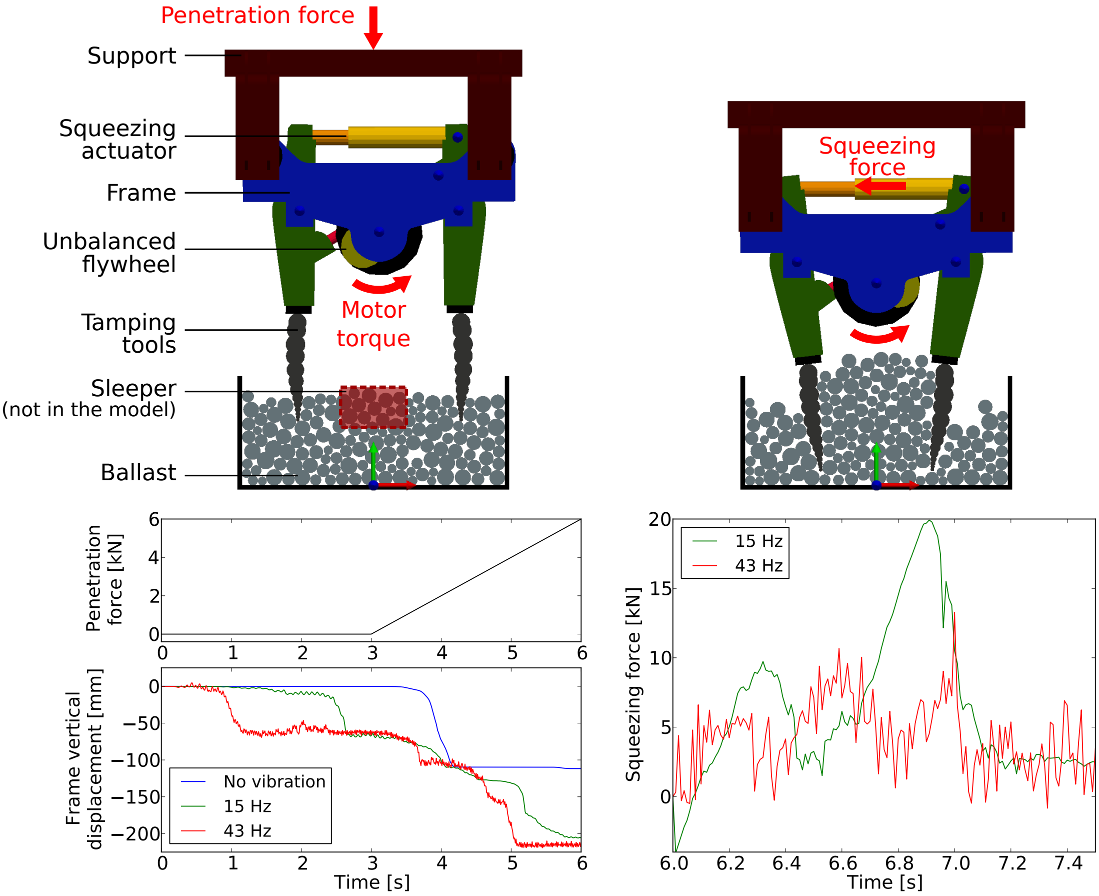

Figure 1: Left: a motor torque is applied on the flywheel for inducing vibrations. From 3 *s*, a growing downward force is applied on the support. The tools dive with a lower force when the vibrating frequency increases. Right: the force to be applied on the actuator to squeeze the ballast is globally smaller when the vibration frequency increases.

A planar model of a tamping unit operating on a ballast represented by rigid disks was implemented (Fig. 1). The geometry of the tamping tools is modelled as a cluster of disks and the sleeper is not taken into account. The vibration of the machine is induced by the rotation of an unbalanced flywheel. This illustrative application shows that the vibration may effectively reduce the force required for penetrating and squeezing the ballast.

Our presentation will first explain more deeply the resolution strategy and discuss the impact of the time integrator. Moreover, current work is in progress for extending this approach to the three-dimensional case with more representative geometries. This will enable us to present a more realistic modelling of the tamping process.

References

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