F. Biondani, M. Morandini, G.L. Ghiringhelli, M. Terraneo, P. Cordisco
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A SIMPLE DISCRETE ELEMENT CODE FOR PARTICLE DAMPERS

Fabio Biondani **Marco Morandini*** **Gian Luca Ghiringhelli**
Politecnico di Milano
via La Masa 34, 20156, Milano, Italy
Email: fabio.biondani@polimi.it, marco.morandini@polimi.it, gianluca.ghiringhelli@polimi.it

Mauro Terraneo **Potito Cordisco**
Vicoter
Via Stoppani, s.n.c., 23801 Calolziocorte (LC), Italy
Email: mauro.terraneo@vicoter.it, potito.cordisco@vicoter.it

ABSTRACT

Particle damping can provide substantial damping, regardless of external harsh conditions. The numerical analysis of particle dampers is based on the Discrete Element Method (DEM). A GPU penalty-based DEM solver for particle dampers with spherical particles, called PMB, is described and validated. Case studies are analyzed with PMB and other available DEM software programs. To enable the analysis of particle dampers on deformable structures, PMB is coupled with MBDyn, a multibody dynamics analysis software. The coupling algorithm is validated both with a well-known [1] and new in-house experiments.

Particle code

PMB is an explicit integration GPU particle code. The broadphase particle-to-particle contact detection is performed with a uniform grid spatial subdivision [2]: the same method used by the sample "*particles*" by CUDA. Since PMB considers only uniform diameter spherical particles, there is no need to implement more complex and costly broadphase algorithms.

The normal force between two particles (or between a particle and a wall) is computed with a linear spring-dashpot (LSD) model. The tangential force between two particles is computed with a simplified Coulomb's law [1]. Rolling friction is being neglected. Both the particles rotational and linear equations of motion are solved with an explicit time integration scheme from [3].

Coupling with MBDyn

To analyse the application of particle dampers on any structure or multibody system, PMB was coupled with MBDyn, which is a free general purpose multibody dynamics analysis software of widespread use [4]. Coupling between PMB and MBDyn was achieved by setting an interprocess communication employing sockets. The coupling scheme of an integration step, shown in figure 1, was designed to parallelise as much as possible the calculations performed by the two coupled programs.

Amplitude control technique for a coupled multibody - particle damper system

Some experiments were carried out by controlling the measured acceleration RMS. Because of this an iterative procedure was needed in order to find the sinusoidal input force amplitude that allows to achieve the sought RMS acceleration while simulating the system dynamics. For each force amplitude the simulation is run until the response RMS does not vary significantly for a certain number of periods. After that, the input amplitude is iteratively adjusted.

*Address all correspondence to this author.

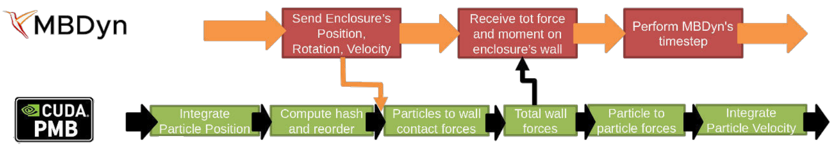

FIGURE 1. MBDyn-PMB coupling scheme.

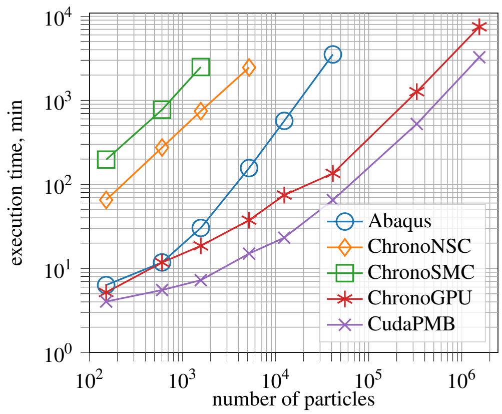

FIGURE 2. Execution times comparison. Hardware: Intel(R) Core(TM) i7-3930K CPU @ 3.20GHz, Nvidia GeForce GTX 1650 4 GB GDDR6

SOFTWARE VALIDATION

A cylindrical particle damper whose motion along its axis is a sine of imposed amplitude and frequency is considered. Gravity is aligned to the particle damper's motion. PMB, Abaqus Explicit, the multithread CPU version of Chrono 4.0 [5] and the GPU version of Chrono 6.0 were used. Regarding Chrono 4.0, both the available smooth (SMC) and non-smooth (NSC) DEM methods have been employed. The results obtained using PMB, Abaqus Explicit and Chrono with smooth contact laws shows an excellent correspondence. The execution times of the analyses are compared in figure 2. The authors speculate that PMB's speed was achieved, beside the use of a consumer GPU, because of its simplicity compared to Chrono and Abaqus, which can simulate bodies with more complex shapes than spheres and therefore need more complex contact detection algorithms and contact laws. In particular, the more than 50% reduction in execution time compared with Chrono GPU was achieved also thanks to contact laws that do not need to pass internal variables from a timestep to the next.

Coupling validation

Both Saeki's experiments [1] and a highly deformable beam coupled with a horizontal particle damper were considered. Good results, comparable with those reported in the literature,

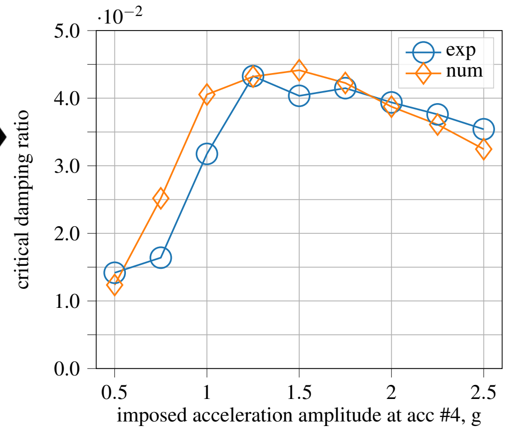

FIGURE 3. Predicted damping ratios

were obtained for Saeki's experiment. As for the new experiment, a significant difference accurs at the lower acceleration amplitudes of 0.75 g and 1.0 g, cfr. Fig. 3. Comparison with a high frame rate film suggests that these differences are likely because the upper layers of particles slides more easily in the simulation than in the experiment, perhaps due to a suboptimal simulation friction model.

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