DEM MODELING OF VACUUM PACKED PARTICLES DAMPERS

P. Chodkiewicz[1], R. Zalewski[1], and J. Lengiewicz[2]

[1]*Faculty of Automotive and Construction Machinery Engineering, Warsaw University of Technology,Warsaw, Poland*
[2]*Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland*

e-mail: pawel@chodkiewicz.com.pl

1. Introduction

We present a method based on Discrete Element Method (DEM) to modeling the Vacuum Packed Particles (VPP)—a class of smart materials/smart structures. Mechanical properties of VPP can be simply adjusted by controlling the underpressure, which makes the structures very interesting from practical point of view, giving raise to numerous applications, including smart grippers [2], dampers [1, 6] or medical tools [5].

VPP are made of loose granular material encapsulated in a hermetic wrappnig. When the pressure inside the structure is equal or higher than the pressure outside, the VPP structure has mechanical properties like a baggy bulk. When the pressure inside is lower than outside, the whole structure behaves more like a solid material. Those special properties of VPP, together with the fact that they are in general cheaper and more eco-friendly than electro- or magnetorheological materials of similar characteristics, make them potentially very promising engineering structures. One of such structures—VPP dampers—are analyzed in this work.

In our previous works, VPP dampers were mostly described by using macroscopic rheological models [7, 8]. This kind of modeling usually requires relatively large number of parameters to be identified even for simple damper designs. Moreover, those parameters are not general and need to be individually adjusted to each design. In the present work we will pursue our earlier attempts, [3], to focus more on understanding how VPP dissipate energy under an oscillatory excitation (see Fig. 1a), which can possibly suggest ideas for a more accurate model. Such model could then be used to describe and analyze not only VPP dampers but possibly also other VPP structures.

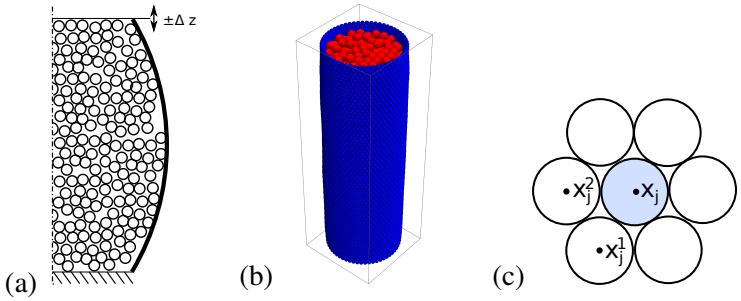

Figure 1: VPP damper: schematics (a), DEM model (b), geometry of an elementary surface element of the warp (c).

2. DEM model of VPP damper

We use open-source Yade DEM software, [4], to model VPP dampers. The granular media is directly represented by spherical discrete particles, and the surrounding foil warp is represented by an array of smaller spherical particles, interconnected by cohesive bonds, see Fig. 1b. Frictional model is assumed for granule-granule and granule-foil contact.

In order to provide the special pressure boundary conditions, which are characteristic to VPP structures, the standard Yade DEM model for foil-warp material has been extended as follows. For each elementary segment j of the warp (which is made of 7 spheres—one in the center with 6 neighbors, see Fig. 1c) we apply the force

$$F_j = A_j \cdot p \tag{1}$$

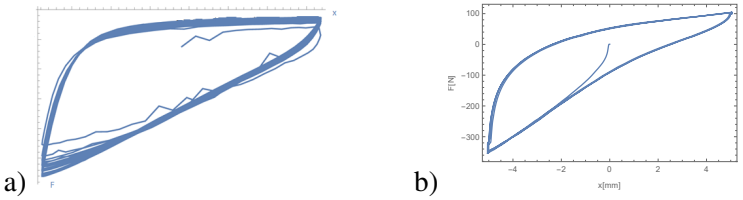

Figure 2: Force-displacement hysteresis loops: DEM results (a), and experimental results (b).

acting on the central sphere of the segment. Here, p is the applied pressure difference, and A_j is the tributary surface area vector,

$$A_j = \frac{1}{6}\sum_{i=1}^{6} s_i, \qquad s_i = (\mathbf{x}_j^i - \mathbf{x}_j) \times (\mathbf{x}_j^{1+(i\%6)} - \mathbf{x}_j), \tag{2}$$

where $\mathbf{x}_j$ is the current position of j-th module of the warp, and $\mathbf{x}_j^i$ is the current position of its i-th neighbor, cf. Fig. 1c.

3. Preliminary results

The performed DEM simulations of cycling loading of VPP damper consists of three steps: (i) the granulate is inserted into the foil warp, (ii) the warp is sealed from the top, (iii) the oscillatory motion of the sealing plane and the top ring of the warp is applied, and the reaction force from the top clamping is acquired. The analysis was performed in the quasi-static regime.

The preliminary results, Fig. 2, prove that DEM model is able to qualitatively capture the, experimentally observed, dissipative effects of VPP dampers. However, the most important advantage of the presented discrete element modeling is the ability to retrieve the individual inter-granular dissipative interactions, observe them along the process, and identify the dissipation patterns in the structure. This is a subject of our ongoing research.

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