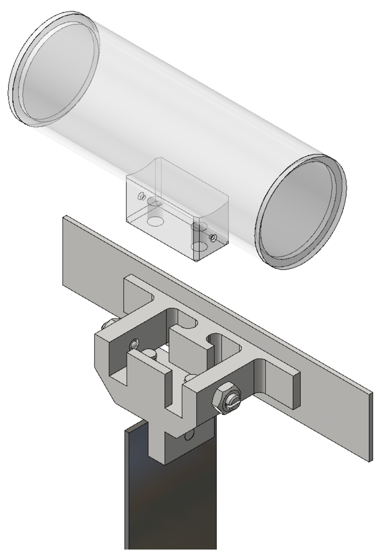
Granular Dampers in Microgravity

Michael Heckel, Achim Sack, Jonathan E. Kollmer, and Thorsten Pöschel
Institute for Multiscale Simulations, Friedrich-Alexander-Universität Erlangen-Nürnberg

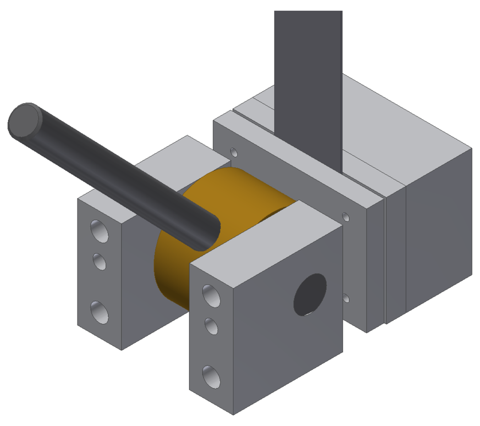
Summary

To confirm a recent theory for granular damping [1-4] we performed experiments on granular dampers for a large abundance of parameters under the conditions of microgravity [5]. In order to meet the special requirements of a parabolic flight we built a setup to perform 16 individual experiments synchronously. Their parameters can be adjusted rapidly in the breaks between parabolas by exchanging the individual damper or the entire spring-damper system. We show that the theory remains approximately valid even beyond the limits of ist derivation.

Quick swap mechanism

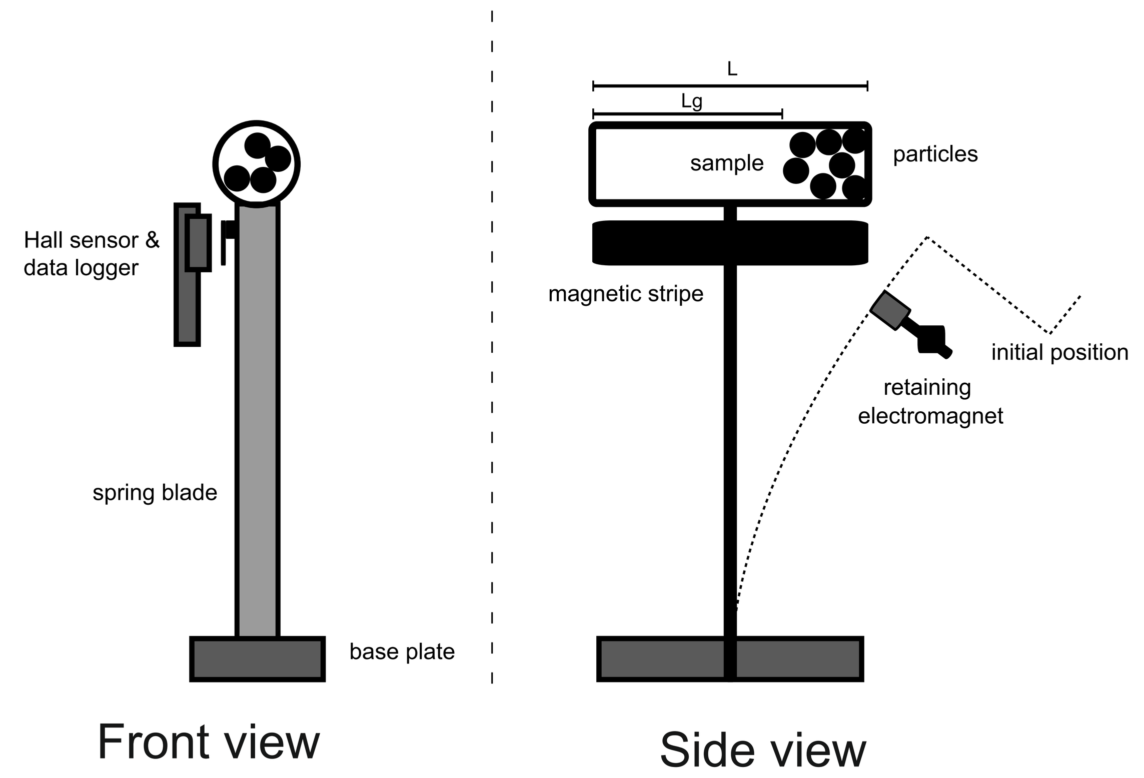


Mechanism to quickly exchange the damper boxes.

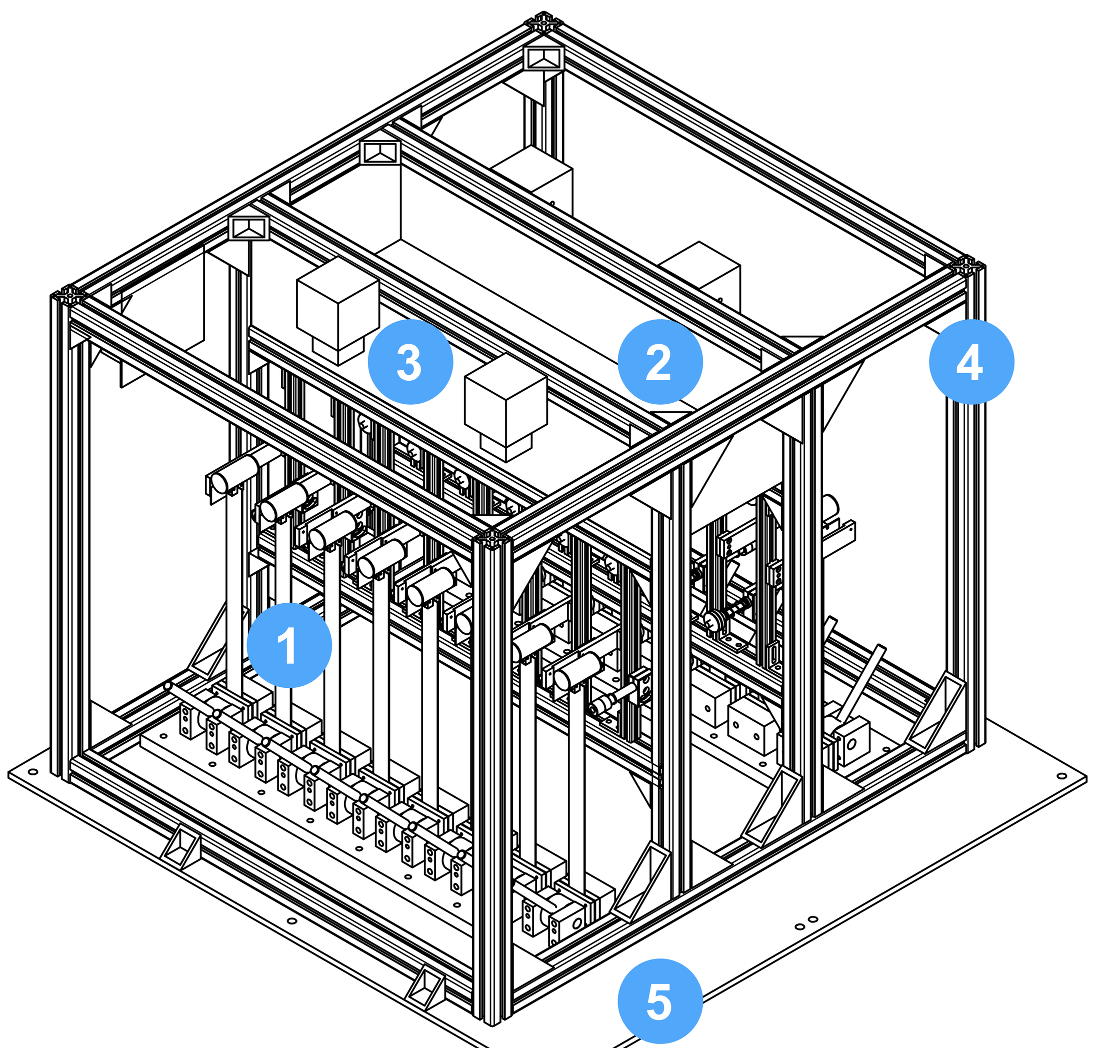


Mechanism to quickly exchange the entire spring-damper system.

Single damper unit

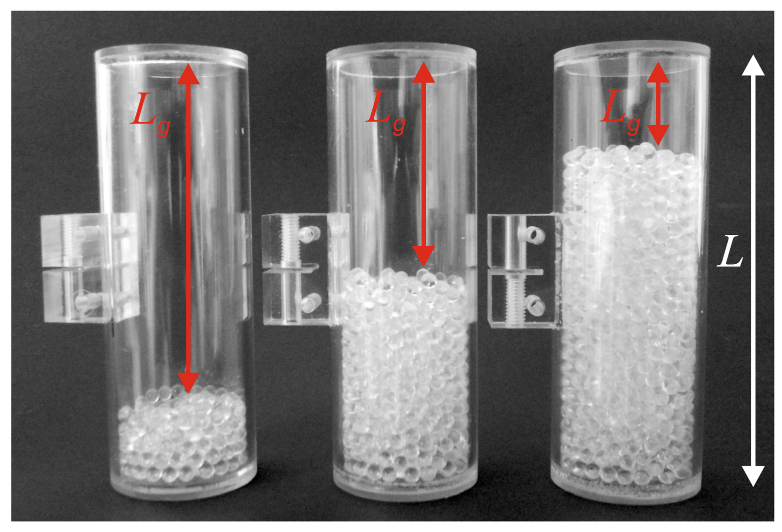


Single damper unit consisting of an Hall-effect sensor combined with a data logger, spring blade, magnetic stripe, sample damper box and a retaining electromagnet.



Sketch of the experiment. 1: Spring-damper units fixed with clamps to the base plate. 2: Storage box for additional dampers and springs. 3: High-speed cameras. 4: Aluminium frame to encapsulate the experiment. 5: Base plate to fix the experiment to the airplane.

Granular dampers



Three different granular damper boxes. They are filled with different amount of glass beads, resulting in different gap sizes L_g.

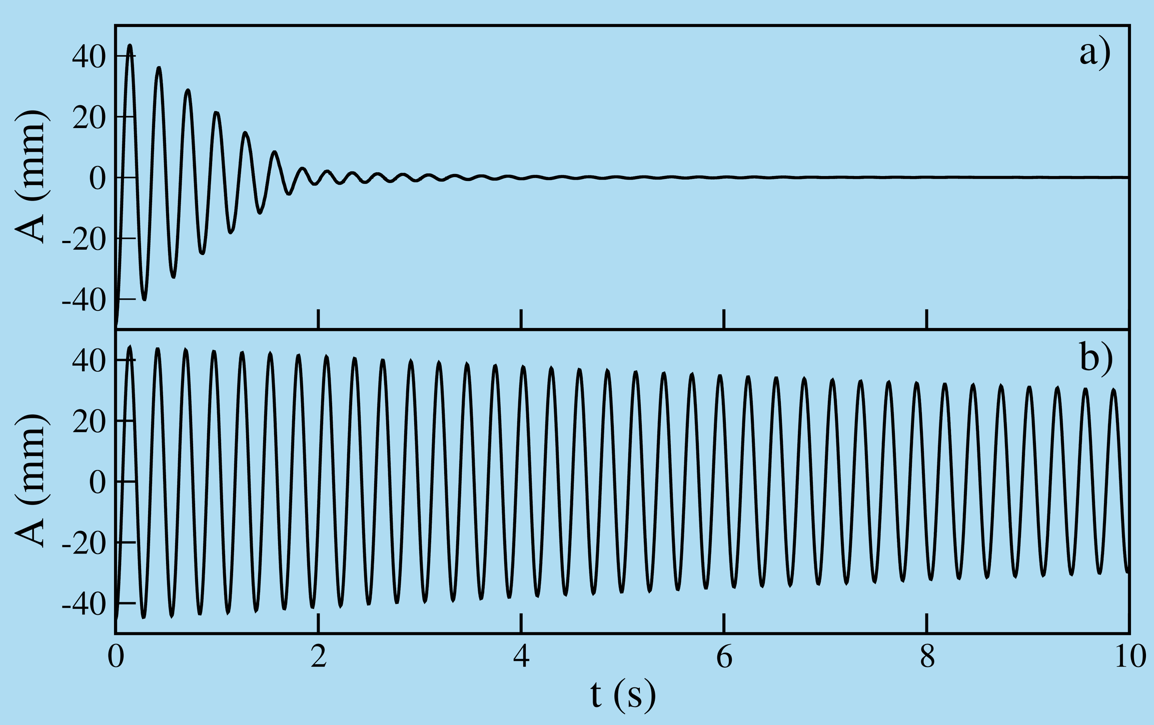
Image of the experiment

Picture of the experiment mounted inside the airplane.

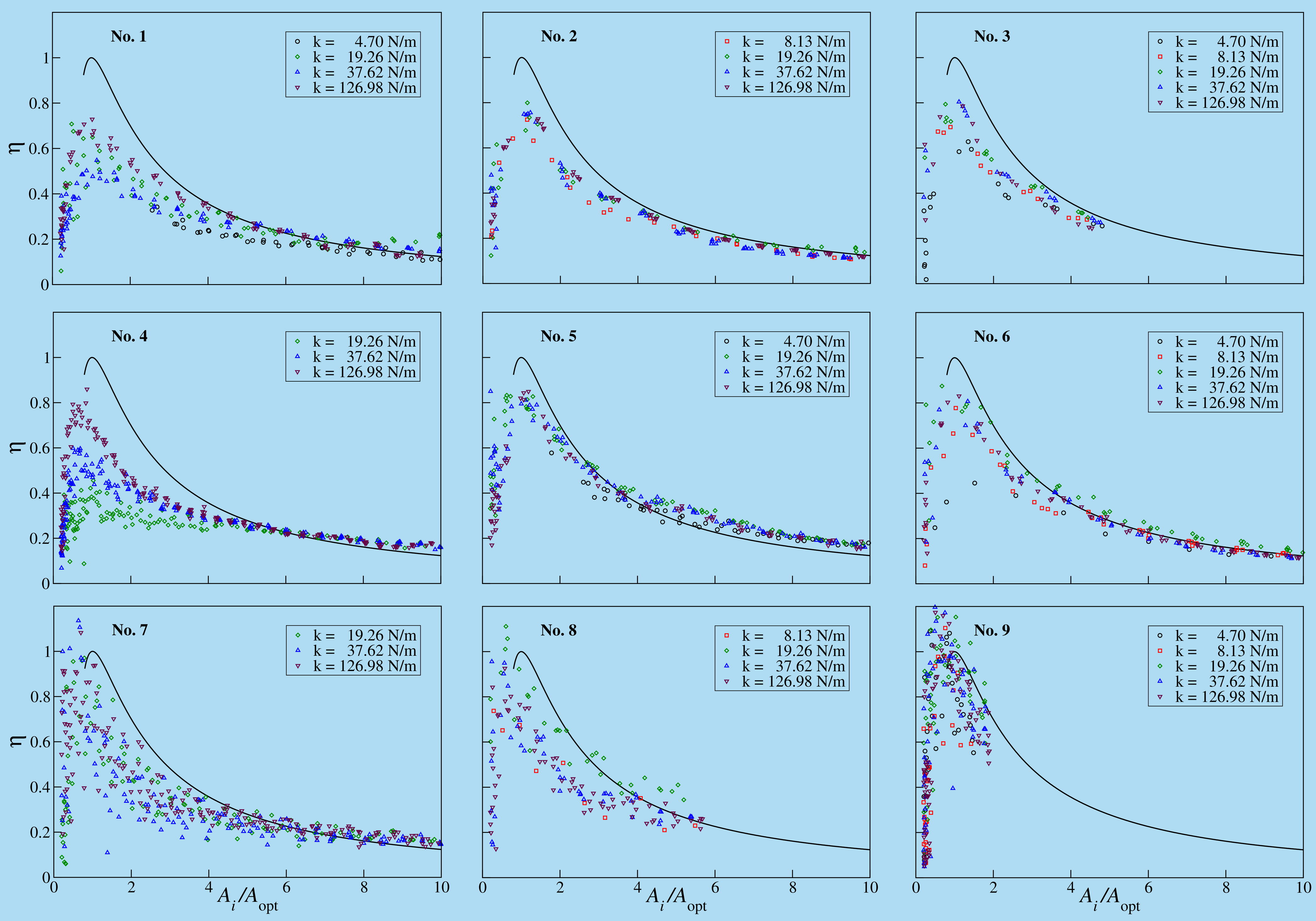
Granular damper comparison

No.	*d* (mm)	*L* (mm)	*m* (g)	L_g (mm)	*k* (N/m)
1	3	20	10	8	4.7, 19.3, 37.6, 127.0
2	3	40	15	10	8.1, 19.3, 37.6, 127.0
3	3	80	30	21	4.7, 8.1, 19.3, 37.6, 127.0
4	4	20	5	13	19.3, 37.6, 127.0
5	4	20	10	6	4.7, 19.3, 37.6, 127.0
6	4	40	25	9	4.7, 8.1, 19.3, 37.6, 127.0
7	10	20	5	10	19.3, 37.6, 127.0
8	10	40	11	22	8.1, 19.3, 37.6, 127.0
9	10	80	5	70	4.7, 8.1, 19.3, 37.6, 127.0
10	-	20	5	-	8.1, 19.3, 37.6, 127.0
11	-	40	5	-	8.1, 37.6, 127.0
12	-	80	10	-	2.4, 8.1, 19.3, 37.6, 127.0
13	-	20	10	-	19.3, 127.0
14	-	40	15	-	19.3, 37.6
15	-	80	30	-	19.3, 127.0
16	-	40	25	-	2.4, 127.0
17	-	80	50	-	4.7, 127.0

System parameters used for the experiments including particle diameter *d*, damper length *L*, filling mass *m*, gap size L_g, and spring constant *k*. The samples 10 to 17 are reference systems with solid mass.



The amplitude versus the time for a) a granular damper (No. 2) and b) a solid reference mass (No. 14) on top of a spring blade with *k*=37.6 N/m.



Energy dissipation rate $\eta = E_{diss,i} / E_{diss,i}(max)$, where $E_{diss,i}(max) = \frac{1}{2} k A_i^2$ is the energy stored in the spring and $E_{diss,i} = E_i - E_{i+1}$ is the energy lost due to the *i*-th impact, obtained from the corresponding pair of consecutive extrema A_i and A_{i+1}. The solid line is the theoretical result of $\eta = \frac{1}{4} [1 - \cos(\omega t_c)]^2$.

References

[1] M.N. Bannerman, J. E. Kollmer, A. Sack, M. Heckel, P. Müller, and T. Pöschel, Phys. Rev. E. **84**, 011301 (2011)
[2] J.E. Kollmer, A. Sack, M. Heckel, and T. Pöschel, New. J. Phys. **15**, 092023 (2013)
[3] A. Sack, M. Heckel, J.E. Kollmer, F. Zimber, and T.Pöschel, Phys. Rev. Lett. **111**, 018001 (2013)
[4] J.E. Kollmer, M. Tupy, M. Heckel, A. Sack, T. Pöschel, Phys. Rev. Applied **3**, 024007 (2015)
[5] A. Sack, M. Heckel, J.E. Kollmer, and T. Pöschel, Granul. Matter **17**, 73 (2015)