Dynamic behaviour of granular matter in a circular vibrated conveyor

UNIVERSITÄT BAYREUTH

Michael Heckel, Christof A. Krülle, Ingo Rehberg

Experimentalphysik V, Universität Bayreuth, 95440 Bayreuth

Abstract

Understanding the behaviour of vibrated granular matter is important because many industrial processes rely on mixed multicomponent substances. The system has to be driven with energy to stay in motion due to dissipative particle interactions. In studies, this is mostly achieved by horizontal or vertical stimulation [1].

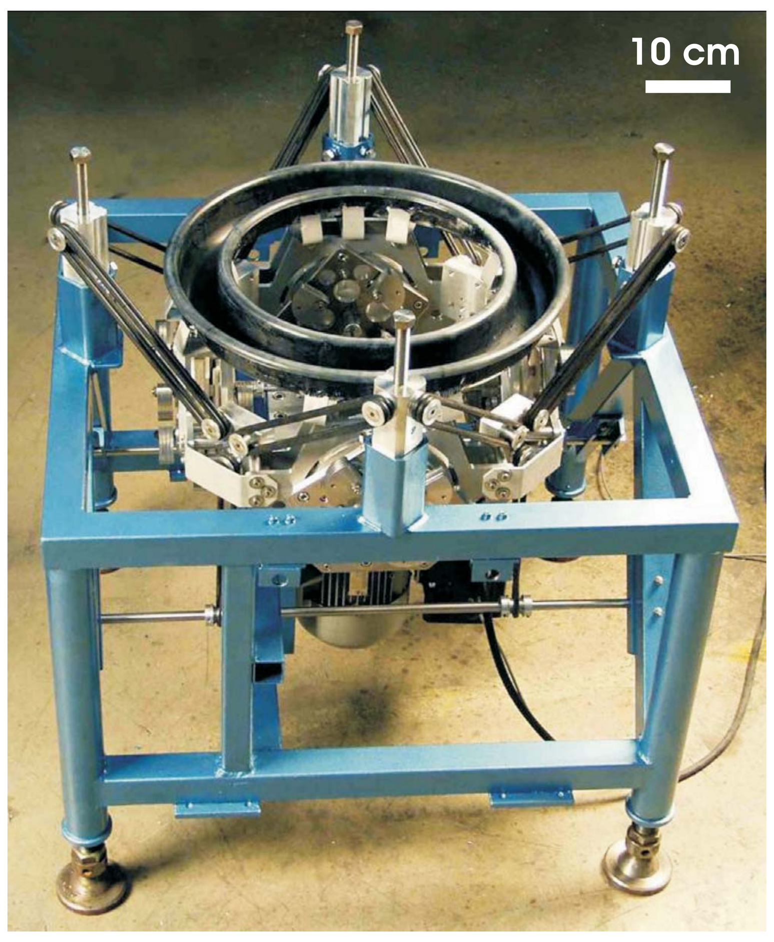
A horizontal and vertical oscillation with the same amplitude was superposed at a phase shift of $\pi/2$. In this way a circular oscillation for each point of the annular container is achieved. As granulate a binary mixture of black glass beads with a diameter of 1 mm and white glass beads with a diameter of 4 mm are used.

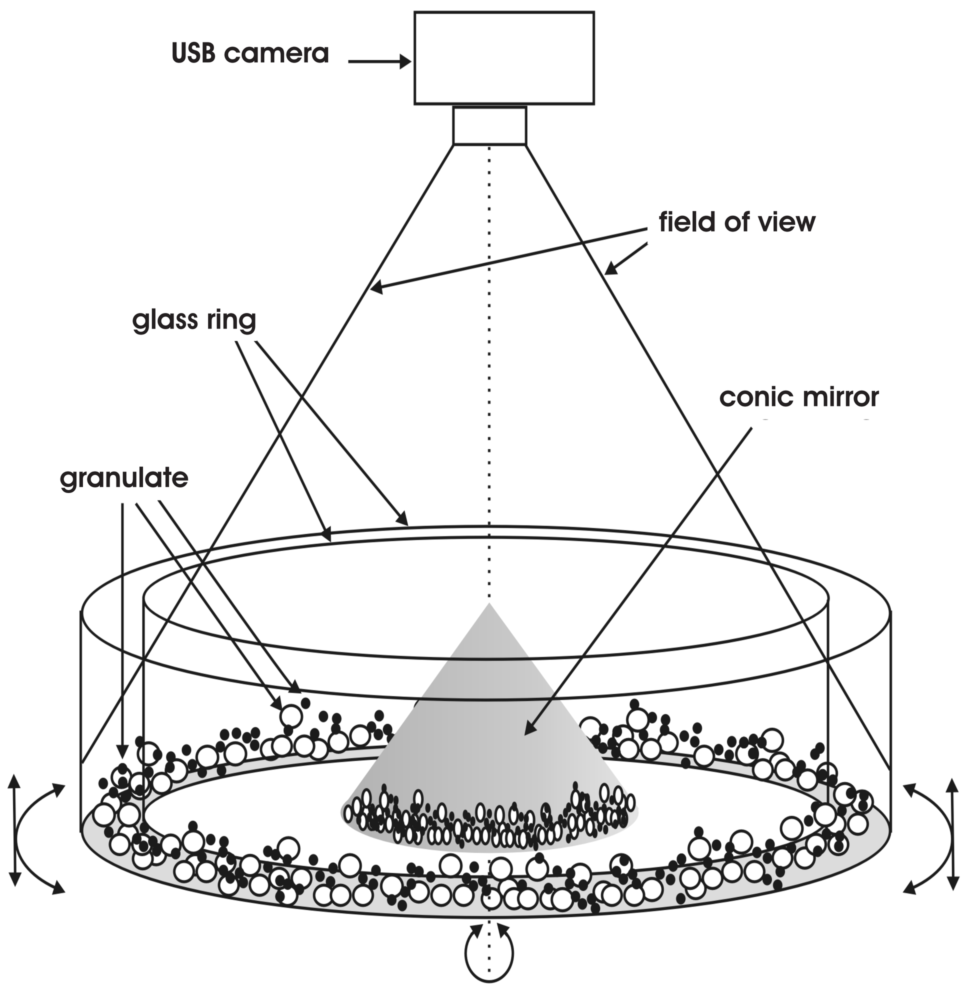
Above a threshold frequency of the excitation the bigger particles move to the top of the granulate which is known as the Brazilnut effect (BNE) [2]. If a second threshold frequency is exceeded, another separation begins to dominate which can be seen as well-separated monodisperse domains in the vibrated bed. By increasing the shaker frequency even further, a final state can be achieved where both particle species are completely separated in two distinct domains.

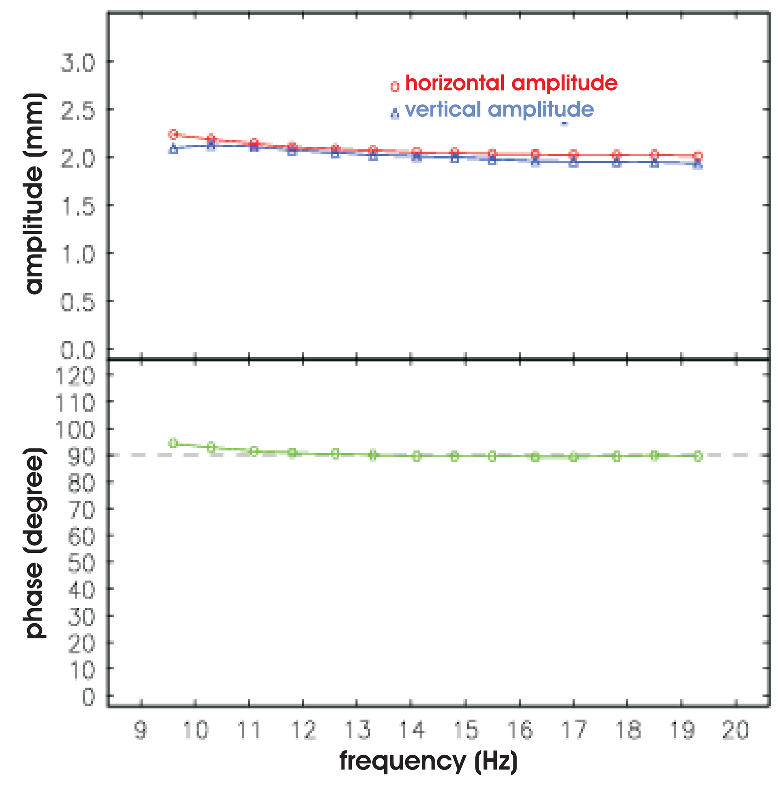
[1] M. Rouijaa, C. Krülle, I. Rehberg, R. Grochowski, and P. Walzel, Chemie Ingenieur Technik 76, 62 (2004)

[2] J. Duran, J. Rajchenbach, and E. Clément, Phys. Rev. Lett. 70, 2431 (1993)

Setup

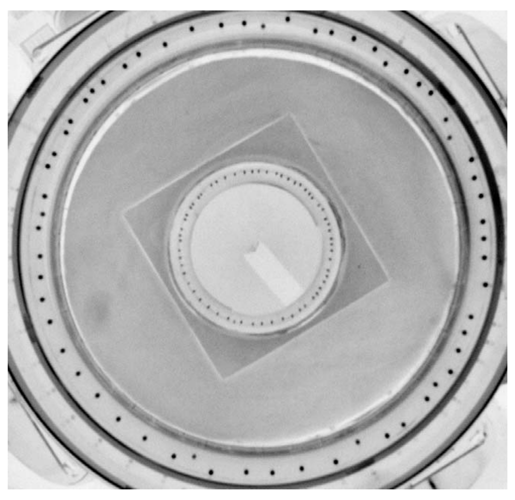




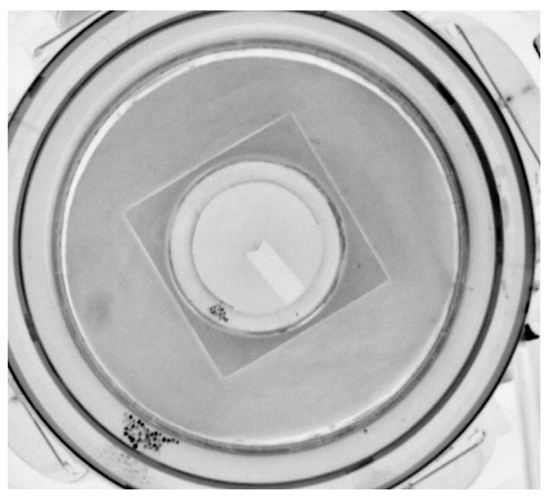


- working range: f = 11.8 .. 19.3 Hz (above resonance frequency)
- $\Gamma = A(2\pi f)^2/g =$ 1.1 .. 3.1

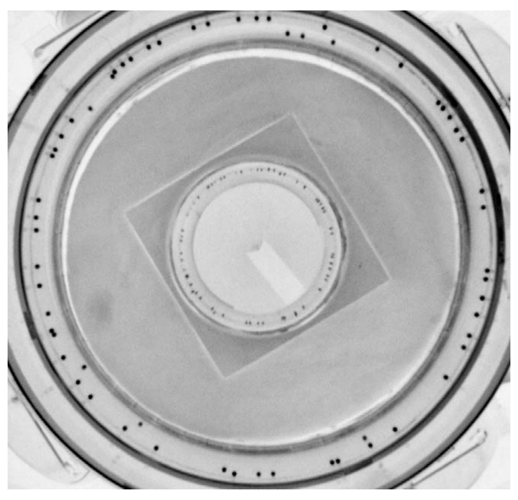
Segregation and mixture of 60 white beads



setting frequency to 16.3 Hz



decreasing frequency to 11.8 Hz



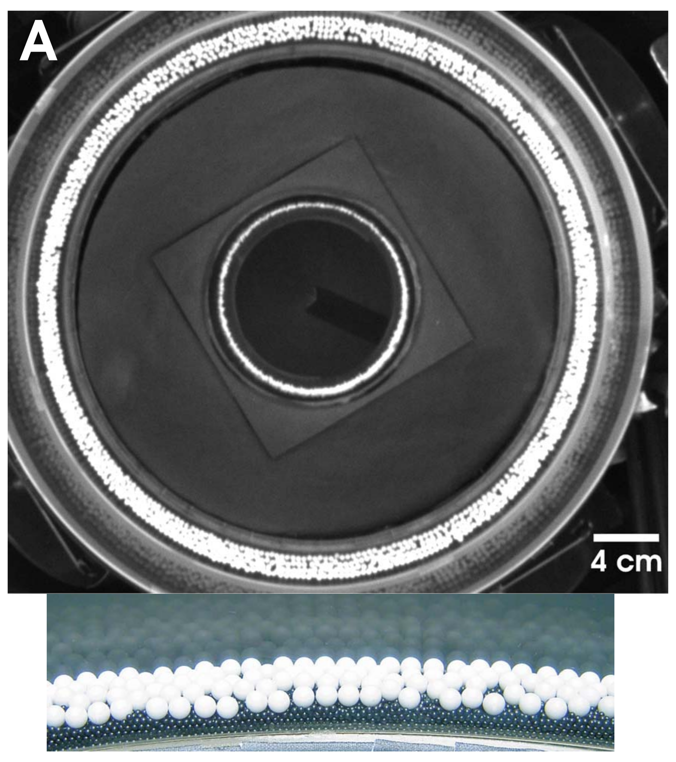
- 60 white beads in a bed of 250 g black beads
- 5 degree distance between white beads

$f > f_{crit}$: lateral segregation

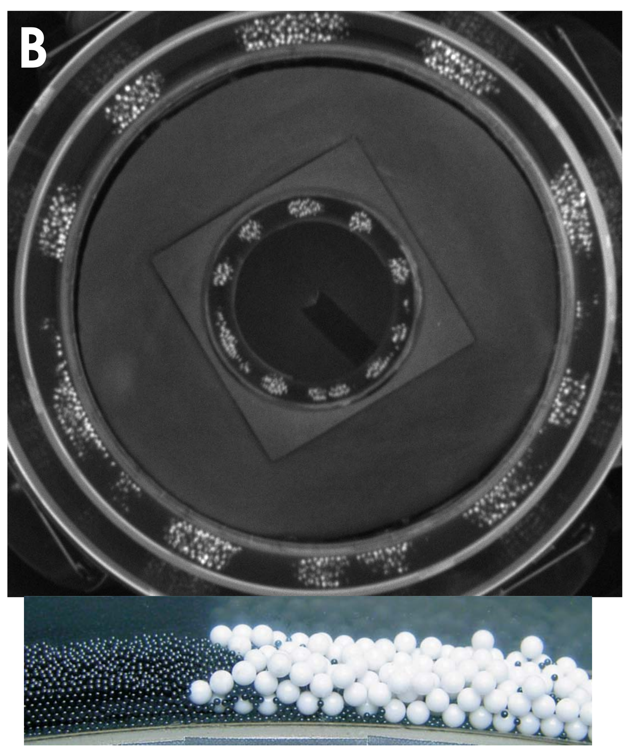
$f < f_{crit}$: almost uniform distribution

Lateral segregation and mixture of a 300 g binary granular mixture

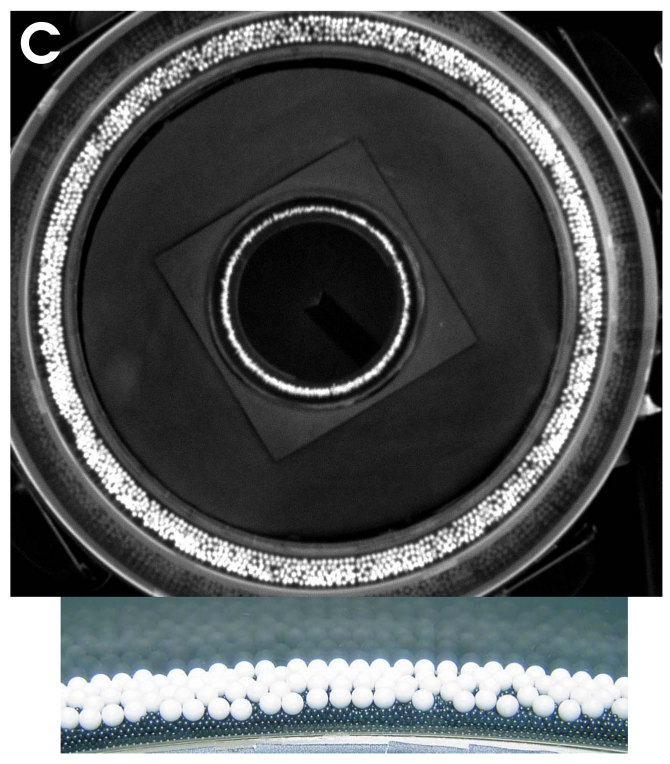
Top and side view of the start situation (A), the final state of the total lateral segregation at 14.8 Hz (B) and the mixture after decreasing the frequency below the critical frequency (C). In images A and C you can see the Brazilnut effect (BNE) which is always present.

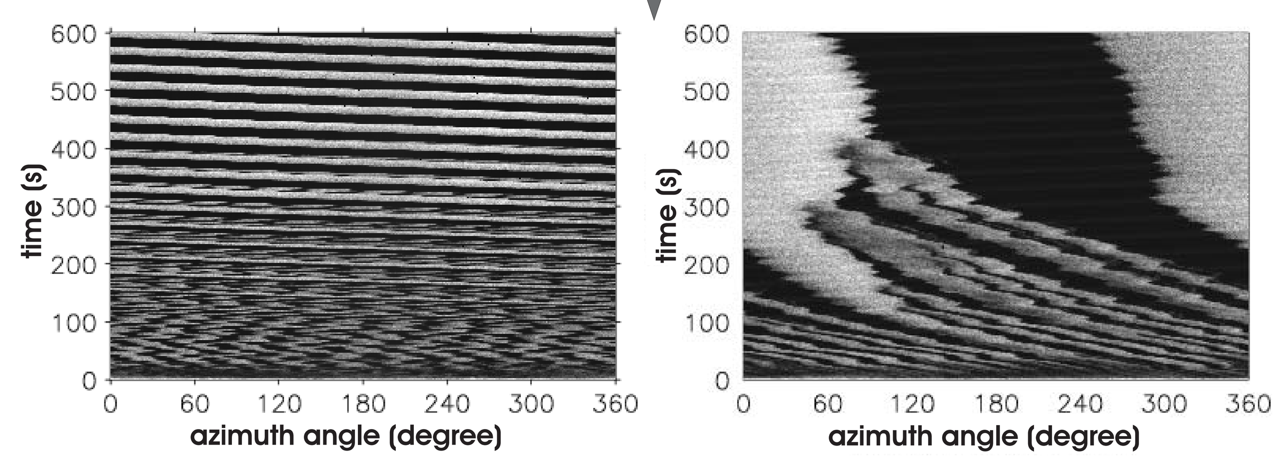


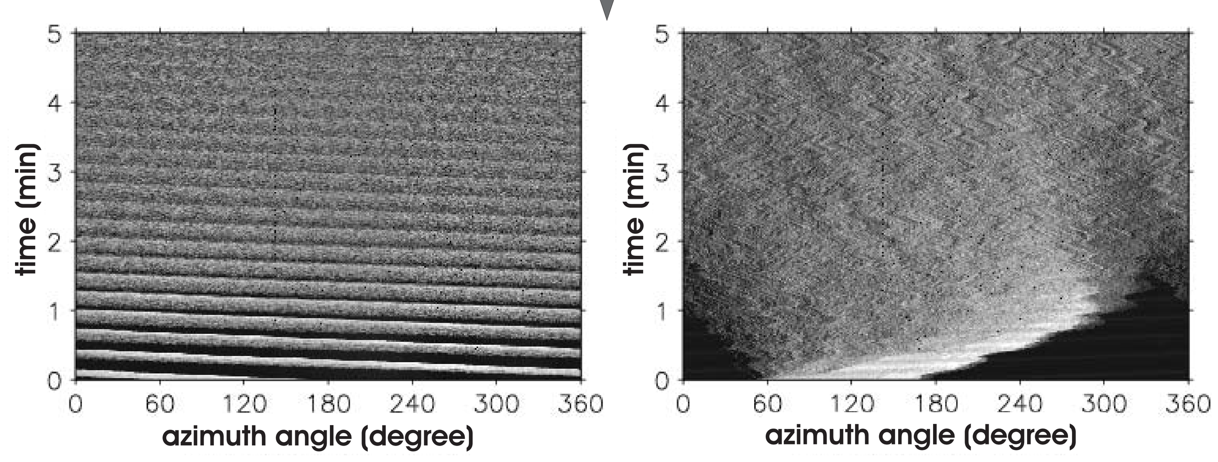
setting frequency to 14.8 Hz



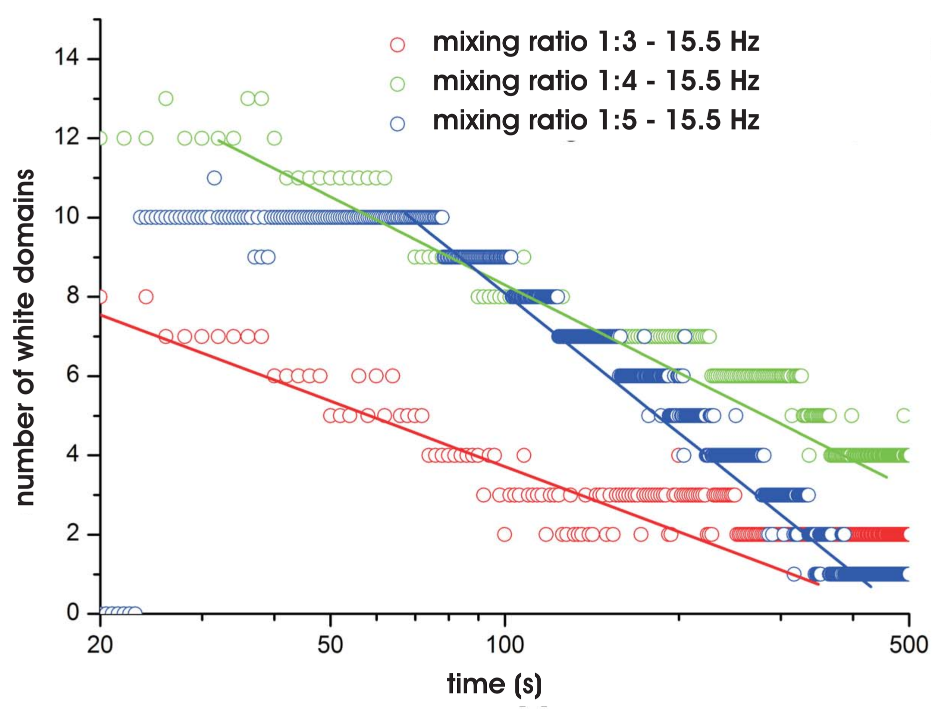
decreasing frequency to 11.8 Hz







Space-time plots visualize the progress of the lateral segregation and the mixture of the granulate. On each right side you see the segregation and mixture in the granulate system (obtained by 2d Fourier transformation).

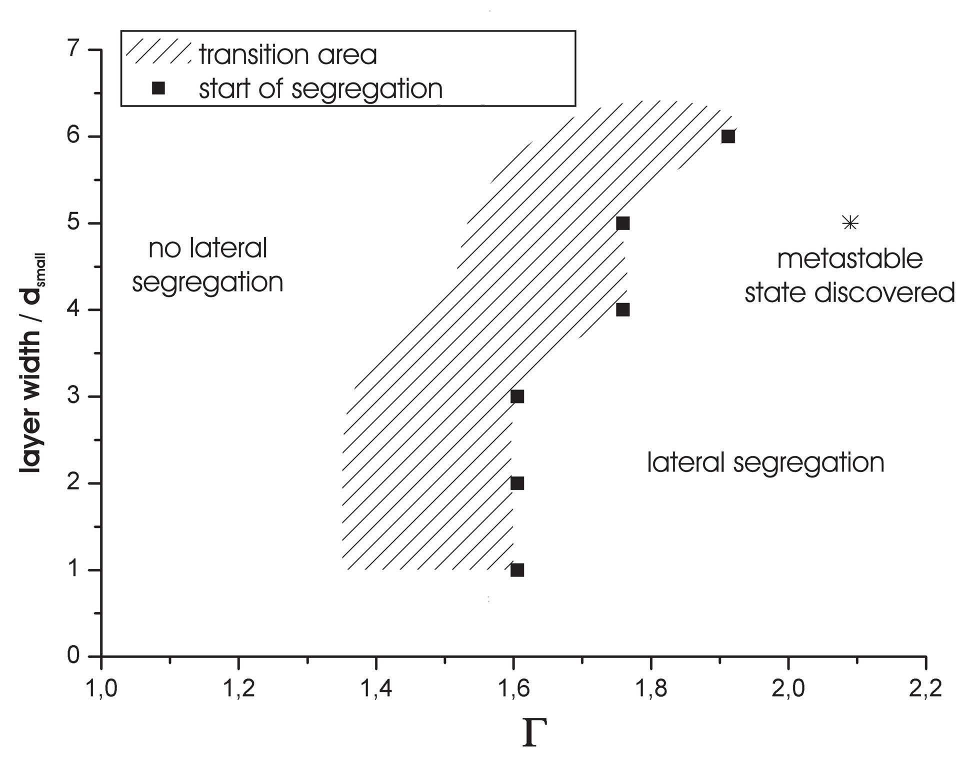


Development of bright stripes over time with different mixing ratios.

visible:
logarithmic relation.

problem:
experiments with different frequencies and mixing ratios seem to possess at least two or more different time dependencies.

Conclusion



- critical frequency exists where lateral segregation begins to dominate the Brazilnut effect
- lateral segregation depends on frequency, humidity, amount of granulate and mixing ratio (among others)
- final state $f > f_{crit}$: completely segregated bidisperse granulate
- final state $f < f_{crit}$: Laterally mixed granulate