IYPT

Brisbane 2004

Team of

AUSTRIA

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Problem Nr. 15: Brazil Nut Effect

When granular mixture is shaken the larger particles may end above the smaller ones. Investigate and explain this phenomenon. Under what conditions can the opposite distribution be obtained?

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Structure

- Common Explanation
- Life Experiments – Observations
- Experimental Setup
- Physical Models
- Quantitative Estimation
- 2-dimensional Setup
- Conclusions
- Literature

Common Explanation

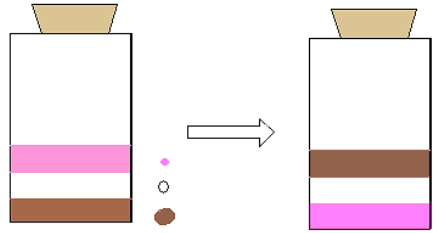
⇒ Small nuts tend to fall through the spaces between the bigger ones

⇒ Small nuts can easier fill the spaces underneath the bigger ones

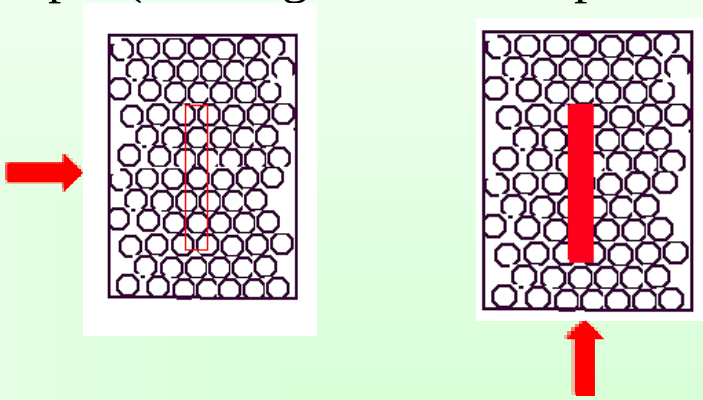
⇒ Especially at the rim of the container less pushes between particles and the rim as in the middle between the particles

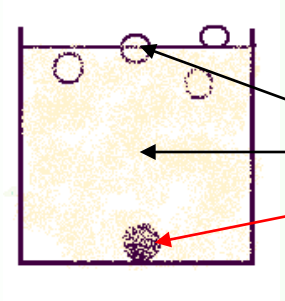
Life Experiments - Observations

"diamonds":
(bigger ones rise to the top)



steel balls with intruders of different shape (shaking direction dependence)





➡ "reverse" Brazil Nuts effect

Experimental Setup

Physical Models

Models treated:

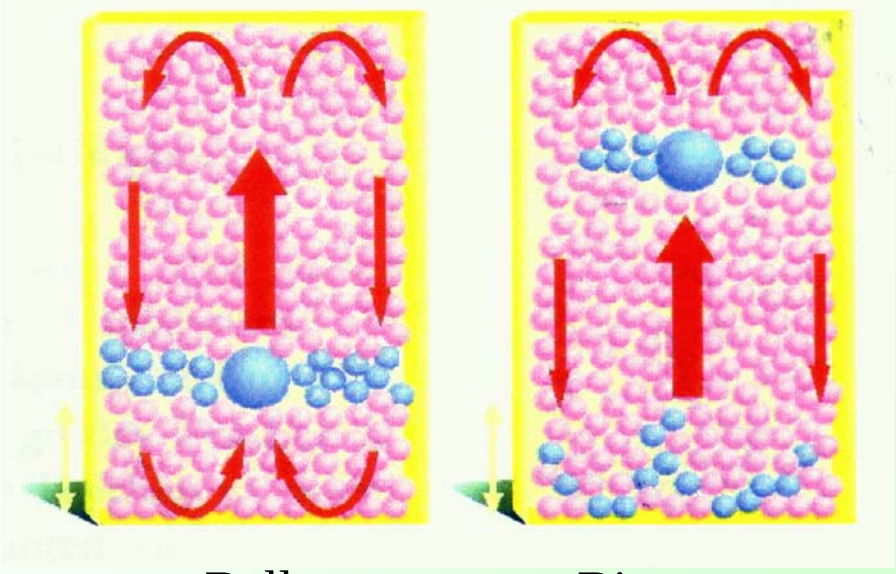
- Convection model
- Condensation model
- Other models can be found in the literature

2 possibilities:

- **B**razil **N**uts **P**roblem – **BNP:** larger particles up
- **R**everse **B**razil **N**uts **P**roblem - **RBNP:** larger particles down (Occurs when the amplitude of the vibration is big enough and the vessel is deep enough.→ E_{kin} of the grains)

Models (1)

a) Convection model



Balls
are moving up

Bigger ones
can't move down

Models (2)

b) Condensation model

(analogy with kinetic theory of thermodynamics)

Assumption:

- "critical temperature" Tc, where the particles somewhat appear to „freeze"
- system of elastic hard spheres with mass m and diameter d in the presence of gravity
- medium kinetic energy of the grains equivalent to the "temperature" T by shaking
- at a certain energy system becomes "fluid"

Quantitative Estimation (1)

a) identical balls: $T_c = mgd\mu$

T … energy due to the vibration of the system

m … mass of one particle

d … diameter of one particle

μ … filling height at the beginning

b) balls with different diameter and mass:

$$\left(\frac{d_A}{d_B}\right)^{D-1} \approx \frac{m_A}{m_B}$$

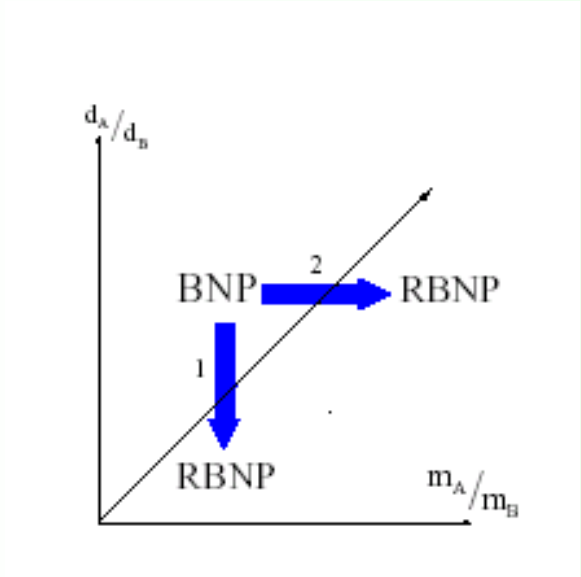
d … diameter of balls A,B, …

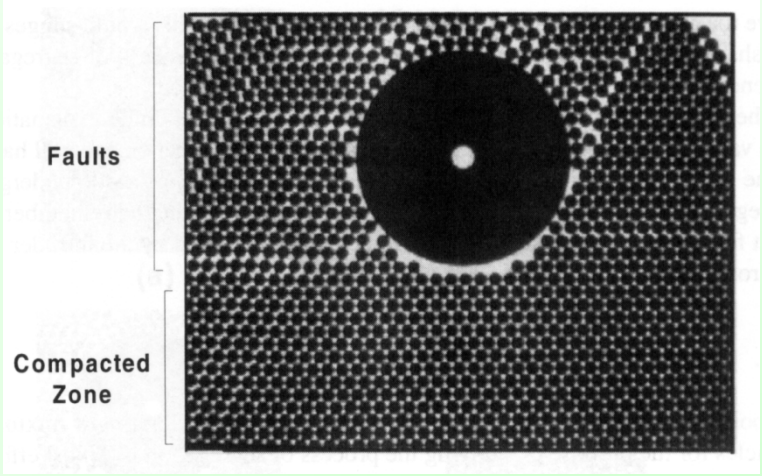
m …mass of balls A, B, …

D …spatial dimension of the container

Quantitative Estimation (2)

For D = 2 (two dimensional containers)



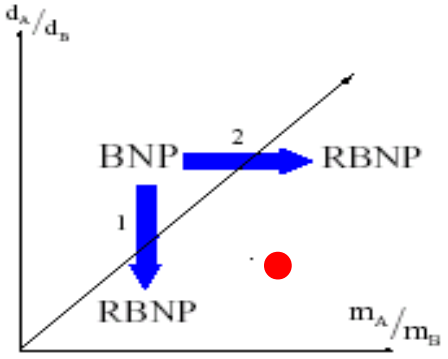


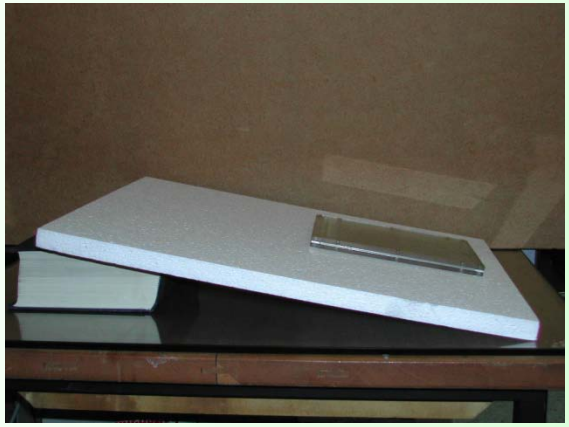
2-dimensional Setup

balls: d_b= 2 mm, m_b = 55mg
disk: d_d =12mm, m_d =855mg

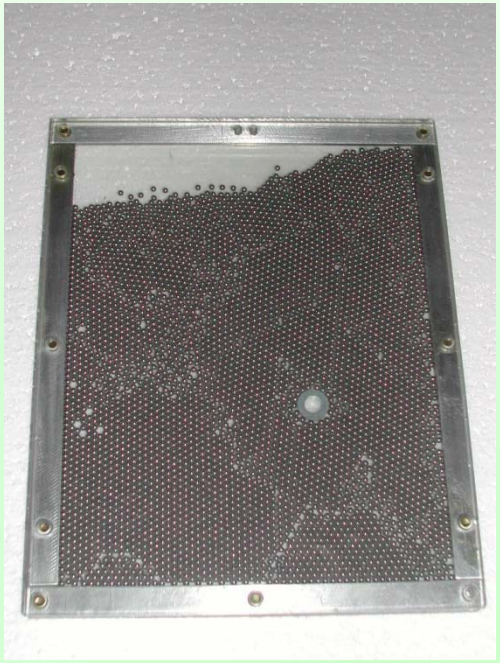
$$\frac{d_d}{d_b} = 5{,}9 \rightarrow \frac{m_d}{m_b} = 15{,}6$$

RBPN





Brazil Nuts\DSCN3343.MOV



Conclusions

- BN-Effect & RBN – Effect shown in several experiments
- good agreement between the experiments and the models found in the literature

Literature:

J. Knight, H. Jaeger and S. Nagel: Phys. Rev. Letters 70, 3728 (1993)
D.C. Hong, P.V. Quinn, S. Luding:
Reverse Brazil Nut Problem: Competition between Percolation and Condensation
Phys. Rev. Letters, 86(15), 3423 (2001)

Opponence
15. Brazil Nuts Effect

What we liked:

What we liked less:

Opponent:

Review
15. Brazil Nuts Effect

 What we liked:

 What we liked less:

In the report:

In the opponence:

Reviewer: