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EXPERIMENTAL ANALYSIS OF ORIENTATION DISTRIBUTION OF CYLINDRICAL PARTICLES IN RANDOM PACKED BEDS

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Abstract: This paper is focused on a simple experimental method that can be used in studies of orientation distribution of axis-symmetrical particles randomly packed in a cylindrical container of diameter D_c. Orientation angle of a particle is defined here as angle φ ($0 \leq \varphi \leq 90$) between the particle's axis and the line parallel to the container's axis (see Fig. 1a). The idea of the method is to fill transparent particles with two immiscible substances, one with relatively low melting point above the ambient temperature (e.g. water and paraffin). When heated up both are in liquid state and can be dumped in the container. Then, at ambient conditions, the slope of the interface between the solid and liquid phase represents the original orientation of a particle inside the packed bed (Fig. 1b). A sample distribution of probability density function (PDF) of the measured orientation angles averaged over three independent series is shown in Fig 1c for D_c/D_p = 11,5 and H_p/D_p = 1,11 (where D_p and H_p are particle diameter and height, respectively). A characteristic feature of the global distribution is the presence of two distinct peaks at 0 and 90° significantly reduced with the bottom section of the bed is excluded. It means that the main contribution to these peaks comes from the bottom layers. In both distributions a local maximum occurs at 45°, together with a local shallow minimum at 65°.

EXPERIMENTAL PROCEDURE

In the present work a new experimental method is proposed for studies of orientation of cylindrical particles randomly dumped in a cylindrical column. The experimental stand consists of a cylindrical column of a diameter Dc, an industrial stove for heating of the particles and a large number of transparent particles-capsules. The particles should have only one axis of symmetry (e.g. cylinders or spherocylinders), so that their orientation can be defined by only one angle – between particle's axis and the container's axis. In the initial stage, the capsules must be filled with two substances, denoted here as "L" and "S", both of approximately the same volume equal to the half of the capsule volume (see Fig. 1).

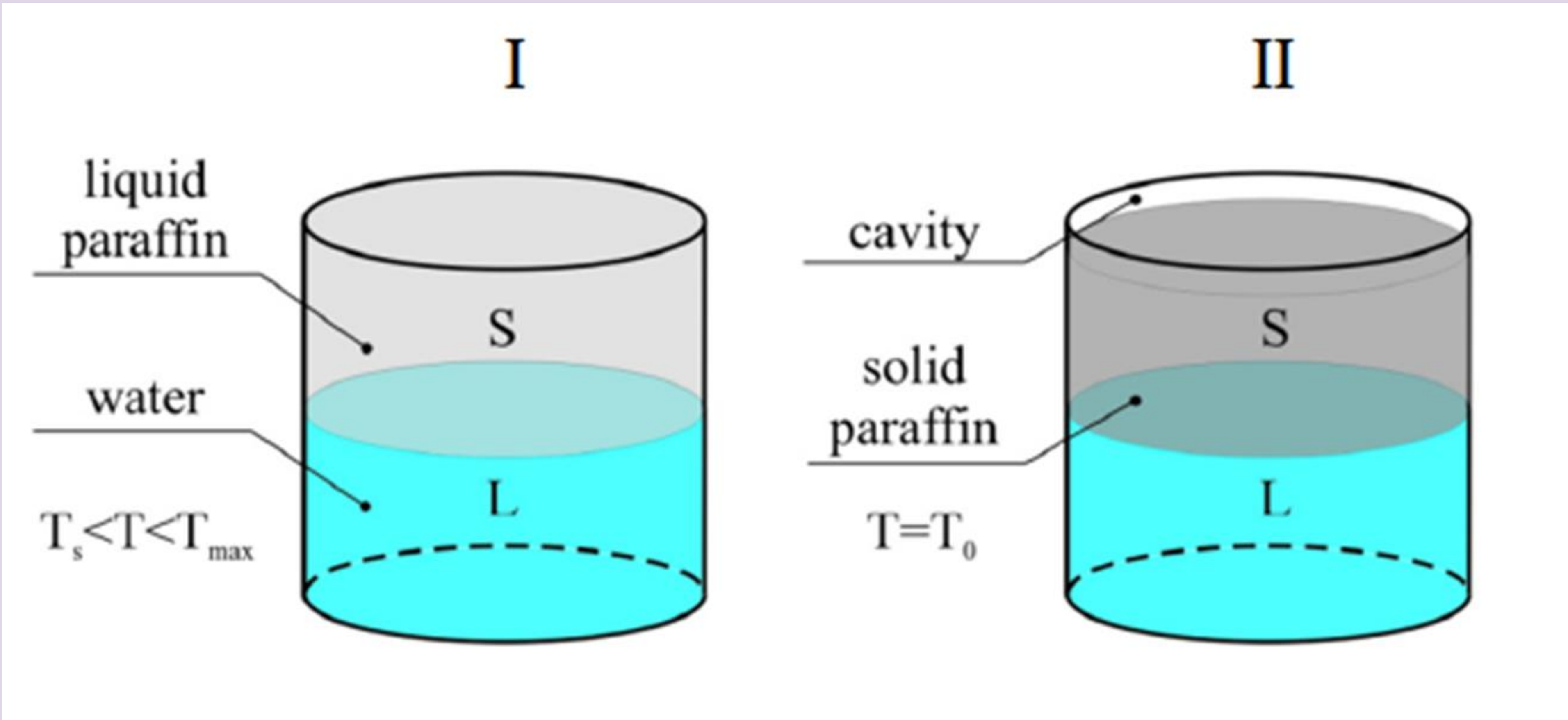

Fig. 1. Particle-capsule filled with substances L and S: I at temperature higher than the melting point of S, II at ambient temperature.

At ambient conditions S solidifies and the interface between L and S remains at a fixed position related to the original particle-capsule orientation within the bed. Thus, the inclination of the interface can be easily measured (see Fig. 2). If we are only interested in global orientation distribution, the capsules may be removed freely but the method offers also possibility of local investigations (e.g. core of the bed, near wall or near bottom region). In such a case, the capsules should be removed with care in order not to alter their original position (not necessarily the orientation) of the remaining capsules
within the bed.

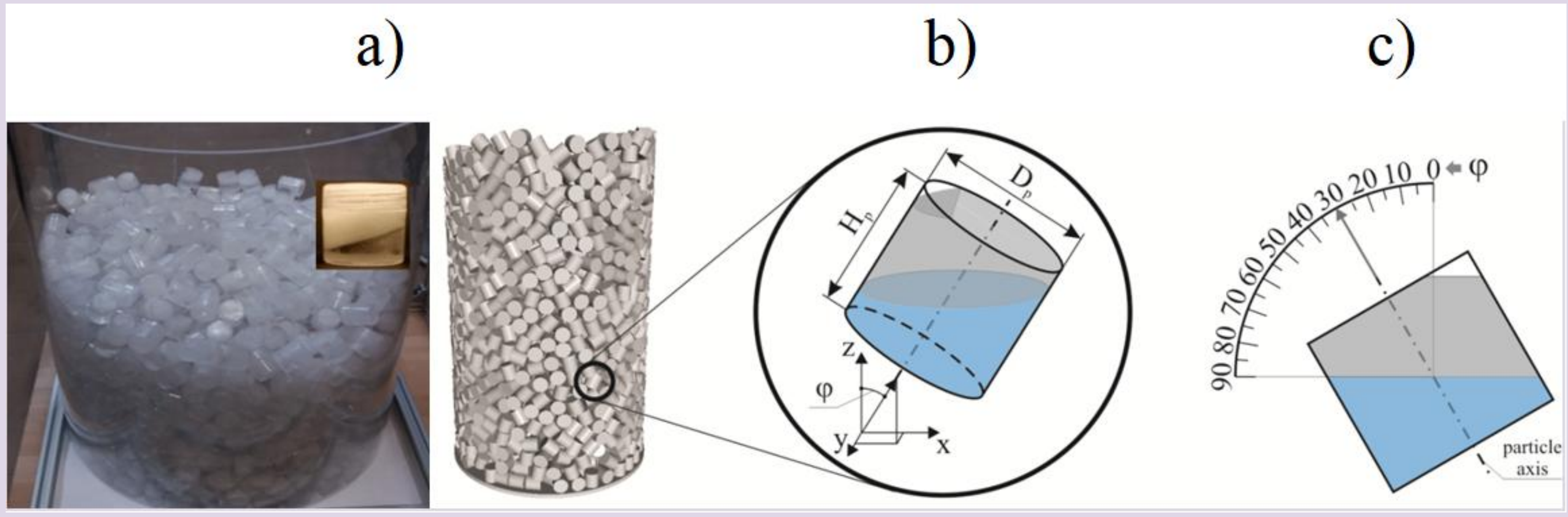

Fig. 2. Idea of the experimental procedure: a) random packed bed, b) particle-capsule at ambient temperature, c) measurement of the orientation angle.

ACKNOWLEDGEMENTS

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SAMPLE RESULTS

A sample distribution of probability density function (PDF) of the measured orientation angles averaged over three independent series is shown in Fig 3 for Dc/Dp = 11,5 and Hp/Dp = 1,11 (where Dp and Hp are particle diameter and height, respectively). A characteristic feature of the global distribution is the presence of two distinct peaks at 0 and 90° significantly reduced with the bottom section of the bed is excluded. It means that the main contribution to these peaks comes from the bottom layers. In both distributions a local maximum occurs at 45°, together with a local shallow minimum at 65°.

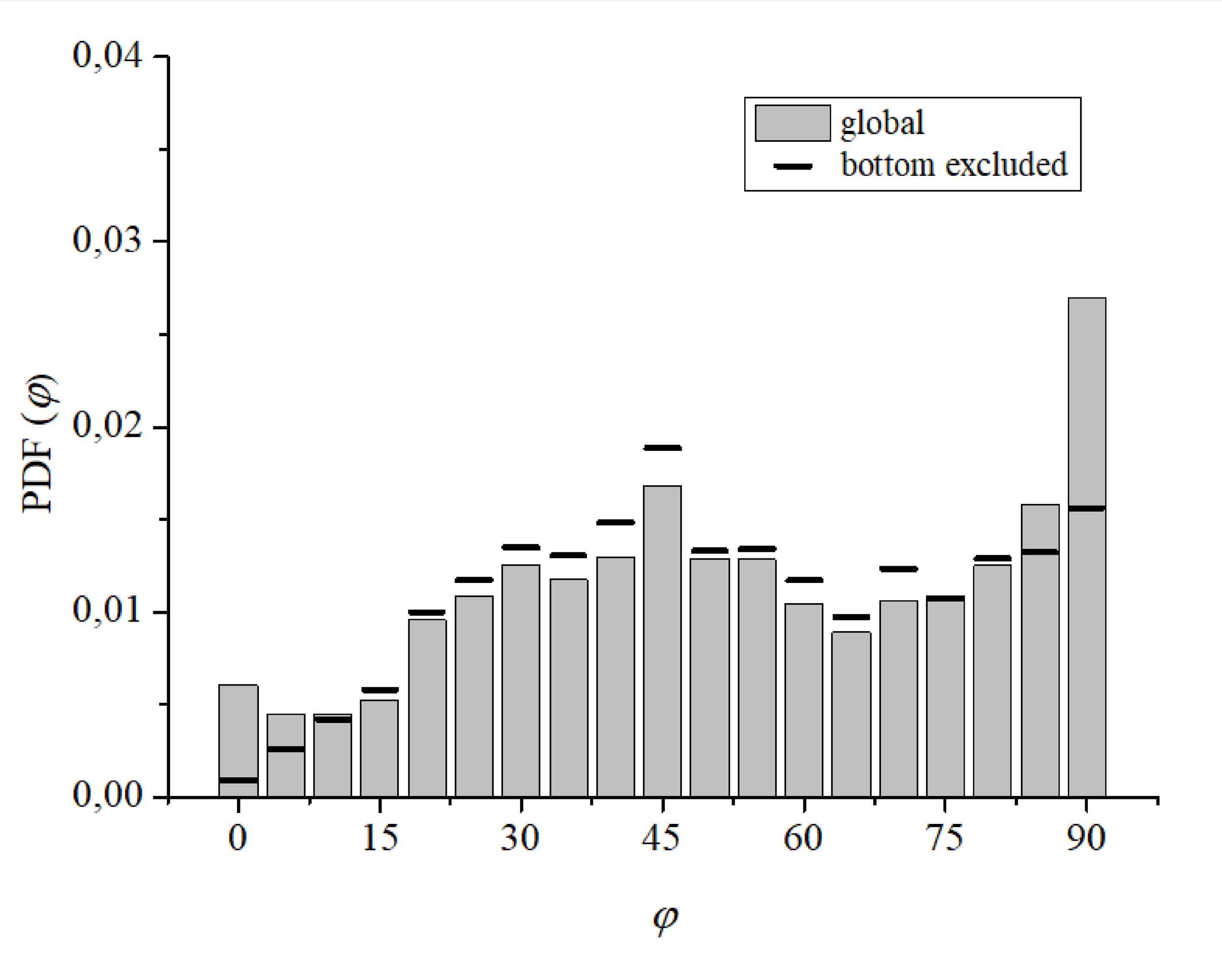

Fig. 3. Probability distribution of the orientation angle of cylindrical particles with Dc/Dp =11,5.

POSSIBLE MODIFICATIONS OF THE METHOD

The method can be quite easily extended to analysis of the orientation of non-cylindrical particles. For that purpose a concept of a "composed capsule" can be employed (see Fig. 4). The idea is to use the equilateral cylindrical capsule with transparent walls (for instance a liquid polymer can be used) as the main body that can be extended with additional elements that need not to be transparent (here any polymer type can be used). The extension of the main body allows for construction of cylinders, rings, spherocylinders and other shapes with various aspect ratios (however, only for Hp=Dp ≥1).

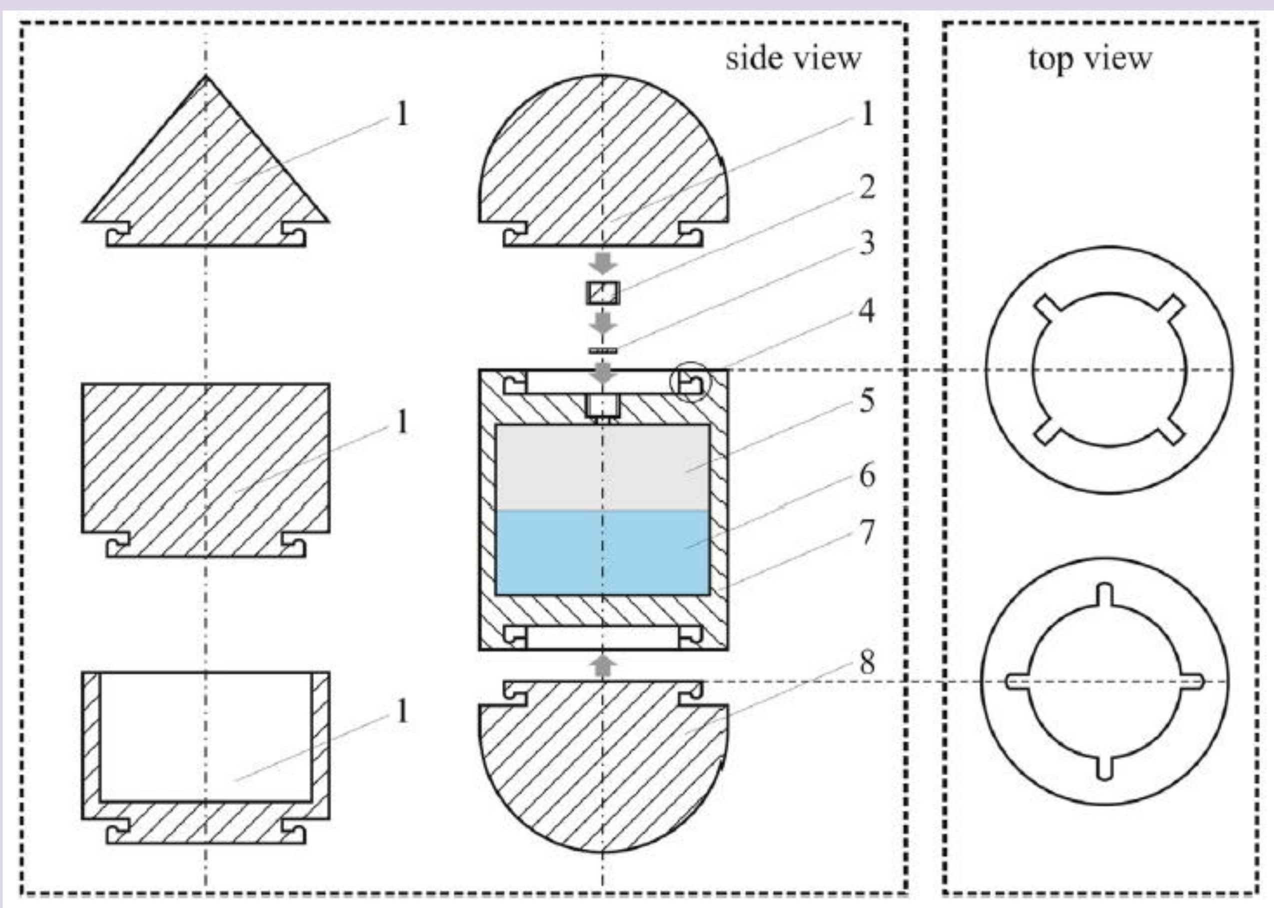

Fig. 4. The concept of a composed capsule: 1 – cap (cone, cylinder, Raschig ring, spherocylinder or any other axisymmetric shape), 2 – plug, 3 – seal, 4 – catch, 5 – substance "S", 6 – substance "L", 7 – main capsule, 8 – lower cap.