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## **Experimental and theoretical study of transverse solids motion in rotary kiln**

**Keywords: solids motion, rotary kilns**

The transverse solids motion influences to great extend the mass- and heat transfer in rotary kilns. The motion modes that occur frequently in industrial rotary kilns are Slumping and Rolling (Figure 1).

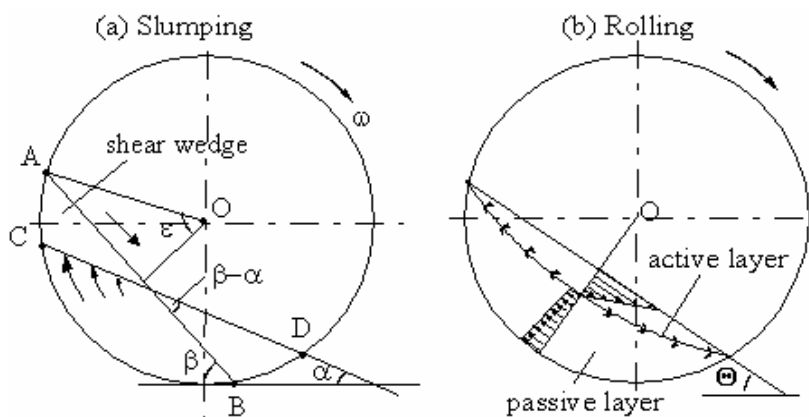


Figure 1. The solids motion: (a) Slumping (b) Rolling

The transition behavior from the slumping mode to the rolling mode was experimentally investigated on rotating cylinders for a variety of materials (Figure 2). A correlation of the two characteristic angles of repose of a slumping bed was obtained. To calculate the critical Froude number, a mathematical model was developed. It demonstrates that the size ratio (particle to cylinder diameter) represents an important influencing parameter. This model is advantageous for practical uses. Its validity was tested by own and foreign measurements (Figure 3).

For the rolling mode, the model from Mellmann was further developed. With it the influence of the rotation speed, the filling degree, the cylinder diameter and the materials can be well described. No fitting parameters are needed for the model calculation. Good agreement was found between the model and experimental measurements in the present work as well as in the literature. For the extreme case (Froude number be zero), an analytical solution was derived. Comparisons with the numerical solution demonstrate that, at high dynamic angles of repose and low Froude numbers the deviation between the analytical and numerical solutions is negligibly small(Figure 4).



Figure 2. Experimental set-up.

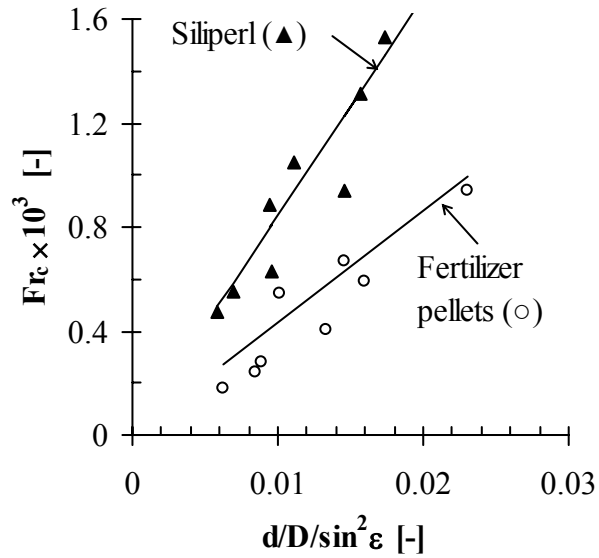


Figure 3. Measured and calculated critical Froude number in dependence on the dimensionless variable  $d/D/(\sin^2 \epsilon)$

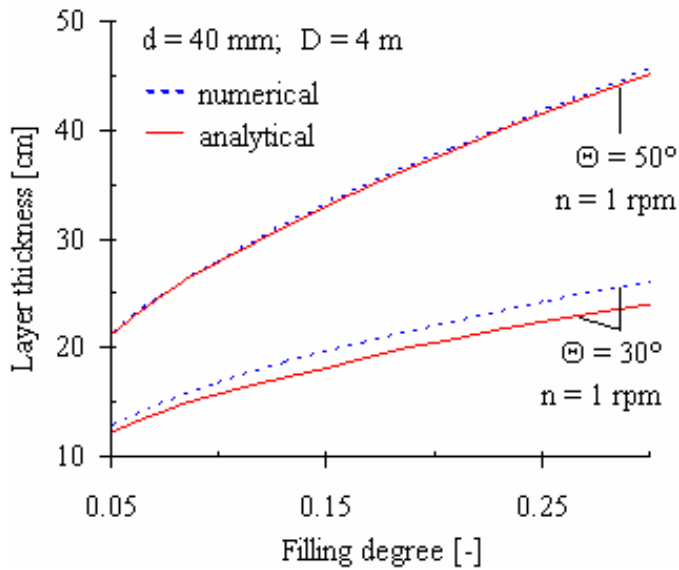


Figure 4 Comparison of the analytical solution with the numerical solution

The warming process of a rolling bed was investigated on a direct-heated pilot kiln. With the developed measuring technique, it was possible to measure the temperatures within the solid bed. It was shown that, in the plug flow region of the bed the temperatures keeps approximately constant in the circumferential direction. In the radial direction, however, there exist great temperature differences. The experimental results can be used in the future for the mathematical modeling of the heat transfer within the solid bed.

## Publications

- (1) Liu, X.Y., Specht, E., Mellmann, J. (2005). Factors influencing the rolling motion and transverse particle residence time in rotary kilns. *Zement-Kalk-Gips International*, 58 (2), 62-72.
- (2) Liu, X.Y.; Specht, E.; Mellmann, J.(2005). Slumping-rolling transition of granular solids in rotary kilns. *Chemical Engineering Science* (accepted).
- (3) Mellmann, J., Specht, E., Liu, X.Y. (2004). Prediction of rolling bed motion in rotating cylinders. *AIChE*, 50, 2783-2793.
- (4) Mellmann, J. & Specht, E. (2001).Mathematical modelling of the transition behaviour between the various forms of transverse motion of bulk materials in rotating cylinders. *ZKG International*, 54, 6/7, 281-296 and 380-402.
- (5) Liu, X.Y., Specht, E., Mellmann, J: Predicting the slumping and rolling zones of the granular solids in rotary kilns. *VDI-GVC-Workshop 'Agglomerations- und Schüttguttechnik'*. 14./15, March 2005. Tübingen, Germany.
- (6) Liu, X.Y., Specht, E.: Untersuchung des Wärmetransportes in der bewegten Schüttung eines Drehrohres im Bereich des Abrollens. *VDI-GVC-Workshop 'Wärme- und Stoffübertragung'*. 22./23, March 2004. Schwäbisch Hall, Germany.