# COATED MATERIAL OBSERVATION

*Slíva A., Zegzulka J.*
*Laboratory of Bulk Materials, Faculty of Mechanical Engineering, VSB-Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, CZ*

# ZKOUMÁNÍ VLASTNOSTÍ POVRCHOVĚ MODIFIKOVANÝCH HMOT

*Slíva A., Zegzulka J.*[1]
*Laboratoř sypkých hmot, Fakulta strojní, VŠB-Technická univerzita Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, ČR*

**Abstrakt**

Důležitou vlastností sypkých hmot, zvláště v procesu dopravy, manipulace a skladování je tekutost v zásobnících a skladovacích zařízeních. Tekutost je vlastnost, která ovlivňuje tvorbu poruch jako např. tvorba oblouků, komínování, klenbování, náhlý sesuv hmoty ve skladovacích systémech. Kromě toho tekutost závisí na vnějších faktorech a z tohoto důvodu je tato vlastnost naprosto nepředvídatelná.

Tento příspěvek se týká povrchové modifikace malým množstvím aditiva, které snižuje úhel vnitřního tření a je jedním ze způsobů zlepšení tokových vlastností skladovaných sypkých hmot. I když dochází viditelně ke zlepšení tokových vlastností, nadále zůstávají otázky užití v potravinářství a množství aditiva nezbytného pro optimální skladování takto modifikované hmoty.

**Abstract**

An essential property, especially during storage, handling and processing of a particulate material is flowability in vessels, bunkers, and silos. The flowability as a property influences the creation of falls, such an arching, piping, rat-holing, sudden avalanching in a storage transport system. In addition, flowability more notably depends on environmental factors and often is constantly changing so that the powder behavior is not often predictable.

This paper deals with Coating (surface modification) a small amount of additive, and thereby decreasing the angle of internal friction, which is one way of improvement flow properties of storage particulate materials. Although flow property improving of a particulate material is achieved, issues such as the applicability for food industry and quantifying how much coating batch is necessary for optimal storage of transport conditions still remain.

**Key words:** coating, flowability

## Measured properties of MAICoated material: Angle of Repose Measured on Hosokowa Powder Tester

Angle of Repose (AOR) belongs to the more easily measured quantities. The angle of repose is a commonly used as a flow evaluation index. Hence, it is used to evaluate the coating effectiveness in terms of improving flow properties. There are a lot of measurement procedures for receiving of correct comparable AOR values described in literature. For example, by using both Rotating Drum and movable bed placed in open vessel, a lot of credible results can be attained. In particularly, a principle of the particle material passed though a vibrating funnel and dropped down on bed is utilized for Hosokawa Powder Tester design.

Fig.1 Uncoated Cornstarch heap

Fig.2 Coated Cornstarch heap

The AOR is an angle heap relate to considered bed plane. According to this development method, AOR for uncoated and MAICoated cornstarch (Fig.1 and Fig.2) were measured and surveyed by using adjustable rotate scale, and values of the AOR were found out on a digital display of the Hosokawa powder tester device. The AOR was investigated for three independence measurement and the average value was considered.

**Dependence of processing time on process of the 20 nm MAICoating by hydrophobic and hydrophilic silica**

Providing of identical processing conditions by measurement, AOR values of pure cornstarch and pure silica and MAICoated cornstarch by 1% of 0.02 μm hydrophobic and hydrophilic fumed silica for 5, 10, 20 and 40 mins, that demonstrative flowability improvement, were displayed to Fig.3. The Figure 3 reveals significant AOR reduction of coated cornstarch.

**Results and Discussion**

Results of angle of repose measurement received by Hosokawa powder tester measurement are depicted in Fig.3. According to [3], the value of an angle of repose very well proves flowability of the individual sample. There are also some recommendations for AOR range to guarantee degree of flowability in reference [2]. Remarkable model of coating is found in [3], where the model describes interparticle interaction on base of the surface energy of a host and guest particle displacement.

Every coated sample shows visible flowability improvement in comparison with original pure cornstarch and hydrophobic and hydrophilic silica. The improvement is almost 50 % of original value of the pure cornstarch. Notice, that both pure cornstarch and pure silica are characterized by almost twice value of coated materials in case of the best 10 mins coating. According to [2], measured coated sample displays degree of flowability improvement from "Bad" for pure cornstarch (Flowability index 20-39) to "Very Good" for coated materials (Flowability index 90-100).

As mentioned above, comparison of the coated values of the MAICoated cornstarch by silica for 5, 10, 20 and 40 mins, 5 mins MIACoating is efficient to ensure improvement to

50% of the original value of pure cornstarch. Probably as recorded in [4], 5 mins coating causes deformation of a host particle and creation of more host particle surface for another guest particle by MAICoating. So, the value of the 10 mins coating is recorded as the best coating processing time both coating of hydrophobic and hydrophilic silica. Probably, coating energy surface brings about angle of repose increase after 10 mins of the coating.

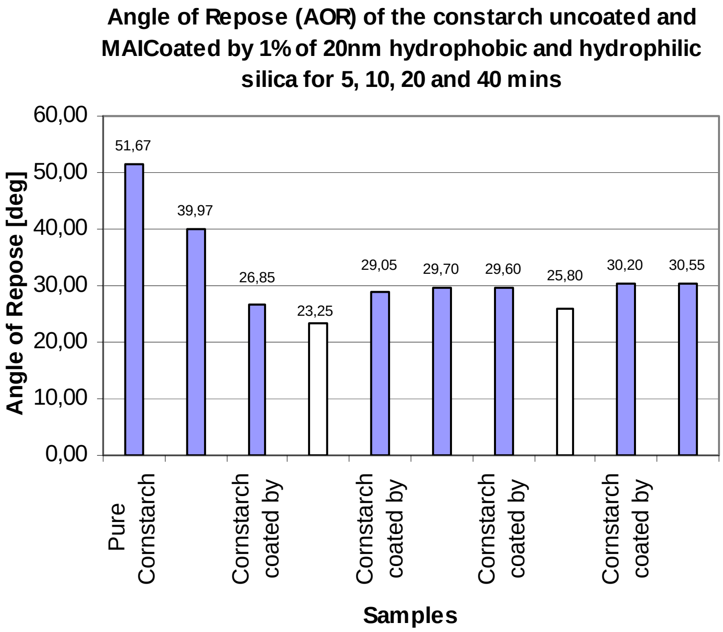


Fig.3 Hosokawa Powder Tester: AOR vs. coated and uncoated material

Explanation of the phenomenon is very simple. After deformation of the host particles by 10 mins of coating, host particles cover the created surface totally and further coating of the fully covered host particle surface is possible on a guest-guest particle surface only. Taking into account of Hamaker constant of the guest-guest and host-guest particles (i.e. silica-silica and cornstarch-silica), the Hamaker constant of guest-guest particles is recorded $6.5x10^{-20}$J and Hamaker constant approximate for host-host particles may be calculated by knowing of refractive index ($n=1.7 \Rightarrow C \approx 13x10^{-20}$J). Comparison of the Hamaker constants (i.e. silica-silica: $6.5x10^{-20}$J and cornstarch-silica: $9.19x10^{-20}$J), the endeavor to keep guest particle onto host particle surface is visible.

Considering the hydrophilic and hydrophobic silica coating effect, cornstarch coated by the hydrophobic silica keeps AOR value less for every coating processing time. The difference is identical approximately and confirms assumption of OH inter-particle layer conservation by processing time increase [4]. These repulsion forces of the inter-particle layer created by cornstarch MAICoating with hydrophobic silica seem to keep particles in certain distance. In consequence of the inter-particle keeping, low-limited friction among particles has been attained. The phenomenon of AOR reduction is found by further measurement methods (Rotating Drum, Jenike Powder Tester).

**MAICoating of cornstarch with 600 nm hydrophilic silica**

AOR and fall measured on Hosokowa powder tester vs. cornstarch MAICoated by 1, 2 and 20 % of 600 nm silica for 10 mins and AOR and fall of 20 % of 600 nm silica for 5, 10, 20 and 40 mins are investigated in Fig.4 and Fig.5.

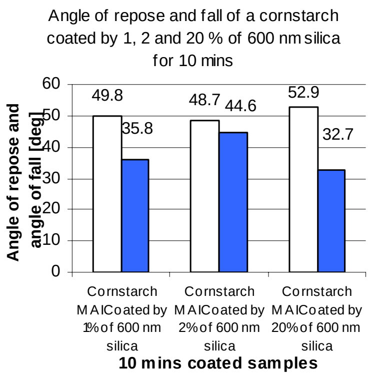


Fig.4 Hosokowa Powder Tester: AOR and fall vs. MAICoated cornstarch by 1, 2 and 20 % of 600 nm silica for 10 mins

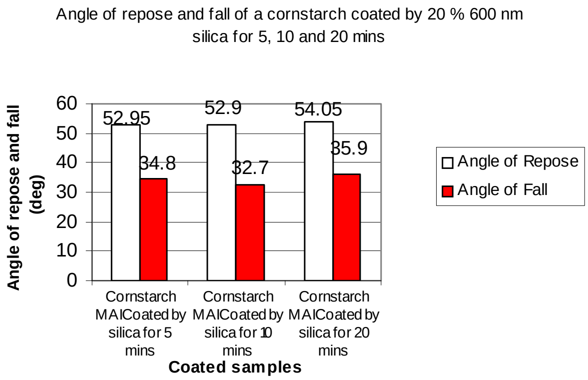


Fig.5 Hosokowa Powder Tester: AOR and fall vs. cornstarch MAICoated by 20 % of 600 nm silica for 5, 10 and 20 mins

Considering the AOR measurement only, increase of 600 nm silica from 1 % to 2 % leads to negligible decrease of the AOR in the Fig. 1 and 2. Even though the value is increased to 20 %, the AOF is almost unchanged or slightly arose.

Fig.5 registers almost the same level of AOR by 10 mins of coating or slow decrease.

**Minimal coating material amount (wt %) of the 20 nm silica MAICoating by considering of the 90-100 value of Flowability Index [2])**

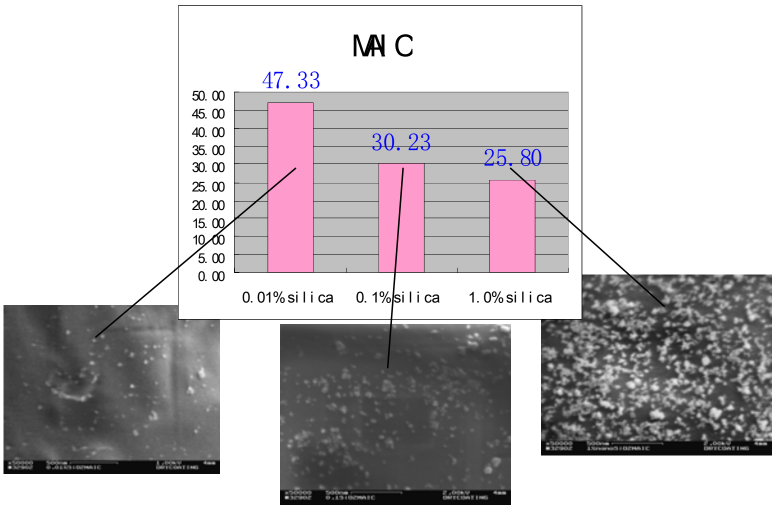


Fig.6 SEM pictures and AOR of the 0.01, 0.1 and 1 % cornstarch MAICoated by 20 nm hydrophilic silica for 10 mins

As seen of the Fig.6, the AOR value of the 0.1 % of hydrophilic silica of the MAICoated cornstarch for 10 mins is convenient to guarantee “Very Good” degree of flowability with Flowability Index of 90-100. By the flowability level Bridge-Breaking Measures are not required [2].

**Effect of the guest particle size distribution (MAICoating of cornstarch with 20nm, 600 nm and 2 μm hydrophilic silica)**

Theoretically, the finest guest coating particles may decrease the AOR. Although the conjecture is true generally, the effect of guest particle size distribution plays the main role (Fig.7).

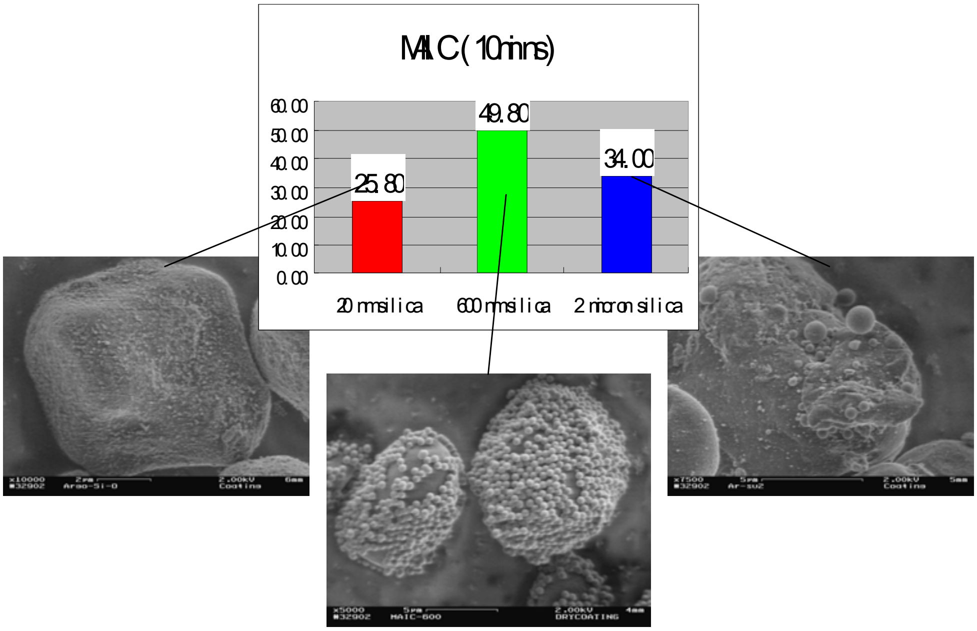


Fig.7 SEM pictures and AOR of the cornstarch MAICoated by 1% of the 20 nm, 600 nm and 2 μm hydrophilic silica for 10 mins

**Conclusions**

The conclusions not only carry out of the paper are summarized into these paragraphs:
Coating with nano silica can ensure improvement of flowability about 50 % (thanks to lubrication effect) in comparison with pure cornstarch.
Coating decreases stability of the material in storage systems; dangerous to sudden fall creation. The hydrophobic silica due to lubrication effect is more sensitive to the phenomenon than hydrophilic-coated material.
The more processing time of submitted coated material the more instability and tendency to avalanching.
Using coating device (MAIC, Hybrodizer) in comparison with mixing device (V-Blender) improves a coated particle cover efficiently.

Size distribution of a guest particles influences flowability of the coated sample sufficiently. Even a small particle appearance inside the size distribution of the guest particle improves flowability.

Coated material requires more energy by small movement in storage system (requirement to quick and stabile continuous discharge).

Coating of a material causes to creation of a compact and tendency to dead zone, arc and funnel creation, especially by long-time storage in high silos (high pressure). The tendency is 3 times more with hydrophobic coating material and 5 times more with hydrophilic coating material in comparison with pure uncoated material.

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