

A case study on: Product loss in a closed pneumatic conveying system



Pneumatic conveying is a widely utilized transport method that requires a fair amount of knowledge not only on the principle of pneumatic conveying, but also on the properties of the conveyed materials; one pneumatic conveying system cannot be universally used to transport every type of materials.

Every material comes with its own set of physical and chemical properties, which can lead to several challenges during pneumatic conveying. The more well known challenges include the wear of particles and the erosion of the pneumatic conveying system. However, those are just two of many challenges. Lesser known challenges include the seemingly sudden loss of product and the conveying of materials that can potentially become sticky.

Case

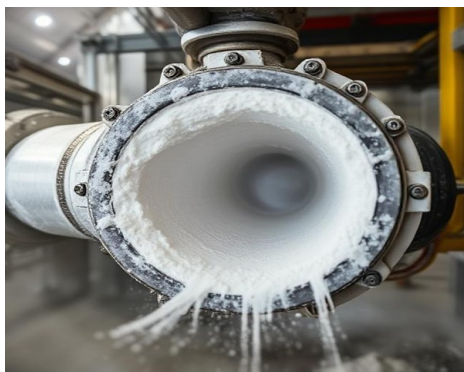
Delft Solids Solutions has worked on several projects in which powders have been transported using pneumatic conveying. One such a case involved the dilute phase pneumatic transport of sugars. During the case sugar was transported using an unconditioned airflow. This does not necessarily have to be an issue. However, in this particular case the unconditioned airflow resulted in a significant loss of product and unnecessarily long downtime of the conveying line for cleaning purposes.

While transporting various sugar batches it was observed that transporting some batches would result in significant loss of product between the starting location



Coarse sugar (left) and fine powdered sugar (right).

and the final destination. Interestingly, the key difference between those batches being that the batches with the most significant amount of loss had been milled prior to conveying. During periodic cleaning of the system, most of the missing product was found to have formed a crust inside of the conveying system, predominately near the bends.



Sugar build up in the pipeline.

What has been investigated?

Based on the provided information, several hypotheses were established. One of the hypotheses why the milled sugar formed a crust near the bends included the milled sugar being too cohesive, while other hypotheses focussed more on the unregulated temperature and/or humidity of the carrier gas. To investigate the established hypotheses comparative experiments were setup using Rheology and Dynamic Vapour Sorption (DVS), in order to surmise the difference between the various samples.

Rheology

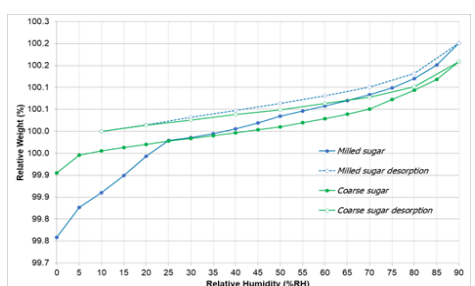
The rheology experiments focussed on monitoring the torque of the sugar samples at a temperature reflecting that of the unconditioned airflow used during conveying, while the relative humidity was gradually increased. The expectation was that the coarse sugar would have a relatively constant torque over the entire range, while the more cohesive nature of the milled sugar would result in a higher

torque. By varying the relative humidity, any change in behaviour due to conditions of the airflow would be observable by a drastic change in torque.

The rheology experiments showed that the torque of the milled sugar was consistently slightly higher than that of the coarse sugar. However, no drastic change in torque due to a change in behaviour was observed. The degree at which the torque of the milled sugar was higher was also not substantial enough to claim that the milled sugar was drastically more cohesive than the coarse variant, making it improbable that the crust formation was solely due to the material being too cohesive. The lack of a change in behaviour also hinted that something other than the unconditioned airflow was responsible for the crust formation.

Dynamic Vapour Sorption

Through the use of dynamic vapor sorption (DVS) within the range of 0% and 90% relative humidity at a temperature matching that of the unconditioned airflow of the pneumatic conveying system, a significant difference was observed. Although, both batches showed a small overall moisture uptake, the milled sugar batch showed a much steeper moisture uptake within the range of 0% to 25% relative humidity. After this the degree of moisture uptake matched that of the coarse sugar. This indicated that the milled sugar did not consist of a singular phase such as the coarse sugar, but that the milled sugar contained an additional more moisture sensitive phase.



Dynamic vapour sorption results.

Product loss in a closed pneumatic conveying system

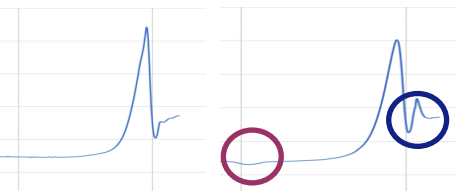
New hypothesis

The new insights of the rheology and DVS investigations lead to new hypothesis. The new hypothesis was that the second more moisture sensitive phase observed in the DVS investigation could become sticky during pneumatic conveying and eventually form a crust on the inside of the pipeline. However, the rheology experiments showed that the unconditioned airflow was not solely responsible for the sticky behaviour. Presumably an additional source of energy is required to initiate the material change. During pneumatic conveying, the most likely source for that additional energy would be the particle impacts that occur near the bends of the conveying system.

Two techniques were selected to investigate the newly established hypothesis. Differential Scanning Calorimetry (DSC) was used to investigate the nature of the second phase in the milled product, while repeated impact testing was selected to simulate the conveying of the two kinds of sugar batches at various climate conditions in order to establish the effect of impacts on the physical change of the sugar batches at various climate conditions.

Differential Scanning Calorimetry

DSC was used in the range of -20 °C to 230 °C on both the coarse and milled sugar. The analysis showed two key differences between the two sugar species, namely an exothermic peak and a second endothermic peak indicating the presence of an amorphous phase in the milled sugar sample. After additional literature research, it was found that the amorphous phase observed in the DSC analysis is in fact more moisture sensitive, confirming that the steeper moisture uptake observed in the DVS analysis was in fact caused by the presence of the additional sugar phase.



The DSC curve of the coarse sugar (left) and the milled sugar (right). Note the exothermic peak (purple) and the second endothermic peak (blue) in the milled sugar curve.



Repeated impact tester.

Repeated impact testing

Repeated impact testing (RIT) is a technique that is used to simulate the impacts that materials experience during dilute phase pneumatic conveying. The benefit of the technique is that a wide variety of pneumatic conveying systems can be simulated using a singular setup. This is done by calculating the kinetic energy experienced during conveying and running the repeated impact tests using a similar amount of kinetic energy.

$$E_{m,kin} = \frac{m_n}{2} \times v_{particle}^2 \times collisions$$

Formula used for the calculation of the kinetic energy.

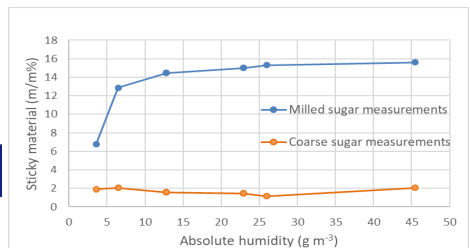
Typically this technique is used to quantify the wear of the conveyed particles. However, during this particular case, the technique was used to quantify the sticky behaviour that occurs during conveying. This was done by quantifying the mass percentage of sample that would stick to the inside of the sample chamber after testing.

The kinetic energy that the sugar particles would experience during pneumatic conveying was calculated and used to establish the experimental conditions. The sugar samples were conditioned at six different climate conditions. The 60 °C conditions were selected based on the slopes observed during the dynamic vapor sorption investigation, while the 40 °C conditions were selected to establish if a correlation existed between the degree of sticky behaviour and the temperature.

The tested conditions during the repeated impact investigations.

Temperature (°C)	Relative humidity (%)	Absolute humidity (g m ⁻³)
40	5	4
	25	13
	45	23
60	5	6
	20	26
	35	45

As expected for the coarse sugar samples the repeated impact tests showed little to no sticky behaviour at any of the tested conditions. However, the milled sugar sample showed a drastically different correlation. Each of the tested conditions showed a certain degree of sticky behaviour. However, the degree of that seemed to approach a asymptotic trend. The eventual asymptote was surmised to have been due to all of the moisture sensitive sugar species in the milled batch having turned sticky.



Correlation between the stickiness of the milled sugar sample after repeated impact testing and the utilized absolute humidity.

The repeated impact tests showed that conveying the milled sugar batch at lower absolute humidities resulted significantly less sticky behaviour.

Conclusion

The described case showed a lesser known challenge in the world of pneumatic conveying. Even when transporting relatively well-known materials such as sugar, it is important to know the materials' properties and the ideal conditions at which to transport them.

In the described case, the client was advised to switch to the use of a dry air flow or an inert gas. After implementation of a drying system, the client reported a significant drop in product loss and substantially less down time for cleaning.