

Attrition during granular feed processing



Particle attrition in the process can occur which can cause unwanted fine particles at the end of the process. This is mostly caused for brittle particles and particles with irregular shapes. The definition of fine particles can be different for each product being a few millimeters to sub-micron particles. First of all these “fines” can cause subsequent issues in handling the product on site or at the customers’ site due to e.g. the poorer flow properties of the product or blockage of certain unit operations. It can also negatively impact the final quality, application or performance of the product.

Case

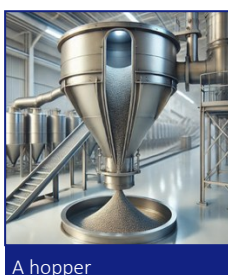
This case concerns a feed producing client in Belgium that produces particles of a few millimeters up to centimeters. At the end of the process, some unwanted fine particles are observed, which are classified as particles smaller than 600 µm. They have several unit operations in the process which could be the reason for the attrition and thus



Animal feed product mm particles (left) and the collected fines < 600 µm (right).

fines of this material. The different unit operations in the client’s process are therefore considered to indicate which one produces the (most) fines.

The unit operations identified as a causing factor are the following three unit operations: a hopper, a drop-pipe and big-bag storage. The unit operations



A hopper

are made of stainless steel, except the big bags which are made of synthetics.

What has been investigated?

To mimic the production of fines in the different unit operations, a technique is selected which correlates with the unit operation. First, **shear stress experiments** were conducted. Here the impact of movement of the particles compacted under a certain stress is measured (dynamic conditions) which is correlated to the *flow in a hopper*.

To correlate the attrition in *big bag storage*, a technique called **Bulk Crush Strength (BCS)** was used. Here the force of the particles under static conditions is measured, which thus relates to static storage of the particles, like in a big bag.



Big bag storage.

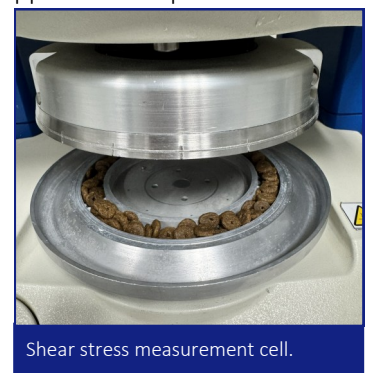
A third technique is measuring the **strength of single particles by crushing** them (SPCS). Here a force required to break a particle is measured and these results are combined with a falling test of letting particles drop from the first floor into a collecting dish. This can then be correlated to the usage of a *drop-pipe* in the process. For all methods the fines upon breaking/crushing are quantified. The expectation of the client is that storage will produce the least amount of fines and that the hopper will produce the most fines.



A drop-pipe.

Flow in a hopper

With the **shear stress** measurement, a maximum stress of 6.2 kPa is applied on the granules during the measurement. This is calculated based on the size of the silo and the stress which will be applied on the particles when they



Shear stress measurement cell.

move from the top to the bottom in the silo. After the measurement the fines are determined by sieving the used sample over 600 µm.

With the **shear stress** experiments, the force applied was indeed producing fines. The table below shows the masses used and of the obtained fines.

The percentage of fines upon shear stress.	
Mass sample (g)	216.5
Mass fines < 600 µm (g)	5.6951
m/m% fines < 600 µm	2.6

It can be concluded that in the silo, approx. 2.6 m/m% fines is produced. So, quite some attrition will be obtained when the particles are transported from the top of the silo to the outlet.

Big bag storage

For the **BCS** experiments, different pressures are applied for a certain time and the percentage fines after the experiments were determined. The pressure needed to obtain 1% of fines is selected by obtaining results with low pressure resulting in low fines and higher pressures resulting in higher

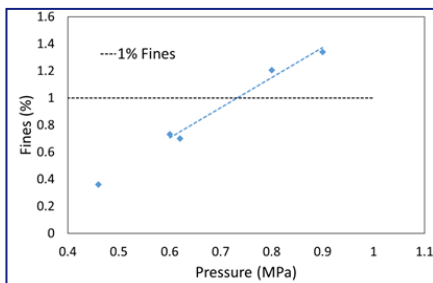
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fines. The pressure needed to obtain 1% of fines is selected by obtaining results with low pressure resulting in low fines and higher pressures re-



Bulk Crush Strength measurement cell.

sulting in higher fines. The pressure needed to obtain 1% fines with this technique is compared with the pressure which is applied in a big bag of 1 m³.



The percentage of fines of measured with different pressures on BCS.

The Figure below shows the BCS data of the sample and the percentage of fines obtained with the correlating pressure.

It is observed that the percentage fines increases with applying a higher pressure. With the method, 1 m/m% fines is obtained when a pressure of 0.73 MPa is applied. Knowing that a full big bag (1 m³) of the material weighs around 1200 kg, the force applied on the particles on the bottom is 0.012 MPa. This force is much lower than the bulk crush strength, where 1 m/m% fines are obtained when a pressure is applied of 0.73 MPa. This makes this unit operation (storage) being a very low contributor to produce fines.

Drop-pipe

For the SPCS methodology, after crushing 100 particles, all particles were collected to calculate the amount of fines obtained after the test. Then also 100



SPCS measurement system.

particles are dropped 1 floor (approx. 3 m) into a collecting dish and again the percentage fines is determined of the collected particles in the dish. From the dropping the maximum force needed to crush the particles is calculated and correlated to the strength of the particles.

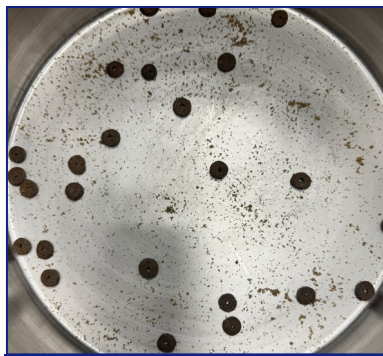
The force and percentage of fines of measured with dropping and SPCS.

	Force (N)	Fines (m/m%)
SPCS	51*	7.2
Dropping	55**	6.8

* Average crushing strength of the particles.

** Maximum impact force when dropping 3 m.

With the SPCS instrument, an average crushing force of 51 N and a percentage of fines of 7.2 m/m% is obtained. When letting the particles drop from approx. 3 m, the percentage of fines is comparable with 6.8 m/m%. It can be concluded that with both methods, the percentage of fines is quite high. The maximum impact force as worst case scenario can be calculated 55 N. This value is very similar as the strength of the particles measured at 51 N. It can thus be concluded that a considerable amount of fines can be produced as the impact force is higher than the average strength of the particles.



Collecting dish with high fines.

Conclusion

Overall it can be concluded that storage in a big bag shall not produce any fines of this material. The force needed to produce fines in this unit operation is more than 50 times higher. With the transport of the particles through a silo, a percentage of almost 3 m/m% fines is obtained, being a significant contribution for obtaining fines.

However, the highest contribution of fines is obtained by dropping the particles in a drop-pipe. Here the impact is higher than the strength of the particles, resulting in a fraction of around 7 m/m% fines.

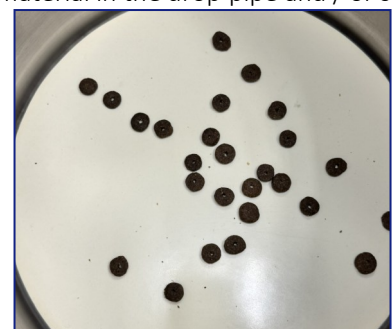
The drop-pipe is thus the main unit operation which produces fines. All unit operations investigated are made of stainless steel. It can be recommended to use other material which is softer, or bring a soft coating on the wall of the silo and on the bottom of the drop-pipe. With softer material, the impact force can lower significantly and also when softer walls are obtained, the shear stress will also be less. This thus can lower the amount of fines obtained and thus reduce problems like flow and blockage.

The percentage of fines of measured with dropping on stainless steel and soft material.

	Fines (m/m%)
Dropping Steel	6.8
Dropping soft material	0.7

The impact of softer material was also shortly investigated, by placing a plate of soft material in the collecting dish of the dropping test. With this test, the fines are then calculated again, resulting in the fines with stainless steel and with a soft material. The results of this experiment are given in the table below.

It can be concluded that the usage of a softer bottom plate, significantly reduces the amount of fines produced. The fines produces by dropping them 3 m, are almost a factor 10 lower with the softer material. It is therefore highly recommended to use or add some soft material in the drop-pipe and / or silo.



Collecting dish with soft plate and low fines.

