A case study on:
The effect of flow properties on mixing quality

Powder mixing is a fundamental unit operation in many industrial processes, yet it demands a deep understanding not only of mixing principles but also of the widely ranging characteristics of the powders involved. No single mixing approach can be universally applied to every material, as each powder exhibits its own unique physical and chemical properties that influence how it behaves during mixing. These properties introduce a variety of challenges that must be carefully managed to achieve a homogeneous blend.

Commonly recognized challenges include segregation, insufficient dispersion, and degradation of sensitive particles. Also some less obvious difficulties such as unexpected agglomeration, moisture-induced cohesion, or hidden dead zones within the mixer can significantly impact product quality and process reliability. Understanding and quantifying these issues is crucial for designing robust mixing strategies and ensuring consistent results across diverse materials.

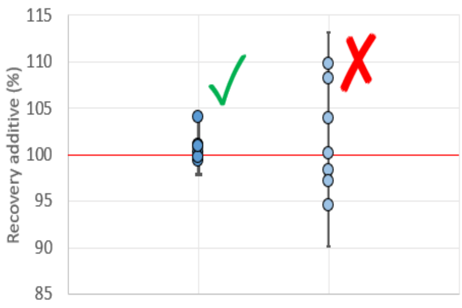

Non-homogenous powder mixture in a mixer.

Case

A client wants to install a new mixer for their product of two components. A major component with poor flow properties and a flowing agent as a minor component. The difficulty being the poor flow of the major component and the low concentration of the minor component, which was around 1% by weight. Normally preblending would be advised but due to mixer availability constraints from the client only one mixer was used. The poor flow meant that sufficient energy was required to agitate the bulk powder and mix in the minor component, but the particle size difference between the components would cause de-mixing if too much energy was used. Also the low concentration of the flowing agent could mean relatively large variation in samples taken from a mix. The goal for this project was to quantify the mixing quality of different mixers and evaluate the effect of mixing quality on the flow properties.

What was investigated?

Two different flowing agents with different properties were mixed. One of the flowing agents was free flowing while the other had cohesive flow properties, mainly due to a difference in particle size. The components were mixed on **high-shear and low-shear mixers** to measure the effect of a different energy input during mixing. The mixing quality was evaluated by **sampling** at different points throughout the mixer and **analysing the concentration** of the minor component in those samples. If there was a large spread in concentrations then the mix would be deemed of insufficient quality, if all samples had a near identical concentration of minor component than the mix would be considered a high degree of homogeneity. For the client a deviation of 10% was acceptable, though this number is different per application. Additionally the non-consolidated flow behaviour of the mixed product was measured. This was done using **Flow Through Orifice** (FTO) measurements, whereby a powder is put in a funnel with a specific sized opening and the time it takes for the powder to flow through the funnel is measured. Powders that are more free flowing will flow through in less time, while more cohesive powders will take more time or might not even flow through at all. Also the **skeletal density** and **particle size** of the major component and different additives were measured to relate the mixing quality to the primary physical properties of the components. This was done using laser diffraction to measure the particle size and helium pycnometry to measure the skeletal density.



Quantification of homogeneity of a mixture.

Mixing

Two different additives were mixed on two different mixers resulting in 4 mixtures total. Both mixers were sampled at 7 points throughout the mixer, taking into account zones where the mixture might segregate.


The position of the seven sampling points in the mixer.

Effect of flow properties on mixing quality

The sampling was done with a sample thief and the top, bottom, middle and sides of the mixture were sampled carefully. Using the sample thief samples could be taken while minimally disturbing the surrounding powder. Sampling at different points through the mixer gives an understanding of the homogeneity throughout the mixer.

In each of the samples the concentration of the minor component was measured. The measured concentration was then related to the expected concentration and a recovery was calculated. The variation between the samples, and thus the variation in concentration in different points through the mixture gives a measure of the homogeneity, reported as the relative standard deviation (RSD)

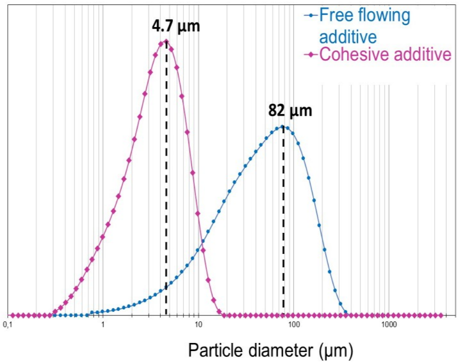
Flow Through Orifice analysis set-up

Flow

The flow behavior of the additives themselves and of the mixtures after mixing was measured via Flow Through Orifice measurements. One additive had smaller particles and a cohesive flowing behavior, while the other additive consisted of larger particles with free flowing properties.
The density for the additives was similair and also similair to the bulk so no demixing caused by the difference in density was expected.

flow (g/s)	High shear	Low shear
Cohesive	1.39	0.64
Free flowing	0.84	0.39

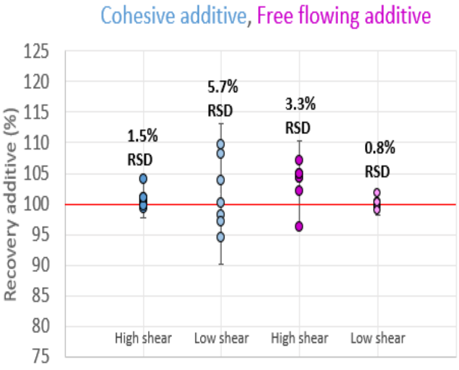
Flow properties of the mixtures after mixing.



Difference in particle size distribution of the additives.

Results

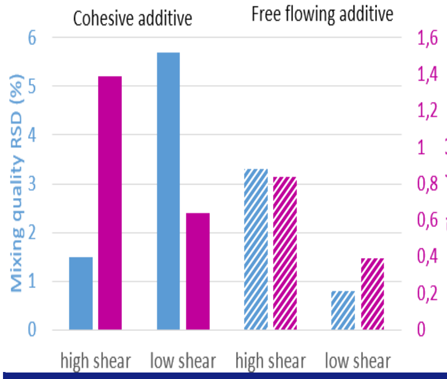
The mixing study demonstrated that the intrinsic properties of the two additives, particularly particle size, density, and flow behavior, had a decisive influence on their mixing performance in different mixers. The cohesive additive, characterized by its smaller particle size and poorer flowability, benefited significantly from the higher shear environment. The increased shear energy was able to break up agglomerates, reduce cohesive interactions, and distribute the fine particles more uniformly throughout the mixture, resulting in a lower RSD and thus superior homogeneity.
In contrast, the free-flowing additive, consisting of larger, less cohesive particles, exhibited an opposite behavior. Its inherent ability to move easily within the mix allowed it to reach good homogeneity under low-shear. However, when exposed to too strong shear energy, segregation tendencies became more pronounced. The additional energy likely amplified differences in particle momentum, causing the larger free-flowing particles to migrate or stratify, ultimately increasing the RSD.



Results of the mixing quality.

It was found that the mixing quality had no siginifcant influence on the flow behaviour for these samples. As the samples with a higher mixing quality, shown in blue, did not nessecarily have the best flow, shown in purple.

However it was found that the mixing type did influence the flow properties. The blends that were mixed on the high-shear mixer showed a better flowability, than those mixed with the low -shear mixer. Curiously, even though the mixing quality for the free flowing additive was worse with the high shear mixer the mixture still had better flow properties than the free flowing additive mixed on the low shear mixer. Also the cohesive additive had the best flowing mixture, however the flow was dependent on the amount of shear used.



Results of the mixing quality and flow properties summarized.

Conclusion

In the end, the client was satisfied with the results and its requirement for the homogeneity of the mixture was satisfied for both mixtures and additives. At our recommendation they chose to install a new low-shear mixer for both the free flowing additive product as well as the cohesive additive product as both products had a good homogeneity. Also low-shear mixers are often easier to clean and work with as less extreme forces are generated. They are also more energy efficient, saving energy costs.