

Focus on mixer performance and glass batch quality

*Creating an optimal glass batch quality is not only a matter of mixer performance, says **Fons Rikken***.*

Batch mixers, which belong to the group of mechanical intensive or non-intensive agitators, cover a capacity range from 1 litre to 5m³.

Types like rotating pan mixers; ribbon mixers; orbiting screw mixers; ploughshare mixers and ring trough mixers are very common in glassmaking. Improvement of the agitator tools is still going on in combination with a more efficient way of supplying energy into the batch. Due to an increasing variety of materials to be mixed and an increasing "batch quality" demand, many mixers have been adapted to more than one application. Like other process equipment, the development of mixers has been empirical. The lack of reliable up-scaling rules is a problem in choosing the best mixer for each application.

Of course mixer manufacturers possess much empirical data from their own test runs. However it is regrettable that most mixer manufacturers publish their mixer performance data in a rather confusing way. This often covers their commercial interest, while the mixer performance data is often missing the correct information to enable an objective comparison, and is mainly presented in terms of "degree of variation", whatever that means. It would appear that all mixer

types perform at top class with a degree of variation below 0.5%.

Philips in mixing

Philips glass industry has met this diffuse data problem several times during the past 25 years, in trying to make a mixer choice for its glass and non-glass batch plants and shows an arbitrary variety of mixers for the same application.

Worldwide Philips has some 40 mixers in operation for its powder batching activities with a total bulk amount of about 600,000 tonnes per year. Some 15 years ago Philips glass industry took the decision to eliminate the less efficient premix groups for micro ingredients (<500ppm). New types of intensive mixers were able to perform "in line mixing" for micro ingredients down to 100ppm. To investigate this new phenomena and check

the factual mixer performance data, a reliable batch homogeneity measurement was needed. The "variance analyses" method had already proven reliable in defining the "variation coefficient" (VC) as an index for the batch homogeneity. In micro ingredients "in line mixing", VC-results showed that the performance of intensive mixers was indeed comparable with the traditional premix process or even better. Consequently,

► Sample spoon with cover.



Philips has since eliminated all the premix groups in its batch houses. The variation analysis method proved to be sustainable and is still used for checking the performance of batch mixers and batch quality.

Defining VC mixer performance

Although some mixer manufacturers doubt the reliability of defining the batch homogeneity in the mixer itself (preferring sampling downstream), Philips does so because the reproducibility has shown good results with the chosen method. A significant measurable tracer as representative of the total batch is important for a reliable result and an amount of 100ppm is added to the batch. For tracer analysis in the batch, X-ray fluorescence is commonly applied. Also photo spectral analysis and acid soluble methods are in use. For the purpose of analysis, five (20ppm) samples are taken at different positions in the mixer (a series of ten samples are tested as well, however, the results are not significantly different). Samples are not taken from the batch surface layer, which means that a sample spoon with removable cover must be applied (see picture).

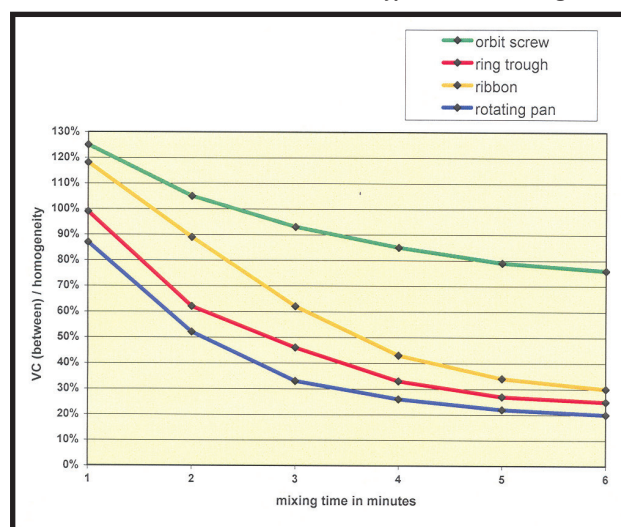


► Sampling the mixer.

▼ Example of calculation chart of one series with 5x4 samples.

Calculation chart "variance analysis"					
Tracer step 100 ppm, mixing time = 2 minutes (intensive mixer, dry batch)					
Analyses results	sample 1	sample 2	sample 3	sample 4	sample 5
sub 1	97	103	106	96	93
sub 2	98	102	105	97	94
sub 3	98	102	105	95	92
sub 4	96	103	105	95	93
total average	98,8				
Calculation	sum of sq.	free.degr.	variance	stand. dev.	
total samples	411,8	19	21,7	4,7	
within samples	9,3	15	0,6	0,8	
between samples	402,5	4	100,6	10,0	
Ftest. > 3	163,2				
V.C. (between)	10% = (standard deviation / total average) * 100%				

▼ Performance of four non-intensive mixer types (~1-2kW/100kg).



Sample size is limited to 30ppm for a reliable application of the variance analysis method. The samples are taken out of the batch in the mixer, by stopping the mixer normally at one-minute intervals.

Each sample is divided into four sub-samples, giving 20 samples to be analysed. The reason for the sub-sampling is the correct interpretation of the variance analyses by excluding the measuring failure in defining the so called "in between variance" instead of the "total variance". The total variance outcome always shows a better result and is therefore more often used. The correct interpretation of the variance analyses is checked by the F factor, a statistical check for the variance analysis application: "F factor" = $s^2(\text{between})/s^2(\text{within})$ to be > 3 .

The formula for the "variance between" is:

$$s^2(\text{between}) = \frac{\{(\text{sum of squares total} - \text{sum of squares within})\}}{\{(\text{degrees of freedom total}) - (\text{degrees of freedom within})\}}$$

The formula for the variation coefficient (homogeneity index):

$$VC(\text{between}) = s(\text{between})/\text{total average} * 100\%$$

Performance of mixer types

With the application of the "variance analyses method" Philips has checked the performance of almost all its batch mixers. For each mixer type, a series of 5x4 samples were taken in one-minute intervals up to a total mixing time of 6 minutes. For checking the reproducibility the procedure was repeated twice. Each point in the VC curve is the outcome of 20 analyses, so in total 120 analyses are required to present a VC curve for one mixer. Although the analysis method is expensive, it can be compensated by an efficient selection of the tracer material. Costs must always be in coherence with expected results.

The first series of VC measurements shows the performance of four "non-intensive" mixers, processing dry "light-

► Performance of four intensive mixer types (~5kW/100kg).

ing" glass batch without cullet, factoring in: the screw orbit mixer, ribbon mixer, ring trough mixer and rotating pan mixer. The batch energy consumption comes to 1kW/100kg for orbit screw and ribbon mixers and 2kW/100kg for the ring pan and rotating pan mixers.

The rotating pan mixer shows from one minute mixing time onwards the best result. The performance of the orbit screw mixer after 30 minutes showed a VC level of about 35%.

The second series of VC measurements shows the performance of four "intensive mixers" processing dry "lighting" glass batch without cullet, factoring in: the ring trough mixer with intensive rotor, plough share mixer with intensive rotor, rotating pan mixer (horizontal type) with intensive rotor and rotating pan mixer (20° inclined type) with intensive rotor. Energy consumption was 5kW/100kg.

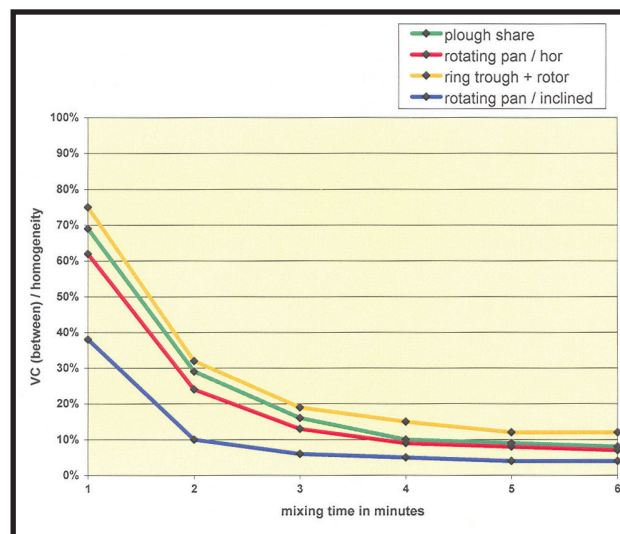
In this series the inclined rotating pan mixer is superior to the other ones. However it is essential to know if the highest created batch homogeneity level is really required. It mattered when Philips tried to optimise the productivity of a specific glass plant. In trying to increase the melting capacity of a tube light furnace, Philips performed some investigations in the relation between batch homogeneity and the specific glass-melting rate (SMR). Results showed that for keeping the 90% furnace productivity, the SMR could only be raised from 60 to 75 (kg/m².hr), by increasing the batch homogeneity at a level of VC <10. Philips now prefers to use inclined rotating pan

mixers for specific applications. In Philips TV glass business, batch homogeneity requirement are even more strict down to VC <5.

What about batch quality?

In the glass industry, batch quality is more than mixer performance, it is the outcome of a

◀ Decrease of batch homogeneity in downstream transport from intensive mixer to furnace.



chosen compromise between homogeneity, consistency and flow behaviour conditions, knowing that batch consistency and flow behaviour are always in conflict with each other. The maximum attainable batch homogeneity is only related to the mixer performance under the given material grain size conditions. It is common in batch processing that "homogeneity decrease" starts at the moment of mixer discharge and continues downstream by transport manipulation. To restrict the homogeneity decrease is therefore a matter of correct batch consistency and flow conditions.

Batch consistency can be improved by selecting the batch ingredients in a small grain size, small grain size distribution and batch moisturising (mainly water or oil). Batch flow behaviour can be improved by selecting the batch ingredients in larger grain size and preferably dry batch. Because of the compromise it is important that the batch mixing and transport equipment are chosen correctly.

The third series of VC measurements shows the decrease of batch homogeneity downstream from mixer to furnace batch charging in coherence with the batch moisture content.

Conclusion

Batch quality requires an optimal choice of batch consistency to restrict segregation in downstream transport while keeping the optimal batch flow conditions. Batch quality also requires a considered selection of transport equipment and "mass flow" silo design for storage. While realising that the required batch homogeneity will be different for each glass application. Personally I think the intensive mixer is a must in the glass industry, because the attainable homogeneity increases favour productivity and furnace energy consumption.

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