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Progress with grinding aids for VRMs

Sika AG's Matthias Dietrich shows the added value of carefully selected grinding aids for vertical roller mills (VRMs)...

The effect of grinding aids on the comminution of cement is based on the dispersion of fine particles. It is a misunderstanding that grinding aids for vertical roller mills (VRMs) should stabilise the material bed between the rollers and the table by adhesive forces between the particles. Grinding aids reduce the polarity of the cleaved surface and the attraction forces between particles. This means that agglomerates of fine particles and the packing of fine particles around a larger particle are dissipated, resulting in an improved efficiency of the separator. The internal circulation of fine particles is reduced and the clinker on the grinding track becomes coarser. The interparticle friction and thereby the effectiveness of the comminution process is increased. In this way, grinding aids stabilise the material bed on the grinding table, facilitate compaction and de-aeration, increase the production rate and reduce vibration of vertical roller mills (See Figure 1).

The adhesion forces between particles decisively affects the flowability of powders. They are proportional to the particle size: the smaller the particle, the lower the powder flowability. Grinding aids reduce the adhesion forces between particles without a negative impact on the stability of the material bed and fluidisation. In ball mills, where the grinding time is longer than in a VRM, excessive powder flowability can lead to insufficient or inefficient grinding because the material flows too fast through the mill. In contrast to ball mills, VRMs have a very high internal circulation, a short mill retention time and a huge number of classifying steps that carry the well-dispersed fines out of the mill system.

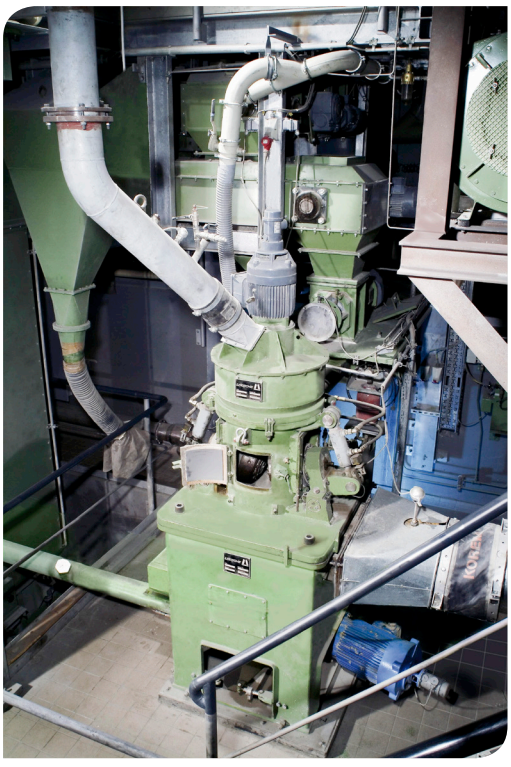
The conclusion? Grinding aids for VRMs increase the powder flowability of the finished cement without reduction of the stability of the material bed. The impact of grinding aids depends strongly on the fineness of the cement: The higher the surface area, the bigger the attraction force and therefore the bigger the benefit from an appropriate grinding aid.

The optimum grinding aid is still, to a large extent, selected empirically. However, Sika has found that a deeper understanding of the mechanism of grinding aids from tests in a laboratory or pilot mills,[1] are helpful for selection.

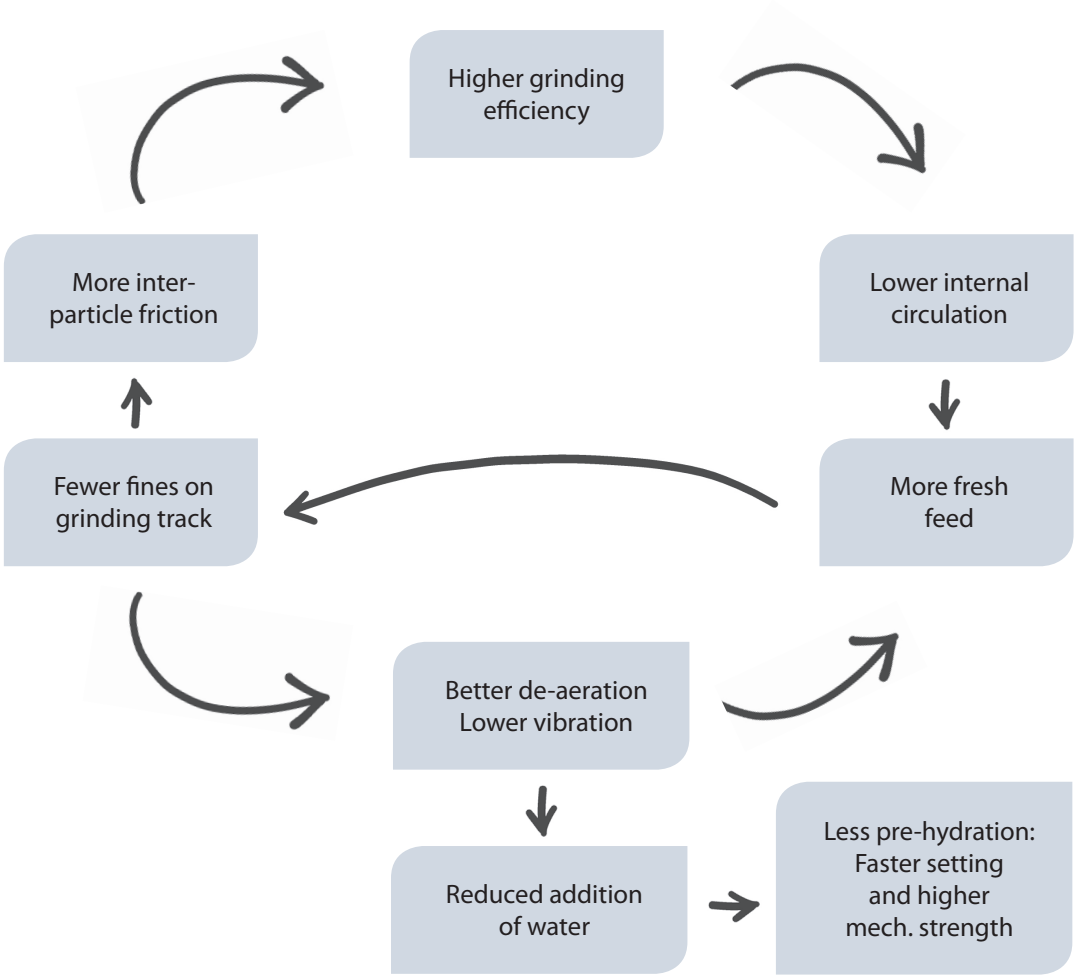
Testing at Loesche

Loesche GmbH is a leading VRM manufacturer for the cement sector. It operates a technical centre for the development of new technologies, new materials and for the optimisation of mill settings. Sika has used this excellent facility to increase the knowledge about mechanisms and to test advanced grinding aids.[2] During these tests, the pilot mill worked with the following parameters and dimensions:

- Table diameter: 36 cm
- Number of rollers Two
- Fresh feed, clinker alone: 130kg/hr
- Table speed: 98rpm
- Working pressure: 150bar
- Separator speed: 650rpm
- Fresh air: 480m^3/hr
- Temperature (after separator): 90°C
- ΔP_{mill} 21mBar
- Fineness (Blaine) target: 4200cm^2/g



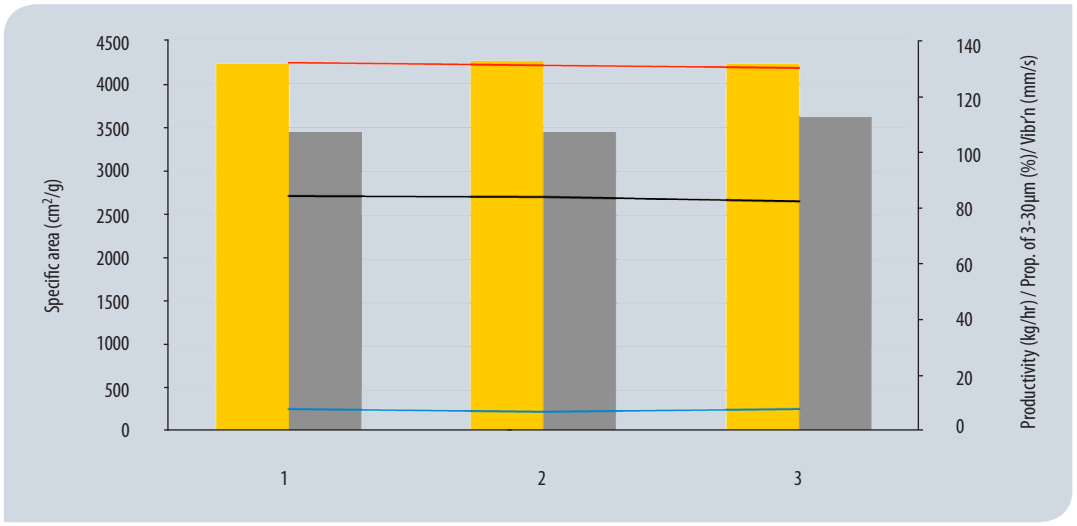
Left: The Loesche pilot mill used by Sika.



Right - Figure 1: Mode of action of grinding aids.

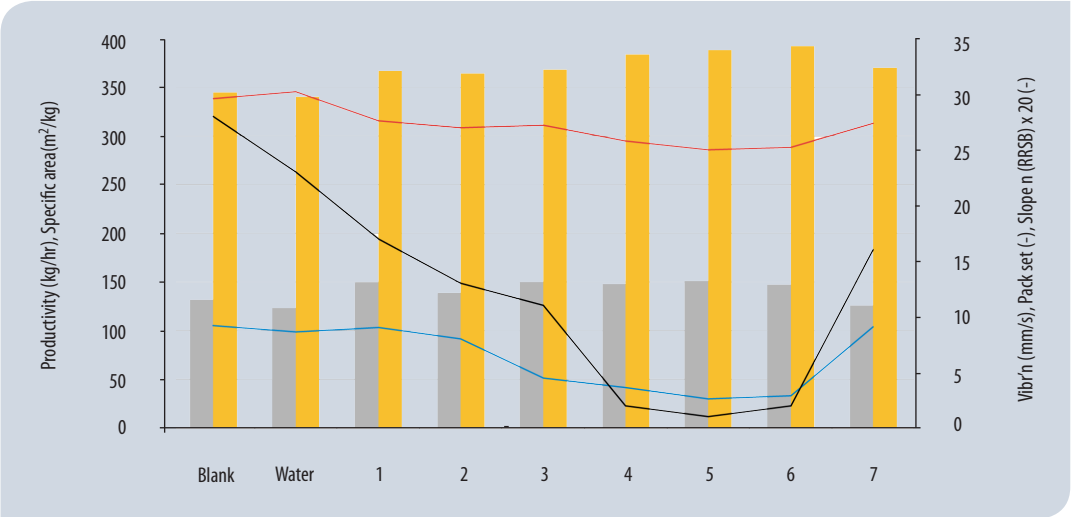
The differential pressure between the inlet and outlet of the mill (ΔP_{mill}) is an important process variable for the testing of grinding aids. ΔP_{mill} reflects the load and the filling level of the mill. At unchanged separator settings, the increase of ΔP_{mill} indicates more internal circulations and more fines. As a result of the higher ΔP_{mill}, the mill vibration increases (8-10mm/s), which results in a good opportunity to test the effect of the grinding aid. In contrast to tests with ball mills, the effect of grinding aids in a VRM is already visible and audible after 10-20min.

Before the addition of the grinding aid, a blank test was run to confirm reproducibility (See Figure 2). Starting from this baseline, the new grinding aids were added onto the transport belt of the clinker, right in front of the mill. Unfortunately, at that time



Right - Figure 2: Blank tests show excellent reproducibility.

Specific area (Blaine)
Specific area (Laser)
Productivity (kg/hr)
Content 3-30µm
Vibration (mm/s)



Left - Figure 3: Grinding results and cement properties using new grinding aids.

Specific area (Laser)
Productivity
Slope n (RRSB) x 20 (-)
Pack set (-)
Vibration (mm/s)

	Water	Blank	1	2	3	4	5	6	7
Productivity (kg/hr)	132	123	149	139	150	148	151	147	126
Vibration (mm/s)	9.2	8.6	9	8	4.5	3.6	2.6	2.9	9.1
Specific area (Laser) (m^2/kg)	345	340	367	364	368	384	388	392	370
Pack set (-)	28	23	17	13	11	2	1	2	16
Slope n (RRSB) x 20 (-)	29.6	30.2	27.6	27	27.2	25.8	25	25.2	27.4

Left - Table 1: Data used to produce Figure 3.

it was not possible to spray or sprinkle the grinding aid into the mill close to the rollers. Each grinding aid was added until constant mill parameters were achieved, within a maximum of 20min. To clean the mill from remaining grinding aid, the mill was run blank in between. It took up to 90mins to come back to the base line. The chemical structure of the added grinding aids was previously carefully selected, based on practical experiences in industrial VRMs, in combination with new molecules. A certain class of chemicals with the same functional group showed very promising test results (See Figure 3 and Table 1).

The most promising results were achieved with the Grinding Aids N° 4, 5 and 6. Their chemical structure is very similar. The achievements of Product N° 5, compared with blank are:

Productivity: +14%
Fineness: +12%
Vibration: -72%

The pack set of the finished cement, measured two days after grinding, was reduced from 28 to 1 revolution. It should not be disregarded that the pack set is measured with the finished cement, not with the material on the grinding track! Besides, pack-set is a standard term that refers to the condition in bulk cement, which inhibits 'the start of flow.' It can be

	Blank	SikaGrind-455	Δ (%)	SikaGrind VRM-40	Δ (%)
Cement	OPC (CEM I)	OPC (CEM I)	-	OPC (CEM I)	-
Dosage (%)	0.00	0.05	-	0.05	-
Water addition (%)	3.8	2.4	-37	1.8	-53
Vibration (mm/s)	5.1	4.7	-8	3.9	-24
Production (t/hr)	143	156	+9	159	+11
Specific energy (kWh/t)	38.0	34.9	-8	34.2	-10
Surface area (Blaine) (cm^2/g)	4110	4140	+1	4390	+7
Slope n (RRSB)	-	0.97	-	0.93	-

Left - Table 2: Comparison in cement properties and VRM operating parameters for blank, SikaGrind-455 and SikaGrind VRM-40.

Right - Figure 4: Slope n (RRSB) (-).

viewed as comparable to static friction and not as 'flowability'.[3]

The particle size distribution (PSD) also benefits from the new grinding aid. The PSD becomes broader as shown in the slope 'n' according to RRSB (See Figure 5). The potential for strength development is decreased as the cement PSD becomes broader but the workability of mortar and concrete is improved.

Effect	De-agglomeration
Influence on separator	Higher efficiency, recirculation
Effects on material bed	Fewer fines
Consequences on grinding	Increased internal friction Ease of de-aeration Reduced vibration, less wear Lower water addition
Effect on productivity	Reduced ΔP_{mill} Increased production Reduced specific energy demand
Effects on cement	Broader particle size distribution Increased power flowability Reduced pre-hydration Faster intial setting
Consequences for concrete	Improved workability Fast strength development

Right - Table 3: Summary of benefits of grinding aids for vertical roller mills.

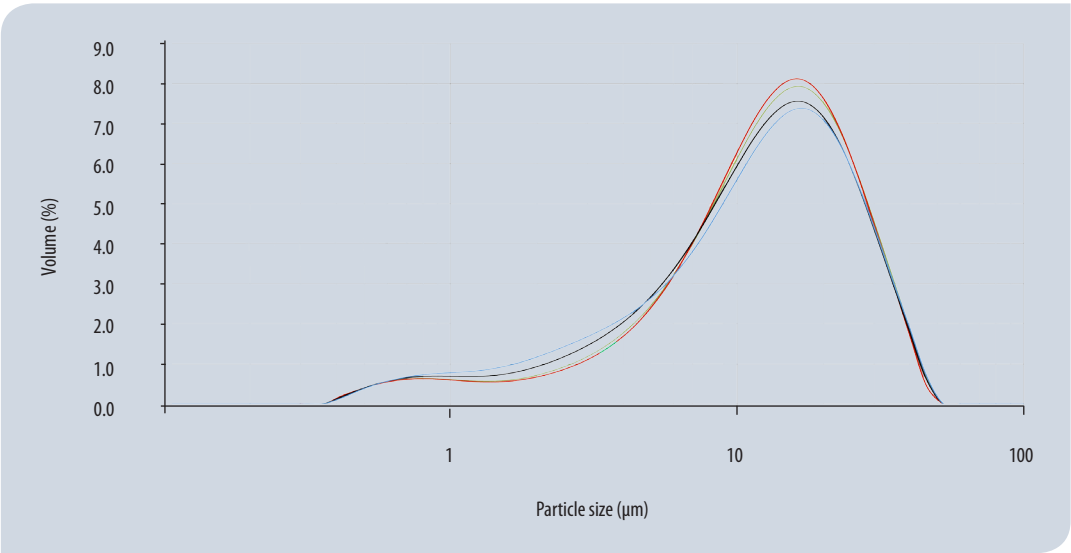
Industrial trial with molecule N° 5

One of the new molecules (N° 5 - SikaGrind VRM-40) was tested in an industrial VRM in comparison to a common grinding aid (See Table 2). The OPC (CEM I) made, with a surface area of 4100cm^2/g Blaine, was of higher quality and quantity. The reductions seen in the need for water injection and the reductions in vibration are remarkable.

The construction industry demands improvements of the performance and evenness of the cement properties. The speed of strength development is decisive, good and long workability as well as durability is required. With respect to the special properties of cement which is ground with VRM, innovative grinding aids make a contribution to fulfil these requirements.

References

1. Mishra, R.K.; Weibel, M.; Müller, T.; Heinz, H.; & Flatt, R.J. *'Energy-effective grinding of Inorganic solids using organic additives,' Chimia,* **2017**, 71, No. 7/8. **2.** Patent WO 2016/055376 A1; **3.** *'Innovations in Portland Cement Manufacturing,'* PCA, **2011**, pp. 744.



Right - Figure 5: Particle size distribution of cements made using different grinding aids.