Figure 3: The Insitec, showing connection lines to the process. All pictures courtesy of Malvern Instruments Ltd.

Marble fillers made to measure

With installation of two continuous particle size analysers, Italian marble producer Ferrari Granulati, has been able to break into the finer sized fillers market. *Alberto Ferrari* and *David Pugh* examine how continuous particle size measurement can be used to develop innovative processing solutions

FERRARI GRANULATI SAS, of Verona, Italy, is a leading producer of marble granulates and powders, primarily for the construction industry. The company mills a wide range of marble, of different colours, to produce materials in defined size ranges, the largest of which is 50-80mm.

Granulate mixtures are tailored to meet specific customer requirements. Two white marbles are milled at the site, the first Bianca Carrara from Italy, and the second a Greek marble, the "Extra White", which is exclusive to Ferrari Granulati. This material offers unsurpassed whiteness.

There is an extensive market in the paper, paint and plastics industries, among others, for finer calcium carbonate products, produced by milling white marble. These applications demand materials with closely defined particle size and distribution as this parameter directly impacts performance.

For example, very fine calcium carbonate with a specific surface area that is too high will make a paint dry, too low and the paint will be too wet. The formulator can tailor properties by specifying particle size.

Over the past three years Ferrari Granulati has invested in new technology to more effectively produce finer materials for these potentially lucrative markets. An essential part of this development has been the installation of two continuous particle size analysers: an in-line Parsum probe and an on-line Insitec laser diffraction system, supplied by Malvern Instruments, UK.

With innovative milling technology and automated control now in place, Ferrari Granulati is producing materials of exceptional quality at competitive variable cost.

Historically...

The first step in the production of finer white powders is sieving of the 0-1.8mm fraction produced in upstream milling processes. The sieve stack used produces the following fractions:

1.2-1.8mm
0.7-1.2mm
0.4-0.7mm
0.1-0.4mm
<0.1mm-fines

The lower fractions can be marketed as two different products, one with a specified particle size range of 0.1-0.4mm (<5% less than 0.1mm), the other a 0-0.4mm product with no specification on fines. The latter is the last two fractions combined.

The 0.1- 0.4mm product is used in the production of artificial marbles where particle size is closely controlled to optimise packing/material usage, and paints.

The 0-0.4mm product is relatively easy to produce as quality is not compromised by poor performance of the sieve stack. The more tightly specified product on the other hand is more difficult.

When the sieves operate sub-optimally the last cut is not "clean" enough to keep fines out of the 0.1-0.4mm fraction and so product quality can fall. Humidity has a major impact on the process and is constantly monitored.

If humidity rises above 0.1% then it is not viable to produce the 0.1-0.4mm fraction and only the more forgiving product is manufactured. With low humidity (<0.05%) the process works well and the 0.1-0.4mm fraction can be easily produced at an overall feed rate to the sieves of around 10-15 tph.

At intermediate humidity levels the process works well if closely controlled. Some producers get around this problem by drying the feed but this obviously incurs a penalty in terms of energy consumption.

Prior to the installation of continuous particle size measurement this separation process was controlled with reference to off-line sieve analysis carried out every two hours. The feed rate to the sieves was manually manipulated to control the level of fines in the product, a decrease in feed rate reducing the carryover of fines.

During the day this approach worked sufficiently well as long as humidity was acceptably low, although it was relatively labour intensive. At night no manual input was available so the feed was dropped to a minimum value of around 5 tph to ensure that the product remained within specification.

Dropping the feed rate in this way impacts throughput but also creates another problem. During the day, while the plant is on manual control the product contains perhaps 2-3% fines (<0.1mm).

At night, if humidity stays low, the level of fines can drop to almost zero, as the sieves give a very clean cut with such a low flow. Although the product was always within specification using this approach it was therefore very variable, making it less attractive to customers.

A further inefficiency associated with the production of this material was the 0-0.1mm waste stream. When the 0.1-0.4mm fraction is being produced the fines are available for alternative uses but the company had no way of processing this material into a saleable product.

The potential to use this stream as the feed for a micronisation process was clear. The company began to assess options for a new milling circuit to achieve this aim and allow them to access new markets.

New mill and on-line analyser

In 2004, Ferrari Granulati decided to buy new technology to process the 0-0.1mm (0-100 micron) waste stream into whitening products/fillers for the paper and plastics industries. If particle size could be closely controlled the company had the potential to produce materials of unsurpassed quality given the colour of the base material.

The particle size specification for these applications is a Dv50 (volume median particle diameter) of between 3 and 8 microns, but upper size limit is also important and Dv98 is specified. A new mill with appropriate controls was required.

A ball mill, as used by other producers, was perhaps the most obvious solution but footprint and energy consumption were significant drawbacks. A vertical roller mill was a more attractive option but product size presented an obstacle. Such mills are successfully used in the cement industry but only to mill down to a top particle size limit of around 50 microns (Dv98).

After detailed research, Ferrari Granulati decided to modify a basic vertical roller mill design to meet their requirements, and development of a novel milling circuit, with manufacturer STM of Varese, Italy, began.

To develop and optimise an innovative micronisation process the company realised that it would need real-time particle size measurement right from the outset. The Insitec on-line particle size analyser from Malvern Instruments was selected on the basis of measurement speed and suitability.

The Insitec, a laser diffraction system, measures particle size four times each second, and is designed specifically for continuous use in an industrial environment, rather than being a modified laboratory instrument.

Its robust nature particularly appealed to Ferrari Granulati. With a measurement range of 0.1 to 1,000 microns the system was ideal for this application. After some initial pilot-scale milling trials at STM, a new mill was installed, along with the on-line analyser (*see Figure 1*). A classifier was also included in the milling circuit for closer control of the final product fraction (*see Figure 2*).

The Insitec was quick and easy to install and worked well from the start. Optimisation of the sampling point was the only issue that needed resolution. In terms of sample quality the best place to extract material was on the vertical process line from the classifier to storage.

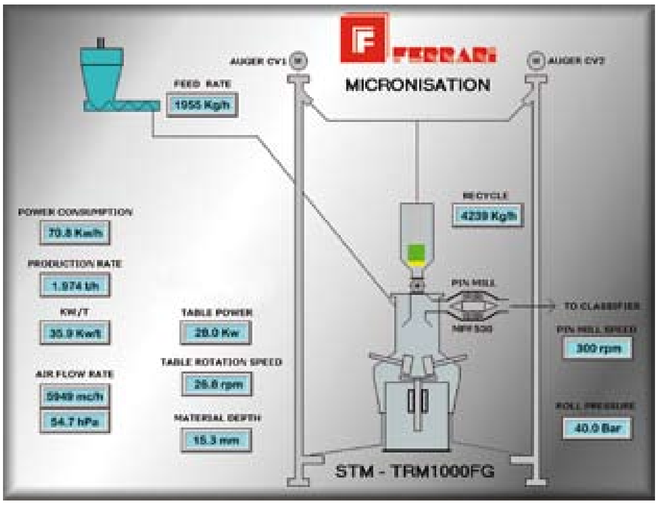
With dry processes, a sample is usually extracted using a flute; a pipe with holes that extends across the diameter of the process line to ensure a representative sample. Installing the flute in a line where material is flowing downward under gravity is usually the best option. This approach worked well here but other sample points were assessed to try and eliminate the minor time delay introduced by sampling after the classifier.

The sample flute is now installed within the extractor that takes material from the classifier to the filter, rather than on a process line. In the extractor discharge line there is some segregation so the flute is installed in the casing where flow is turbulent.

A booster compressor transports sample to the analyser which is located some way below (*see title picture*). The sample obtained at this point is not perfectly representative and there is, as a result, a slight, constant, offset between off and on-line measurement.

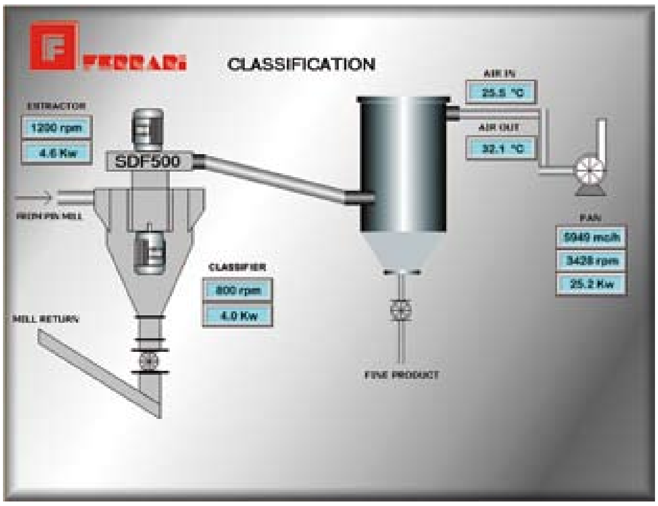
This compromise is accepted because sampling here gives such a fast response, making it possible to control the mill extremely tightly. An algorithm developed for this application corrects

Figure 1



Schematic of the micronisation mill.

Figure 2



Schematic of the classifier.

for the observed offset and so the data presented on the control screen is consistent with off-line measurements. The Insitec is extremely reliable and requires very little manual intervention.

Refining mill design

With on-line particle size analysis in place, Ferrari Granulati was able to work on optimising the design of the mill, developing innovative solutions that would enable them to make high quality products extremely efficiently.

The impact of any changes on product quality, which is principally defined by particle size, was immediately obvious and the company was therefore able to learn quickly.

Mechanical modifications were installed and recipes developed for each of the products ensuring consistent and optimised production. Power consumption per tonne is used as a key performance indicator.

The mill now has a number of unique features that deliver exemplary performance with no manual input, these are detailed below.

Monitoring & control of powder depth

With a vertical roller mill the rollers sit directly on the surface of the powder, crushing it as the table rotates. With a conventional system there is no control of the depth of powder on the table and fine materials tend to simply flow under the rollers without being broken up. This is the primary reason why these mills are not typically used to produce powders with a Dv98 less than fifty microns in size.

Ferrari Granulati has installed a simple mechanical transducer on the arm of the compaction rollers which move up and down according to the level of material on the table (*Figure 3*).

This calibrated system provides continuous measurement of the powder depth and is used to automatically vary the table's speed of rotation. If the depth of powder is too low then rotational speed is reduced to allow the level to build up. Maintaining a minimum powder depth maximises the impact of the rollers.

There are wear implications however, as vibration tends to increase when the powder layer is very thin. The optimal depth is around 15mm, and the table, which has a diameter of 1,000mm, rotates at speeds of around 25 to 30 rpm.

In-line pin mill for agglomerate break-up

An additional problem associated with producing finer material is the tendency to form agglomerates. Interparticle forces increase with decreasing particle size, particularly below 10 microns, encouraging particles to stick together.

Any agglomerates formed are classified by the separator as large particles and recycled to the mill to be broken down. This sets up unnecessary internal recycling, decreasing energy efficiency and throughput.

To reduce electrostatic charges and discourage this behaviour, Ferrari Granulati uses an additive – a glycol-water mixture that is introduced into the mill at a very low flow rate – but this alone is not a complete solution. An in-line pin mill has therefore been installed in the circuit.

The pin mill is positioned immediately upstream of the classifier. It sits in the process line and rotates relatively slowly for a pin mill at about 300-400 rpm; the external diameter of the mill is 500mm. This provides sufficient energy to break-up most agglomerates before they reach the classifier, improving energy efficiency, optimising mill throughput and avoiding excessive wear.

Mechanical powder recycle/ constant air flow rate

Air flowing through the milling circuit has two roles. Firstly, within the mill, it lifts powder that falls off the edge back onto the table for further milling. Secondly, it transports material through the milling circuit to the classifier.

In a conventional system, producing coarser materials, the air flow required for these two duties is roughly comparable, but with finer materials there is a mismatch. The air flow required for pneumatic transport/classifier operation is much lower than that needed to contain material on the table. This situation is heightened by decreasing particle size.

Since an excessively high air flow through the system has negative implications for energy consumption, Ferrari Granulati chooses to operate with an air flow sufficient only for classifier operation.

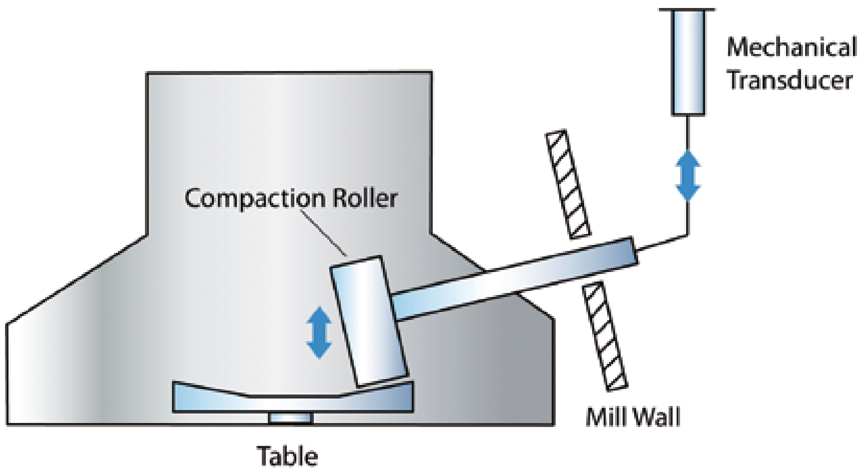
Material that falls from the table is collected from the base of the mill and transported using a screw auger. It is fed back into the inlet of the pin mill, passing through the classifier back to the table, or to product storage, depending on particle size. A load cell monitors the flow rate of this return stream.

Once set to give effective transport through the circuit and classifier operation, volumetric air flow rate – rather than fan power consumption – is kept constant during the production of any given product. This makes the feed to the classifier extremely consistent and intrinsically stable ensuring that particle size remains within the defined specification.

Routine mill operation

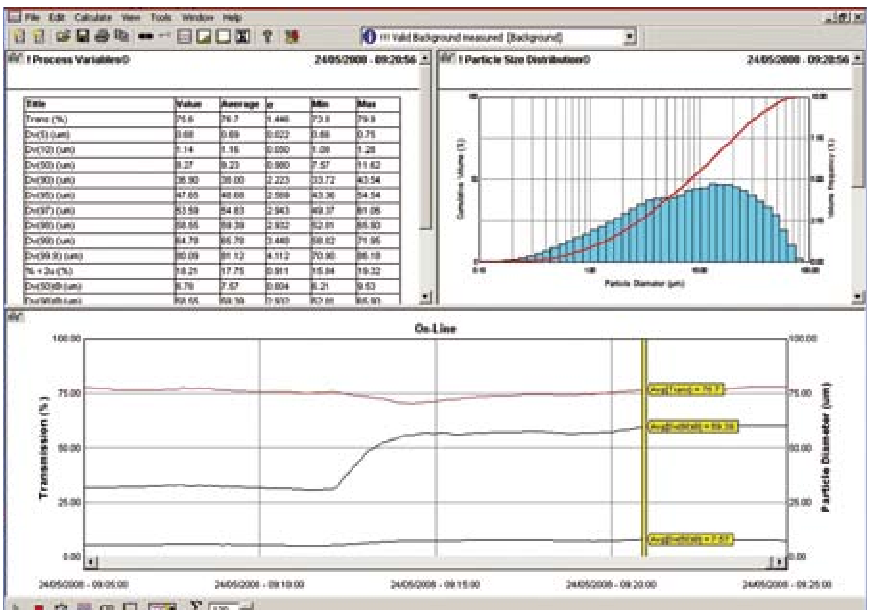
The mill is extremely stable and very responsive. It operates with no manual intervention, the operator simply inputs the set points defined for each product at the beginning of a campaign. This can be done locally, in the dedicated control room, or remotely. The mill is almost always run at night, when electricity is cheaper, but runs 24/7 when demand is high. It produces 15,000-25,000 tpa of micronised powder.

Figure 3



The mechanical system for powder depth monitoring and control.

Figure 4



Screen shot showing product changeover (from Dv98 of 30 microns to Dv98 of 60 microns)

Three products are manufactured, each with a Dv50 of 3, 5 or 8 microns and a Dv98 of 15, 30 and 50 microns respectively. Set points for recycle flow rate from the classifier and classifier speed are defined for each product.

Feed flow to the mill is automatically controlled from the recycle rate from the classifier to maintain a consistent total feed flow to the mill. When the recycle rate is higher, as it is when a finer product is being made, fresh feed flow will therefore tend to wind down and vice-versa.

The pressure used for compaction can be varied but is usually maintained at 40 bar. Air flow rate is set at a constant value and the speed of rotation of the table varies to maintain a constant depth of powder (as described above). The Insitec continuously monitors Dv50 and Dv98 and an off-line check is only carried out once for each silo ie. every 60 tonnes.

Energy costs are relatively low. Power consumption per tonne of product is continuously monitored and has been minimised for each product during optimisation studies. It is estimated that the relatively high cost of the vertical roller mill, compared with that of a ball mill, will be offset by energy savings alone after five to eight years of operation, the rising costs of energy favouring the adopted approach.

The product has unsurpassed quality – excellent consistency, a tight particle size distribution and the superior colour of the feed material. The mill has a very short response time so switching from the production of one material to another is very easy.

Figure 4 shows a product changeover. From the x-axis it is clear that the system reaches the new steady state after just a few minutes making it easy for Ferrari Granulati to produce what they need when they need it.

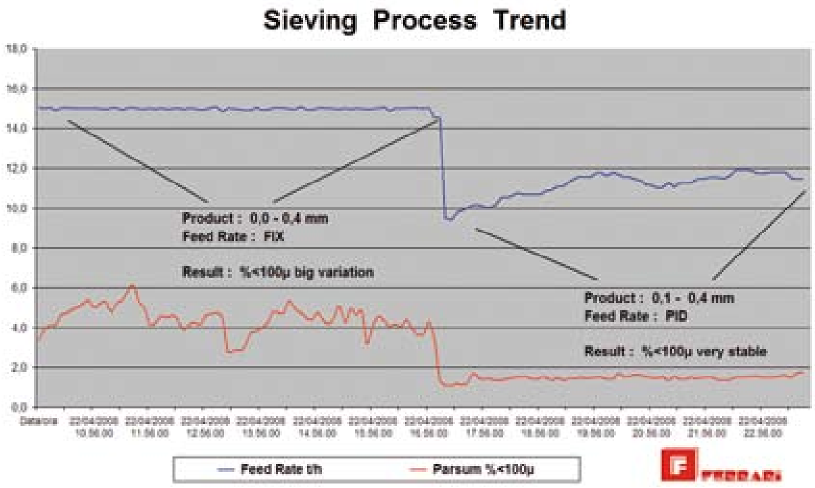
When switching from a finer material to a coarser one the change is effectively instantaneous as any residual fine material can be tolerated in the new final product.

The opposite switch, from a larger to a smaller particle size takes a little longer as material is swept from all the process lines. During the changeover the operator continues to divert product to the silo containing the large sized product so there is no waste and no re-work.

Figure 5

The Parsum installed in-line, on the take-off from the sieve stack.

Figure 6



Screen shot showing a change on the sieving process.

Improving sieving control

Having established its micronisation mill, Ferrari Granulati returned to the issue of improving control of the upstream sieving process. The decision was taken to switch from off- to continuous in-line measurement of fines in the 0.1 to 0.4mm fraction and automate control of the feed to the sieves.

A Parsum in-line particle size measurement probe was installed. The Parsum uses the principle of spatial filter velocimetry to measure the size and velocity of particles in the size range 50 to 6,000 microns.

Like the Insitec it is designed for process use and is easy to install. For this application the Parsum was inserted in the exit line carrying the 0.1 to 0.4 mm fraction from the sieve stack (see *Figure* 5).

Installation of the Parsum was trouble-free and it now runs continuously with little attention. When the 0-0.4mm product is being produced the Parsum sees quite a lot of fines (see *Figure 6*) and can become fouled so periodic cleaning (once per week) is then required. The probe is simply withdrawn from the line and cleaned with a pulse of air.

A PID control loop manipulates feed to the sieves to maintain the level of fines in the 0.1-0.4mm product at the specified set point, which is typically around 1.5%. This well-tuned loop offsets the impact of slight variations in humidity, automatically maintaining consistent sieving efficiency. The unit is now run day and night, without manual input, at the maximum possible throughput.

The responsiveness of the system is shown in Figure 6. The first half of the screen shot shows production of the 0-0.4mm material. The feed rate to the sieves is fixed, rather than controlled, and there is significant variation in the level of fines. For this product this is not, of course, a problem.

During the second half of the monitored period the 0.1-0.4mm product is being made so the system is now under automatic control. The PID loop is manipulating feed on the basis of measurements of the level of fines (material less than 100 microns) to ensure the defined specification is met.

Feed rate falls to between 10 and 12 tph, as above this rate sieve performance compromises product quality. The level of fines is maintained at the set point of 1.5%, feed rate varying to offset the impact of changes in humidity.

By operating the control loop within defined limits Ferrari Granulati is able to prevent re-work or waste. For example, when the set point is 1.5% fines, if the level of fines is 2% or more for more than 10 minutes the control system takes the unit out of the PID loop and simply sets the feed rate at a minimum level. A greater than 500 micron alarm has also been implemented to alert the operator to a sieve breakage.

With this system Ferrari Granulati is able to produce a consistent 0.1-0.4mm product without drying the feed. Where a producer uses drying, it typically accounts for 10 -15% of the production cost so this is a significant saving.

Furthermore, automated control has maximised unit throughput, increasing production in the winter season by as much as 20-30%. The payback time for the Parsum and all other elements of the control system is expected to be as little as two years.

In conclusion

Ferrari Granulati has used both on- and in-line particle size analysis to automate, and optimise, the production of calcium carbonate powders. Using real-time measurement the company has developed a novel milling circuit that produces fine powders of unsurpassed quality at a competitive variable cost.

Upstream, automatic control of the sieving process deals with the impact of humidity, eliminating the need for drying, prior to processing.

By exploiting the potential of continuous measurement the company has developed imaginative and intelligent processing solutions that position it as a market leader in its chosen sectors. im

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