TSV® : The high-efficiency dynamic classifier and its latest developments

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1. General remarks on classifiers

The use of classifiers on a powdery product with a given grain size allows the product to be divided into two parts: the first one made up of fine particles and the second one of coarser particles. However, depending on the quality of the classifier cut, the segregation of fine and coarse particles is more or less precise.

One of the traditional classifier applications is found in grinding plants for which the ground product feeds the classifier which sends the coarse part to the grinding mill inlet. This enables regularity of the finished product to be obtained in accordance with specific criteria for fineness. The performance of a grinding plant depends of course on the grinding mill used with however a significant part depending on the classifier's capabilities.

The principle of separation lies in the use of centrifugal force generated by way of a flow with vortex (cyclone and derivatives, etc.) for static classifiers or a rotating turbine for dynamic classifiers.

The evolution in the technology of classifiers can be summarized briefly.

The first classifiers of the "static" type separate the coarse particles from the fine particles by a cyclone effect although limited with regard to the admissible material load for inlet as well as separation efficiency.

The next generation, called first generation dynamic classifiers, has a rotating plate to disperse particles with a small axial selection turbine. Air circulation is ensured by a centrifugal rotor which is placed in the upper part. The fine product is recovered by decantation in a double conic casing.

By adding an external air circuit to suck in the gas output with the fine particles instead of the integrated rotor, we have come to second generation dynamic classifiers which are traditionally installed with peripheral cyclones.

The third generation includes a radial turbine which ensures radial separation and no longer axial separation.

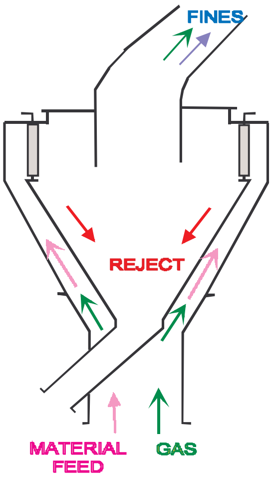


Figure 1 : Static classifier

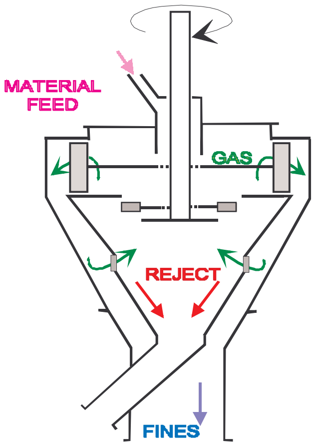
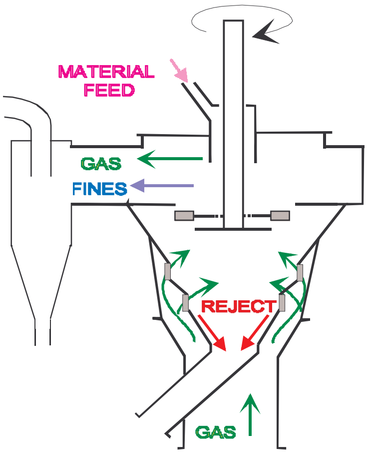


Figure 2 : First generation



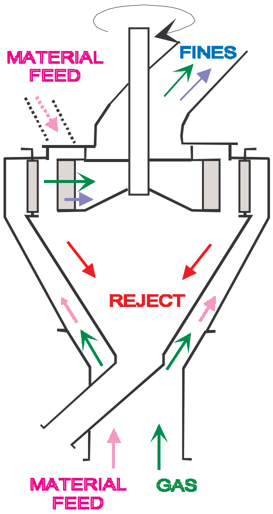


Figure 3 : Second generation

Figure 4 :Third generation

The TSV® developed in 1990 by FCB, the technology of which will be explained in Part 2, is an advanced third generation classifier.

The evolution of classifiers has followed a policy of improvement of their cutting ability, characterized by a better sorting of fine and coarse particles and a weaker by-pass.

Furthermore, in Part 3, we will present the industrial results of the TSVs® set up in different grinding plants (traditional or ventilated ball mills, vertical mills, Horomill®) working on different materials (cement, cement works raw materials and coal), before covering the energy performance of the TSV® and will conclude by presenting the latest evolution for TSV® : TSV2.

2. Description and advantages of TSV®

TSV® is a third generation classifier for which separation is carried out in the turbine blade channels, the particles being subjected to two opposing forces: centrifugal force due to turbine rotation and drag force due to the centripetal arrival of gases.

The particle in equilibrium, subjected to centrifugal force which is equal to the drag force, defines the cutting diameter. The choice of the turbine rotation speed enables, for a given gas output, the cutting diameter of the classifier to be adjusted. The particles which are coarser than the cutting diameter undergoing centrifugal force which is higher than the drag force are ejected towards the outside and fall by gravity into the reject cone. The fine particles for which the centrifugal force is lower than the drag force are attracted towards the centre and are driven by the carrier gas towards the outside.

2.1. *Feed flexibility*

One of the characteristics of TSV® is its flexible installations from the different possible feed configurations. It can be divided into four groups:

⇒ air-swept TSV®:

The matter is placed in suspension in the fluid flow and it all feeds TSV® from the bottom. This type of feed allows less space to be taken up and use in vertical grinding mills or air-swept ball mills.

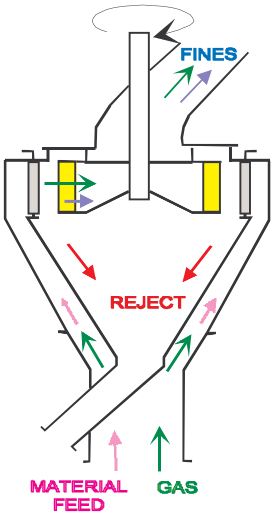


Figure 5 : Air-swept TSV®

⇒ top feeding TSV®:

The matter arrives in bulk from the top of the classifier onto the roof of the turbine which disperses the material between the stator and rotor blades. As for the clean gas, feeds the TSV® from the bottom. This configuration allows for a higher matter throughput.

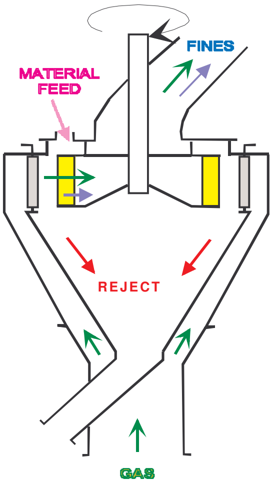


Figure 6 : Top-feeding TSV®

⇒ mixed TSV®:

The classifier is fed from the bottom with matter in suspension in the gas as well as from the top by matter in bulk. This type of feed allows the matter throughput to be increased.

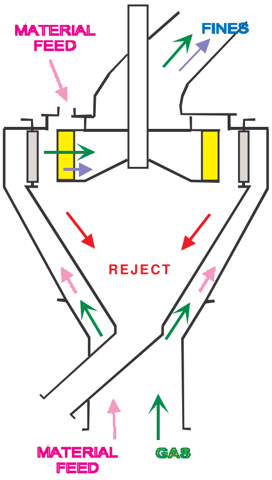


Figure 7 : Mixed TSV®

⇒ TSV® with volute :

The matter is fed in bulk from the top whereas clean gas is fed by volute. This takes up less space.

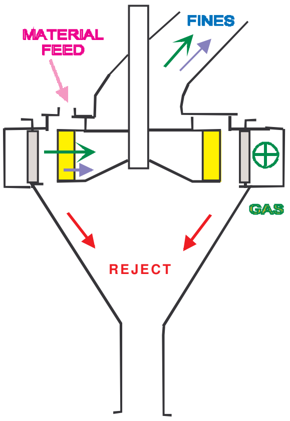


Figure 8 : TSV® with volute

These different configurations allow the TSV® to be integrated more easily into existing installations to replace the older generation classifier or in grinding plants regardless of the grinding mill used (ball mill either air-swept or not, vertical grinding mills or ball mills, HOROMILL®, etc.).

2.2. The distributor blades

The flow of gas is rectified by way of the adjustable stator blades, which allows the tangential speed of the gas to be adapted to the turbine rotation speed so as to obtain only a radial speed of the fluid of the turbine. Therefore, a drag speed which is directly centripetal and opposing the centrifugal force is obtained which limits wear of the blades by the absence of particle impact on the latter. A closing which is adapted to the blades causes pressure loss which is favourable to the proper homogeneity of the speed profiles upon inlet of the turbine on its periphery and its height.

2.3. Patented turbine blade profiles

Cutting precision, which is characterized by weak imperfection or by a high slope of the (separation curve), is reached by using a patented turbine blade profile. The blades are designed in a way so as, regardless of the position in the passage between two turbine blades, the cutting diameter is the same, which means that the centrifugal and drag forces are equal for a given diameter of the particle. Since the closer one is to the centre of the turbine, the more the centrifugal force decreases, the drag force must be decreased. This is obtained by slowing down the radial speed by widening the passage when moving towards the turbine axis. So the separation area is not limited to the rotor periphery but extends in all the passages between the turbine blades. This is essential to ensure great cutting quality for practical conditions far from ideal operating conditions, such as important turbulence of running speeds which are not even upon turbine inlet.

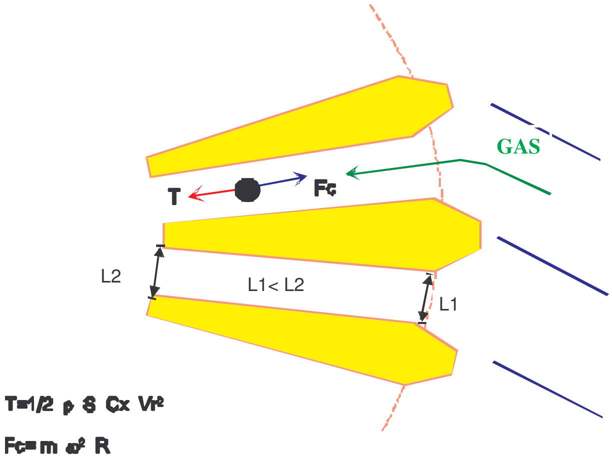


Figure 9 : Blade aerodynamics

2.4. Vortex-breaking system

For better evacuation of the fine particles with the gas and to rectify the rotational flow of the outlet gas, a vortex system made up of radial blades is added to the centre of the turbine. This original set-up presents three decisive advantages:

- pressure loss induced by the presence of a vortex is avoided.
- rotation energy of the fluid is transferred to the turbine which reduces the energy consumption required to drive it, while preventing any dissipation of energy into a central vortex.
- the tangential speeds in the outlet sheath are low, which presents an advantage with respect to wear.

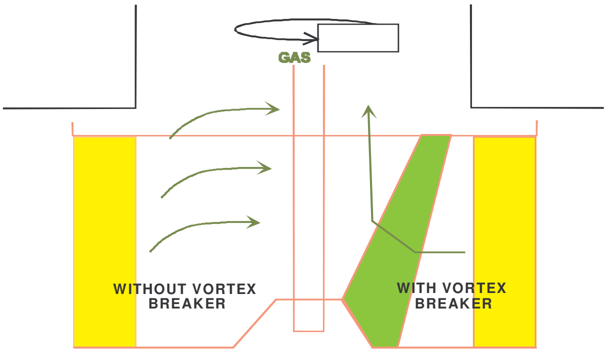


Figure 10 : Vortex-breaking system

2.5. Cutting characteristics of the classifier

The intrinsic performance of a divider is determined from the sharing curve which demonstrates the output for each particle category. The parameters are defined as follows:

- cutting mesh (mesh for which the separation output is 50%)
- imperfection $= \frac{d75 - d25}{2.d50}$, acuity $\frac{d25}{d75}$ as well as the output curve slope
- global by-pass (by-pass percentage) and the corresponding limit point
- maximum by-pass

The curve for the cumulative output of fines can also be traced. This gives, through its maximum output values, a global indication of the classifier's efficiency in a grinding circuit and enables assessment of the impact on grinding mill operation.

Also, the CL circulating load and RL recycled load can be defined by:

$$CL = \frac{\text{Feed rate}}{\text{Fine rate}} \quad \text{and} \quad RL = \frac{\text{Reject rate}}{\text{Fine rate}} = CL - 1$$

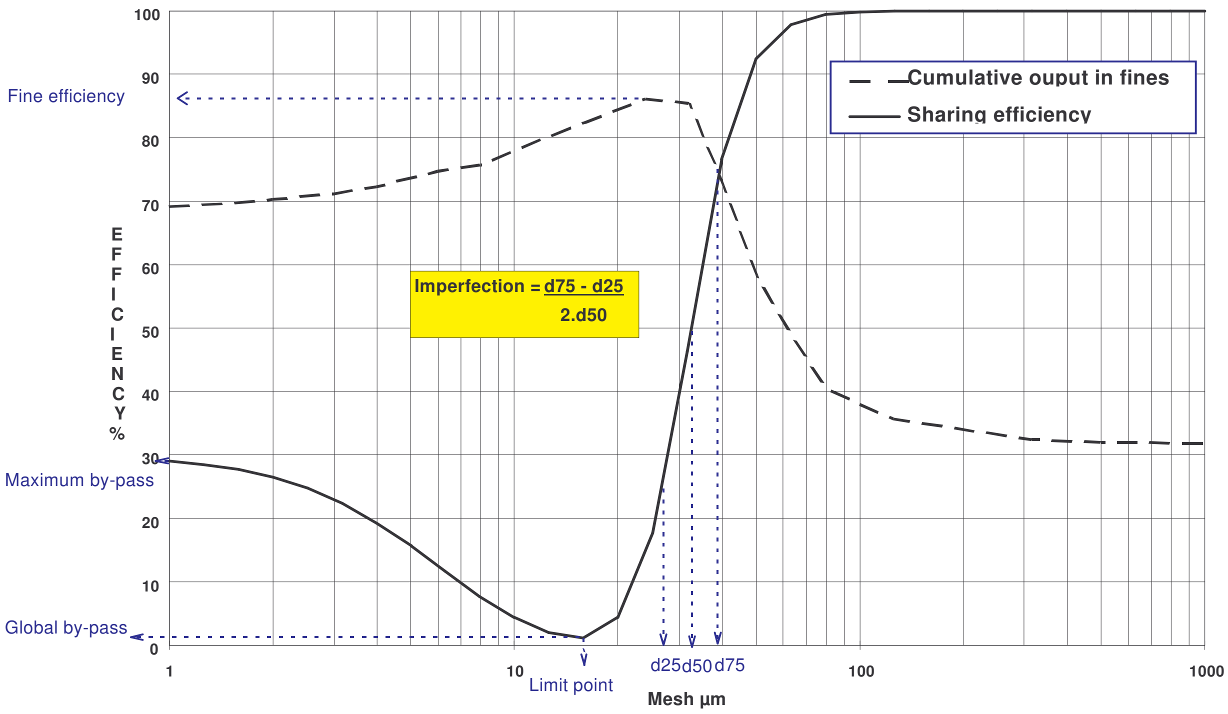


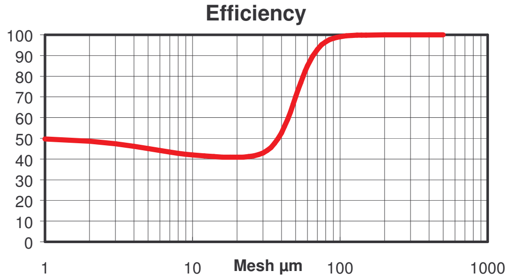
Figure 11 : Sharing curve

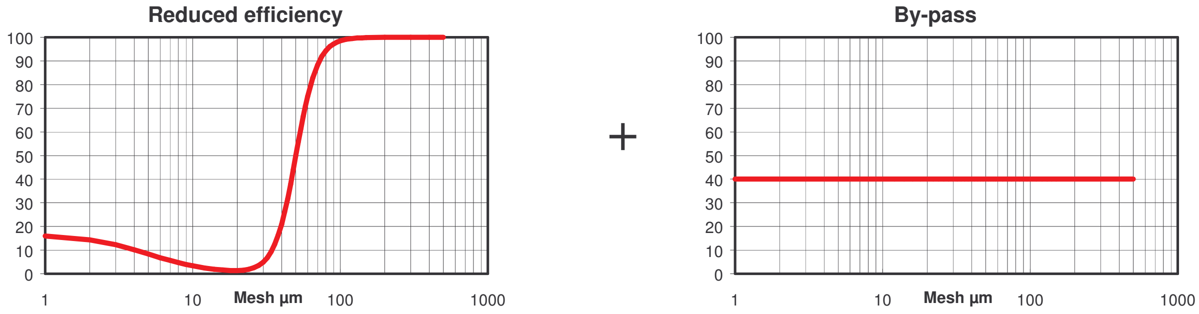
2.6. Cutting quality of the classifiers

2.6.1. Definition of reduced coordinates

To assess the cutting quality of a classifier, directly linked to the technology of the selection system (turbine, blades, etc.), apart from the quality of the product's being placed in suspension and the matter load (kg matter/m³ of gas), characterized by the by-pass level of the classifier, the output curve is traced in reduced coordinates. The classifier is therefore broken down into a combination of a classifier without by-pass and a by-pass. The output curve for the selection obtained for the classifier without global by-pass is called the output curve in reduced coordinates.

The output curve in reduced coordinates is defined as: $\dfrac{\text{Efficiency} - \text{global bypass}}{1 - \text{global bypass}}$





This passage in reduced coordinates is essential for classifiers presenting great global by-pass. Indeed, with a global by-pass of 30%, the d25 is not defined and therefore and no longer enables imperfection to be calculated.

2.6.2. Simulation model of the sharing curve

FCB has adapted a general mathematical formula for the sharing curve of a grain-size classifier (See Figure 12). This function give us the output value R_i for mesh X_i [2]. It consists of a combination of two S-shaped curves, one describing the grain-size cut and the other the by-pass in the fines.

The parameters of this function have a physical sense:

Mc : Classifier cutting mesh.
Pt : Slope.
Ms : By-pass “cutting” mesh.
Pts : By-pass slope.
St : Maximum by-pass.
Stg : Global by-pass.

Their meaning is demonstrated in Figure 13. Figure 14 shows us in what way the parameters enable simulation of any type of classifier.

$$R_i = Stg + (1 - Stg) \cdot \left[\frac{Str}{1 + \left(\frac{X_i}{Ms}\right)^{Pts}} + \frac{1 - \dfrac{Str}{1 + \left(\frac{X_i}{Ms}\right)^{Pts}}}{1 + \left(\frac{Mc}{X_i}\right)^{Pt}} \right]$$

$$Avec{:}Str = \frac{St - Stg}{1 - Stg}$$

Figure 12 : Formula of the model set for the FCB sharing curve

	First Generation	Second Generation	Third Generation
Mc	20	20	20
Pt	2.5	3.5	6
Ms	6	5	6
Pts	1.5	2	2.5
St	0.7	0.5	0.2
Stg	0.4	0.3	-0.05

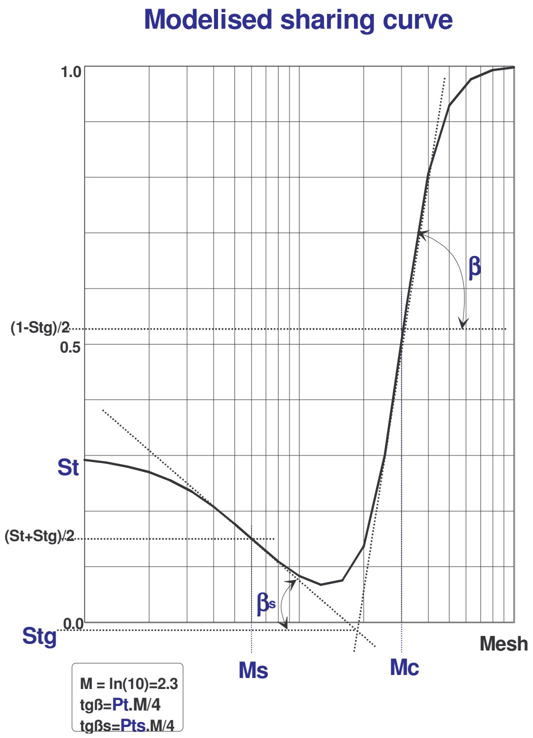


Figure 13 : Meaning of the parameters

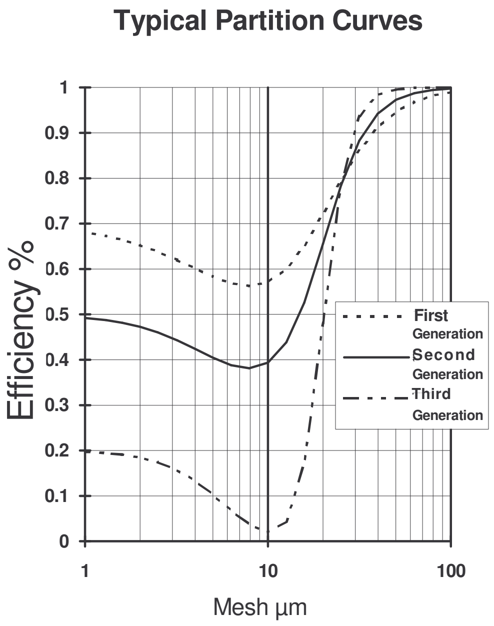


Figure 14 : Models set for three classifiers

2.6.3. Comparison between classifiers in reduced coordinates

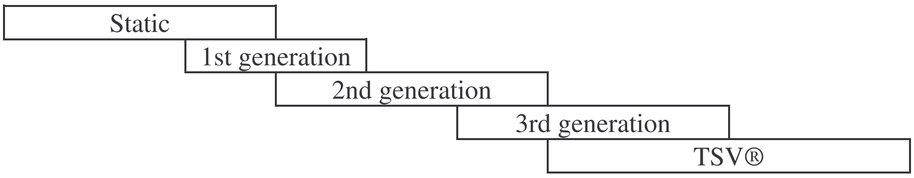
The sizes which allow the slope of the sharing curve to be assessed are defined in reduced coordinates:

- Imperfection $I = \frac{d75 - d25}{2.d50}$
- Acuity $\chi = \frac{d25}{d75}$
- The slope of the straight line obtained through linearisation of the cutting area of the sharing curve in reduced coordinates expressed in a diagram semi-Log : θ = Atan(-0.5/log(Acuity))

The evolution of the classifiers has followed a rationale of decreasing imperfection, global by-pass and the presence of outsized coarse particles in the finished product, for matter loads which are greater and greater. Also, the TSV® does not depart from this evolution, by allowing better discrimination of the fine particles from the coarse particles. Therefore, what is obtained appears in the following table:

Table 1 : Cutting qualities of classifiers in reduced coordinates

imperfection	I	0.75	0.64	0.55	0.47	0.41	0.35	0.3	0.26	0.22	0.18
acuity	χ	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
slope (°)	θ	42	46	50	54	58	61	65	68	71	74



Furthermore, global by-pass levels are about:

- 20 to 70 % for a first generation classifier (very variable depending on the load)
- 20 to 40 % for a second generation classifier
- 0 to 25 % for a third generation classifier
- 0 to 20 % for a TSV®

3. Examples of TSV® industrial performance

Classifier performance has a great effect on that of grinding plants by allowing, above all, work in a closed-loop. Different output from grinding plants is compared in terms of Specific Energy (SE) which gives the number of kWh necessary to grind one metric ton of matter for a given criterion of fineness.

FCB developed in the 80s a grindability test called the FCB Index which simulated grinding in ball mills as well as possible [1] [2]. The FCB Index gives directly, for traditional criteria of fineness d50-d80 and Blaine surface, the specific energy corresponding to a closed-circuit grinding mill which has been well optimized with respect to grinding (ball load, ventilation) as well as to the classifier (weak by-pass and good imperfection). We define the efficiency of the grinding circuit by $\sigma = \frac{\text{SE test}}{\text{Industrial SE}}$ which characterizes the performance of the industrial installation compared to the FCB index reference. The installation is considered as being of high performance for σ near 1.

For grinding plants with a grinding mill other than a ball mill, a ratio called substitution rate $\tau = \frac{\text{SE test}}{\text{Industrial SE}}$ is defined which compares the specific energy of the grinding mill considered to the FCB Index and enables assessment of the performance of the different types of grinding mills.

3.1. Choice of criteria for the assessment of TSV® performance

According to the criterion for the fineness considered, the energy gain generated by the use of the TSV® appears to be more or less important. The following results come from a grinding plant in Halyps (Greece) composed of what is called an E-type ball mill which operates on coal of the Hardgrove Grindability Index of 45 (hard coal) for a production of 10.3 t/hr.

Table 2 : TSV® performance according to the criterion considered

Criterion	**R40**	**R80**	**d80**
Criterion value	43.5 %	8.1 %	62.9 µm
SE grinding (kWh/t mech.)	12.4	12.4	12.4
FCB Index (kWh/t mech.)	21.0	25.3	23.9
Substitution rate τ	**1.69**	**2.04**	**1.92**

With the classifier cutting mesh close to 50 µm, if one takes into consideration the criteria linked to diameters which are higher than this, which means diameters for which classifier action is evident, the gain in the substitution rate would be great. However, if one takes a criterion concerning a lower diameter (R40), the gain in substitution rate would be lower as the presence of the classifier has less of an impact on these particle diameters, at least, when the by-pass is weak.

In the same way, for a cement grinding plant for which the criterion for fineness is expressed in terms of specific Blaine surface, imperfection plays a lesser role on grinding performance while the global by-pass is very important through its action on the over-grinding of recycled fines.

3.2. Raw material grinding of cement works

The installation being considered here is the raw material grinding plant of Martres-Tolosanne which is equipped with a closed-circuit ball with a 3600 mm-TSV® classifier and which produces 89 t/hr of finished product. The TSV® replaces a first generation Sturtevant classifier. It has a mixed feeding system: gravity feed by elevator at the grinding mill outlet and take-up of gas from the grinding mill and the flash sheath upon grinding mill inlet.

For the same specific grinding energy, the TSV® allows rejects for 100µm of 6.1% as opposed to 13.6% for the grinding plant equipped with a first generation classifier. While for the first generation classifier, we are well above the FCB Index, this is different for the TSV® for which the lower the reject percentage at 100µm, the better the performance with respect to the FCB Index!

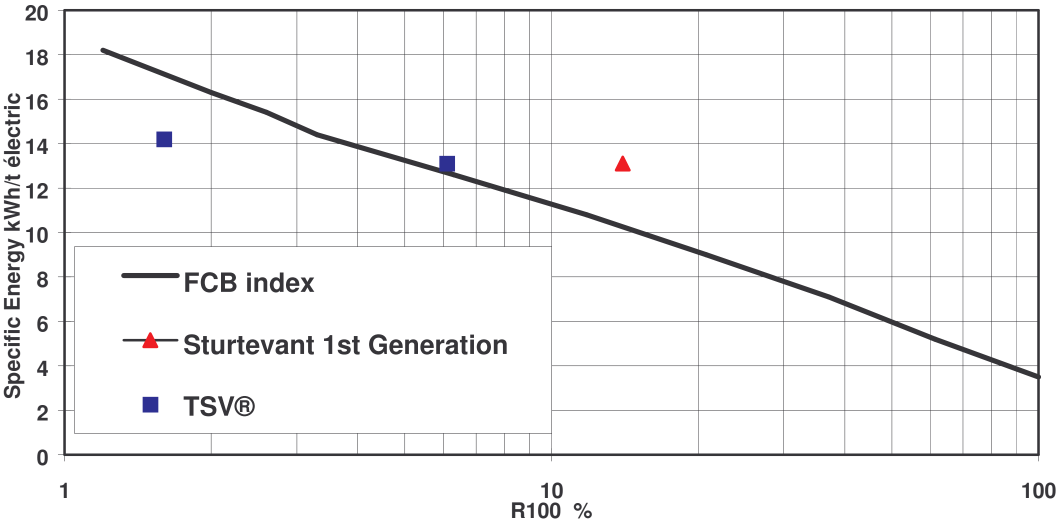


Figure 15 : Grinding plant with TSV® and first generation classifier

If we compare the results of grinding plants equipped with two different classifiers, we obtain:

Table 3 : Performance of the Martres-Tolosanne grinding plant

Classifier	R100	daPa pressure loss	TSV® power kW	Rotation speed rpm	Production t/hr	SE kWh/t	Output σ
Sturtevant	13.6 %				80.5	13.1	0.78
TSV®	6.1 %	160	11	100	89.2	13.1	0.97
TSV®	1.6 %	190	17	120	82.1	14.2	1.18

It is observed that the presence of the TSV® leads to grinding plant output which is close to or even higher than 1 (compared to 0.78 for the Sturtevant), thus demonstrating the quality of the grinding plant which is equipped as such. Furthermore, when criterion R100 becomes more drastic, the grinding plant output increases which shows the absence of outsized coarse particles in the fines. In addition, for TSV® power of 17 kW and a production of 82.1 t/hr, an R90 of 4.5%, R100 of 1.6% and R200 of 0% are obtained.

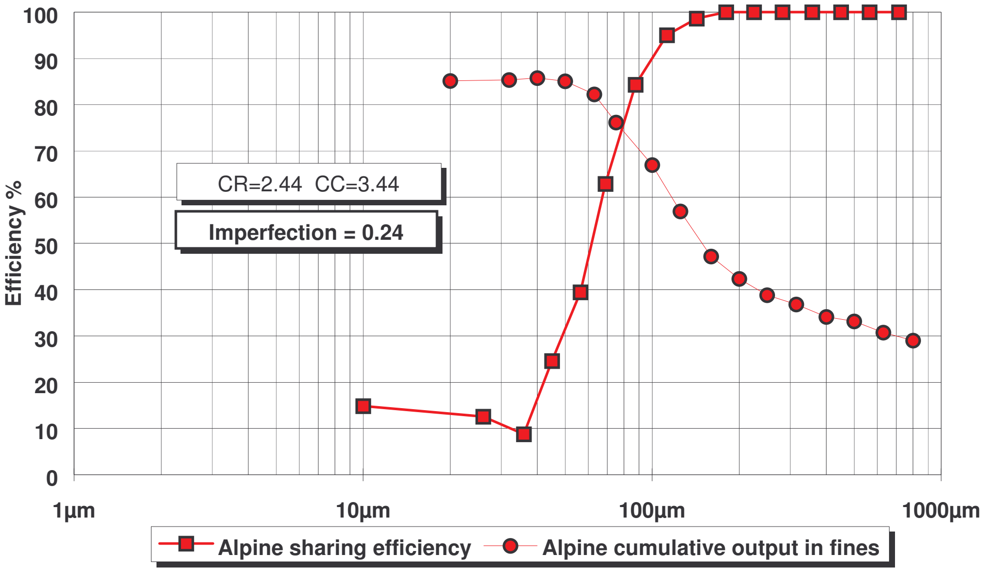


Figure 16 : TSV® Martres-Tolosanne output for R100=1.6%

For this grinding plant with TSV®, a global by-pass of 10% is obtained, due to the product's disintegration during sieving more than to a true classifier by-pass, an imperfection of 0.24 and cumulative output in the fines of 85%. Such results explain the grinding performance obtained.

3.3. The grinding of coal and coke

3.3.1. Ball mills

The grinding plant being considered is that of Alba, which includes a ball mill and a 1600-mm TSV®, operating on calcined petrol coke used for the manufacture of anodes for the aluminum industry. The TSV® is bottom feeding and produces 12.5 t/hr of finished product.

On the sharing curve, an imperfection of 0.27 is observed as well as a global by-pass which is practically nil, while the cumulative output curve in the fines points out that almost all the fines are recovered and that there is no problem of matter aggregation.

On the Rosin-Rammler diagram of the finished product, the presence of two different slopes can be observed, contrary to traditional plants for which a single slope is obtained. The grain-size slope less than 80µm demonstrates a natural slope of the product in the fines, with a value of 0.81 compared to 1.17 for the full grain-size of the finished product. The fraction of the product which is higher than 80µm shows a slope which is considerably higher, 1.64. This characteristic mark of the TSV® on the grain-size curve of the finished product is a direct indication of the performance of selection.

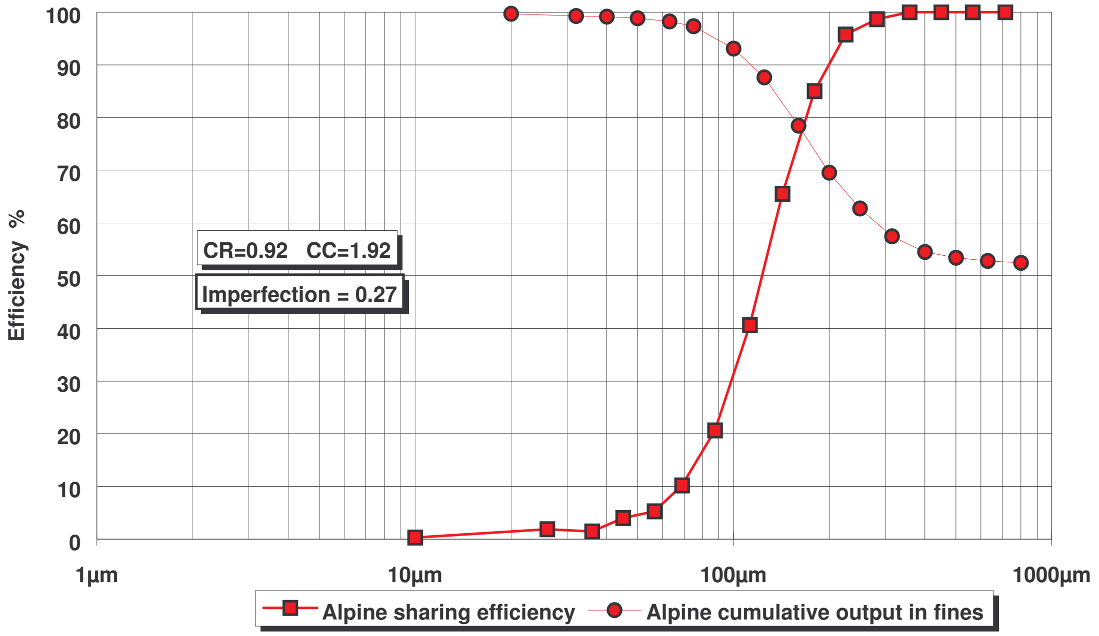


Figure 17 : TSV® output of the Alba grinding plant

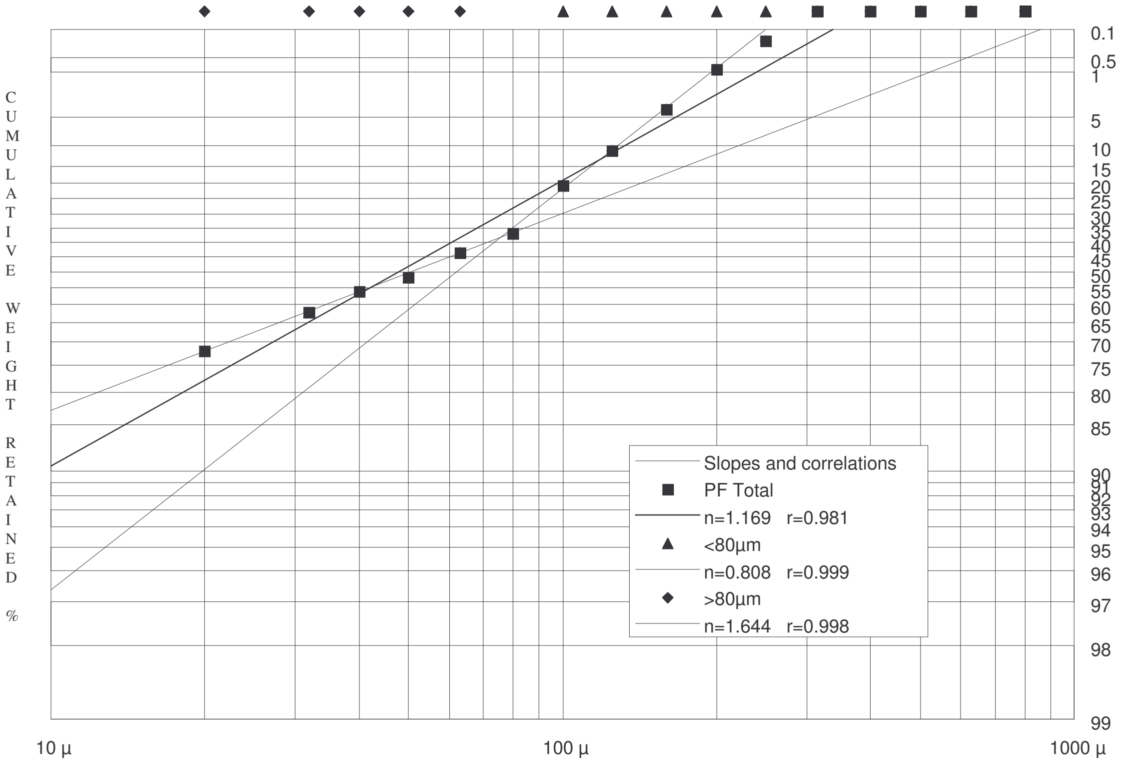


Figure 18 : Rosin-Rammler diagram of the finished product of the Alba grinding plant

3.3.2. Vertical mill

The grinding plant being considered is that of Halyps which is made up of a vertical mill working on coal of a grindability index of 45 and d80=24.5 mm, equipped with a TSV® of 2000 mm in diameter (bottom feeding), producing 11.8 t/hr (dry) of the finished product.

On such mills, access is only easy for the grain-size curve of the finished product, the mill and classifier forming a whole. As for the previous example, the grain-size slope for diameters lower than 50µm is 0.88 compared to 1.3 for full grain-size. However a grain size which is higher than 50 µm is 1.57. This shows the impact of the TSV® for diameters above 50µm which represent approximately the cutting diameter. This absence of outsized coarse particles in the fines is very important to obtain better coal combustion and a lower pollution level.

For R80=13.5%, specific electrical energy of 11.4 kWh/t is obtained, i.e. a substitution rate of 1.89.

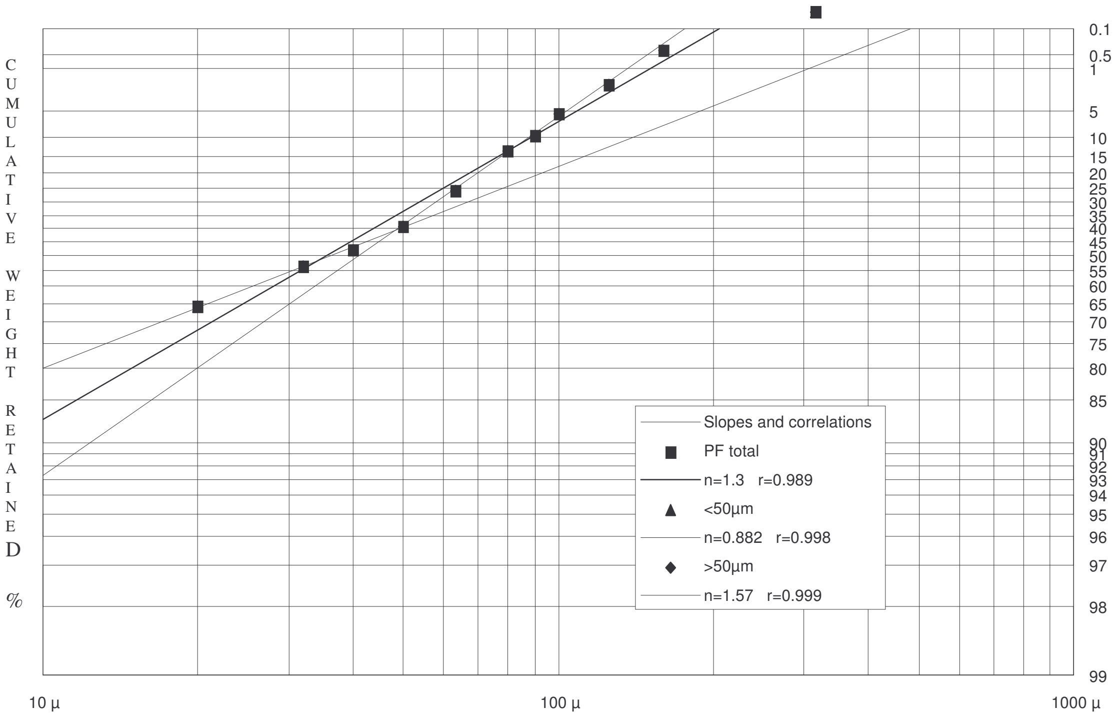


Figure 19 : Rosin-Rammler diagram of the finished product of the Halyps plant

3.4. Cement grinding

3.4.1. Ball mills

The grinding plant being considered here is that of Port-La-Nouvelle which is made up of a ball mill and a 3600 mm-diameter TSV®, producing 80 t/hr of ‘CPA55’ (PC 42.5) cement at 3100 Blaine and 52 t/hr of ‘HPR’ (PC52.5R) cement at 4200 Blaine.
The TSV® is top feeding and has a volute.

* <u>CPA55 cement</u>:

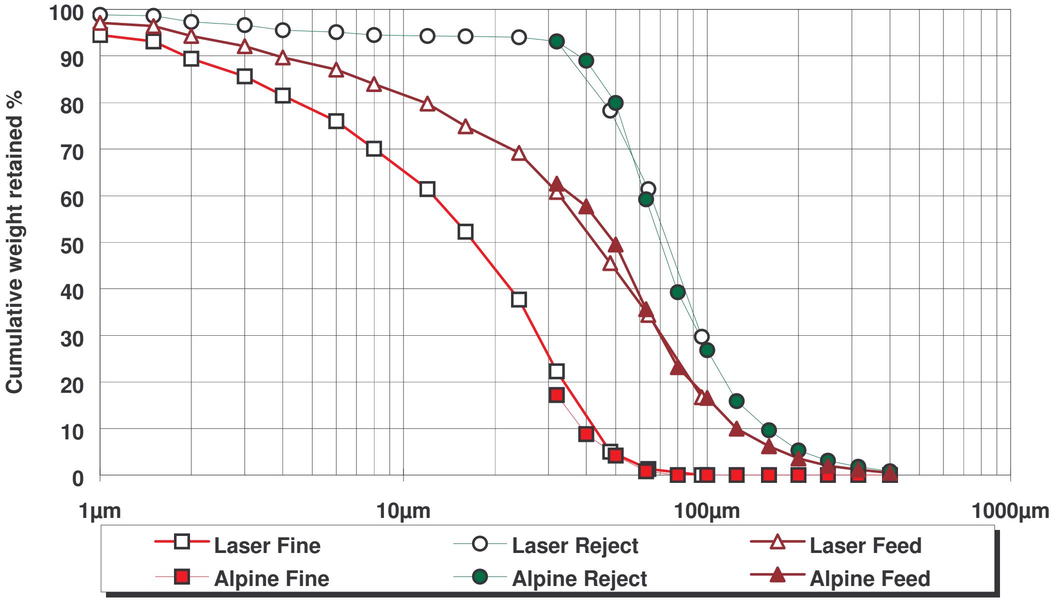


Figure 20 : Grain sizes of the Port-La-Nouvelle grinding plant for the CPA55 cement

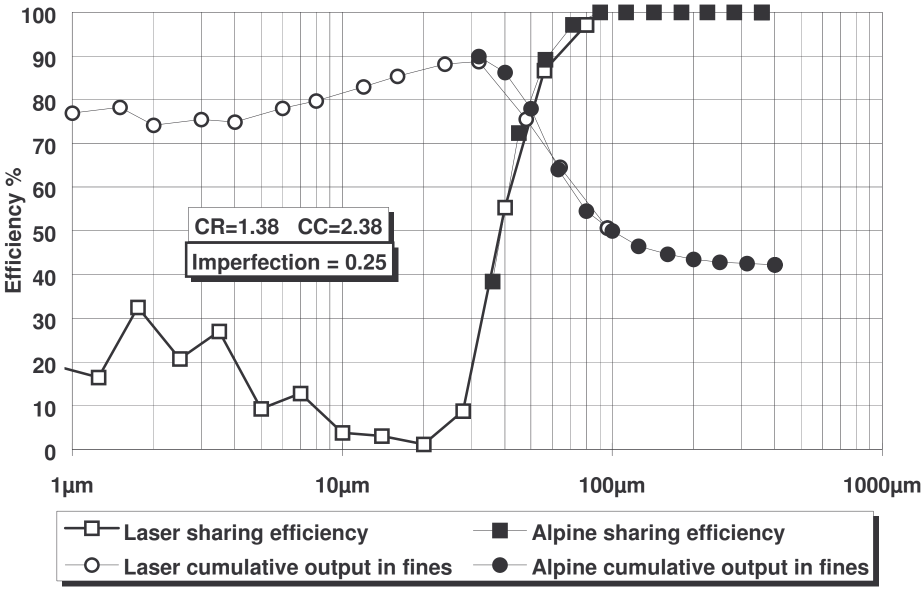


Figure 21 : TSV® ouput of the Port-La-Nouvelle grinding plant for the CPA55 cement

* <u>HPR cement</u>:

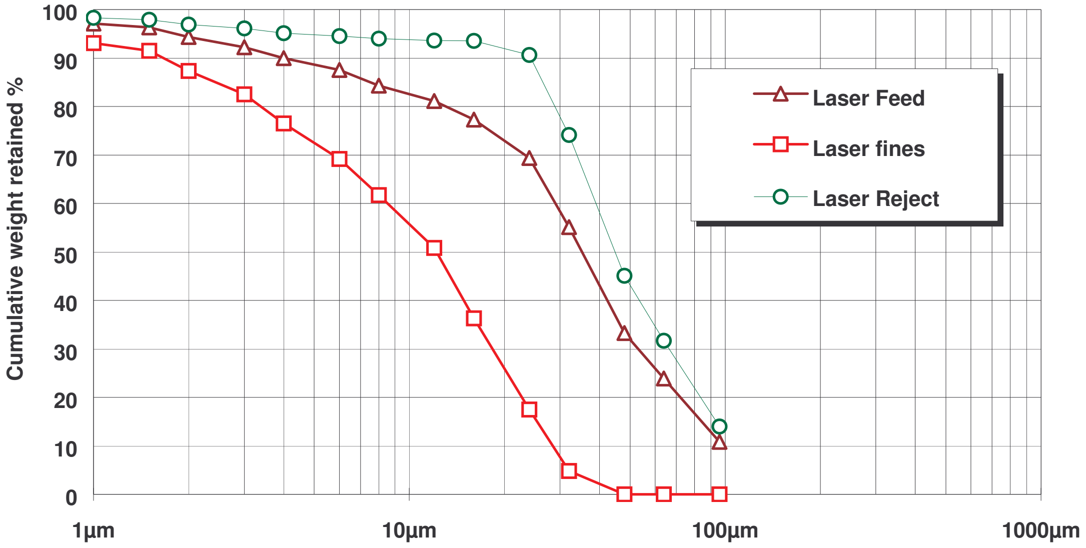


Figure 22 : Grain sizes of the Port-La-Nouvelle grinding plant for the HPR cement

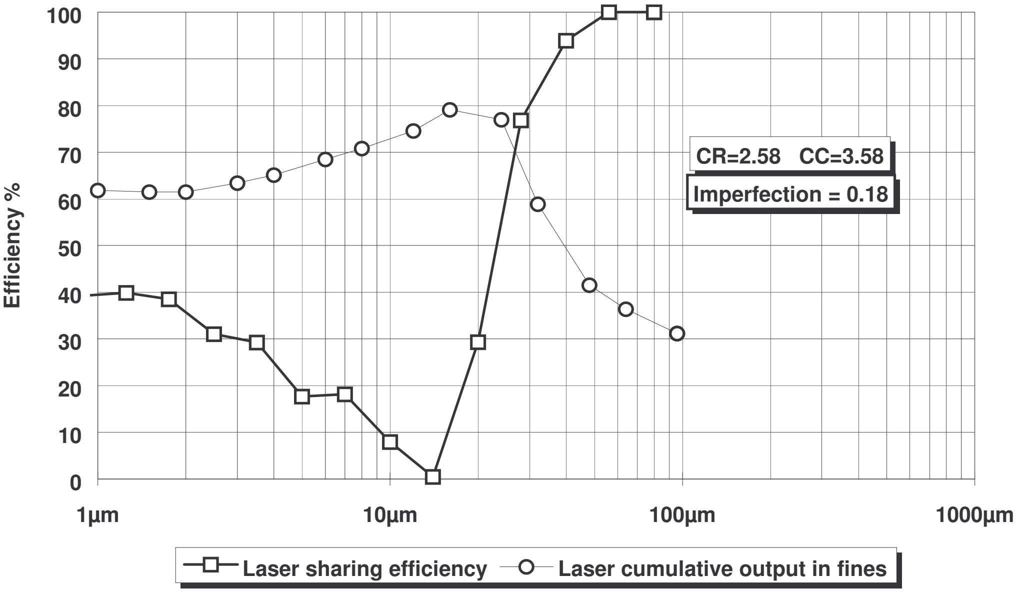


Figure 23 : TSV® output of the Port-La-Nouvelle grinding plant for HPR cement

The grain-size curves of rejects for both cements show cumulated rejects of about 95% for a rather wide range of fines (1-30 µm for the CPA55 and a cutting diameter of 37 µm, 1-20 µm for the HPR and a cutting diameter of 22 µm). This demonstrates the good TSV® output level with respect to fines.

The output curves, however, show imperfections of 0.25 and 0.18 respectively for cements CPA55 and HPR, global by-passes which are nil and global cumulative output in fines of 90% and 80% for cements CPA55 et HPR.

Table 4: TSV® Performance at Port-La-Nouvelle

Cement	TSV® power kW	Rotation speed	Material load kg/m^3	Pressure loss daPa
CPA55	16	136 RPM	1.4	220
HPR	52	210 RPM	1.5	260

3.4.2. Horomill®

The Trino grinding plant which is being considered has a Horomill® and a TSV® of 2600 mm in diameter. The material used is CP42.5R cement.

On the grain size curve for rejects, a range for the fines can be observed for which the cumulated rejects are close to 98%, demonstrating in this way that the TSV® has recovered practically all the fines.

The grain size curve of the finished product shows the absence of the coarse oversized materials in the fines with 5 % of rejects at 40µm.

The output curves show an imperfection of 0.26, a global by-pass of about 2 to 3 % while the cumulated output of fines reaches 90%. One would expect the cumulated output of fines to have been greater since the grain size curve for the rejects (very good recovery of the fines), however the RL recycled load must be taken into account which is equivalent to 4.58 and therefore significant enough compared to 2.5 of an optimized workshop with a tube mill but normal for a Horomill®.

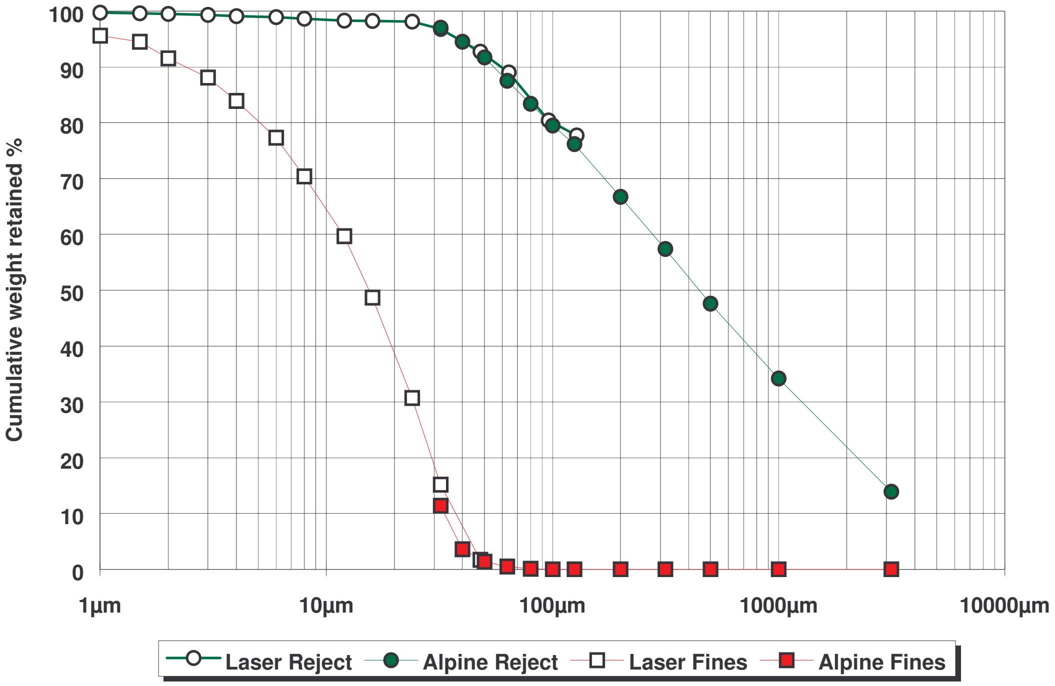


Figure 24 : Grain sizes for the Trino grinding plant for a 140 t/h feed

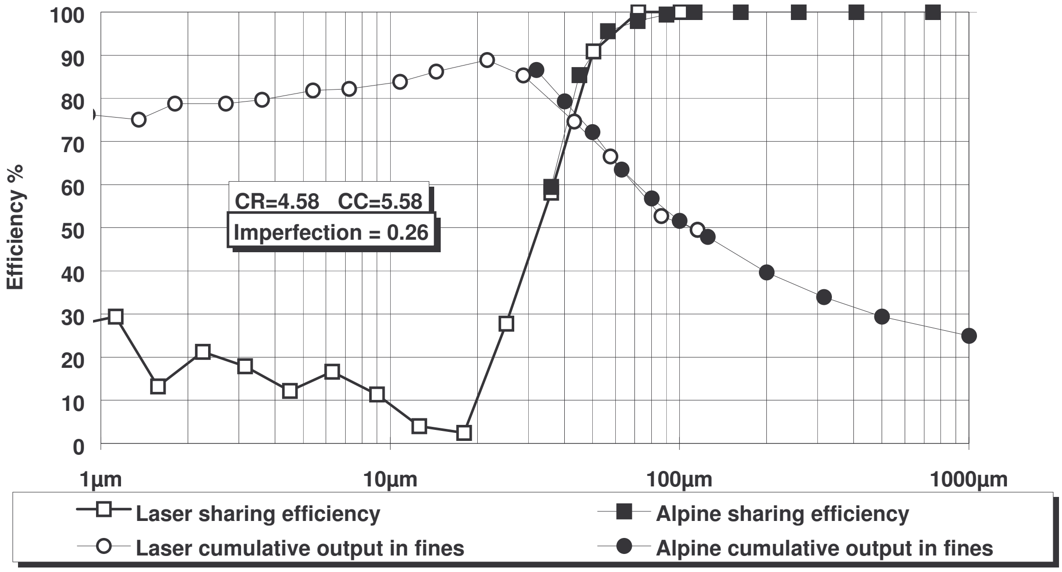


Figure 25 : TSV® output from the Trino grinding plant for a 140 t/h feed

An important element of the TSV® is that when the material load is increased, the cutting diameter barely varies at all, thus ensuring the finished product very high regularity.

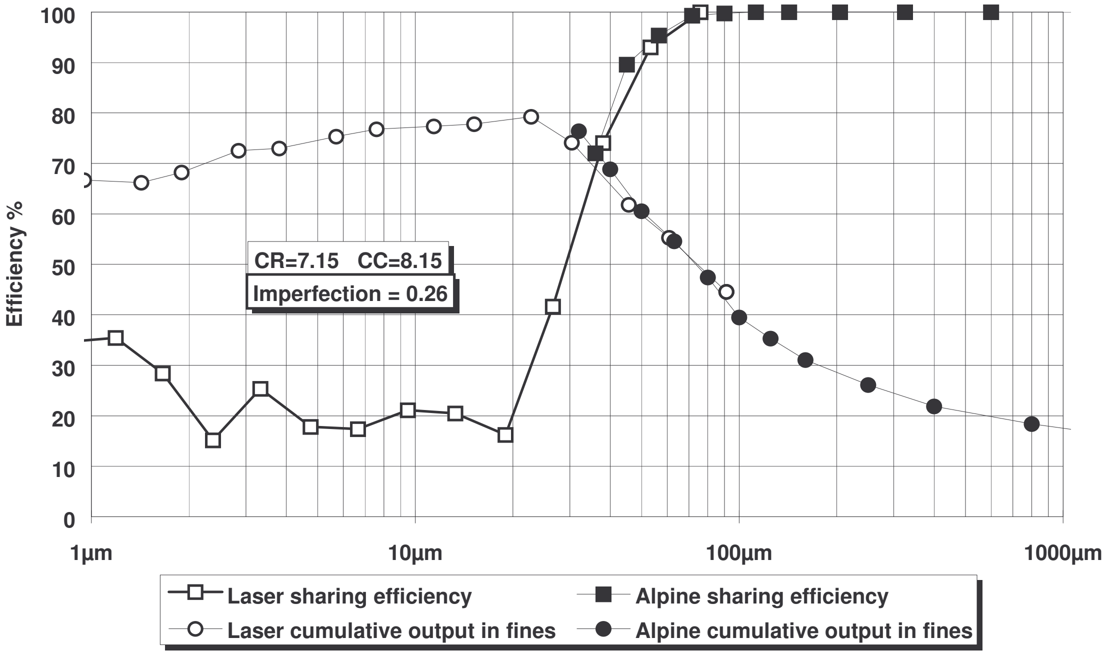


Figure 26 : TSV® output from the Trino grinding plant for a 220 rev./hr. feed

The comparison in performance for a TSV® for different material loads (shown in table 5), demonstrate that loading the classifier has more or less barely any effect on its sharing curve except for perhaps the by-pass. It is remarkable to be able to feed the TSV® up to 3.2 kg of material per m^3 of gas without deteriorating the selection output significantly.

Table 5: TSV® performance comparison for different material loads

Feed	t/h	220	140
Throughput gas	m^3/h	69000	69000
Material load	kg/m^3	3.2	2.0
Recycled LoadL		7.1	4.6
R8µm	%	70.4	70
Dcut	µm	33	33
Reduced imperfection		0.26	0.26
Global by-pass	%	16	2
Pressure loss daPa		160	110
Turbine power	kW	14	9

4. Energy Performance

4.1. *Specific separation energy*

The following table provides the average values of specific energy depending on the type of grinding plant.

Tableau 6 : Specific separation energy

Material	Coal	Raw materials from cement works	Cement (~3000 Blaine and dcut=35 µm)	Cement (~4000 Blaine and dcut=22 µm)
Turbine kWh/t	0.15	0.15	0.25	1.1
Ventilation kWh/t	0.9	0.9	1.2	2.5

The ventilation power indicated corresponds to the share of absorbed power of the draught fan due to classifier pressure loss.

4.2. *Saving energy in the TSV® grinding plants*

4.2.1. Tube mills

The following table gives an account, for tube mills, of the grinding output with respect to the FCB Index, depending on the classifier used.

Tableau 7 : Grinding output with ball mills

Installation	Material	Classifier	R90 %	R100 %	cm2/g	Output σ
Gaurain Ramecroix	coal	TSV® 1600 air-swept	7.6			1.11
Joppa	raw	1st generation + Stat	16.2			0.80
Sth Ferriby	raw	1st generation + Stat	8.9			0.90
Martres-Tolosanne	raw	TSV® 3600 mixed		6.1		0.97
Martres-Tolosanne	raw	TSV® 3600 mixed		1.6		1.18
Ankara	raw	TSV® 5000 air-swept	9.6			1.07
Average inst.	cement	Open circuit				0.75-0.85
Average inst.	cement	1st generation				0.80-0.95
Average inst.	cement	2nd generation				0.85-1.00
Average inst.	cement	3rd generation				0.90-1.05
Port la Nlle	cement	TSV® 3600 with volute			4280	1.01
Safi	cement	TSV® 3600 top-feeding			3120	1.05

It has been observed that in plants equipped with the TSV®, the output obtained is practically always very close to 1 or even considerably higher than 1 for criteria in R90 or R100 thanks to the very small amount of imperfections obtained.

For cement grinding plants, the average values correspond to a great number of industrial reports, part of which have already been published [1]. These ranges are quite large and vary from one designer to another.

4.2.2. Vertical mills for coal

The following table indicates the substitution rates for vertical mills for coal, depending on the classifier used.

Table 8 : Substitution rate for vertical mills on coal

Installation	Classifier	R80 %	R90 %	d80 µm	τ
Beaucaire	Static	17.4			1.55
Halyps	TSV® 2000	8.1			2.04
Halyps	TSV® 2000			62.9	1.92
Hope	TSV® 2000		3.4		2.3
Hope	TSV® 2000			61.9	1.68

It is to be observed that the installation of a TSV® saves about 30% in energy for a given R80. For this type of installation, the TSV® presents a number of additional advantages such as:

- regularity of the finished product
- absence of coarse grains in the fines (favourable to combustion, less pollution)
- better operation of the grinding at the dynamic level as well as for the absorbed power.

5. The TSV2 : an adjustable imperfection classifier

If the absence of by-pass is a quality that is forever sought, this may differ for the imperfection of specific products. It is also interesting to control the classifier's sharing curve to be able to obtain a bigger grain size of the finished product while maintaining a maximum grinding output thanks to minimum by-pass.

To reach this objective industrially, two classifiers must be installed in parallel or in a series which cut at two different meshes.

FCB has just developed and patented a new TSV® model which allows this function to be performed with only one classifier: a TSV® with no by-pass and adjustable imperfection.

The principle consists in controlling, with only one turbine, two gaseous flows at different speeds which set two different cutting meshes. The classifier's sharing curve is then the combination of two output curves which correspond to these two cutting diameters.

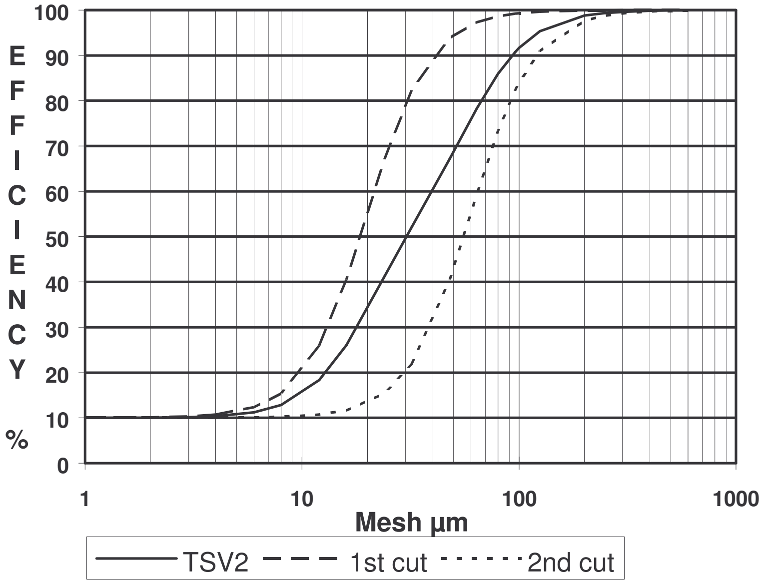


Figure 27 : Schema of the TSV2 Sharing Curve

Tests on hard limestone run on the first experimental model of the TSV® of 1 m in diameter have shown the following significant results:

Table 9 : TSV® and TSV2 comparison

Classifier	TSV®	TSV2
Feed (t/h)	7.7	7.9
Product (t/h)	2.0	2.2
Dcut µm	67.8	79
Imperfection	0.27	0.32
Global by-pass	8 %	8 %

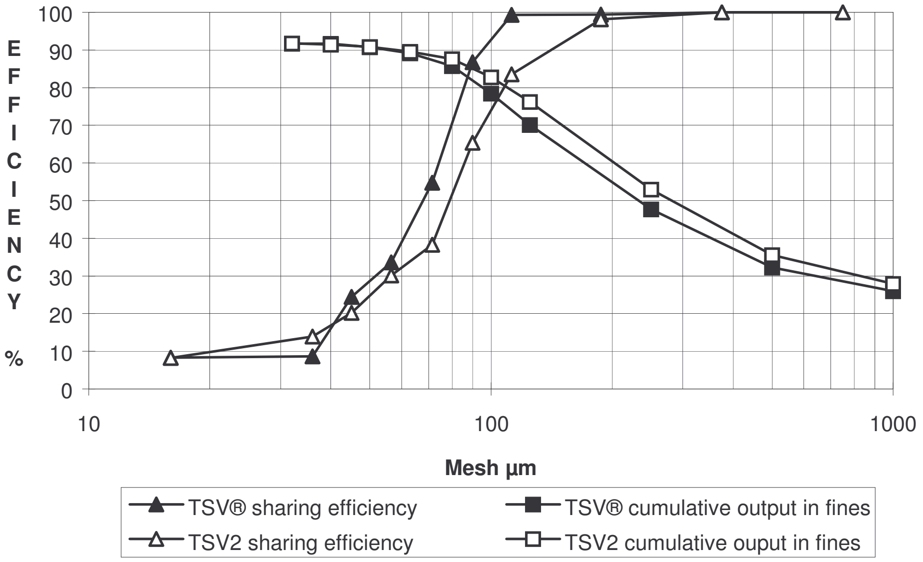


Figure 28 : Sharing curves for the TSV® and TSV2

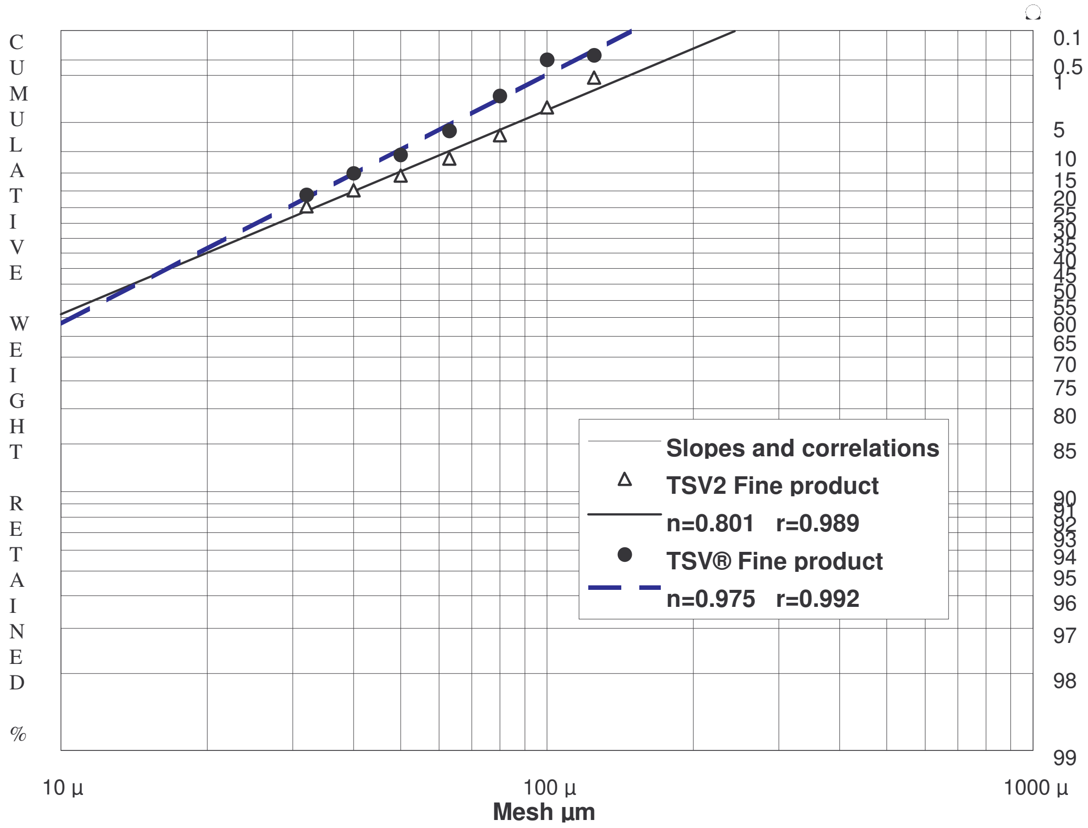


Figure 29 : Rosin-Rammler diagrams for the TSV® and TSV2

Greater imperfection is obtained with the same global by-pass for the TSV2 with respect to the TSV®. The Rosin-Rammler diagram shows weaker distribution for the product from the TSV2, which stresses the fact that the grain size of the product is greater.

The industrial model is currently undergoing technological development.

6. Conclusions

Over the past five years, the TSV® has undergone vast industrial development, putting into practice its performance for very different products (cement, raw material from cement works, coal, ores, etc.) as well as its great ability to adapt to all types of grinding circuits (ball mills, traditional or air-swept grinding, vertical mills, Horomill®, etc.).

The different examples which have been presented demonstrate TSV® performance with respect to by-pass as well as to imperfection, even with high material loads.

As regards energy, the TSV® shows high-rate performance through its impact on the energy performance of grinding as well as through its own energy consumption for selection.

A new TSV® model, the TSV2 allows for direct imperfection adjustment of the sharing curve without increasing by-pass, thus opening up new perspectives for the control of the grain size curve of the finished product.

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