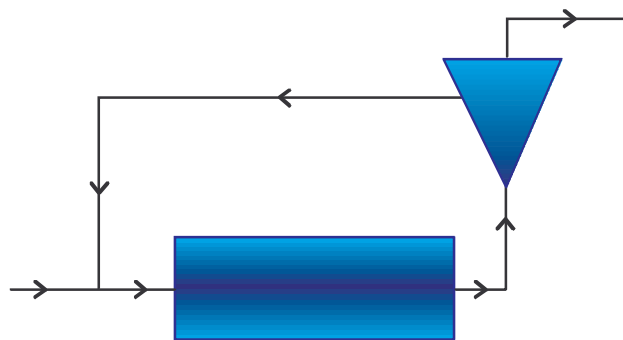


# Grinding Plants

## Optimization and Modelling

(CEMTECH 93 , St Petersburg)



**Alain Cordonnier - Christophe Obry**

## 1. Introduction

For the last few years, FCB has conducted extensive research works in the grinding field and particularly in the digital simulation of the ball mill. A portion of these works performed in that time in cooperation with *Société des Ciments Français* has been presented during the "study days on new grinding techniques and energy savings" on October 25 and 26, 1989 in Paris and was published by the review "World Cement" in August and September 1991. This publication exposes the underlying theoretic principles for the modelling and simulation of any grinding circuit equipped with a ball mill.

After completion of these works, FCB was endowed with two new tools :

- ✓ A precise, accurate and reliable grindability test (FCB Index) fully representative of the comminution process as it occurs in an industrial ball mill. This test permits to define the relative efficiency, called  $\sigma$  (sigma) of a grinding plant with respect to the FCB Index :

$$\sigma = \frac{\text{FCB Index Specific Energy}}{\text{Industrial Specific Energy}}$$

- ✓ A computation program for the simulation of grinding plant with ball mill, including a new formulation of the grinding functions. This programme takes into account all configurations and operating conditions of an industrial plant (classifier, ball charge and classifying, ventilation, etc..).

Today we are able to bring a number of complementary improvements concerning the last theoretical developments as well as the results obtained on the field.

Finally, the success achieved in all cases where we applied the modelling has enabled us to define two investigation methods now routinely used.

## 2. Theoretical Advances

### 2.1. Blaine Model

#### 2.1.1. Objective

Digital simulation is based on the computation and the evolution of the different particle size distributions in a circuit, but ignores the concept of the Blaine specific surface area which is the most generally used criterion in ciment grinding. It was therefore important to be able to compute the Blaine value directly from the complete size distribution. In fact, simple correlations (Blaine vs.  $R_{8\mu}$  and other) are insufficient because they do not take into account the size grading homogeneity (Rosin Rammler slope, for instance) which depends on the plant (classifier, circulating load, etc.).

### 2.1.2. Means

A systematic study of the correlations between the Blaine specific surface area and the size distribution for different products has shown that it was impossible to achieve a model independent of the material being investigated. The solution requires a complement of calculation in addition to the grindability test (FCB Index) and to the determination of the S and B function (see figure 1).

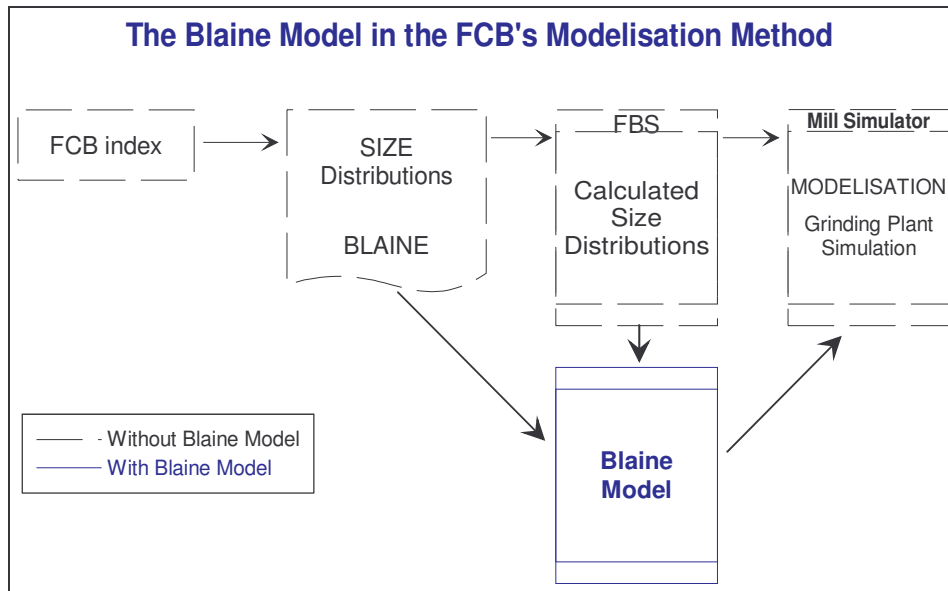


Figure 1 : The Blaine model in the modelling method

In fact, the FCB Index gives, for standard conditions, a set of measured values (grainsize distribution and Blaine surface area) covering the considered range (cement of approx. 2000 to 4000 Blaine). These data are then consolidated (FCB Index examination and calculation of the size distribution by FBS: first modelling step). This permits to secure both parameters of the Blaine model on consistent data.

### 2.1.3. Conclusions

- The Blaine model completes the characterization of the investigated material.
- Entered in our ball mill simulator, it enables us to associate the corresponding Blaine value to all calculated size distributions.
- We can now impose on the simulator to search for a circuit solution which permits to produce a given Blaine value. For instance, if the Blaine value and the circulating load are first selected, the simulator shall determine the classifier setting and the end product throughput, as the operator of an industrial circuit would do.

## 2.2. Partition Curve Model of size classifiers

FCB has developed, tested and now validated a mathematic universal formulation of the partition curve of a classifier (see figure 1). This function gives the efficiency value  $R_i$  for the mesh  $X_i$ . It consists in the combination of two sigmoids (S-shaped curves): one curve describes the size while the other describes the fines bypassing.

The parameters of this function have a physical meaning :

- Mc : separation mesh of the classifier
- Pt : slope
- Ms : separation mesh of the fines bypassing
- Pts : fines bypassing slope
- St : maximum fines bypassing
- Stg : global fines bypassing

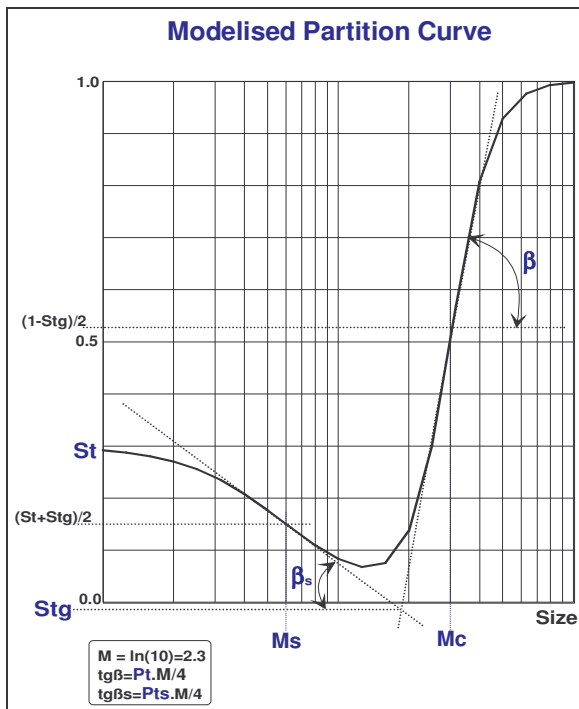
Their meaning is shown on the figure 2. The figure 3 shows us to which extent the parameters enable us to simulate any classifier type.

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

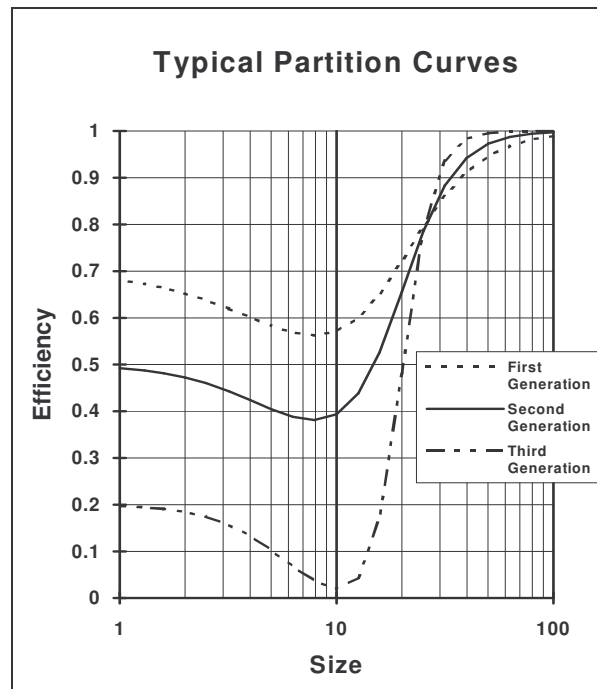
$$Avec: Str = \frac{St - Stg}{1 - Stg}$$

**Figure 1 :** Universal FCB's formula for efficiency calculation.

	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

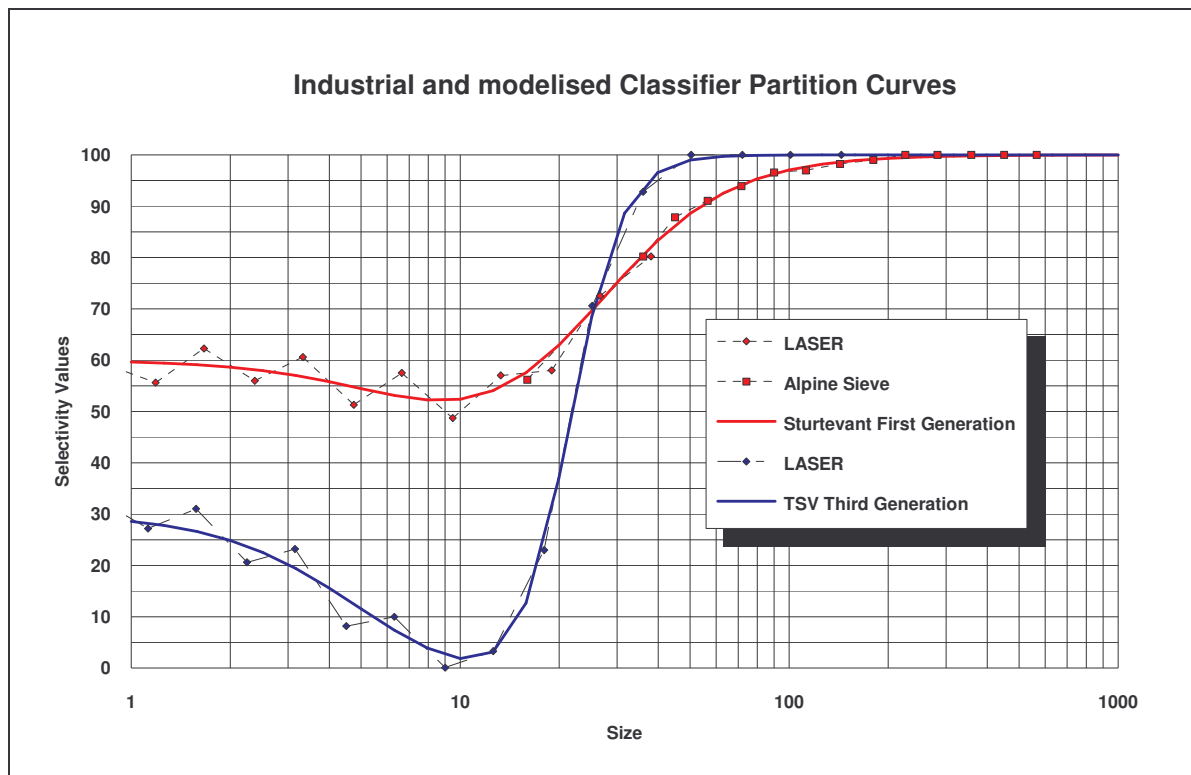


**Figure 2 :** Parameters Meaning



**Figure 3 :** Modelling of the three classifiers generation

Two practical cases of partition curve modelling from industrial size distributions are summarized in the figure below. The curve for the Sturtevant classifier is an example of a first generation classifier, while the other curve (TSV) shows the third generation FCB classifier.



### 2.3. Residence time distribution

The operation balances of different existing industrial plants achieved during the simulator validation period showed that the material flow in a mill is a very complex process closely dependent on the mill design.

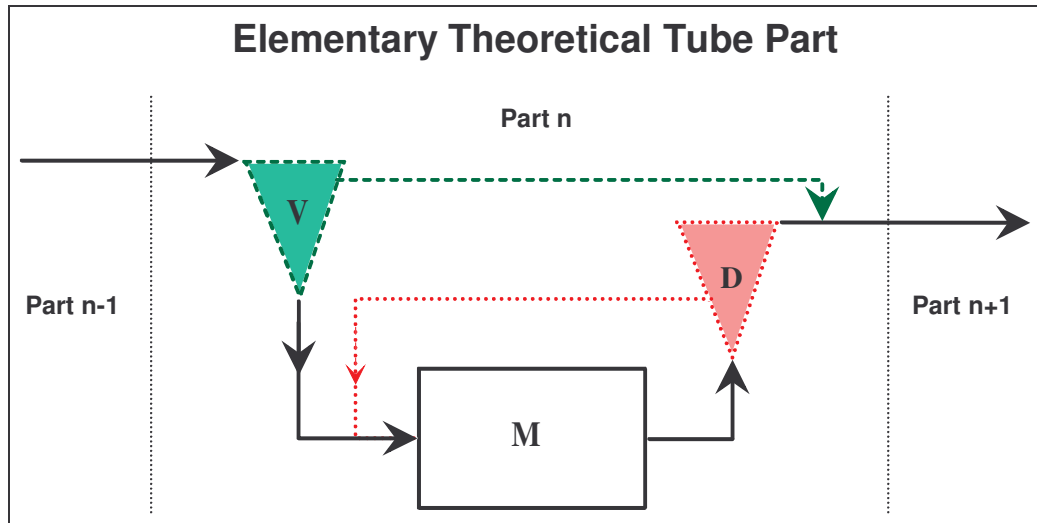
In fact, in an industrial mill, the flow is not at all of the "plug flow" type, but presents an important mixing ratio; in practice, the mill can be assimilated to a succession of perfect mixers with each a length-to-diameter ratio of about 0.5.

This approach is however complicated by other phenomena :

- ✓ Air sweep in the mill which causes a differential advance of the fines with respect to the coarser sizes.
- ✓ Ball coating tendency with slowing down and overgrinding of a fines portion.
- ✓ Mill overfilling which shows itself in a portion of the material passing through the mill without being ground.
- ✓ Partition effect which not only locally increases the gas velocity and the quantity of air entrained material, but also screens the material.

These different phenomena are simulated as follows :

- The mill is split into several elementary sections.
- Each elementary section is equipped with two virtual classifiers which permit to simulate the different points above mentioned.



V : Simulation of ventilation and/or bypass (overflowing)

D : Simulation of a grate and/or coating

M : Elementary mill section assimilated to a perfect mixer.

This sectional mill approach has permitted a simple and modular programming of the simulator and gives a high flexibility of use.

### 3. Modelling on the field

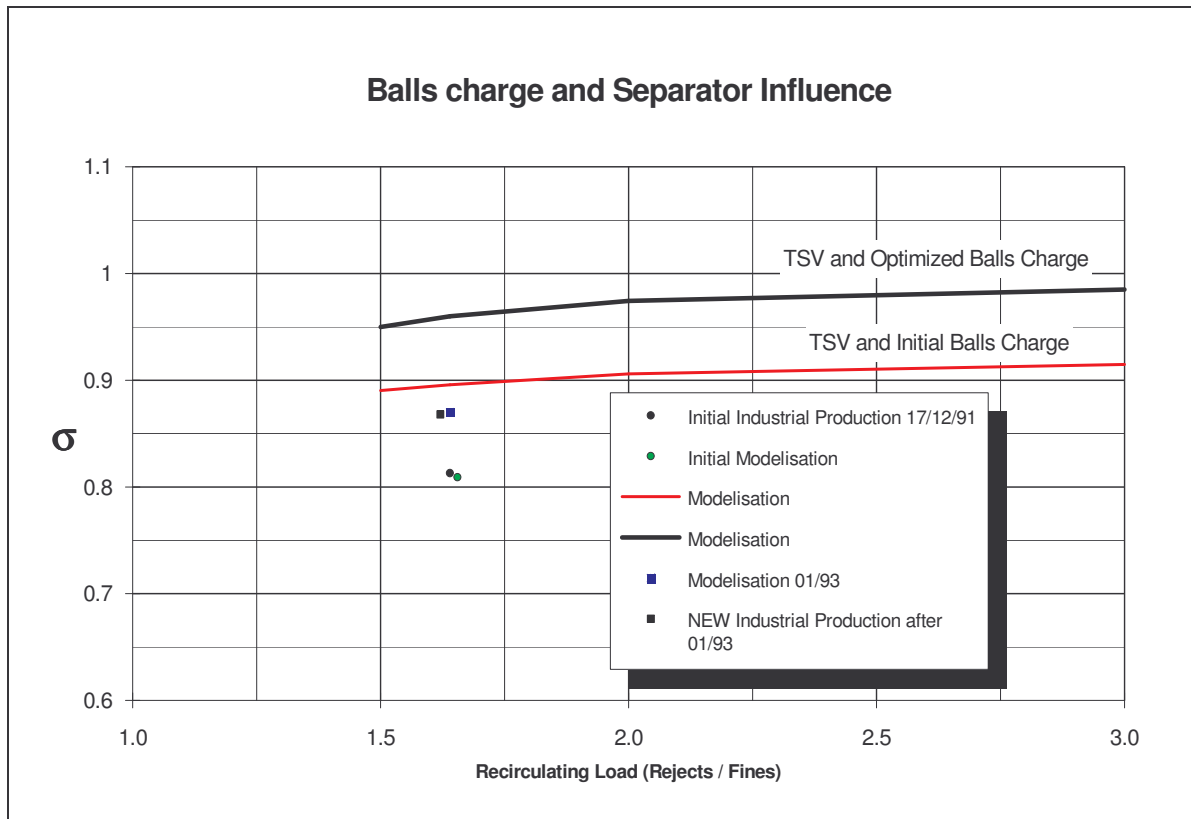
#### 3.1. Ball Charge Recommendation

For a Belgian cement producer who want to optimize the operation of his grinding plant for a cement of 3700 Blaine with 48.5 % slag, we have achieved a complete modelling including a balance of the industrial operation, a simulation of the existing plant and several theoretic simulations whose purpose was to find solutions for production increase. These simulations have lead to two concrete proposals :

- Recommendation of a new ball charge
- Installation of a TSV classifier instead of the two first generation Sturtevant classifiers.

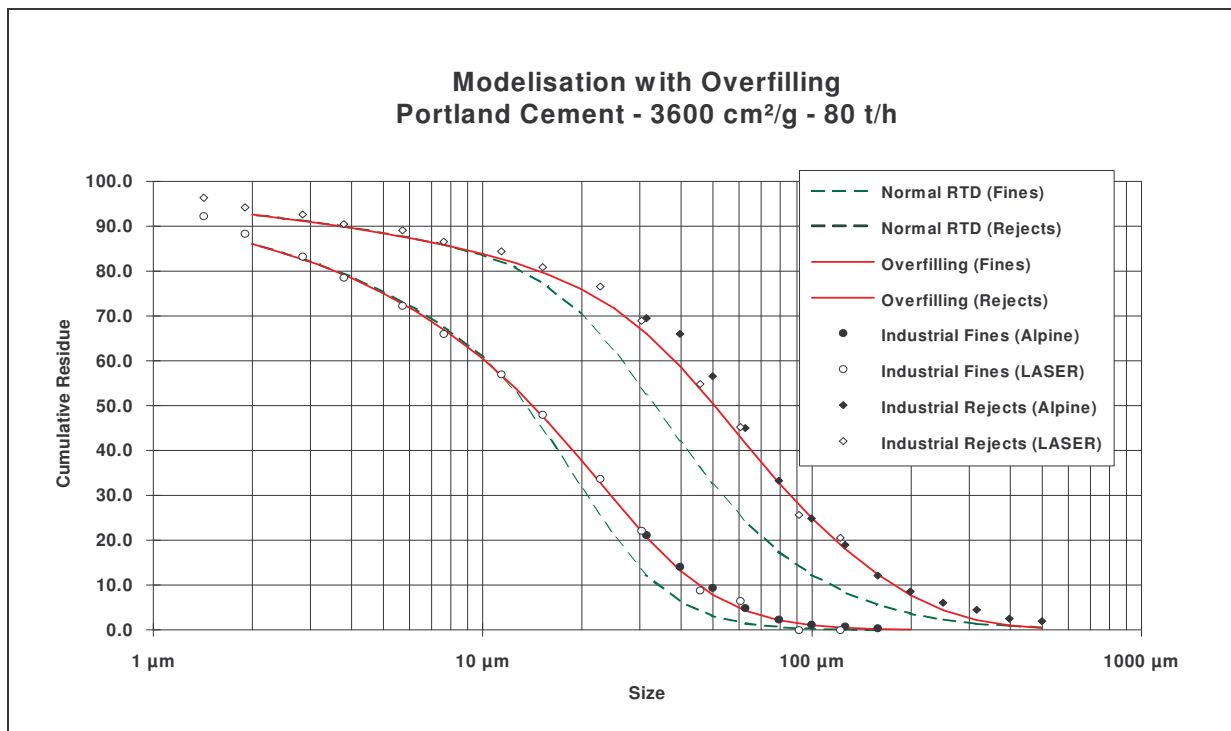
We had predicted a potential gain of 7.2 % with the new ball charge. The operator has modified the charge in compliance with our recommendations. Today, statistics for more than 6 months of operation show an average gain of 7 % with this new charge of grinding balls !

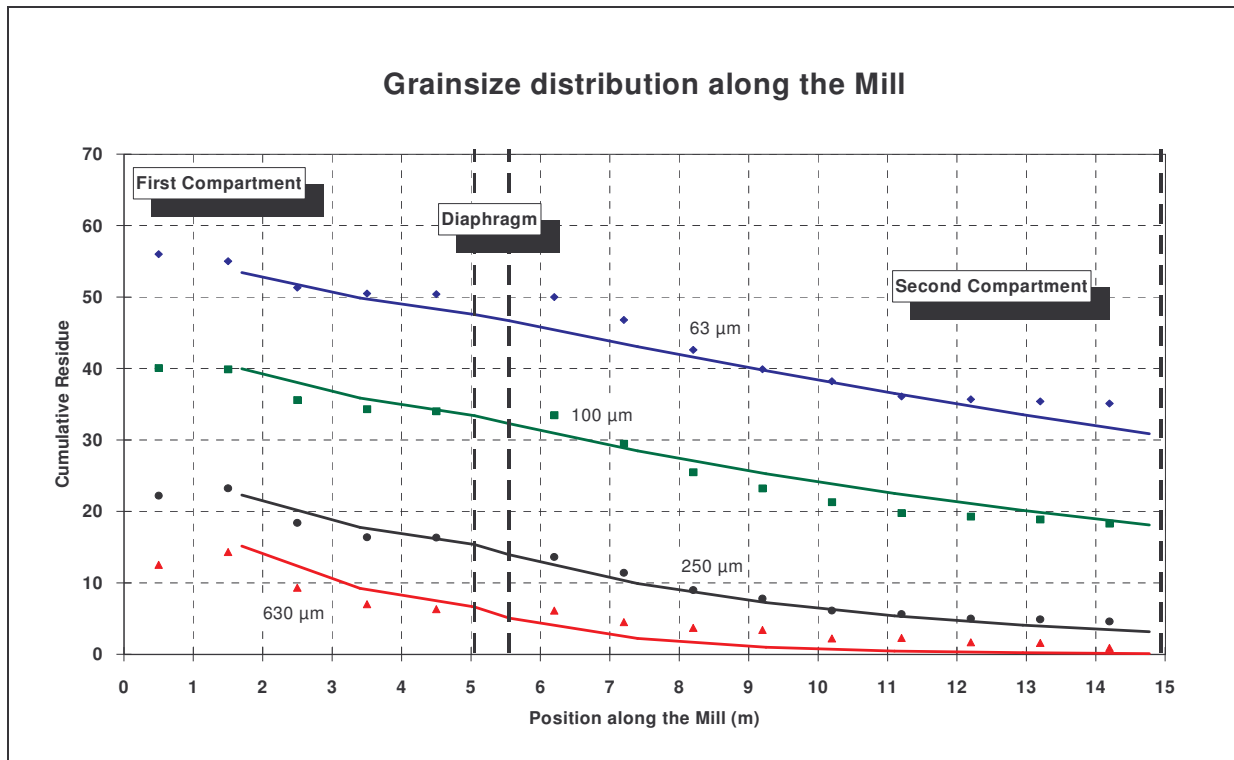
For the classifier, we can predict and ensure an additional gain of 10 %. We have no feedback from industrial operation yet because the change of classifier is still in the project stage.



### 3.2. Grinding with "overfilling"

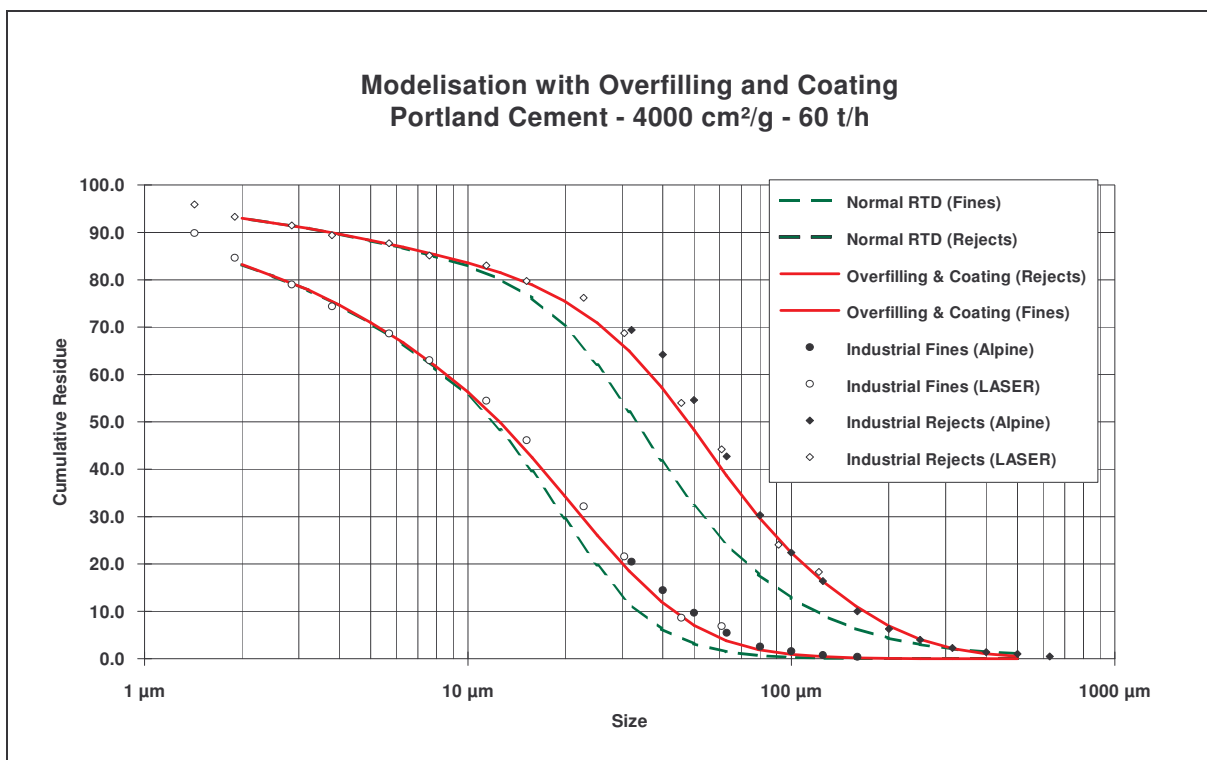
When modelling a classical grinding plant for the production of portland cement in Canada, we identified and quantified overfilling in the second compartment. This has been achieved with theoretical "V" type classifiers (see figure of par. 2.3) of the elementary sections of the second compartment. With a very high accuracy, we have then retrieved not only the grainsize distributions in the circuit but also in the mill.





### 3.3. Grinding with balls coating

A grinding plant for Portland Cement with 20 % limestone has enabled us to go still further in the simulation of malfunctions. There was an important overflowing in the second compartment, but in spite of the integration of this parameter (as for the above mentioned grinding plant in Canada), the simulation was not fully satisfactory. The simulation was correct only after integrating in the model the problem of ball coating which had been shown by the plant operation balance. In this case, the theoretical classifiers used in the simulation are of the "D" type.

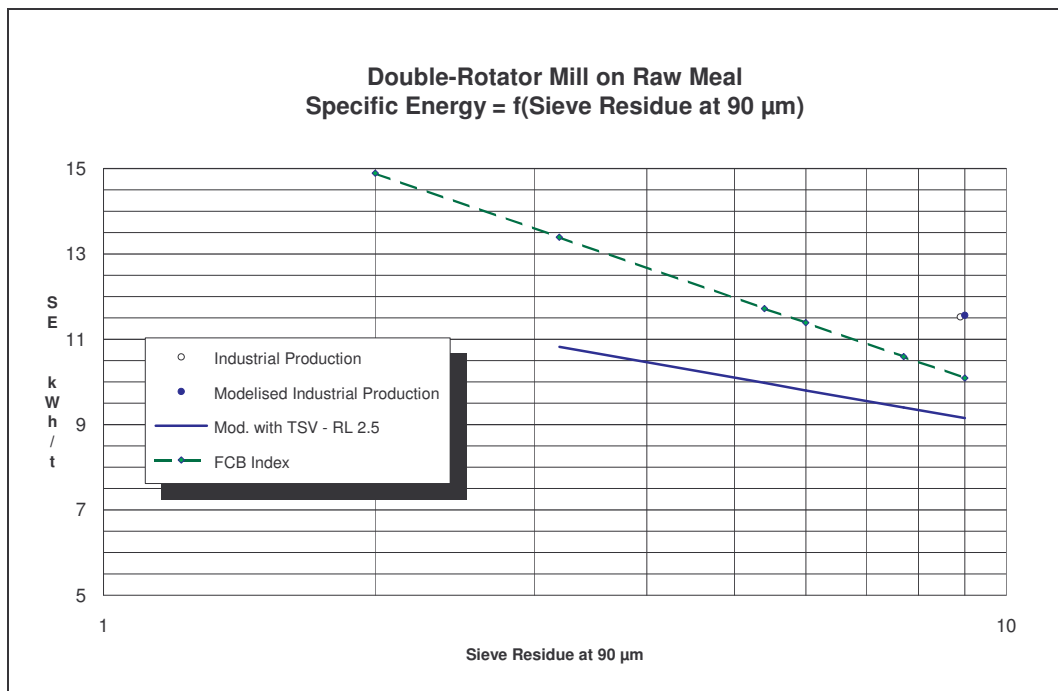


The modelling of these malfunctions (coating and overfilling) of course permits to get a better understanding of the operation of the investigated plant, but also to quantify the effects on the throughput and the finished product, and therefore to objectively assess the benefit of a considered modification.

### 3.4. Quantifying the influence of a classifier

#### 3.4.1. Case of a raw meal double rotator

For the projected installation of a TSV classifier in a raw meal grinding plant in Great Britain, we were lead to model a more complicate circuit equipped with a double rotator. The simulation of the existing circuit was in all respects consistent with the industrial operation balance. The simulation permitted to quantify the possible production increases to be achieved by the installation of a TSV classifier and the optimization of the ball charge.

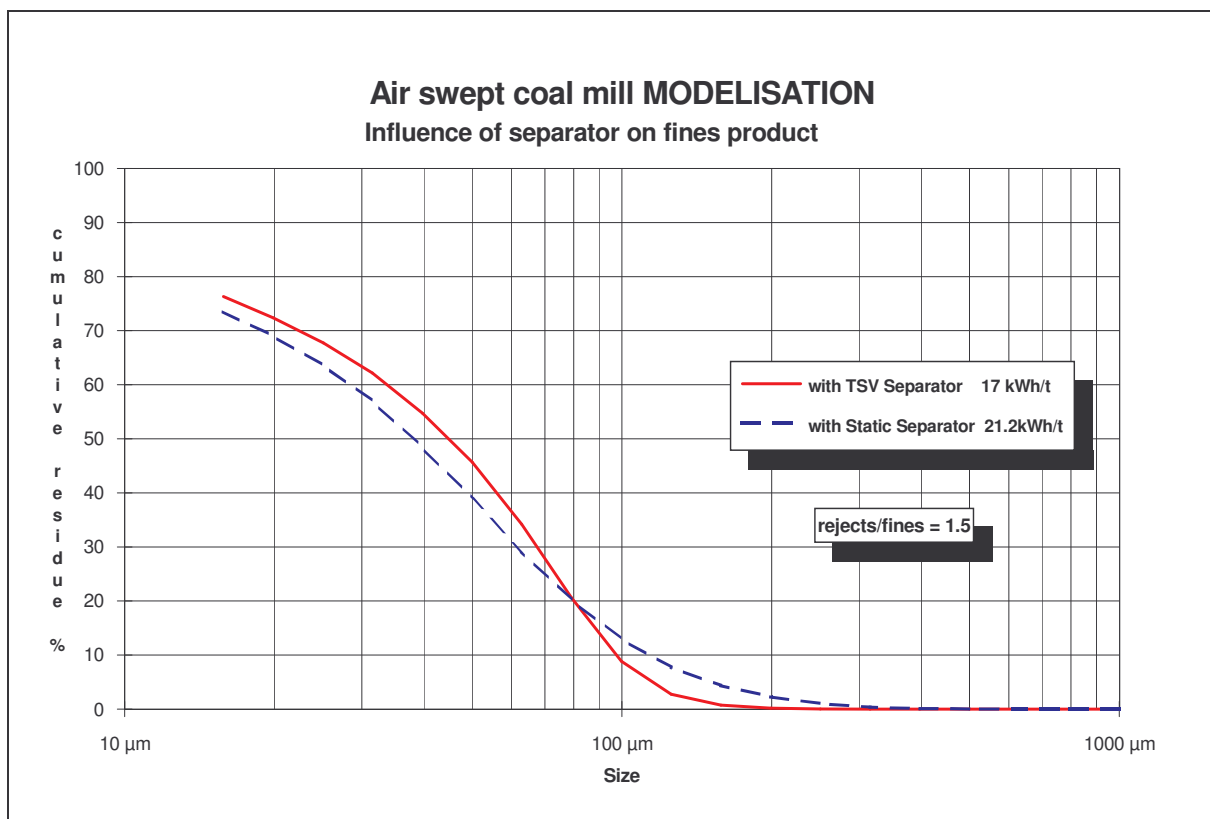
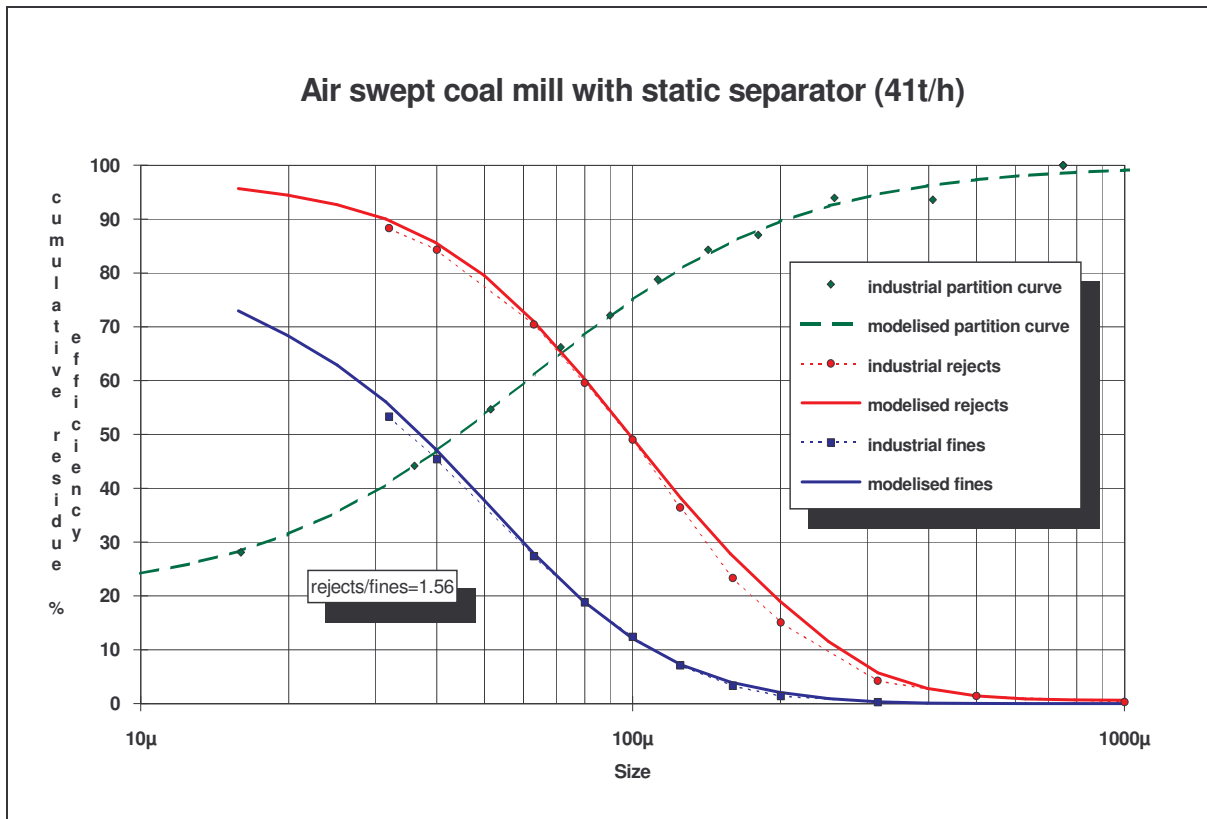


#### 3.4.2. Case of a coal grinding plant.

The simulation of two coal grinding plants in the steel industry has been performed to investigate and quantify the advantages of dynamic TSV classifiers instead of existing static classifiers. They were air-swept FCB ball mills with pneumatic extraction of the finished product at outlet.

The model proves to be quite able to simulate this type of mill with a very high ventilation (3 to 4 m/s in the tube) which modifies the residence time distribution strongly. A perfect consistency is obtained with the grainsize distributions in the circuit as well as with the throughput.

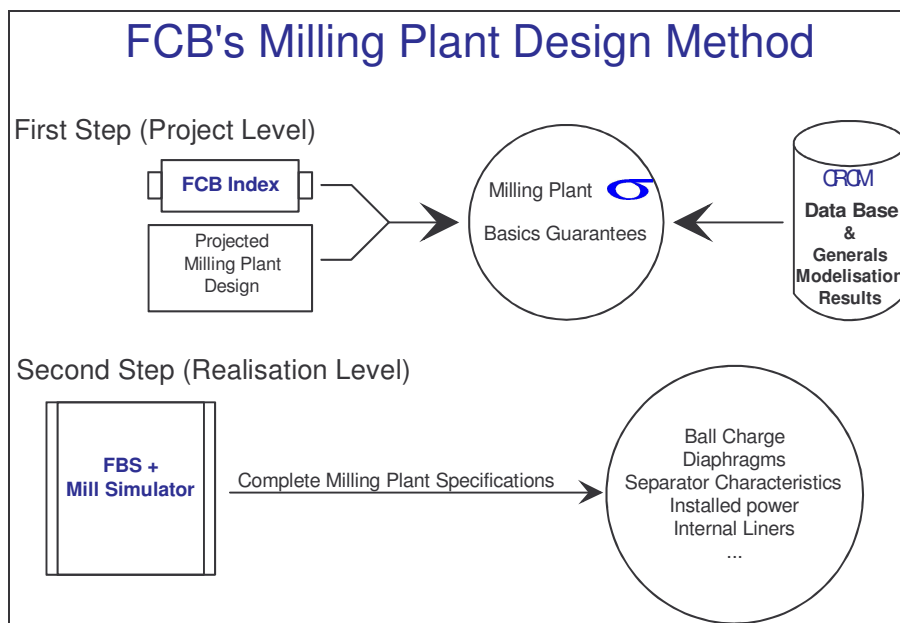
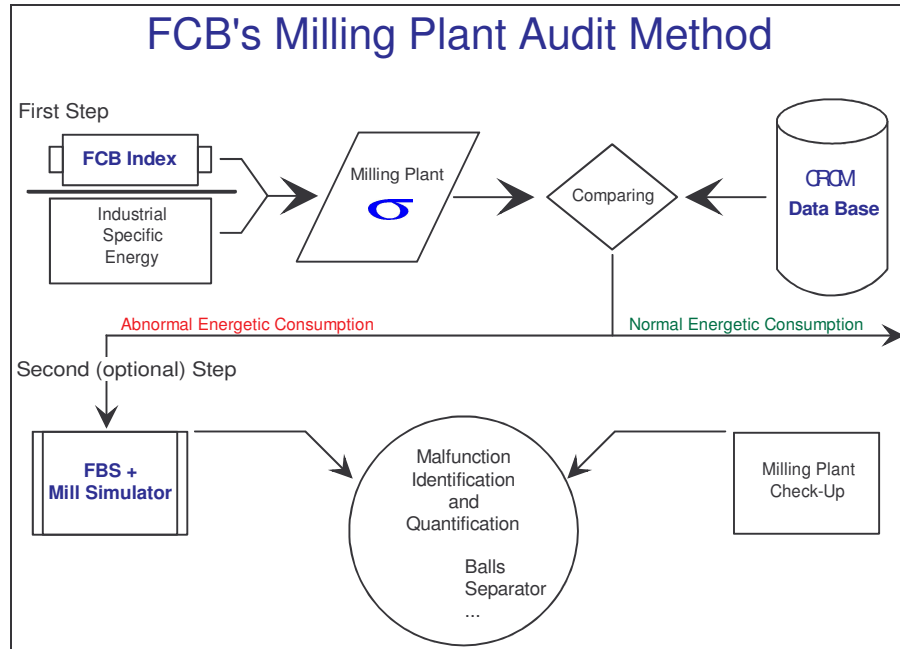
The simulation permitted to quantify the impact of a TSV classifier on the throughput of the grinding plant and on the size distribution curve of the finished product. Thus for the same d80 of 80µ and a constant circulating load, the TSV classifier brings a 25 % throughput increase and gives a finished product with a closer size distribution; 40 µ oversize has gone up from 48 % to 54 % while 160 µ oversize has gone down from 4.3 % to 0.7 %.



The installation of both TSV classifiers was carried out on the end of 1992 and has confirmed the calculations.

## 4. FCB investigation methods

Two methods are presently routinely used. The first is related to the audits of existing plants for equipment optimization or replacement. The second permits to precisely define a new plant in the project and construction stages.



It is very important to note that all grindability data of the material are determined by the grindability test (FCB Index) and that the simulator is able to determine the throughput without any required "securing" of the model by means of an industrial operation balance.

The industrial operation data are only used in order to take into account the specific features of the circuit

:

- Separation curve of the classifier
- Possible troubles such as overfilling and coating
- Ventilation in the mill.

## 5. Conclusions

- ✓ The model is reliable for any configurations encountered in the grinding plants for cement or other materials.
- ✓ The model allows for the simulation of plants with malfunctions. We do not simulate perfect standard grinding plants only ! We can also simulate and QUANTIFY such complex phenomena as mill overfilling, ball coating or also high air flows.
- ✓ The model can be applied to and is today applied to many materials such as clinker, of course, but also coal, raw mix, limestone, slag, coke, phosphate rock, etc.
- ✓ Stimulated by these results obtained with the classical grinding process in ball mill, FCB will pursue their efforts in the modelling field, in order to extend its scope of application to the bed grinding process. This should give rise to a complementary model which will enable us to integrate not only roll presses to our digital grinding plants, but also new machines based on similar principles. Certain of these machines are in the final development stage at FCB and will be brought to light by the end of this year.