Modelling the minerals diversity: a challenge for ore processing simulation

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1. INTRODUCTION

Since 1986, the Process Simulation Group of BRGM has been developing a powerful software package, USIM PAC [1-3]. It is an easy to use steady-state simulator which makes it possible for the mineral processing specialist to profit by himself from available experimental data to model plant operations, and then find an optimal plant configuration to meet his objectives. Designers of new plants can also work with this simulator to calculate the sizes and settings required to achieve a given circuit objective.

This software package includes functions to manage experimental data, to calculate coherent material balances, sizes and settings of units of equipment, physical properties of the processed material, to simulate plant operations and display results on tables and graphics.

Mineral processing is the industry which transforms the ore issued from the mine or the quarry to a concentrate (e.g., in the case of copper, zinc or lead) or to the final product (e.g., carbonate, kaolin or gold). This industry is characterised by the great diversity in the raw material. This diversity appears through the mineralogical and chemical constitution of the ore or through the variability of its properties (mechanical, chemical or physical properties). Consequently, it involves a great diversity in the processes and in the unit operations (from grinding to leaching, from gravity separation to flotation). Owing to the minerals diversity and the wide range of application, ore processing simulation is a real challenge.

Numerous mathematical models for unit operations are included in USIM PAC and most of the physical and hydrometallurgical treatments of mineral processing can be reproduced by the simulator. The great variety of models (due to the diversity of unit operations and objectives) requires a great flexibility for the simulator.

This approach used both to design the software and to describe a simulation problem can be defined as an *object oriented approach*. A real adaptability has been experienced within a wide range of applications from the mineral processes to other fields such as the hydrometallurgical treatments or the environmental applications.

The aim of this paper is to show the necessary adaptability of the simulator and means to reach it. First, some new concepts are defined to take into account the great variety of material description. Second, the relationship between the mathematical models and this material description is shown. In conclusion, USIM PAC is presented as a new kind of simulator largely centred on the material description.

2. MATERIAL DESCRIPTION

For a steady state simulator, a good material description is as fundamental as a good unit operation model. The great diversity in raw materials, process solutions, unit operations and simulation objectives involves a wide range of simulator applications. So, the material description must be as flexible as possible to take into account this diversity. Consequently, it takes a large place in the simulation approach.

2.1. Example of the diversity

The material description must be able to describe all material flows in a plant such as raw material (ore or contaminated soils), pulp water, additional reagents (not only liquid, but also solid or gas), precipitates. Besides, it has to take into account all the properties necessary to the plant simulator, according to the simulation objective, the choice of unit operation models and the available data. To illustrate this point, let us consider four examples:

1. a preliminary design of a grinding plant,
2. an optimisation of a grinding plant,
3. a grinding and flotation plant,
4. a complete gold ore treatment.

Figures 1, 2, 3 and 4 show the respective manners of describing the material. The raw material is identical in each case but the description is adapted to the objective.

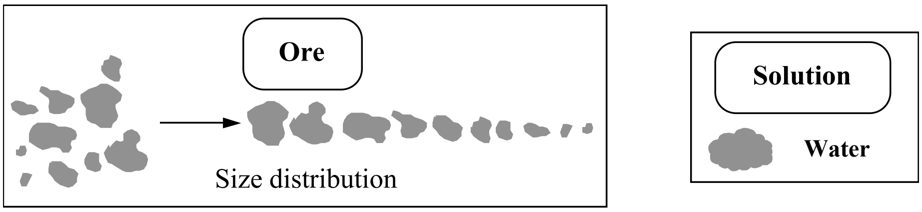

Figure 1. Preliminary grinding plant design.

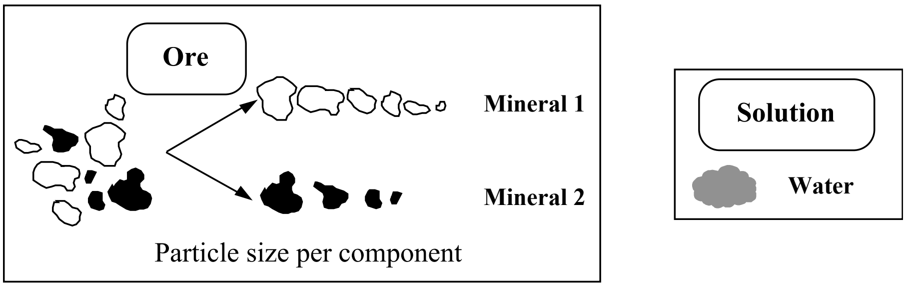

Figure 2. Grinding plant optimisation.

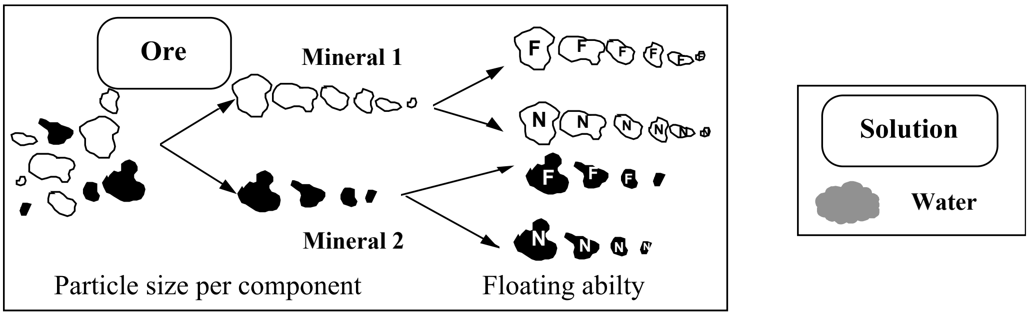

Figure 3. Grinding and flotation plant (F: Floating particles, N: No Floating particles).

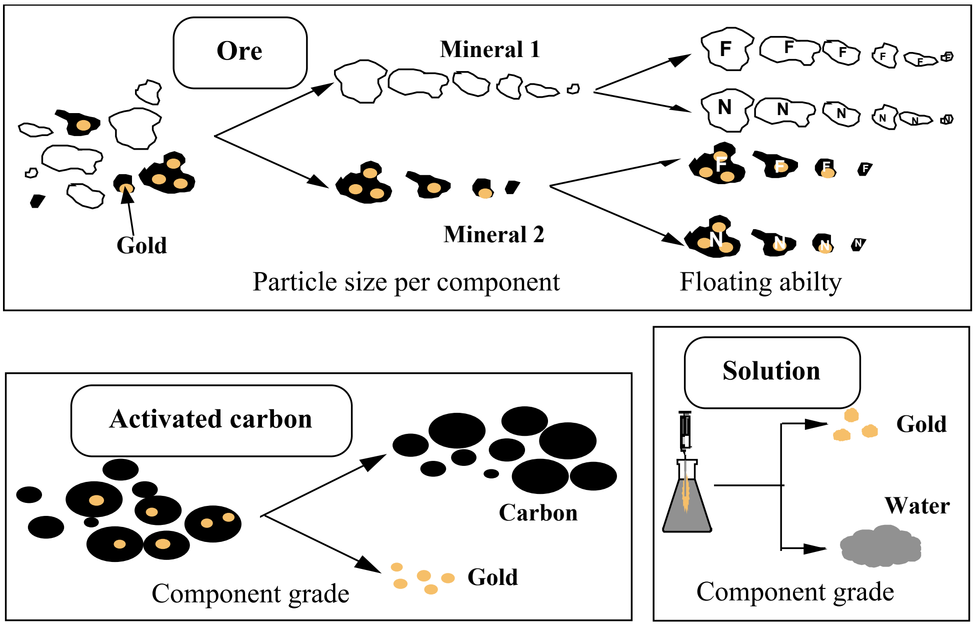

Figure 4. Gold ore treatment plant.

Material is divided into physical phases: solid (ore, activated carbon) or liquid (solution). Phase material can be classified by particle size, mineralogical or chemical composition or floating properties.

2.2. New concepts

To describe the material, we define four new general concepts:

- *phase*,
- *classification criterion*,
- *description hierarchy*,
- *physical property*.

In USIM PAC, four phase types have been predefined: ore, solid, liquid and gas, which describe the matter in terms of physical phases (i.e., solid, liquid or gas). The special type *ore*, classified as solid, may include specific properties that the other solids (such as carbon, resin) do not need. The flow material will be first described in terms of phases.

A classification criterion represents a description parameter type, i.e. a way to classify the material according to a property, an analytical method or a statistical population distribution. The classification criteria currently used in USIM PAC are the mineralogical or chemical composition, the particle size and the floatability. For each criterion, a set of classes is defined (such as components, size classes, floating abilities). For each phase, a set of classification criteria is predefined.

A description hierarchy defines the criterion application order to describe finely the material. This hierarchy can be use to describe the material flowrates in the flowsheet in terms of partial flowrate according to the application of some criteria (0, 1 or more). In USIM PAC there are now five flowrate description hierarchies:

- *phase flowrate* (no criterion),
- *size distribution* (particle size),
- *component grade* (composition),
- *component grade per size* (particle size and then composition),

– *floating ability per component* (composition and then floating ability).

These hierarchies generate arrays per stream of the plant flowsheet. The first hierarchy generates a 0-dimension array which contains the global phase flowrate. The second and third generate a 1-dimension array while the forth and fifth generate a 2-dimension array, each of them containing partial flowrates.

A physical property describes a material property for the entire phase, for each class of a classification criterion or for a combination of these classes. It is similar to a description hierarchy but it generates a unique array of data (located with the material description). Currently, there are only two physical properties in USIM PAC:

– *phase density* (no criterion),
– *component density* (composition).

These new concepts generates a set of *objects*. These objects are assembled to built the material description. Table 1 shows these building for the four examples.

These general concepts permit an easy extension to other application fields.

Example	Phase	Criterion	Hierarchy and property
Preliminary grinding plant design	Ore	Particle size	Size distribution
	Solution		Phase flowrate
Grinding plant optimisation	Ore	Particle size Composition	Component grade per size
	Solution		Phase flowrate
Grinding and flotation plant	Ore	Particle size Composition Floatability	Component grade per size Floatability per component
	Solution		Phase flowrate
Gold ore treatment plant	Ore	Particle size Composition Floatability	Component grade per size Floatability per component Component density
	Solution	Composition	Component grade Phase density
	Activated carbon	Composition	Component grade

Table 1. Material descriptions of the four examples.

3. RELATION WITH MATHEMATICAL MODELS

In fact, a unit operation model is using a material description adapted to the type of this unit, the theory used and its objective. This local material description is a restricted part of the entire description required for the whole process. Only this restricted description is understood and used by the model. A *peripheral layer* has been developed to translate the entire material description of the input streams into a material description devoted to a particular model and, conversely, to translate the restrictive material description of calculated output streams in the entire material description according to a set of rules based on the material conservation and some heuristics.

To illustrate this point, let us consider an example: a screen model. The global material description is that of the Figure 4 and the forth part of Table 1 but the local material description used by the model is largely different.

A screen is a unit operation witch separates coarse and fine particles by sifting (Figure 5) with water addition. It has one input and two output streams.

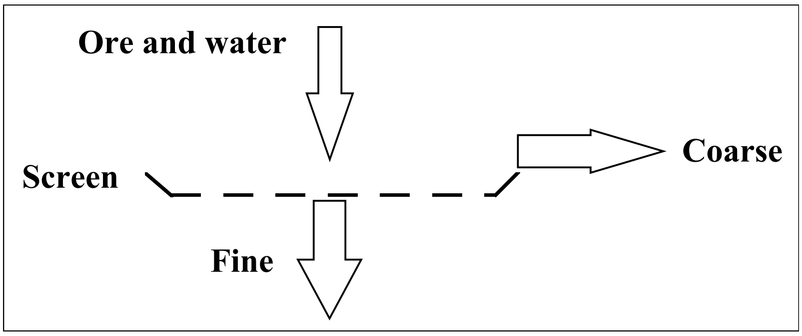

Figure 5. The screen model.

As shown on the Figure 6, the screen model does not process the *activated carbon* in gold ore treatment. It uses only the *particle size* criterion and the *size distribution* hierarchy of phase *ore* and the *global flowrate* hierarchy of phase *solution*.

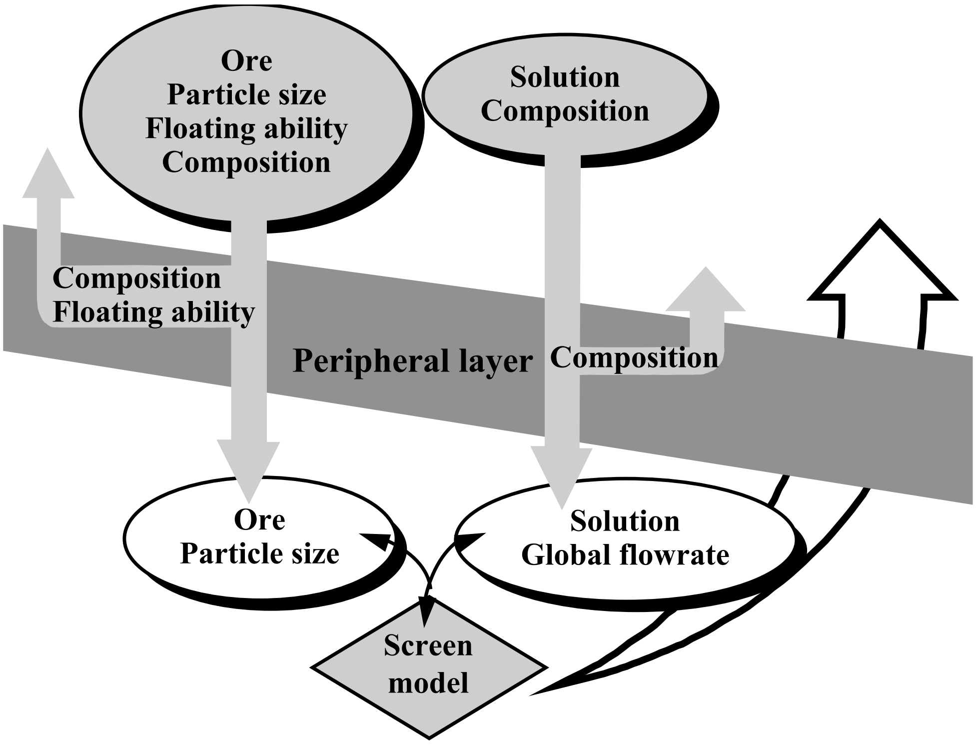

Figure 6. Exchanges between a screen model and the stream material description data.

The translation between the global material description of the simulator and the local material description understood by the model is made by the *peripheral layer* in the two directions.

The *component grade per size* hierarchy array of phase *ore* in the input stream is contracted by summation along components to give the *size distribution* hierarchy array to the model. Conversely, the *size distribution* hierarchy arrays calculated by the model are expanded to give the *component grade per size* hierarchy arrays to output streams. This expansion is made by distribution, in each size class, of partial flowrate between components, relatively to the component grades of the input stream and some predefined rules. In the same phase, the *floatability per component* hierarchy arrays of the output streams are calculated relatively to the global flowrate partition and rules. The translation of the phase *solution* obeys the same rules.

Each unit operation in a plant have its own local material description different from each other. The global material description must be a union of these local descriptions.

A set of rules has been defined to manage the default behaviour in the peripheral layer. This set can be modulated by some instructions, about material conservation, given by the model to the peripheral layer, such as *no size distribution conservation* in the case of a grinding model. The translation rules are also related to a couple of description hierarchy (global and local) in a phase type. So, the default behaviour is particularly adapted to the set of material description object building.

4. CONCLUSION

The minerals diversity needs a great adaptability for the simulator. The definition of new concepts and an object oriented approach for the material description, as well as the development of a peripheral layer to translate the global material description of the simulator to the local description understood by each unit operation model, form an original approach for a steady state simulator. They give to USIM PAC a great adaptability in a wide range of applications. So, this new kind of simulator is largely centred on the material description.

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