CONCEPTION AND ANALYSIS OF SENSIBILITY AND RISK OF IRON ORE TREATMENT PLANTS USING TECHNIQUES OF STATIC AND DYNAMIC [1]

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Abstract

Mineral process simulation technology is consolidating more and more in the day by day of mineral process engineers, operation and planners, for the diagnosis of circuits, plants projects, equipment sizing, material balances, sensibility analysis and risk of iron ore treatment plants. The stationary simulation of mineral process can easily generated flowsheets with coherent and realistic mass balances through phenomenological mathematical models that represent the performances of the several existent unitary stages in an iron ore treatment plant. Using more complex mathematical models it is possible through retro-calculation to size the equipments and to estimate the investment cost. Using the static simulation it is possible to vary flowsheets and characteristics of the ore that feeds the plant accomplishing with extreme agility a sensibility analysis and risk for several flowsheets options. The dynamic simulation performed with a specialist system and mathematical models to represent the varies unitary options, enables to analyze the performance of the plant for a lifetime of the mine in a short space of time, obtaining precisely the global recoveries, the production of reject, etc.

Key words: Simulation; Conceptual project.

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1 INTRODUTION

The objective of this work is to show the techniques and methodologies of static and dynamic simulation for conception and analyze of sensibility and risks for plants of iron ore improvement, using modern simulation softwares.

A modern simulation software should has a good base of mathematical models, a friendly interface work, it should integrate complete flowsheets, to possess an open structure with module of mass balances and great presentation of results, with outputs in tables, drawings and graphs.

The mathematical modeling of mineral process is not recent subject. There is some time the first works already appeared (Fulford & Pei - 1969; Bender - 1978; Jacoby & Kowalik - 1978; Herbst & Mular - 1979, among other), and in the end of the 70's it was placed at the market the first simulation softwares. Initially these models were used for project and optimization services. With the progress of the computation, the development of this technology happened in a natural way, with the increase of the publication of works presenting new and enhanced mathematical models, and on another side it went being developed a simulator structure accessible to the user.

A mathematical model is an equation, or a group of equations that defines, scientifically, knowledge of a physical or chemical process. It can basically be define three types of models, the theoretical ones, the empiric and the phenomenological.

The theoretical models reflect the principles established scientifically, by the physics and chemistry laws, or physical-chemistry, for instance the transport phenomena.

The empiric models are the simplest and it was developed starting from experimental or industrial data, generated in the several unitary operations. These usually express the performance of the process making use of the method of linear regression calculating, for example, the data of a size distribution curve of crusher's product in certain operational condition. The models reflect peculiar process with a great number of data industrially collected. Those that use partition curves of classification process are typical examples. In spite of some specialists not accept these models, the same ones are usual, easy, and represent a good level of knowledge of the process.

The phenomenological models are developed starting from the description of the process mechanism associated to the degree of influence of the physical parameters of the process. These models are powerful, constituting a realistic representation of the process. In this category there was the largest development of works in the last years. We can mention as example those that describe the grinding operations based on the kinetic theory, and more recently those that describe the flotation operations.

The simulation has as objectives the following aspects:

1. To supply a qualitative and quantitative formal structure for understanding of the process;
2. To supply a good base of data for planning and evaluation of laboratory tests, pilot plant, or existent circuits, for determination of the process parameters and scale-up criteria and definition of the control strategies;
3. The simulation makes possible great capacity of analysis of the process, besides agility and costs reduction, for flowsheet definitions, operation, control, optimization and capacity increase;
4. It constitutes excellent tool for teaching, learning and training.

The simulation offers great advantages, mainly when the program of tests is repetitive. The experimentation in laboratory and pilot plant presents, usually, a great number of results with mistakes due to factors of difficult control, which can be avoided in the simulation. The table 1 mentions some advantages of the use of this technology and the benefits associated with the use of this powerful tool:

Table 1 – Advantages and Benefits of Simulation

ADVANTAGES	**BENEFITS**
➪ It can be investigated the effect of different flowsheets and operational variables under controlled conditions, without interference in the production;	♂ It is possible to plan laboratory tests and pilot plant with more objectivity to identify and to solve potential problems, saving time and resources;
➪ It can be evaluated answers, extrapolating or interpolating data of the process of known conditions;	♂ It makes possible the identification of problems in start-up operations;
➪ It can be analyzed the sensibility and stability of extreme situations, under safe conditions;	♂ It makes possible the study of changes in the flowsheet without the need of alteration of the industrial equipments and without production reduction;
➪ It supplies a formal and consistent base for decision-making in relation to the randomness of casual studies;	♂ It allows an optimization of the performance of the plant, with minimization of operational costs and maximization of the available resources;
➪ It is an extremely agile tool, with significant earnings in time and resources.	♂ It allows a consistent and systematic data analysis for economical evaluation in definition studies and process alternatives and flowsheet.

Simulation process based on models can be divided in two types, when the factor time is involved. This way the simulation can be static or dynamics.
The static simulation is a software package capable to predict the operation of the plant in agreement with the characteristics of the feeding of the ore and of the circuit. The prediction of the water and ore streams, and other phases of a statistically operated plant under given conditions is called direct simulation. The retro-calculation of the plant configuration (such as size of the required equipment) to obtain a given plant operation condition is called reverse simulation.

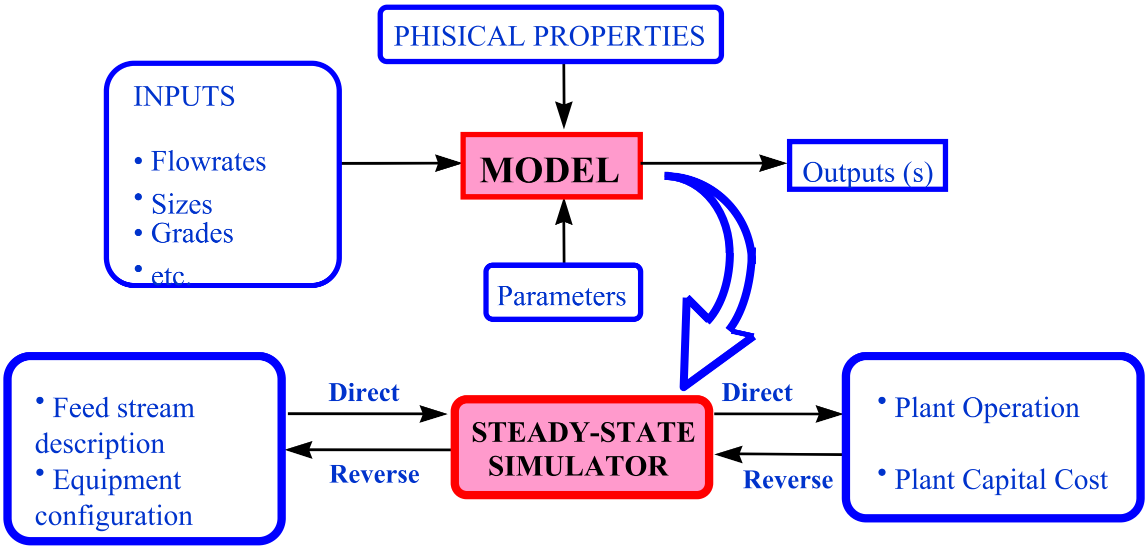

Figure 1 – Static Simulation Basis

Static simulation is an essential tool for plant design and optimization. The static simulation is typically employed to optimize the circuit design and to define equipment sizing before setting a pre-control system.

Static simulation is also an effective approach for plant design as it provides several possibilities, such as:

- a large amount of hypothesis can be taken into account in the flowsheet conception, equipment etc;
- process equipment and the unit operation for material handling can be designed;
- an industrial plant optimum configuration can be achieved in a very short time.

The evolution generated by the availability of these process simulators has been very pronounced and resulted in changes in the planning and supervision process of pre-industrial assessments. Traditionally, these were produced on a small scale in all the possible configurations for the new industrial plant. In the future, it is suggested that simulation will be the basic tool for the selection of most unit operations within a production circuit taking into account the chosen design and operational goals.

USIM PAC 3.1 is one of these softwares and it was produced by BRGM - Orleans - France and represented in Brazil by CEMI - Consultoria em Engenharia Mineral. It was projected for engineers in industrial operations, engineering companies and technical centers involved in the project and improvement of hydrometallurgical and mineral processing plants. Its principal functions are reconciliation of data, plant simulation, optimization, project and cost estimate from crushing to refine.

USIMPAC 3 is a simulator that includes the basic functions requested to apply project methodologies and optimization, such as:

- Facilities in data entry and presentation of results;
- A function for the establishment of coherent material balances. This function proved to be necessary to adjust experimental data before the calibration of the model (HOUYDOIN 1980, Herbst, 1988);
- Direct and reverse simulation;
- Estimate of investment costs.
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2 METHODOLOGY OF THE PROJECT CONCEPTION

The first steps use characteristics of the feeding and the principal production objectives to define the characteristics of the flows of the future plant. Starting from a typical flowsheet and of the characterization of the feeding of the plant, it is used mathematical phenomenological models to represent the unitary performances of the several equipments of the process, and this way, to obtain the detailed description of the flows of the future plant.

Starting from the description of the flows, more advanced mathematical models are used, that consider the dimensions of the equipments, to take place a retro-calculation of that dimensions aiming at the mass balances previously generated. For that sizing it should be had additional information on the ore, as: work index, kinetics, etc.

After the sizing it should be made a technical and economical evaluation of the flowsheet to analyze the viability of the project.

Figure 2, to proceed, shows the methodology to develop a preliminary project of a new plant.

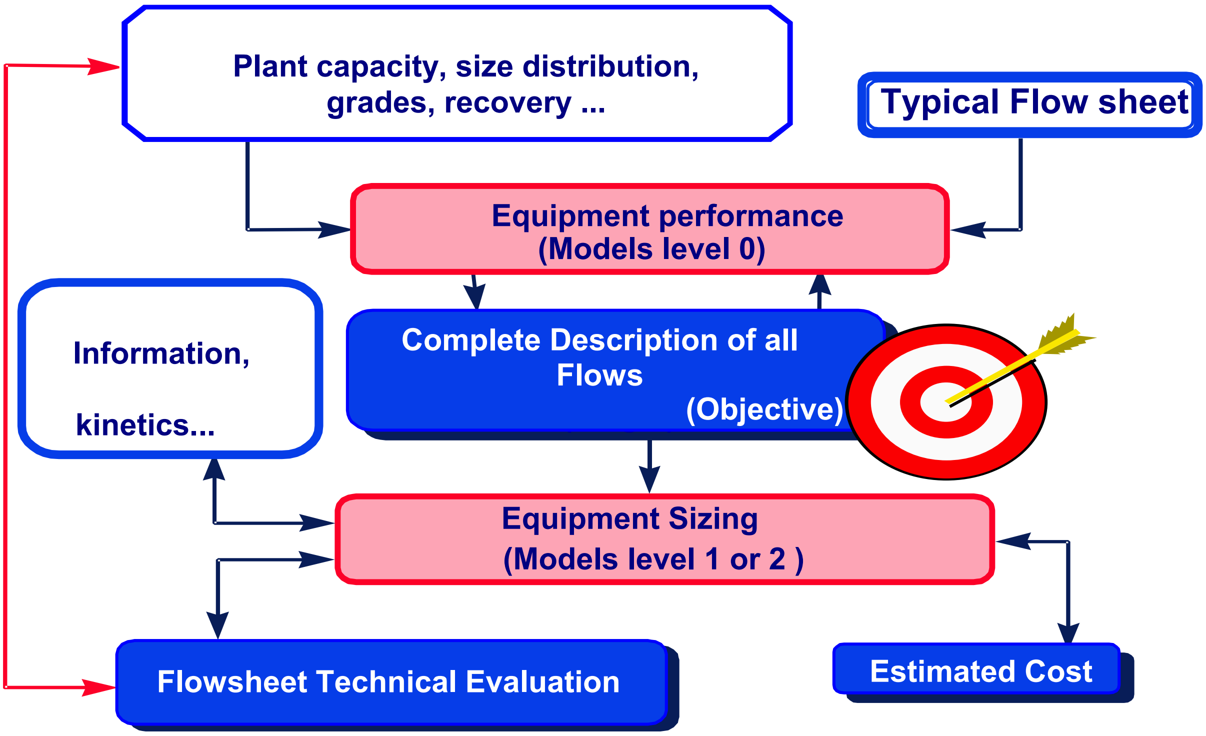

Figure 2 – Project methodology

The simulation allows us, in an extremely agile way, to develop many routes of process. These simulations can easily be compared in subjects related to the recovery, risks, capex, opex, etc. To follow it is presented some flowsheets developed for an iron ore treatment plant, still in stage of conceptual project:

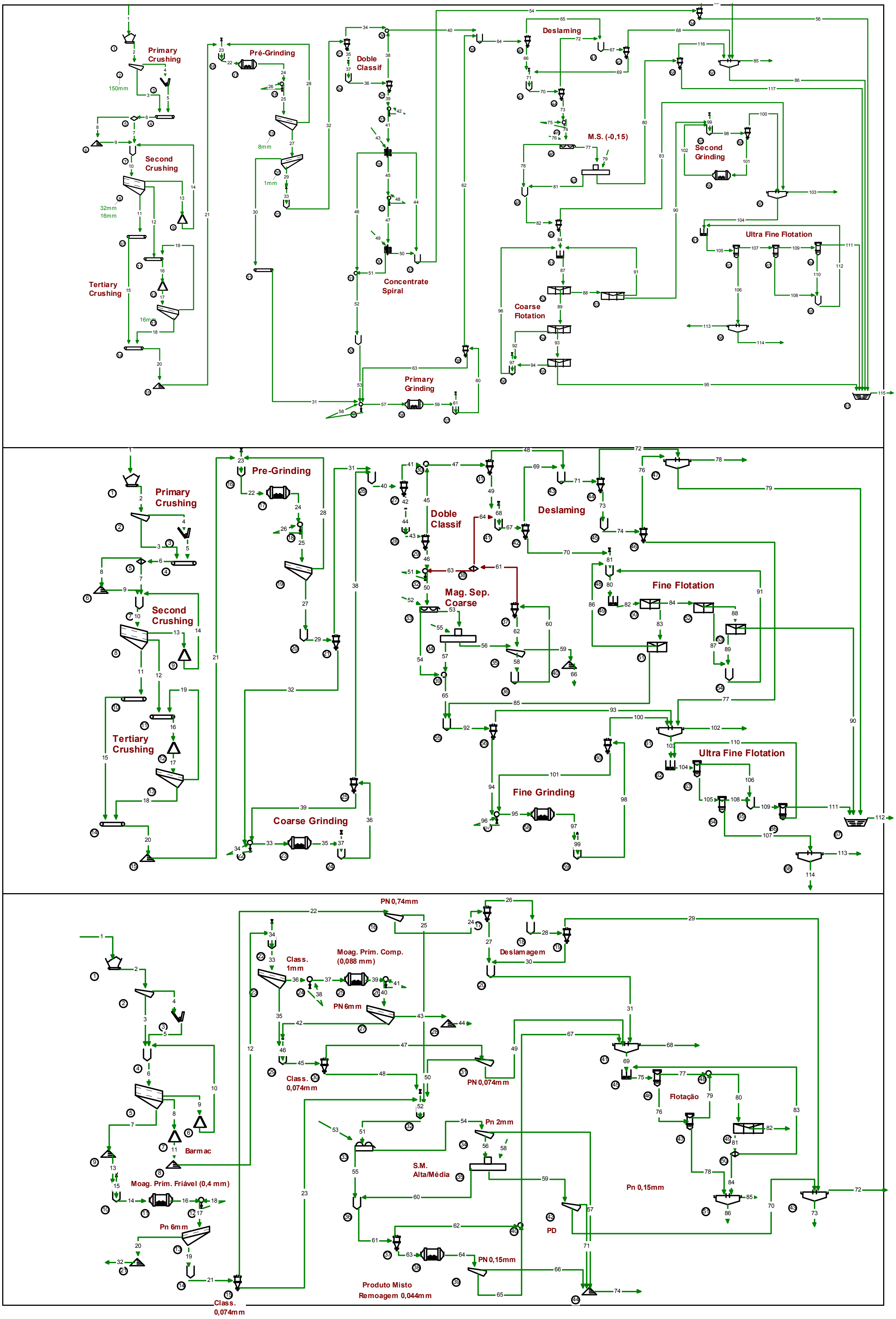

Figure 3: Example of Routes of Process for iron ore

3 SENSIBILITY ANALYSIS

The static simulation is an excellent tool for the analysis of sensibility of a process route. After generating the mass balances with the phenomenological model, the ROM can be varied, so much in size distribution, as in grade and generate several mass balances to verify the different partitions of masses. The figure to proceed, presents an example of the variation of the ROM, so much of size distribution as of grade:

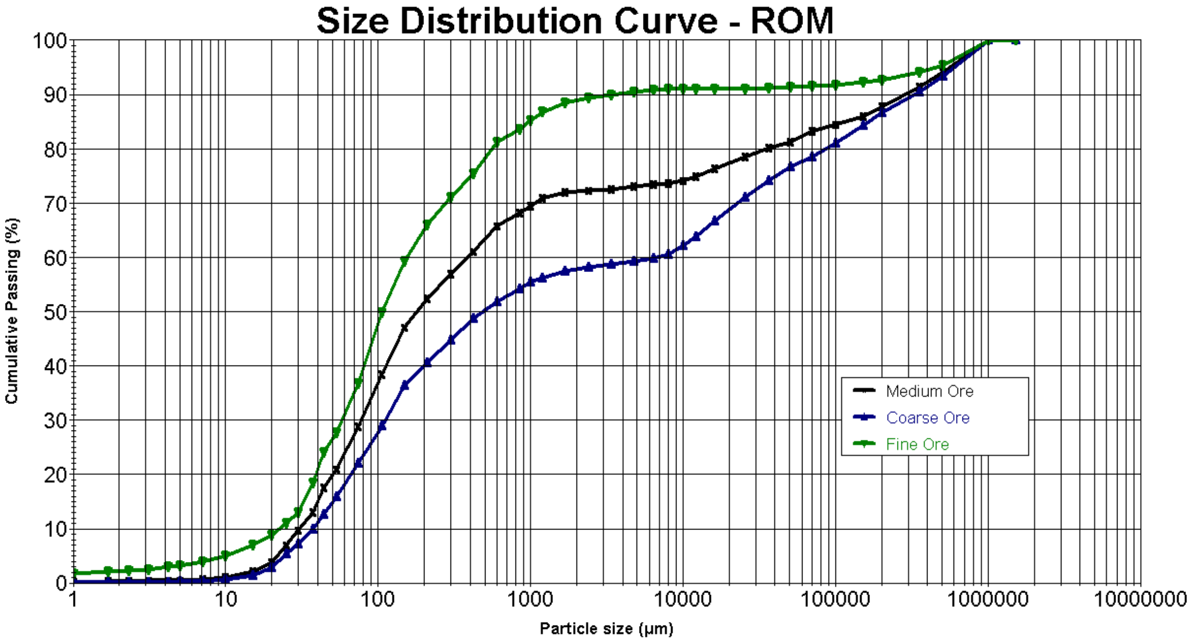

Figure 4: Variation of the size distribution of the ROM

With the results of the several mass balances the different recoveries, size distributions and grades that will feed each stage of the process can be compared. The Table 2 to proceed presents and compares the different mass balances found, for the variation of the ROM in agreement with the previous graph:

Table 2: Analysis of Sensibility with the Variation of the ROM

#	Stream definition:	Recovery Mass (%)			Variation Recovery Relative Opt 40% Fe(%)		Recovery Fe (%)			d80 (µm)			Grade of Fe (%)			Grade of SiO2 (%)		
		35% Fe	40% Fe	45% Fe	35% Fe	45% Fe	35% Fe	40% Fe	45% Fe	35% Fe	40% Fe	45% Fe	35% Fe	40% Fe	45% Fe	35% Fe	40% Fe	45% Fe
1	ROM	113.3	113.3	113.3	0.0	0.0	113.3	113.3	113.3	87739	35112	564	34.9	40.0	45.4	47.2	39.6	31.4
2	Crumbly Ore -16mm Natural	79.2	85.7	94.6	-7.6	10.4	80.6	86.3	93.9	6609	862	443	35.5	40.3	45.1	46.3	39.2	32.0
3	Compact Ore	20.8	14.3	5.4	45.5	-62.2	19.4	13.7	6.1	6747	10122	13629	32.5	38.3	51.0	50.8	41.8	22.0
4	+6 mm - Crumbly Grinding Tail	3.0	2.1	0.8	43.8	-62.3	2.8	2.0	0.9	12057	12535	12861	33.0	38.9	52.8	50.2	41.2	19.3
5	Crumbly Grinding Product	76.2	83.6	93.8	-8.9	12.2	77.9	84.3	93.0	573	371	265	35.6	40.3	45.0	46.1	39.2	32.1
6	Desliming Feed -0,074mm	17.3	21.4	26.8	-19.4	25.1	23.5	27.1	31.8	51	50	48	43.4	48.0	52.5	34.5	27.6	20.6
7	Classification +0,074mm	59.0	62.2	67.0	-5.2	7.7	54.3	57.2	61.3	905	527	390	33.0	37.5	42.0	50.0	43.5	36.8
8	Slimes	1.1	1.4	3.4	-20.5	133.9	1.8	2.0	4.2	9	9	7	33.8	40.2	50.6	47.4	37.4	20.2
9	Fine Natural	16.1	20.0	23.4	-19.3	17.2	21.8	25.1	27.5	52	51	50	44.6	48.8	52.8	33.0	26.5	20.6
10	Compact Grinding Product	20.8	14.3	5.4	45.5	-62.1	19.4	13.7	6.1	553	507	353	32.5	38.3	51.0	50.8	41.8	22.0
11	+6 mm - Compact Grinding Tail	0.0	0.0	0.0	85.7	-85.0	0.0	0.0	0.0	14639	14470	14195	32.5	38.4	52.4	50.7	41.7	19.7
12	Classification -0,074mm	7.2	5.8	2.9	24.3	-49.8	12.1	8.8	4.1	50	44	25	31.7	37.9	52.0	51.8	42.4	20.4
13	Classification +0,074mm	13.5	8.5	2.5	60.1	-70.6	7.2	4.9	2.0	713	679	590	33.4	39.0	49.2	49.6	41.0	25.0
14	MS Feed	72.5	70.7	69.5	2.6	-1.7	61.5	62.1	63.3	831	557	402	33.1	37.6	42.2	49.9	43.2	36.4
15	MS Concentrate	31.6	35.9	40.8	-11.9	13.8	56.7	57.6	58.9	700	502	389	51.8	55.0	57.8	24.0	19.4	15.4
16	MS Tails	40.9	34.8	28.7	17.5	-17.6	4.8	4.5	4.4	903	588	410	8.0	9.8	12.0	84.6	81.4	77.2
17	Second Grinding Product	31.1	35.3	40.2	-11.9	13.8	56.0	56.8	58.1	40	42	44	51.8	55.0	57.8	24.0	19.4	15.4
18	+0,15mm - Tails	0.5	0.5	0.6	-11.7	14.6	0.7	0.8	0.8	173	169	165	53.2	56.1	58.6	22.1	18.2	14.6
19	Flotation Feed	54.5	61.2	66.6	-10.9	8.8	89.9	90.7	89.6	46	46	47	46.5	51.1	55.9	31.1	24.3	17.4
20	Flotation Concentrate	44.2	51.2	57.5	-13.6	12.4	84.3	85.5	84.9	38	40	42	66.7	67.0	67.7	2.1	2.1	1.0
21	Flotation Tails	10.3	10.0	9.0	3.2	-9.6	5.7	5.2	4.7	69	68	67	7.7	10.5	14.7	86.4	81.3	74.2
22	Tails	55.8	48.8	42.5	14.3	-13.0	15.7	14.5	15.1	903	553	329	10.5	13.0	17.7	81.7	77.2	69.3

4 DYNAMIC SIMULATION

The dynamic simulation includes the factor time, generating information of the behavior of the plant along its operation. The dynamic simulator should have the same tools of the more modern static simulation software's, associated with a specialist system. This specialist system is responsible for analyzing each unit of time, what corresponds to a static simulation on that moment, which is happening with the process and execute the most coherent attitude that the operator would execute, this way we can:

- Simulate the global recovery of the plant along the time, with the mining sequence, with the variation of the size distribution, with the hardness of the ore, with the feeding grades of the ROM, etc.
- Identify bottlenecks in the future plant, in the main equipments and in the transports of the ore. In several existent treatment plants, we came across bottlenecks that limit the production, the capacity of the convenyor belts and of the bombs of pulps.

5 CONCLUSION

Using the simulation methodology, static and dynamic, it is possible to obtain in the short term and at low cost a qualitative and quantitative formal structure for understanding of the process. To obtain a good base of data for planning and evaluation of laboratory tests, pilot plant, or existent circuits, for determination of the process parameters and scale-up criteria.

The simulation makes possible great capacity of analysis of the process for flowsheet definitions, operation, control, optimization and capacity increase and constitutes excellent tool for teaching, learning and training.

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