ANALYSIS OF THE PARTICLE SIZE DISTRIBUTION UNDER 500 µm WHEN THEY DON´T MATCH WITH A ROSIN-RAMMLER BEHAVIOUR

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ABSTRACT

In the field of mineral processing es very common the use of the Rosin-Rammler model to analyze the Particle Size Distributions (PSD), especifically in the finer fractions (Austin & Concha, 1974; Austin, 1984; Dabak & Yucel, 1987; Funk & Dinger, 1994; He *et al.*, 2006; Hopkins & Woodcock, 1990; Kim & Luckham, 1993; Klimpel, 1998; Logos &. Nguyen, 1996; Mohanty *et al.,* 2002; Tory & Ford, 2004, and others). This analysis is fundamental to determine critical variables and factors in processes such as classification, grinding, synthesis, and others. The correct evaluation of particle size is vital for processes control and design of materials and industrial processes. Nevertheless, there are some materials that because of their processing, or by their own nature have particle distributions far away of the behaviour defined by the mathematical function of Rosin-Rammler. Other authors as Mianowski (Mianowski, 1988) and Funk (Funk & Dinger, 1994) have proposed mathematical models different of Rosin-Rammler to evaluate this kind of materials, involving variables only with mathematical sense, without any physical meaning. Most of times, Rosin-Rammler´s model and similar expressions (as Harris, Gaudin-Meloy or Schumann distributions) give parameters with physical meaning for the particulate system, as the size parameter k_{rr} and the parameter of dispersion of distribution m. In this sense, this model is better than the others, despite the low prediction in some cases. In this work a new mathematical and physical analysis of several particle size distributions is exposed, for those particle size distributions far away from a behaviour that can be described for Rosin-Rammler model, still with physical meaning.

KEYWORDS: particle size distribution; Rosin-Rammler analysis; classification; grinding.

1. INTRODUCTION

When it´s necessary to evaluate a material for knowing its incidence over a particular process, is very important to know specifically the properties that define the performance of the material. In the field of materials and mineral processing, it was observed that the Particle Size Distribution (PSD) is one of those physical variables most important to have in account, because it defines properties as viscosity, thixotropy or pseudoplasticity (rheological behavior in general), ion exchange capacity, melting point or specific surface area. In consequence, the performance of the materials in any process, depends on the parameters mentioned.

Despite its importance, the available models used to analyze and simulate the tendence of the different particle size distributions, as the very widely used Rosin-Rammler model, are not suitable in some cases. In figure 1 an example of a particle size distribution of a shale generated by fine grinding and a bad approach with Rosin-Rammler model is showed.

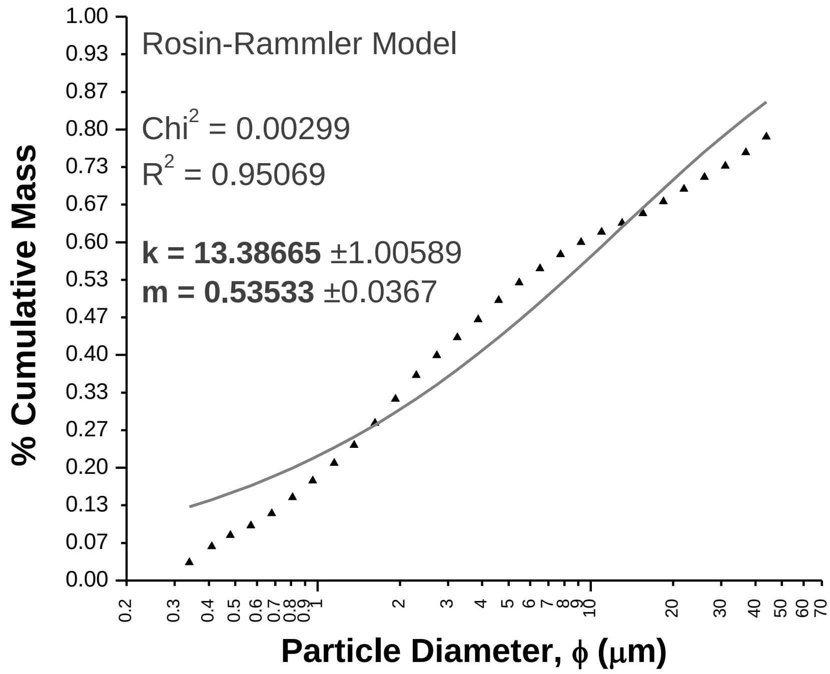

Figure 1. Particle Size Distribution of a shale after grinding analyzed with Rosin-Rammler model.

The Rosin-Rammler model is defined with the following expression:

$$f(x) = 1 - exp\left(-\left(\frac{x}{k_{rr}} \right)^m \right) \tag{1}$$

Where x is the measured diameter of the particle. This model is appropiated in the evaluation of materials because gives the Rosin-Rammler constant k_{rr}, wich is a particle size factor, and the distribution parameter *m*, wich is a factor that describes the dispersion condition of the distribution. This is the true reason because this model is often used over other mathematical models, besides the good suitability of fitted curve in most of PSD´s. Nevertheless, some PSD´s has not good fitting with this model, as shown in figure 1.

In other hand, it´s important to have in account that the PSD is closely attached with mineralogy of the materials, wich has direct relationship with physico-chemical properties of the particles. That is why is very important open the analysis capability of critical variables, as the PSD, and try to find a closest adjustment of simulated with curve to the natural particle size distibutions.

In this work some particular cases in which particle size distributions of different kind of materials don´t match with the Rosin-Rammler model, and a proposal of a new approach to adjust in a better way the PSD´s in a mathematical and physical way.

2. METHODOLOGY AND EQUIPMENT

For the PSD analysis 16 different materials were choosen, with different mineralogy and differences in tendences between them. Each one was analyzed with the Rosin-Rammler model, and the parameters k_{rr} and m were found. Afterwards, the Rosin-Rammler model is changed with new parameters, as a new approach to the PSD analysis. Then the the statistical analysis was done of all cases.

In figure 2 different Particle Size Distributions are shown, with different mineralogies for each one, including a wide range of tendences of PSD´s. In every case the size of particles is below the standard mesh US Tyler No 325 (44 □m). The particle size ditribution was measured with a sedigraph 5100 Micromeritics, wich uses the particle detection by X-rays.

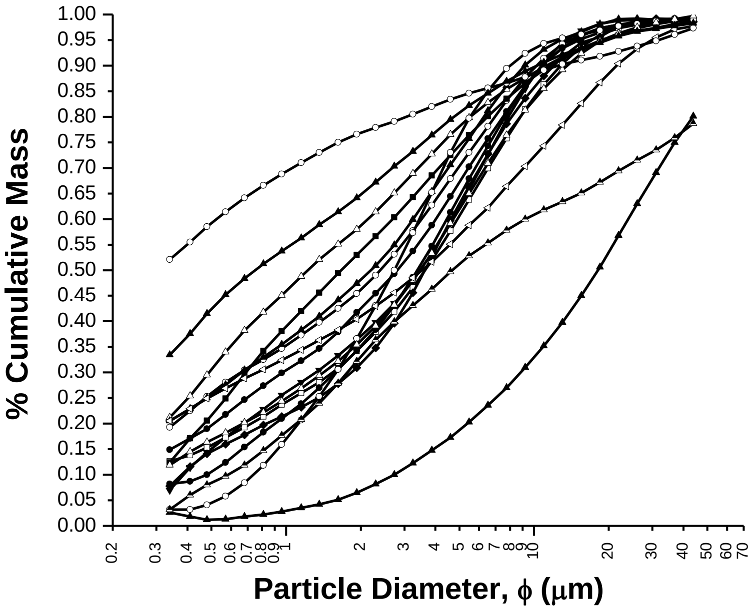

Figure 2. Different Particle Size Distribution of the different materials under study.

3. PARTICLE SIZE DISTRIBUTION WHEN DON´T MATCH WITH ROSIN-RAMMLER BEHAVIOR

There are cases where the PSD´s of the materials don´t fit with the behavior described of Rosin-Rammler model, but the tendence of the curve matches with the curve produced for the model, as shown in figure 3.

In this case, the value of the parameter of distribution can be used for the analysis. In other cases it is not possible because no parameter is good; the Rosin-Rammler model does not give any correct value, as shown in figure 4.

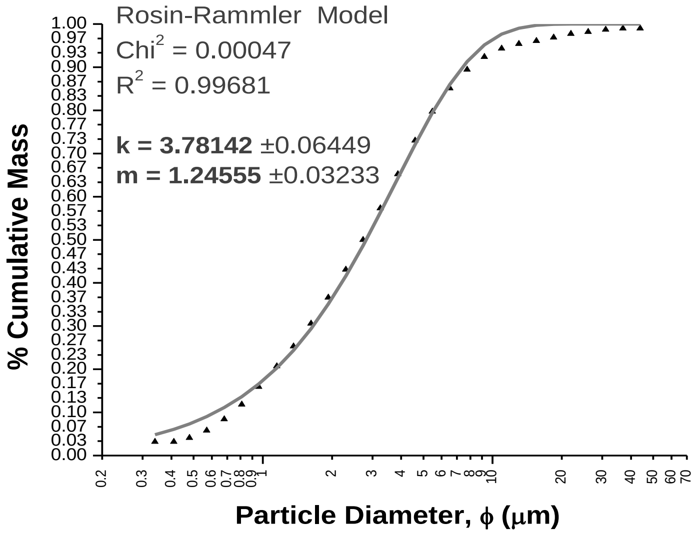

Figure 3. Adjustment of the Rosin-Rammler model to a fine limestone.

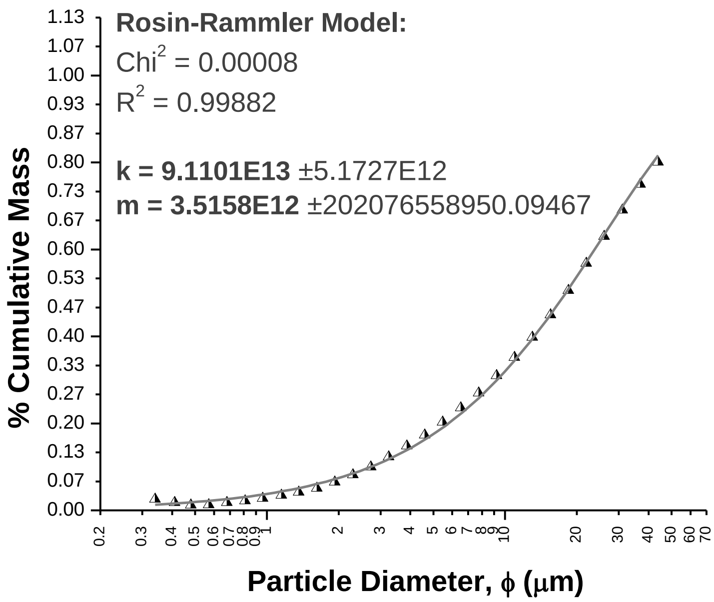

Figure 4. Wrong adjustment of the Rosin-Rammler model to a silica sand.

In this case, if the mathematical and statistical parameters are very good, but the parameters of size and distribution have no sense. This kind of cases are very usual, and the values of important variables are accepted only because the mathematical adjustment is good, as a unique criteria against the realistic criteria, those with physical sense.

4. PARTICLE SIZE DISTRIBUTION UNDER A NEW APPROACH

After the evaluation of the Rosin-Rammler model with the materials of figure 2, twelve of sixteen are not reproducibles with the model. There are no few examples where this model does not offer good variable values for analysis, as the example shown in figure 4. Thus, is necessary a new approach able to produce size and distribution parameters, besides to reproduce a good fit of every point of the curve. In this case, Rosin-Rammler is a specific case of the new approach, from the mathematical point of view.

The results of the approach for the particle size distributions of different materials with Rosin-Rammler model are shown in table I.

Table I. Rosin-Rammler data for different materials.

	PARAMETERS OF ROSIN-RAMMLER MODEL			
MATERIAL	**k_{rr}**	**m**	**Chi^2**	**R^2**
Clay 1	1.78	10.47	0.00009	0.99798
Clay 2	0.65	0.30	0.00021	0.98805
Shale	13.39	0.54	0.00299	0.95069
Fine Silica Sand	NA			
Medium size kaolin	3.28	0.70	0.00041	0.99519
Coarse kaolin	4.75	0.95	0.00009	0.99927
Kaolin	3.57	0.68	0.00049	0.99424
Calcined kaolin	4.14	0.76	0.00028	0.99712
Fine limestone	3.78	1.25	0.00047	0.99681
Kaolin A1	3.17	0.68	0.00055	0.99339
Caolin A2	2.51	0.59	0.00026	0.99598
Mixture 1	5.96	0.55	0.00061	0.99097
Mixture 2	5.09	0.80	0.00021	0.99801
Kaolin A3	5.19	0.83	0.00033	0.99697
Kaolin A4	4.72	0.86	0.00057	0.99504
Kaolin A5	5.11	10.92	0.00040	0.99662

The new approach is given by the following expression:

$$f(x) = a - b * exp\left(-\left(\frac{x}{K_{ag}}\right)^{m}\right) \qquad (2)$$

Where a and b are new constants, wich depend of each material. With the new approach the new fit results are shown in figures 5, 6 and 7; here the adjustment of the curve generated is good, using the experimental data of the measured PSD.

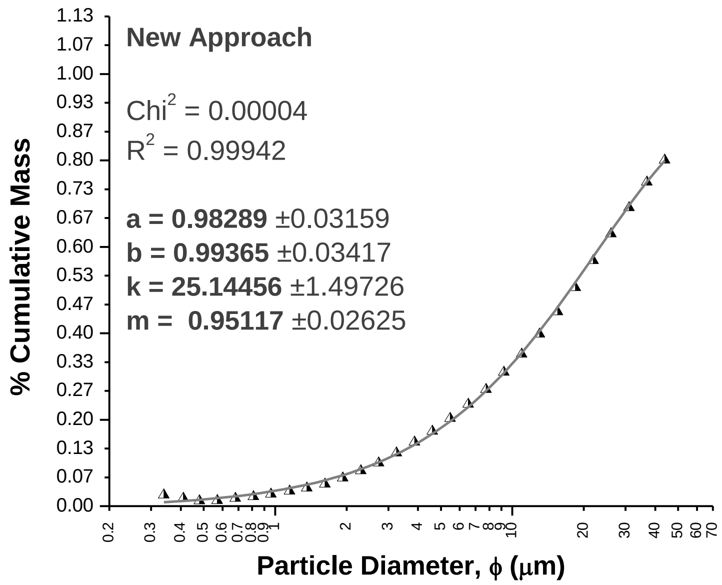

Figure 5. PSD of a fine silica sand described with the new approach.

Besides, it can be seen that the mathematical fit is good, the size and distribution parameters remain with physical meaning. This fact allows the analysis of PSD in any process and any scenario. To show in a better way this affirmation, for the fine sílica sand shown in figure 4, The Rosin-Rammler model does not give a good information of parameters despite the good mathematical fit. In the new analysis, tha adjustment of the new approach shown in figure 5 is better, in the mathematical sense and in the physical sense.

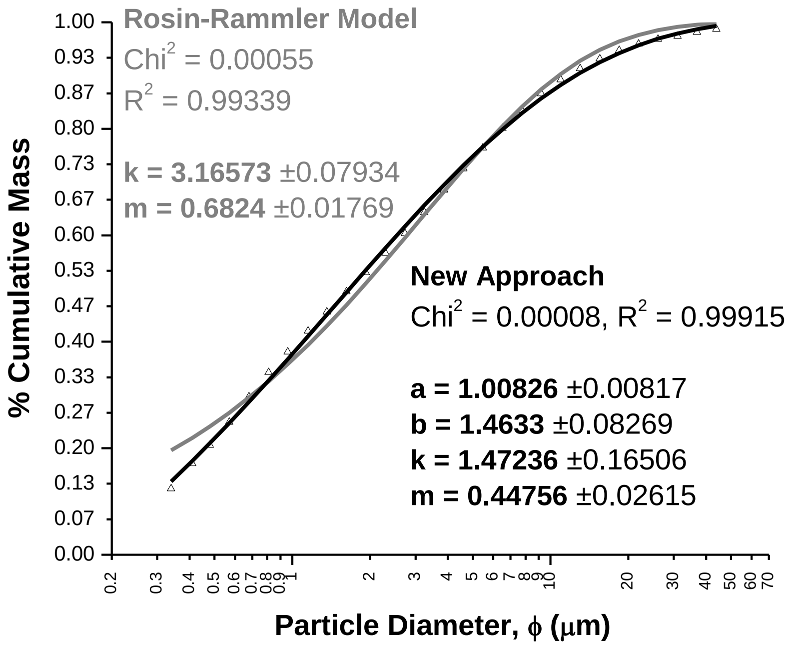

Figure 6. PSD for caolin A1 described with Rosin-Rammler model and the new approach.

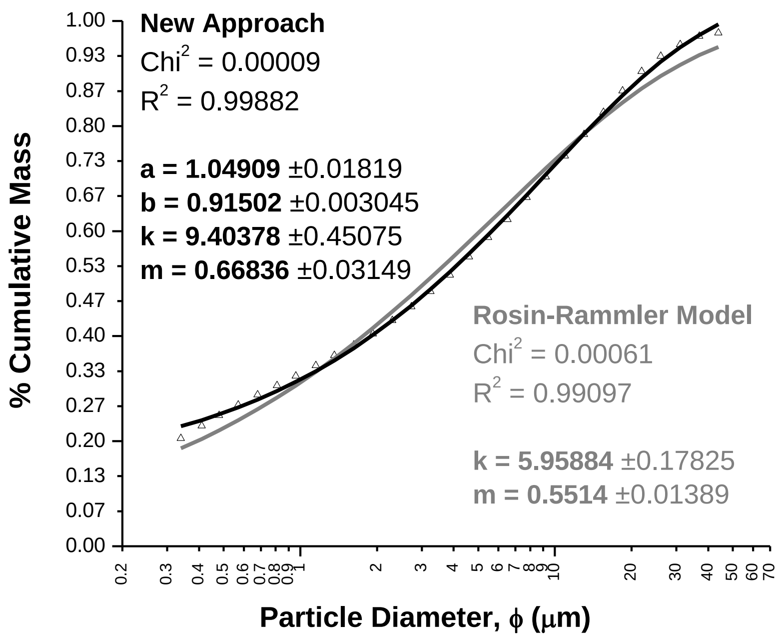

Figure 7. PSD for Mixture 1 described with Rosin-Rammler model and the new approach.

Table II. New approach data for different materials.

	PARAMETERS OF ROSIN-RAMMLER MODEL					
MATERIAL	**a**	**b**	**k_{rr}**	**m**	**Chi^2**	**R^2**
Clay 1	1.00	1.18	1.18	0.41	0.00007	0.99858
Clay 2	0.98	1.69	0.09	0.23	0.0001	0.9948

Shale	0.80	1.24	2.14	0.41	0.00018	0.99724
Fine Silica Sand	0.98	0.99	25.14	0.95	0.00004	0.99942
Medium size kaolin	1.00	0.85	4.18	0.93	0.00011	0.99884
Coarse kaolin	0.99	0.97	4.82	1.01	0.00007	0.99945
Kaolin	0.99	0.84	4.59	0.92	0.00015	0.99839
Calcined kaolin	0.99	0.90	4.74	0.92	0.00012	0.99887
Fine limestone	0.98	1.04	3.39	1.13	0.00007	0.99956
Kaolin A1	1.01	1.46	1.47	0.45	0.00008	0.99915
Caolin A2	1.02	1.47	1.11	0.40	0.00007	0.99904
Mixture 1	1.05	0.92	9.40	0.67	0.00009	0.99882
Mixture 2	0.99	0.92	5.59	0.94	0.00005	0.99953
Kaolin A3	0.99	0.90	5.81	1.02	0.00005	0.99961
Kaolin A4	1.00	0.93	5.22	0.99	0.00045	0.99636
Kaolin A5	0.99	0.91	5.45	1.12	0.00017	0.99867

5. CONCLUSIONS

The Rosin-Rammler model has not a good adjustment for all kind of materials. This is because the mathematical model fixes two parameters, the coefficients a and b. In some cases, this model works very good, as for materials like clay 1, clay 2, coarse caolin and calcined caolin.

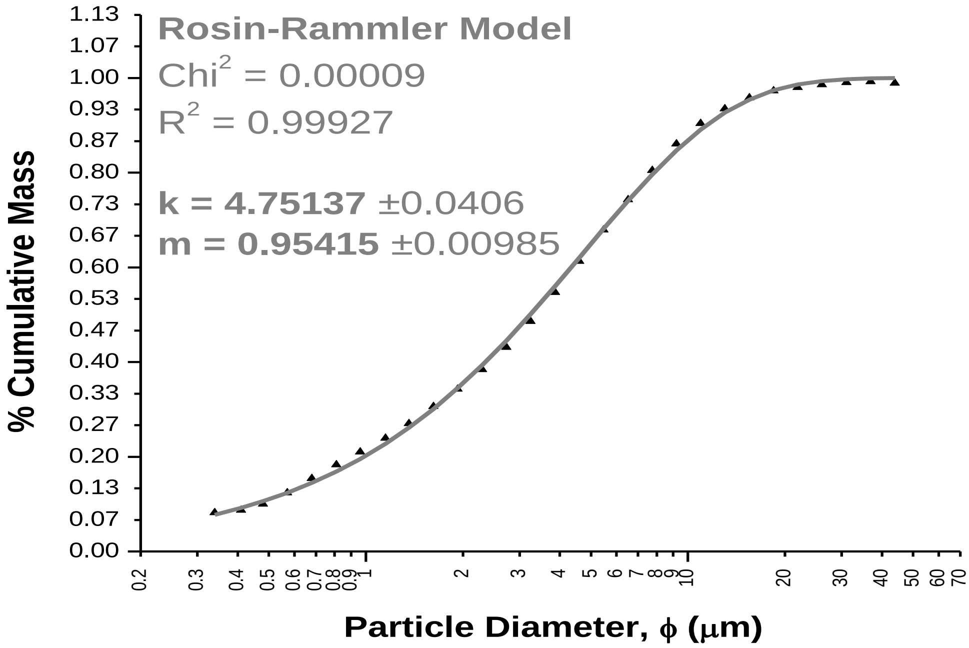

Figure 8. PSD for coarse caolin described with Rosin-Rammler model.

In the opposite way, it is shown for fine sílica sand case. The model does not work and the adjustment is not good either. The solution to this situation is introduce two new parameters for the new approach. Those parameters called a and b depend of the kind of each material. The new approach proposed for PSD analysis as an adjustment of the Rosin-Rammler model has as an expression.:

$$f(x) = a - b * exp\left(-\left(\frac{x}{K_{ag}} \right)^m \right) \quad (3)$$

Where a, b, K_{ag}, y m are constants. The physical meaning of K_{ag} as size parameter, and the variable m as a distribution parameter are the same as in Rosin-Rammler, but with better adjustment. Besides, they are better parameters to give better significant information to real processes. This new approach consists of a family of curves for each value of the constants a and b. In this way, Rosin-Rammler becomes in a particular case of the new approach proposed, where a=1; b= -1, y $K_{rr} = K_{ag}$.

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