



University of Belgrade  
Technical Faculty in Bor



Chamber of Commerce  
and Industry of Serbia

# XV International Mineral Processing & Recycling Conference



INTERNATIONAL MINERAL PROCESSING & RECYCLING CONFERENCE

# Proceedings

Editors:  
Jovica Sokolović  
Milan Trumić

17-19 May  
2023

Belgrade  
SERBIA





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## OPTIMIZATION OF MICRONIZING ZEOLITE GRINDING USING ARTIFICIAL NEURAL NETWORKS

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**ABSTRACT** – The aim of the experiment was to determine the optimal grinding conditions for obtaining a powder with appropriate physico-chemical and microstructural characteristics that would find its potential application as a binder and ion exchanger in structural composites. The analysis of certain classes of zeolite size after micronization was performed through grinding kinetics. An artificial neural network was developed based on the obtained results, and then compared with the obtained experimental results.

**Keywords:** Zeolite, Micronizing Grinding, Specific Surface, Artificial Neural Networks.

### INTRODUCTION

The process of micronizing grinding is intended to grind the mineral raw material to particles of micron size and thus prepare it for direct application or for further technological processing. The application of a prolonged micronization procedure in a certain time interval under certain conditions increases the specific surface area of the treated powder, improves the reactivity and pozzolanic activity of the zeolite material, increases the cation exchange capacity and agglomerates the samples. [1, 2]. The main problem related to micronizing grinding at the industrial level is in the sustainability of this procedure in economic terms, so an ideal balance must be found between the achieved properties of the treated material on the one hand and the time and energy consumption for the process on the other.

Recently, artificial neural networks are increasingly used in modeling and optimizing the grinding process. Flament et al. (1993) [3, 4] in their paper considered the identification of the dynamics and reverse dynamics of a simulated grinding cycle, using neural networks. Ma et al. (2009) [5] developed a series of artificial neural networks (ANN) for the analysis and prediction of correlations between process parameters and morphological characteristics of nanocomposite WC-18 % MgO powders using the backward error propagation algorithm (BP). Ahmadzadeh and Lundberg (2013) [6] in their work tested different methods of predicting the wear of the lining from the mill, in the context of the remaining height and the remaining service life of the lining. In their second work, Ahmadzadeh and Lundberg (2013) [7] attempted to develop a method that predicts the remaining service life of a coating, without the need to stop the mill. Singh et al. (2013) [8] developed a wrestling neural network model to predict the distribution of the granulometric composition of grinding products using available grinding data for different chromite ore grindability. Terzić et al. (2017) [9] examined the mechano-

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chemical activation of bentonite clay in an ultra-centrifugal mill, to obtain a material that is used as a binder and sorbent in building composites due to its physical-mechanical and microstructural characteristics. Terzić et al. (2017) [10] in their second work examined the mechano-chemical activation of natural clinoptilolite-type zeolite from seven deposits in an ultra-centrifugal mill, for the production of powder with appropriate physicochemical and microstructural characteristics that can be used as a binder and ion exchanger in structural composites. Farizhandi et al. (2020) [11] used a planetary mill to develop a rapid assessment procedure to identify the characteristics of powders and granular materials. The modeling of an artificial neural network in this paper aims to optimize the process of micronizing grinding (in order to obtain the shortest time of micronizing grinding, the lowest energy consumption), to obtain materials with the best properties.

## **EXPERIMENTAL**

### **Materials**

The paper plans to examine the dry micronization of zeolite, using modern methods for determining the physicochemical and mineralogical characteristics of micronized zeolite products, and changes in parameters that determine the operation of the vibrating mill with rings, as well as quality analysis of micronizing powder. Based on the obtained results of micronizing grinding, the results will be predicted using artificial neural networks, in order to determine the best grinding conditions and the optimal product.

The zeolite sample is gray, while the crystals are lithocrystalloclastic to crystalloclastic. It contains about 90 % zeolite, in a smaller amount quartz, feldspar, mica and calcite and traces of ilite. The zeolite sample was crushed in a laboratory jaw crusher to an upper limit size of 3.35 mm. For further research, four classes of size (-3.35+0; -3.35+2.36; -2.36+1.18; -1.18+0) mm and different starting masses (50 g, 100 g, 200 g) which were subjected to micronizing grinding.

### **Micronizing grinding**

Micronizing grinding of zeolite was performed in a laboratory vibrating mill with rings of the type "SIEBTECHNIK TS-250", at a speed of 1000 rpm in a time interval of 20s, 45s, 75s, 120s, 300s, 900 seconds. The content of the size class (-5+0)  $\mu\text{m}$  and the specific surface area were monitored on each grinding product.

### **Modeling of artificial neural networks**

In this research, models based on the Multi-Layer Perceptron were used, which in principle consist of three layers (input layer, hidden layer and output layer). The input values of this model were: size class, grinding time and initial mass of the sample, while the output values were: the content of the size class (-5+0)  $\mu\text{m}$  and the specific area.

## **RESULTS AND DISCUSSION**

The increase in the time of micronizing grinding led to a change in the characteristics

of zeolite and the manifestation of differences between unground and ground zeolite. The results of micronizing grinding are shown in Tables 1-4.

**Table 1** Content of the size class (-5+0)  $\mu\text{m}$  of the sample (-3.35+0) mm, after micronizing grinding, starting masses (50, 100 and 200) g

50 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	95.90	97.40	95.86	94.08	81.04	80.18
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1056.02	1070.77	1056.65	1036.41	895.96	888.22
100 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	90.98	94.15	95.83	94.31	82.11	64.99
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1006.26	1039.44	1055.46	1038.20	908.23	723.16
200 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	83.22	92.49	93.48	93.39	90.76	71.49
Spec. surface area ( $\text{m}^2/\text{kg}$ )	922.29	1020.16	1031.95	1031.64	1001.81	797.52

**Table 2** Content of size class (-5+0)  $\mu\text{m}$  of sample (-3.35+2.36) mm, after micronizing grinding, starting masses (50, 100 and 200) g

50 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	93.03	95.71	94.63	91.64	81.03	76.78
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1027.67	1053.86	1042.69	1012.06	897.11	852.43
100 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	89.92	94.83	95.34	94.78	86.63	74.49
Spec. surface area ( $\text{m}^2/\text{kg}$ )	996.46	1046.60	1050.40	1045.26	957.48	826.11
200 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	77.75	90.72	93.01	95.33	92.97	76.82
Spec. surface area ( $\text{m}^2/\text{kg}$ )	864.01	1002.84	1027.77	1050.04	1024.66	849.60

**Table 3** Content of size class (-5+0)  $\mu\text{m}$  of sample (-2.36+1.18) mm, after micronizing grinding, initial masses (50, 100 and 200) g

50 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	94.12	96.53	96.37	93.04	85.80	79.29
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1039.29	1062.18	1060.31	1026.50	946.92	878.86
100 g						
Time	20 s	45 s	75 s	120 s	300 s	900 s

**Table 3 continued** Content of size class (-5+0)  $\mu\text{m}$  of sample (-2.36+1.18) mm, after micronizing grinding, initial masses (50, 100 and 200) g

Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	93.44	93.62	93.94	93.83	84.54	70.48
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1029.96	1035.05	1037.55	1036.92	935.84	784.92
<b>200 g</b>						
Time	<b>20 s</b>	<b>45 s</b>	<b>75 s</b>	<b>120 s</b>	<b>300 s</b>	<b>900 s</b>
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	81.80	92.42	95.61	95.69	93.65	75.18
Spec. surface area ( $\text{m}^2/\text{kg}$ )	906.09	1019.29	1054.08	1054.56	1032.70	833.96

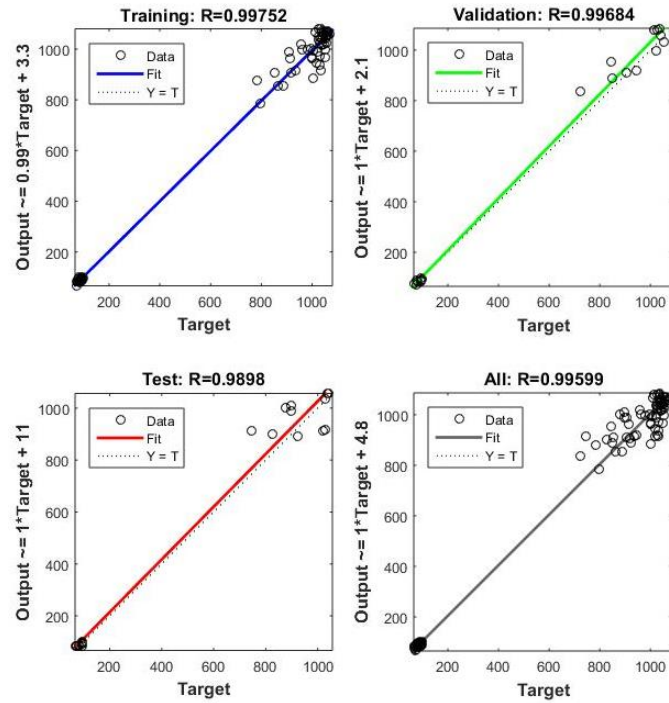
**Table 4** Content of size class (-5+0)  $\mu\text{m}$  of sample (-1.18+0) mm, after micronizing grinding, starting masses (50, 100 and 200) g

<b>50 g</b>						
Time	<b>20 s</b>	<b>45 s</b>	<b>75 s</b>	<b>120 s</b>	<b>300 s</b>	<b>900 s</b>
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	96.28	96.15	92.75	91.72	86.98	82.84
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1059.86	1058.75	1026.59	1015.20	961.18	919.22
<b>100 g</b>						
Time	<b>20 s</b>	<b>45 s</b>	<b>75 s</b>	<b>120 s</b>	<b>300 s</b>	<b>900 s</b>
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	92.87	94.50	95.20	94.16	88.86	66.78
Spec. surface area ( $\text{m}^2/\text{kg}$ )	1025.54	1042.88	1049.27	1038.06	980.73	745.39
<b>200 g</b>						
Time	<b>20 s</b>	<b>45 s</b>	<b>75 s</b>	<b>120 s</b>	<b>300 s</b>	<b>900 s</b>
Size class ( $\mu\text{m}$ )	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0	- 5 + 0
W (%)	82.41	92.72	94.37	93.87	90.60	76.17
Spec. surface area ( $\text{m}^2/\text{kg}$ )	912.77	1023.59	1040.74	1036.79	1001.55	844.26

As the time of micronized grinding increases, the content of the class (-5+0)  $\mu\text{m}$  and the specific surface area [7] increase until a certain grinding time, and after that it is assumed that agglomeration of samples occurs. For all samples, the optimal grinding time is between (45 and 75) seconds, during which time the sample is crushed and the specific surface area is increased, while after that time the specific surface area is reduced and the agglomeration is assumed.

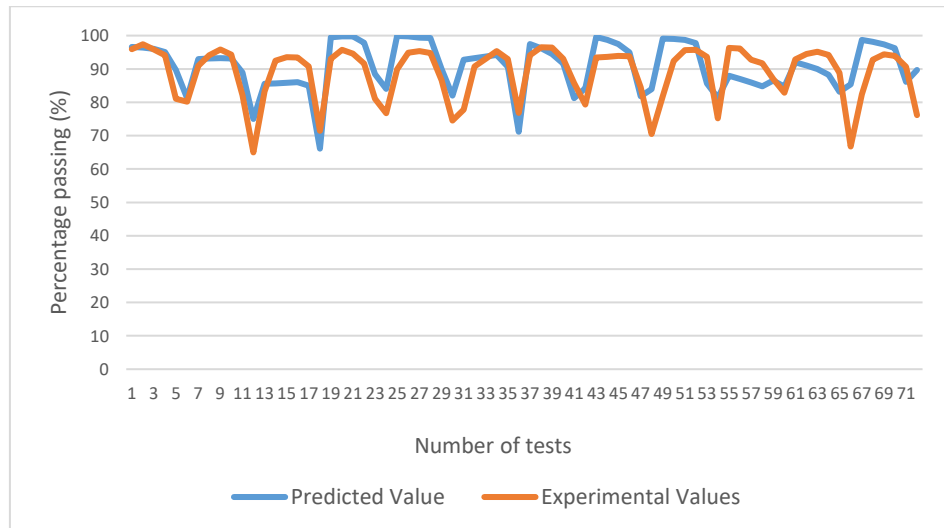
#### Modeling of micronizing zeolite grinding

The input sizes of the models were: size classes (-3.35+0 mm; -3.35+2.36 mm; -2.36+1.18 mm; -1.18+0 mm), grinding time (20 s, 45 s, 75 s, 120 s, 300 s, 900 s) and the initial mass of the sample (50 g, 100 g, 200 g), while the output values were: content of the size class (- 5 + 0)  $\mu\text{m}$  and specific area. The database used for modeling artificial neural networks in Matlab was divided into three sets: a network training set (70 %), a validation set (15 %) and a testing set (15 %). Testing of the model showed that the network achieves good results, which is shown in Figure 1, having in mind a small set of input-output data. The accuracy of the results is confirmed by a very large coefficient R that ranges (0.989 - 0.997), which gives a satisfactory prediction accuracy.

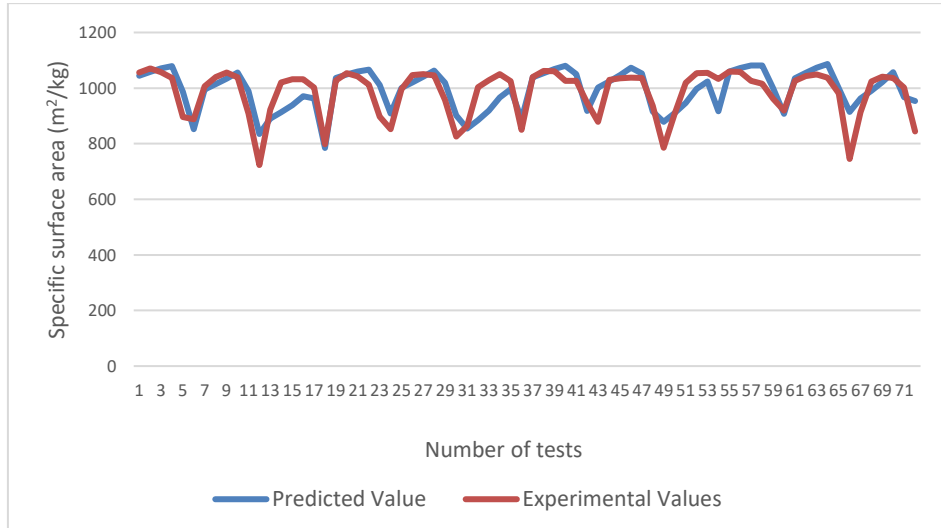


**Figure 1** Experimentally obtained values of parameters  $i$  values obtained using the ANN model

Figures 2 and 3 show a comparison of the calculated values compared with the experimental data for the optimal artificial neural network.



**Figure 2** Comparative values of the content of the class  $(-5+0) \mu\text{m}$  obtained experimentally and using the ANN model



**Figure 3** Comparative values of specific surface obtained experimentally and using the ANN model

From diagrams 2 and 3 it can be seen that the modeling of the network is well done, the neural network has well captured the trend of change of curves obtained on the basis of experimental results. It was calculated that the mean error of the obtained model for the content of the size class (-5+0)  $\mu\text{m}$  is about 6 %, and for a specific area about 4.5 %, which is considered a very good prediction.

## CONCLUSION

The study presents a comprehensive approach of artificial neural networks that can predict the content of the size class (-5+0)  $\mu\text{m}$  and the specific surface with great certainty. Neural networks are applied to this grinding process because neural networks rely less on an accurate physical model. Neural networks can be ideal for modeling this complex grinding process, which is the correlation coefficient and confirmed by its predictive accuracy that ranges (0.989 - 0.997).

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