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Comparative kinetic study of mechanical activation process of mica and talc for industrial application

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ABSTRACT

Mica and talc have wide areas of application as a raw material in a number of industrial branches. Mechanically activated mica has specific applications such as: capacitors, insulators, and pearlescent pigments. Talc is widely used as either a basic raw material or as filler. This paper presents a comparative analysis of mechanically activated samples of mica and talc in ultra-centrifugal mechano-activator "Retsch ZM-1". The following mechano-activator parameters were variable: number of rotor revolutions (rpm); sieve mesh size (μm); current intensity (A). In addition, the following parameters were monitored: duration of mechanical activation, t (min); circumferential rotor speed, v (m/s); capacity of mechano-activator, Q (kg/h); and specific energy consumption, W_e (kW h/t). It was observed that effect of mechanical activation of mica and talc increased with an increase of the load and rotor revolution of ultra-centrifugal mechano-activator. Both mica and talc were successfully treated by mechanical activation procedure. In the processing of mica, mechanical activation is suggested to be applied as a post-treatment, and in the talc processing as a pre-treatment, as the high quality talc is obtained by means of hydrometallurgical concentration method.

1. Introduction

Mechanically activated mica and talc in the ultra-fine powdery form have wide application spectra as raw materials used in the manufacturing of various industrial products such as capacitors, insulators, plastic fillers and pearlescent pigments. Mica is often used as filler in the synthesis of various materials with the special accent on production of the 'smart' materials [35,39,13,21], due to its color, density, particle shape, size and structure, and reflection index, adding the extra quality to synthesized products. For example, technology for production of the mica based glass–ceramics, whose microstructure contained preferentially aligned mica particles, was developed by Barlow and Manning [8] and Cheng et al. [11]. Talc, as a non-metallic raw material accompanied with exceptional physico-chemical characteristics, is irreplaceable in a number of industrial applications: production of paints, ceramics, cast products, rubber, cables, paper, pharmaceutical products, insecticides and herbicides, but also in civil engineering and military industry (Ulusoy [37], Nkoumbou et al. [24], Aoun et al. [4]). The standard way of talc and/or mica processing (comminuting, classification, flotation) can satisfy only a small number of users' requirements, thus the mechanical activation as pre-treatment method was introduced. The primary effect of the mechanical activation is the fragmentation of the mineral particles, which eventually results in the changes in a number of physico-mechanical properties of an investigated system, which was recently confirmed by Mucsi et al. [23]. Balaz and Achimovicová [7] proved that mechanical activation influences the crystal structure of a mineral usually making it disordered and generating crystal lattice defects or other meta-stable forms. During the last couple of decades, the mechanical activation procedure conducted by means of a different type of mechano-activators was extensively investigated: high energy mills, stirred media mills, attritional mills, jet mills, planetary mills, vibratory mills, and mortar mill. It has been reported by Baláz [5], Balaz [6], Erdemoglu et al. [15]; Kristóf-Makó et al. [20] and Tkácová [36] that the application of mechano-activators enables significant change in the structure and in the surface properties of solid phases. Sanchez-Soto et al. [29] and Suraj et al. [34], and later, Pérez-Maqueda et al. [25], Pérez-Maqueda et al. [26], Pérez-Maqueda et al. [27] proved that collection of the submicron and nanometric particles in different mechano-activators is possible.

Grinding, a common industrial procedure, and sonication treatments can change starting characteristics of treated material, however in this research special attention was paid to the

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comparison and evaluation of the changes occurring during talc and mica processing in ultra-fine grinders (mechano-activators). The mechano-activation treatment might promote: the amorphization of treated material, noticeable change of the microstructure, size and shape of particles, etc. Furthermore, ultra-fine grinding kinetic investigation indicates the mechano-chemical reduction of the original particles of talc/mica which appears to have reached a limit at 30 min grinding time. However, longer grinding times might produce an apparent increase in particle size as was proved by Yang et al. [38], Mahadi and Palaniandy [22] and Cho et al. [12].

Even though ultra-fine grinding might appear as an expensive process due to low mill capacity and high energy consumption, there are many studies which prove the benefits of the mechanical activation process on the structural and physico-chemical properties of a material: Baudet et al. [9] investigated mechanical activation of kaolin clay by attrition-milling in a stirred bead mill; Sanchez-Soto et al. [28] examined the effects of dry grinding, using ball-milling, on the structure of kaolinite powders and explained why differently ground kaolinite samples show altered behavior during high-temperature transformations, while Franco et al. [17] studied the influence of the particle-size reduction on the dehydroxylation process of kalolinite. Dellisanti and Valdré [14] and later Hrachová et al. [18] investigated the structural changes of Ca-montmorillonite produced by mechanical activation by means of high-energy ball milling. Based on the study of the available literature, it can be concluded that few papers are dealing with the investigation of the ultra-centrifugal mill as apparatus for talc and mica mechano-activation. Therefore, the aim of the study presented in this paper is to investigate the applicability of ultra-centrifugal mill for mechanical activation of mica and talc from a process engineering point of view.

2. Experimental

The mica ($KAl_2(Si_3Al)O_{10}(OH,F)_2$) from flotation concentration plant Samoljica deposit in Bujanovac, Serbia and the talc from "Bela Stena" mine, Serbia were used in this investigation. Chemical compositions of mica and talc samples are given in Table 1.

The physico-chemical characteristics for both mica and talc samples were determined by means of the standard laboratory procedures. The following results were achieved: density (according to Standard SRPS EN 725-8:2010 [31]) was 3.00 g/cm^3 for mica, 2.70 g/cm^3 for talc; humidity before/after drying (according to Standard SRPS EN 13286-46:2012 [32]) for mica and talc were: 10.00/0.5% and 6.00/0.50%, respectively; bulk density (according to Standard SRPS EN 725-9:2010 [33]) for mica was 1.17 g/cm^3 and for talc 1.50 g/cm^3.

The preparation of mineral samples usually implies the reduction of their particle size, as preparation for the subsequent mechanical activation procedure. However, the mica sample was composed of fine particles, thus it was directly subjected to mechanical activation. On the other hand, the talc sample consisted of coarse particles; therefore the particle reduction was necessary.

Comminuting of talc samples was performed by crushing and afterwards grinding to the particle size that could be used as input for mechanical activation procedure. Primary crushing of talc sample was carried out in a jaw crusher with 10 mm output opening working in a closed circle with a screen. After primary crushing, the talc sample was subjected to secondary crushing in a roll crusher with 5 mm output opening. The grinding of the secondary crushed sample was conducted in the ceramic-lined ball mill. The mill, in which ceramic balls were used as the grinding media, was working in the closed circle with an air classifier, which enabled the liberation of the minerals (Table 2.). Iron minerals were partly liberated, while other minerals (chlorite, quartz, and calcite) were kept. It was afterwards confirmed by microscopic analysis.

The mica and talc samples particle size distribution used as an input for mechanical activation procedure is shown in Table 3.

Ultra-centrifugal mechano-activator "Retsch ZM-1" was used in the investigation of the mechanical activation and improvement of the material reactivity. The original mica sample and the ground sample of talc were subjected to quantitative characterization. Physical characterizations of both samples were determined by

Table 3
Particle size distribution of mica and talc.

Class of coarseness (mm)	Mass portion (%)	D, undersize (%)	R, oversize (%)
Mica			
−0.833 + 0.589	0.10	0.10	100.00
−0.589 + 0.417	4.40	4.50	99.0
−0.417 + 0.295	22.50	27.0	99.5
−0.295 + 0.208	29.00	56.0	73.0
−0.208 + 0.147	23.00	79.0	44.0
−0.147 + 0.104	10.00	89.0	21.0
-0.104 + 0.074	6.00	95.0	10.5
−0.074 + 0.063	1.40	96.4	4.5
−0.063 + 0.053	1.10	97.5	3.1
−0.053 + 0.040	0.80	98.6	2.0
−0.040 + 0.000	1.40	100.00	1.4
Talc			
−0.589 + 0.417	6.67	6.67	100.00
−0.417 + 0.295	13.89	20.57	93.33
−0.295 + 0.208	19.18	39.74	79.43
−0.208 + 0.147	16.60	56.35	60.26
−0.147 + 0.104	15.47	71.82	43.65
−0.104 + 0.074	10.40	82.22	28.18
−0.074 + 0.063	3.33	85.55	17.78
−0.063 + 0.053	3.74	89.28	14.45
−0.053 + 0.040	3.13	92.41	10.72
−0.040 + 0.030	2.80	95.21	7.59
−0.030 + 0.020	2.22	97.43	4.79
−0.020 + 0.000	2.57	100.00	2.57

Table 1
Chemical composition of mica and talc.

Oxide		SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	PS	FeO	LoI
Mica	(%)	57.60	25.50	0.30	0.60	1.90	11.6	1.50	0.03	0.17	0.40	–	0.40
Talc	(%)	49.18	0.68	3.87	28.00	0.02	0.01	2.60	0.42	0.01	–	3.49	11.72

Table 2
Mineralogical composition of ground talc sample.

Mineral	Talc	Chlorite	Quartz	Magnetite	Hematite	Carbonate (Fe, Mg)	Calcite	Limonite	Other
Content (%)	54.1	8.30	2.20	3.40	0.70	29.20	1.00	0.50	0.60