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Mechanical activation of talc in high-energy speed rotary mechanoactivator

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Abstract

This paper presents the results of research on mechanical activation of raw talc in a high-energy speed rotary mechanoactivator. The results of research on effect of mechanically activated talc on the degree of recovery Fe_2O_3 by hydrometallurgical method are also presented. The process and mechanism of mechanical activation in this type of mechanoactivator were achieved by impact.

The variable parameters of the mechanoactivator operation were: rate of rotor revolutions (n_0 = 10,000 and n_0 = 20,000 rpm), circle sieve mesh (80, 120, 200 and 500 μm) and the current intensity. The following parameters of the dry mechanical activation process were studied: mechanical activation time, rotor speed, mechanoactivator capacity and specific energy consumption. The mechanically activated powder was examined by application of differential thermal and thermogravimetric analyses, analysis of the degree of mechanical activation and the specific surface area as well.

According to the obtained results, the highest rate of mechanical activation was obtained with a nominal mechanoactivator load. The degree of mechanical activation increases with increasing the rate of rotor revolution, circle sieve mesh size and with the increasing mechanoactivator load. It was shown that high-grade talc concentrate with low content of Fe_2O_3 can be obtained by physical-chemical process. A new approach for obtaining high-grade talc concentrate was achieved trough mechanically activated talc effect on the degree of recovery of Fe_2O_3 by hydrometallurgical process.

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1. Introduction

In industrial conditions the advanced materials must comply with certain quality standards. The special requirement of advanced materials is the size, in which case the requirements reach a nanosize range. Due to low mill capacity (kg/h) and high energy consumption, production of particles in ultra-fine size range is an extremely difficult and expensive process. Due to these facts, the optimal ratio *G*/*D* of centrifugal mill for ultra-fine grinding was intensively studied [1].

Talc is non-metallic raw material with exceptional physical–chemical characteristics, which is virtually irreplaceable in many industrial applications. The general applications of talc are found in production of paints, ceramics, cast products, rubber, cables, paper, lead, pharmaceutical products, insecticides, herbicides, as well as in civil engineering, military industry and other areas (totalling over 80 applications). The fundamental characteristics of minerals of talc are: white color, softness, greasiness, refractoriness, proneness to fragmentation, etc. These characteristics make talc minerals attractive for using.

The conventional method for talc processing (comminution, classifying, and flotation) cannot always provide a high-grade talc concentrate. Despite this fact, the conventional method can satisfy the requirements in industries such as: ceramics, chemistry, pharmacy, cosmetics, paints and varnishes. This problem can be partly overcome by introducing the process of

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mechanical activation by application of different types of mechanoactivators.

During the last decade, the ultra-fine grinding method used in different types of mechanoactivators such as: stirred media mill, jet mill, planetary mill, vibratory mill, and mortar mill was studied intensively. It was known that the grinding and sonication treatments could modify intrinsic characteristics of material. In this case, the special attention was paid to evaluation of possible changes during ultra-fine grinding process [2,3].

It was shown that the parameters such as: hardness, crystallographic structure, and Young's Modulus directly affected breakage mechanism of the dolomite and talc phase. These parameters have experimentally demonstrated mechanochemical effect of dolomitic talc during fine grinding process in a mortar grinder. Also, mechanochemical treatment can improve the amorphization of talc and it is greatly favorable to the subsequent leaching [4,5]. In addition, ultra-fine dry grinding can affect significantly the structure, particle size and shape of talc. It was proved that for 30 min of grinding, the mechanochemical reduction of the original particles appears to have reached a limit. Longer grinding times produce an increasing degree of amorphism [6].

Hydrometallurgy is an area suitable for successful verification of the knowledge accumulated by mechanical activation of minerals. In these processes, the introduction of a mechanical activation into technological cycle significantly modifies the subsequent operations [7].

Another significant factor is the mechanical activation in a planetary mill and stirred ball mill, as the pre-treatment of subsequent concentration methods, aimed at improving dissolution of mechanically activated olivine and indium-bearing zinc ferrite for carbonate purposes and sulfuric acid, respectively. In this case, mechanically activated contact surface area of the particles is crucial for diffusion-controlled reactions. At the same time, mechanical activation process was considered carefully as possible pre-treatment method for mixtures of different minerals such as: talc and magnesium carbonate, as well as for the formation of forsterite [8–11].

2. Materials and methods

The investigations of the mechanical activation of dry talc were realized in four series of experiments. A representative sample of raw talc from the bed ''Bela Stena'' (middle Serbia) was used as the initial material. It has been estimated that there are 85,000 tonnes of raw talc reserves. For further investigations of mechanical activation, it is necessary to reduce the size of grain of the representative sample.

The primary crushing of the representative sample of raw talc was performed in a closed cycle which consists of the jaw crusher (output opening size 10 mm) and control screen. The primary crushed product was subjected to further crushing in the roll crusher (output opening size 5 mm)-secondary crushing stage. The grinding of the secondary crushed product was performed in the ceramic-lined ball mill which operated in a closed cycle with air classifier. The ceramic balls were used as the grinding media. The ground sample of raw talc was subjected to mechanical activation in high-energy-speed rotary mechanoactivator. Partly the liberation of the iron minerals occurred, while the presence of other minerals such as: chlorite, quartz and calcite was noticed.

The essential minerals are talc and chlorite, while other minerals are magnetite, quartz and carbonates (Mg, Fe). The basic physical–chemical characteristics of raw talc sample were determined by standard laboratory procedure. The following values were achieved: density $\tau = 2.70$ (g/cm^3), humidity $W_1 = 6.00$ (%), $W_2 = 0.50$ (%) (after drying), volume density $\Delta = 1.50$ (g/cm^3). Particle size distribution and chemical composition of the representative (initial) raw talc sample are presented in Table 1.

The mechanical activations were realized in high-energy-speed rotary mechanoactivator ''Retsch ZM-1'' [6]. The mechanoactivator could be operated at nominal rotor speed of $n_0 = 10{,}000$ and $n_0 = 20{,}000$ rpm. In addition it was possible to choose a circle sieve of different mesh sizes (80, 120, 200 and 500 μm) and vary the intensity of the current.

The high-energy-speed rotary mechanoactivator ''Retsch ZM-1'' consists of a rotor made of high alloyed steel. The diameter of the rotor (D) is 100 mm. The circle sieve of

Table 1
The characteristics of the representative raw talc sample.

Class of coarseness in (mm)	M%, mass portion	D%, undersize	R%, oversize	Component	Content (%)
−0.589 + 0.417	6.67	6.67	100	SiO_2	37.18
−0.417 + 0.295	13.89	20.57	93.33	TiO_2	<0.01
−0.295 + 0.208	19.18	39.74	79.43	Al_2O_3	0.68
−0.208 + 0.147	16.60	56.35	60.26	Fe_2O_3	2.60
−0.147 + 0.104	15.47	71.82	43.65	FeO	3.49
−0.104 + 0.074	10.40	82.22	28.18	CaO	3.87
−0.074 + 0.063	3.33	85.55	17.78	MgO	28.88
−0.063 + 0.053	3.74	89.28	14.45	MnO	0.42
−0.053 + 0.040	3.13	92.41	10.72	Na_2O	0.02
−0.040 + 0.030	2.80	95.21	7.59	K_2O	0.01
−0.030 + 0.020	2.22	97.43	4.79	LOI	22.94
−0.020 + 0.000	2.57	100.00	2.57	Total	100.00
Total	100.00	–	–	–	–

different mesh sizes is the static element of the mechanoactivator ''Retsch ZM-1'' made of high alloyed steel as well. These two elements make a reacting system, for mechanical energy transfer, onto mechanical activation product.

The mechanoactivator ''Retsch ZM-1'' can operate either continuously or discontinuously, if it is in conjunction with vibrating feeder. Reduction of course particles is being performed by dynamic counterbalance of material between the rotor and the circle sieve. The rotor cogs are formed as triangular prisms. Each of prismatic cogs is placed on its basis, while one of its sides is turned towards the circle sieve. This shape of cogs enables the stream of air and powder material.

Between the rotor cogs and circle sieve there is a tolerance of 1 mm. According to this tolerance a circle volume of a $V = 4.74\ \text{cm}^3$ is being created during the mechanical activation process. Due to high speed and strong centrifugal force of the rotor, ground and activated material passes trough this space in one direction, from the axe to circle sieve. The principle of dynamic counterbalance is based on the movement of particles from the rotor to the circle sieve and vice versa in the ring zone.

The process of kinetics was analyzed through the changes in the particle size distribution, respectively the specific surface area, with the time of mechanical activation. The analyses of the mechanical activation products were realized using different instrumental techniques.

For detailed powder characterization (determination of the particle size distribution, the mean diameter and specific surface area of the particles) ''Coulter-Electronics-Coulter Multisizer'' was used. A simultaneous thermal analyzer ''STA-409 EP'' was used to define the thermal and thermogravimetric characteristics of the samples. X-ray structural analysis was utilized for the determination as well as observation of the phase composition of the refractory drivers. For this purpose, the X-ray diffractometer ''PW-170'' was utilized. The spectrochemical analysis was utilized for observation and determination of the chemical properties. For this purpose the spectrum analyzer ''BOMEM MB-100 FTIR'' was applied.

During all experiments in all series, the process parameters of dry mechanical activation were observed: mechanical activation time (t), rotor speed (ν), mechanoactivator capacity (Q) and the specific energy consumption (e).

For the characterization of the mechanical activation products the following relevant parameters were studied:

d_1 and d_2 – represent the sieve mesh sizes through which the samples were passed trough (μm).
R_1 and R_2 – represent the cumulative sieve outs (%).
d' – the parameter which depends on the particle size distribution of the sample that gives information concerning the massiveness of a sample and represents the sieve mesh size where $R = 36.79\%$.
n – a direction coefficient which depends on the particle size distribution.
d_{95} – the sieve mesh trough which 95% of the mechanically activated product passes (μm).
S_t – theoretical specific surface area (m^2/kg).
S_r – the real specific surface area (m^2/kg).

3. Result and discussion

3.1. Mathematical interpretation of the kinetic model

According to the kinetic model, the results obtained can be described by Rosin–Ramler–Sperling exponential function and equation [12,13].

Change in the size of the mean diameter of grain (d') which functionally depends on rotor speed (ν) is presented as an exponential function in the form $d' = f(\nu)$. The slopes and positions of the exponential curves can be changeable, depending on the type of material and mechanoactivator load. All exponential curves are being drawn in a coordinate system where the X axis shows the unit of the rotor speed (ν) in a meter per second (m/s), while the Y axis shows the unit of the mean diameter of grain (d') in a micrometers (μm). All exponential curves obtained in the graph, the mean diameter of grain (d') against rotor speed (ν), indicate common form of exponential curve [14].

In accordance with the described exponential function, it can be noted that the mean diameter of grain (d'), decreases rapidly with increasing rotary speed (ν). The downward trend reduces to a value $d' > 0$ and vice versa. This is the common characteristic for all curves presented in the form $d'_i = f_i(\nu)$ [15–19].

The exponential function can be described by the following equation:

$$y = y_0 \cdot \exp^{-kt} \tag{1}$$

where k, kinetic rate which depends on experimental conditions; y_0, initial value of (y) of the analog equation $R = R_0 \exp^{-kt}$.

In the case where the parameter (d') tends to the set value (d'_k), there is the corresponding value (ν'_k). According to this, the value of parameter (d') is divided into two parts: constant part (d'_k) and variable part (d'_x). Based on this the following equation can be developed:

$$d' = d'_x + d'_k \tag{2}$$

Dependence between the parameter (d'_k) and the influential parameter (ν) is determined. If there is an upward trend of the rotor speed (ν), from (ν_1) to (ν_2), for a small value ($\Delta\nu$), then the values (d'_x) will be decreased to the value of (d'_{x1}) for a small value ($\Delta d'_x$). This proportionality must match the exponential function (Eq. (1)). Based on the equation $R = R_0 \exp^{-kt}$, the ratio ($\Delta d'_k/\Delta\nu$) must be equivalent to (d'_x). According to this, the following equation includes the factor of proportionality k:

$$\frac{dd'_k}{\Delta v} = -kd'_k \tag{3}$$

Solving differential equation (Eq. (3)), the next equation is derived:

$$\frac{dd'_k}{dv} = -kd'_k \Rightarrow \frac{dd'_k}{d'_k} = -kdv \tag{4}$$

Table 2
Process parameters, technological parameters and parameters of the mechanical activation products.

Ser. nom	Exp. seq. no.	Parameters of the mechanoactivator "Retsch ZM-1"				Technological parameters "Retsch ZM-1"				Parameters of mechanical activation products								
		Rate of rotor revol. (rpm)	Actual rate of rotor revol. (rpm)	Circle sieve mesh size (μm)	Current intensity (A)	Time of mech. activat. (min)	Rotor speed (m/s)	Mechan. capacity (kg/h)	Spec. energy consum. (kWh/t)	d_1 (μm)	d_2 (μm)	R_1 (%)	R_2 (%)	d' (μm)	n	d_{95} (μm)	S_t (m^2/kg)	S_r (m^2/kg)
I	1	10,000	14,435.96	80	1.40	30.00	74.40	0.100	3080.00	5.00	40.00	92.66	3.60	20.55	1.79	37.20	181.38	544.14
	2	10,000	10,824.26	80	2.30	18.00	55.80	0.167	3029.94	5.00	53.00	94.80	1.80	24.36	1.81	43.60	151.22	453.66
	3	10,000	9,278.34	80	3.00	12.00	48.05	0.250	2640.00	5.00	53.00	94.90	2.18	34.79	1.80	44.50	149.51	448.53
	4	10,000	8,151.96	80	3.75	6.00	42.37	0.500	1650.00	5.00	53.00	95.25	2.90	26.24	1.79	47.20	142.10	426.30
	5	20,000	22,821.45	80	2.10	27.00	117.80	0.111	4162.16	5.00	30.00	90.02	5.10	16.40	1.86	28.94	218.19	654.57
	6	20,000	21,648.52	80	2.30	12.00	111.60	0.250	2024.00	5.00	30.00	90.60	7.00	17.22	1.82	30.73	212.65	637.95
	7	20,000	19,314.29	80	2.80	8.00	100.24	0.375	1642.66	5.00	30.00	91.50	8.00	17.98	1.86	31.64	199.02	597.06
	8	20,000	16,969.57	80	3.50	6.00	87.83	0.500	1540.00	5.00	30.00	92.00	9.00	18.51	1.87	32.47	192.25	576.75
II	1	10,000	14,435.98	120	1.40	6.00	74.40	0.500	616.00	5.00	53.00	95.70	4.00	27.47	1.80	49.25	134.92	404.76
	2	10,000	13,360.13	120	1.60	3.00	69.23	1.000	352.00	5.00	63.00	96.20	1.50	28.77	1.83	51.09	126.53	379.59
	3	10,000	9,863.01	120	2.70	1.50	51.15	2.000	297.00	5.00	63.00	97.60	6.00	36.28	1.84	64.23	99.74	299.22
	4	10,000	8,484.79	120	3.50	1.00	43.92	3.000	257.00	5.00	74.00	97.80	4.30	39.50	1.81	70.59	93.26	279.78
	5	20,000	22,213.92	120	2.20	6.00	114.70	0.500	968.00	5.00	40.00	94.00	5.00	21.99	1.84	38.93	164.55	493.65
	6	20,000	20,626.48	120	2.50	5.00	106.43	0.600	916.66	5.00	53.00	95.70	2.00	25.55	1.89	44.55	137.78	413.34
	7	20,000	18,556.67	120	3.00	4.00	96.10	0.750	880.00	5.00	63.00	96.00	1.90	29.26	1.78	52.81	128.20	384.60
	8	20,000	15,704.92	120	4.00	2.50	81.63	1.200	733.33	5.00	63.00	96.50	2.80	31.22	1.80	55.97	118.72	356.16
III	1	10,000	14,435.96	200	1.40	4.50	74.40	0.667	461.77	5.00	53.00	95.20	2.20	25.50	1.82	45.42	143.60	430.80
	2	10,000	12,092.07	200	1.90	3.00	62.52	1.000	418.00	5.00	63.00	96.80	3.60	32.86	1.80	58.92	112.79	338.80
	3	10,000	9,657.14	200	2.80	2.00	50.12	1.500	410.67	5.00	74.00	98.40	8.50	44.72	1.86	78.68	80.02	240.06
	4	10,000	8,089.58	200	3.80	1.00	41.85	3.000	278.67	5.00	53.00	98.90	16.00	52.42	1.89	91.41	67.16	201.48
	5	20,000	22,213.92	200	2.20	6.00	114.70	0.500	968.00	5.00	53.00	94.00	0.90	22.48	1.82	40.04	162.89	488.67
	6	20,000	20,162.57	200	2.60	3.50	104.37	0.857	667.44	5.00	53.00	95.40	2.00	24.46	1.78	44.14	153.44	460.32
	7	20,000	18,556.67	200	3.00	1.50	96.10	2.000	330.00	5.00	63.00	96.00	3.00	26.99	1.87	47.34	131.85	395.55
	8	20,000	15,704.92	200	4.00	0.50	81.63	6.000	146.67	5.00	147.00	97.40	5.00	64.06	1.86	59.93	105.06	315.18
IV	1	10,000	15,786.12	500	1.20	4.00	81.63	0.750	352.00	5.00	147.00	99.43	4.00	79.15	1.86	139.29	45.21	135.63
	2	10,000	11,738.24	500	2.00	1.00	60.45	3.000	146.67	10.00	147.00	98.50	11.00	96.26	1.86	169.40	37.17	111.51
	3	10,000	9,657.14	500	2.80	0.25	50.12	12.000	51.53	10.00	147.00	98.70	12.00	97.48	1.90	169.52	35.92	107.76
	4	10,000	8,937.45	500	3.20	0.17	45.98	17.960	39.19	10.00	104.00	98.75	14.00	101.27	1.89	176.63	34.76	104.28
	5	20,000	22,213.92	500	2.20	4.00	114.70	0.750	645.33	5.00	147.00	99.36	13.00	71.31	1.88	124.74	49.63	148.89
	6	20,000	21,120.68	500	2.40	0.50	109.53	6.000	88.00	5.00	147.00	99.50	5.50	81.11	1.87	142.31	43.87	131.61
	7	20,000	19,314.29	500	2.80	0.32	100.24	9.460	65.11	5.00	147.00	99.60	7.00	87.09	1.92	150.58	39.79	119.37
	8	20,000	17,874.89	500	3.20	0.17	91.97	17.960	39.19	10.00	147.00	98.30	8.00	89.83	1.87	157.61	39.60	118.80

Further integrating,

$$\int \frac{dd'_k}{d'_k} = \int -k dv \Rightarrow \ln d'_k - \ln d_0 = -kv + kv_k \Rightarrow \ln \frac{d'_k}{d'_0} = -k(v - v_k) \quad (5)$$

The equation in the following form is obtained:

$$d'_x = d'_0 \exp^{-k(v-v_k)} \quad (6)$$

Using Eqs. (2) and (6) finally the following equation is obtained:

$$d' = d'_x + d'_k = d'_k + d'_0 \exp^{-k(v-v_k)} \quad (7)$$

3.2. Experimental results

The values of process parameters, technological parameters and parameters measured to observe the mechanical activation process and evaluate the quality of the mechanical activation products are given in Table 2.

It was noted that the current intensity increases from 1.20 to 4.00 A with increasing the circle sieve mesh from 80 to 500 μm and with the increasing mechanoactivator load. This upward trend of the current intensity for rates of rotor revolution n_0 = 10,000 and n_0 = 20,000 rpm occurred.

According to the results presented in Table 2, it can be deduced that changing the circle sieve mesh size from 80 to 500 μm and increasing the mechanoactivator capacity (Q) led to decreased mechanical activation time (t). Based on the results of particle size distribution, it can be noted that changing the circle sieve mesh size from 80 to 500 μm and increasing the mechanoactivator capacity (Q) led to increased massiveness in the particles (d') and the decrease of the rotor speed (v).

In accordance with reduction of the mechanical activation time and rotor speed (v), as well as increased mechanoactivator capacity, it can be seen that the parameter (d_{95}) which is related to fineness of the mechanical activation process is increased. Based on this results, the values of specific surface area (S_t and S_r) and specific energy consumption (W_e) are decreased.

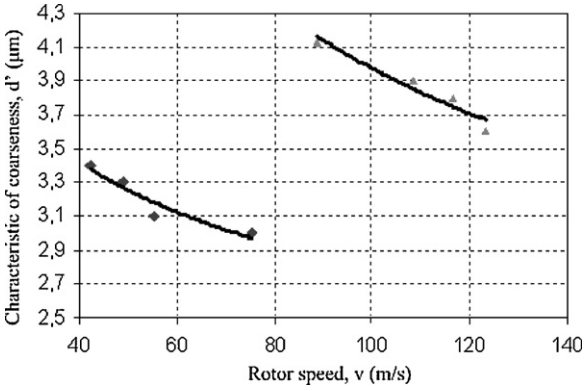

Fig. 1. The mean diameter of grain (d') vs. rotor speed (v) for circle sieve mesh 80 μm.

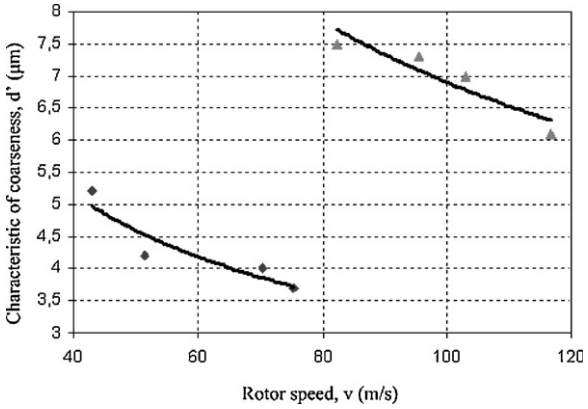

Fig. 2. The mean diameter of grain (d') vs. rotor speed (v) for circle sieve mesh 120 μm.

Therefore, it could be concluded that by increasing the circle sieve mesh size, rate of rotor revolution and mechanoactivator load, the mechanical activation rate, as the main characteristic of mechanical activation kinetics, also increases.

By applying the equation (Eq. (7)) on the measured results in Table 2, the graph ($d' = f(v)$) for each circle sieve mesh is drawn. The graphics, the mean diameter of grain (d') against rotor speed (v) for circle sieves: 80, 120, 200 and 500 μm are displayed in Figs. 1–4, respectively.

The next investigation carried out was aimed at obtaining high-grade talc concentrate with low iron content (Fe_2O_3 = 1.00–1.50%) by hydrometallurgical method. The representative sample of the mechanical activation product with the following characteristics (Table 2): d' = 16.40; t = 27 min, circle sieve 80 μm and n = 20,000 rpm was subjected to leaching test by hydrochloric acid (15 wt%). The leaching process took place in a three-necked bottle at constant temperature (T = 80 °C) and within the time period of 3.5 h. During this process the following products were separated: calcite (green color) at the bottom, talc concentrate (white color) in the upper layer and CO_2 gas. The fine talc particles were carried upward by CO_2, while chlorite particles remained at the bottom of the three-necked bottle. The products of leaching process are the talc concentrate, chlorite, intermediate product (talc-chlorite) and final tailing. All

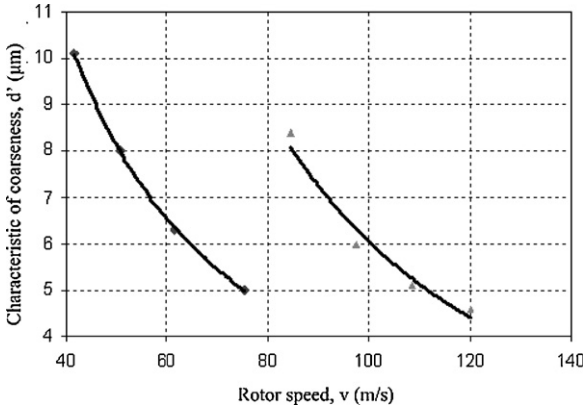

Fig. 3. The mean diameter of grain (d') vs. rotor speed (v) for circle sieve mesh 200 μm.

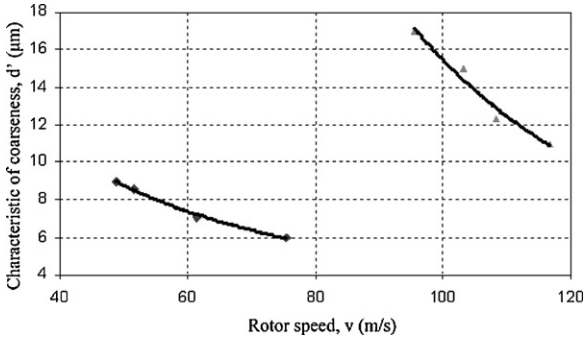

Fig. 4. The mean diameter of grain (d') vs. rotor speed (v) for circle sieve mesh 500 μm.

Table 3
Particle size distribution of the talc concentrate sample.

Class of coarseness (in mm)	*M*%, mass portion	*D*%, undersize	*R*%, oversize
−53 + 40	19.56	19.56	100.00
−40 + 30	13.88	33.44	80.44
−30 + 20	12.56	46.00	66.56
−20 + 15	11.18	57.18	54.00
−15 + 10	10.84	68.02	42.82
−10 + 5	7.88	75.90	31.98
−5 + 0	24.10	100.00	24.10
Total	100.00	–	–

Table 4
Chemical composition and physical-chemical characteristics (concentrate, intermediate product and tailing).

Product	Component and content (in %)				
	M%, mass portion	MgO	Fe_2O_3	LOI	Mineral
Talc concentrate	75.90	28.30	1.15	5.00	Pure talc
Intermediate product	15.77	12.94	5.83	6.90	Talc chlorite
Tailing	8.33	14.57	10.00	9.75	Chlorite
Total	100.00	24.22	2.80	5.84	–

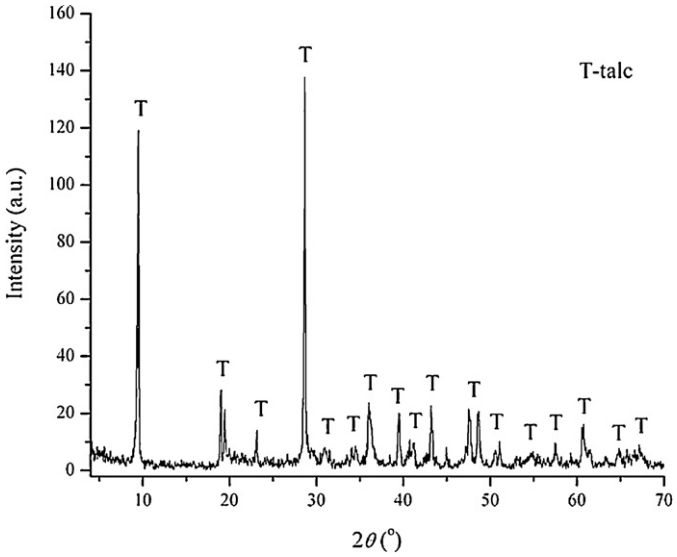

Fig. 5. Diffractogram of the talc concentrate sample.

products in the hot states were rinsed, filtered and dried. The particle size distribution of the talc concentrate sample, chemical composition and physical–chemical characteristics (concentrate, intermediate product and tailing) are shown in Tables 3 and 4, respectively.

The talc concentrate sample was examined by application of thermal, thermogravimetric, IC spectrochemical and X-ray diffraction analyses. The results of the X-ray, DTA, TGA and IC analyses of the talc concentrate sample are shown in Figs. 5–7, respectively.

The X-ray analysis indicates the presence of talc minerals, while the presence of other minerals in the talc concentrate sample was not observed (Fig. 5).

Fig. 6 shows that the talc concentrate sample is thermally stable up to 880 °C with progressive weight loss on heating to 1000 °C; the total weight loss being 4.25%. The start of an endothermic effect was observed in a DTA curve at temperature of around 880 °C. The endothermic effect reached a peak at

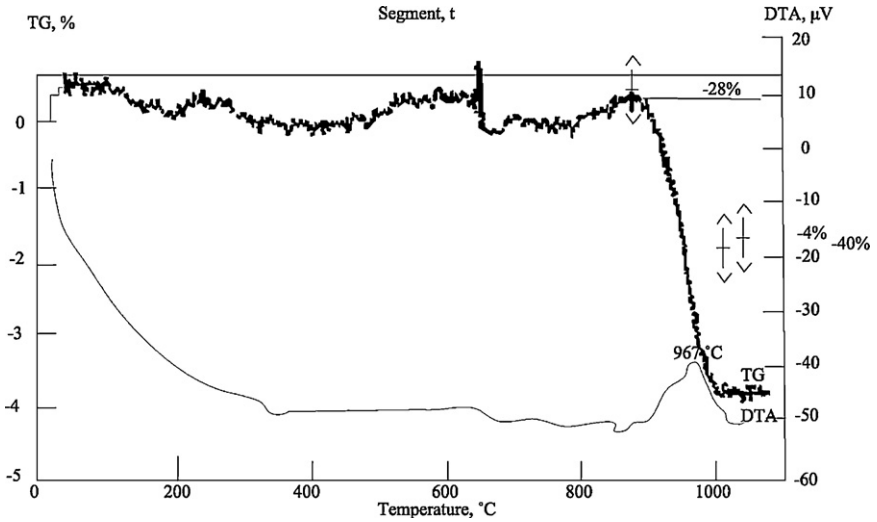

Fig. 6. DTA and TGA results for talc concentrate sample.

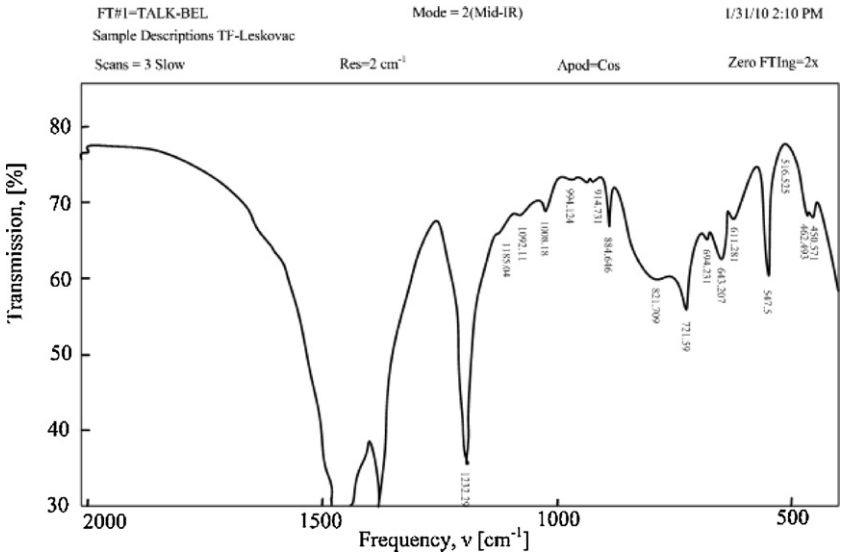

Fig. 7. IC spectrum results for the talc concentrate sample.

967 °C. This effect could be explained by structural water loss with recrystallization into the enstatite ($MgSiO_3$).

The IC spectrum analysis of the present series shows broad and weak absorption in the range from 600 to 800 cm^{-1}. The most striking characteristic in the range from 800 to 400 cm^{-1} is the doublet 450 and 462 cm^{-1} which is noticeable during complete series. The observed absorption was greater in a higher frequency band. It seems clear that the two bands must not be assigned to Mg–O vibrations, but to Si–O bending vibrations.

The bands of around 1090 cm^{-1} are attributed to the $(CO_3)_2$ – carbonate symmetric stretching mode. The observation of this mode in the infrared spectra provides evidence for the distortion of the carbonate anion and consequential loss of symmetry. The $(CO_3)_2$ – carbonate symmetric stretching mode is complemented by the antisymmetric stretching modes found in the range from 1300 to 1450 cm^{-1} where a series of overlapping bands may be observed providing a complex spectral profile.

The results of IC spectrum analysis indicate the presence (absorption) of hydrous magnesium carbonate on the surface of talc minerals.

4. Conclusion

According to the results obtained in this investigation of the kinetics of the mechanical activation of talc in high-energy-speed rotary mechanoactivator, where mechanical activation is realized by impact, the following conclusions were made:

- Good liberation of talc particles was achieved by this type of mechanoactivator. Also, the surfaces of talc particles were well activated for the subsequent leaching treatment. The application of the mechanical activation process as pre-treatment method, was shown to directly affect the increased degree of concentration.
- The mechanical activation rate, as the main characteristic of mechanical activation kinetics, increased with increasing the circle sieve mesh size, rate of revolution and load of the high-energy-speed rotary mechanoactivator. The best results were obtained with a nominal mechanoactivator load.
- The optimum values of the process and technological parameters were defined. Based on these values, the mechanical activation products were determined.
- In accordance with the obtained results and derived mathematical equations, the kinetic model is provided. This model could be used for optimization and automation of mechanical activation process in high-energy-speed rotary mechanoactivator.
- The results obtained in this investigation of mechanical activation contribute to the interpretation of appearances and process arising during talc mechanical activation in this type of mechanoactivator. Also, these results may be useful for the introduction of these processes into practice.
- The iron content in concentrate was obtained in the standard range. Ignition loss of around 5% and 98% of pure talc indicated high-grade talc concentrate. The presence (absorption) of the hydrous magnesium carbonate on the surfaces of talc minerals can be explained by the fact that the talc-magnesium rocks are part of the composition of the bed ''Bela Stena''.
- It can be concluded that the introduced mechanical activation process can significantly improve the degree of recovery either by hydrometallurgical process or by combination with other concentration method. This indicates one new approach for obtaining of high-grade talc concentrate.

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