

DEVELOPMENT OF A COMBINED GRAVITY–MAGNETIC SEPARATION PROCESS FOR MAGNESITE ORE USING HGMS*

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Abstract: Most magnesite deposits in Yugoslavia contain serpentine and olivine as impurities. Heavy medium separation is used for the beneficiation of raw magnesite ore with particle size greater than 0.35 mm. The results of investigations reported in this work indicate a possibility of efficient removal of serpentine and olivine using HGMS and superconducting magnetic separators for fines smaller than 0.35 mm. Based on these results a new technological process for magnesite upgrading was established. The process combines the gravity and magnetic separation processes for treatment of raw material, as well as for magnesite after its decarbonisation. It is possible to upgrade the magnesite fines below 0.35 mm which are rejected from the conventional processes. The grade of the magnesite concentrate of 98% and above may be obtained using this process.

INTRODUCTION

The plant with gravity separation in magnetic suspensions built in the magnesite mine "Goles" contains two technological circuits:

- gravity concentration of raw magnesite, preconcentration and
- gravity concentration of the pre-concentrate from the first circuit, after decarbonisation and hydration.

The flowsheet of this plant is shown in Fig. 1 [1]. The technology of the process consists of the following stages:

- a. The crushing of the ore to the desired size limit which depends on the required degree of liberation of impurities on the one hand, and on the capabilities of the concentrating equipment and imposition by the subsequent products (the production of the dead-burned magnesite and refractory bricks) on the other hand.
- b. Heavy medium separation to discard light fractions containing low-density gangue. This stage is necessary only if the ore contains considerable amounts of light-density impurities (below 2400 kg/m³).
- c. Calcination of the sinks to decarbonise carbonates. The calcination temperature is conditioned by the following factors:
 - if the impurities are only SiO₂-bearing minerals, the calcination temperature is between 870 K to 1370 K, and depends only upon the sintering process to be subsequently applied on cleaned products
 - when the magnesite ore contains dolomite beside SiO₂ as gangue, the calcination temperature should be below 950 K so that only magnesite is decarbonised and dolomite remain unaffected.
 - should the magnesite ore contain, among other impurities calcium carbonate, the calcination temperature should go up to 1370 K in order to bring up full decarbonisation. Calcined products are then immersed in a water solution of a surface-active reagent. Under such conditions, beside other reactions, free CaO is hydrated to Ca(OH)₂. This calcium hydroxide forms the "milk of lime" with the liquid phase and is easily washed away with water.
- d. Decarbonised products are then subjected to hydration which takes place in a water solution of a surface-active reagent of the type:



The hydration process represents the beginning of the second concentration stage.

- e. Separation in heavy medium of decarbonised and hydrated products. In this stage the magnesium oxide and magnesium hydroxide float while silicate-bearing impurities such as undissociated carbonates (dolomite) report in the sink product. It should be noted that densities of decarbonised and hydrated products are reduced to about 2000 kg/m^3 .

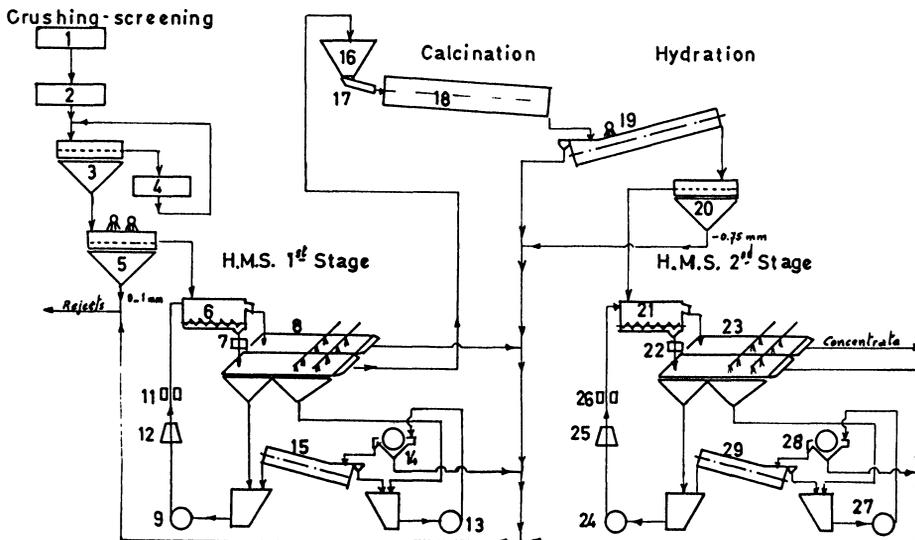


Fig. 1 The flowsheet diagram for magnesite concentration: 1-run-of-mine ore bin, 2-primary crusher, 3-screen, 4-secondary crusher, 5-screen, 6-HMS washing trough (1st stage), 7-electromagnetic valve, 8-draining, 9-undiluted medium pump, 11-density control device, 12-demagnetising coil, 13-diluted medium pump, 14-magnetic separator, 15-densifier, 16-concentrate bin (1st stage), 17-feeder, 18-caustification kiln, 19-hydration device, 20-screen, 21-HMS washing trough (2nd stage), 22-electromagnetic valve, 23-draining and washing screen, 24-undiluted medium pump, 25-demagnetising coil, 26-density control device, 27-diluted medium pump, 28-magnetic separator, 29-densifier.

The conditioning of products with surface-active reagents in the hydration stage and in the concentration process itself is applied in order to prevent flocculation, to increase the wetting of minerals and to disperse fine particles. The surface-active reagent plays a very important role in separation of decarbonised and hydrated magnesite products, taking into account the fact that heavy medium separation is carried out at a high pH value (10–11). By decreasing the surface tension of water to about 0.032 N/m, on top of the effect already mentioned, the surface-active reagents speed up the rate of hydration due to better wetting and keep up dispersion of the fines which is favourable to calcium hydrate washing. It is to be noted that under such conditions, the medium is kept dispersed during hydration and is prevented from blocking this reaction. This has been proved by a large number of tests. By this technological process can only be treated material with grain size +0.35 mm. The material with grain size –0.35 mm, which is contained in total mass of 31.7%, cannot be treated by this process. Table 1 shows the particle size distribution of class –0.35 mm.

Table 1. Particle size distribution of class –0.35 mm

Size range µm	Cum.mass. %	Size range µm	Cum.mass. %
362.0	100.00	39.5	25.8
270.0	96.0	29.4	18.8
201.0	85.8	21.9	12.5
149.0	70.2	16.3	10.0
111.0	52.9	10.5	7.2
53.1	30.1	5.8	2.21

As a result of significant concentration of these particles, the third concentration phase was introduced after the second concentration stage. The third phase represents magnetic concentration by high-gradient magnetic separation (HGMS) at the magnetic field of 2 Tesla [2]. The flowsheet of this stage is shown in Fig. 2.

The major part of $\text{Ca}(\text{OH})_2$, as a harmful compound, leaves the system with the slurry, while $\text{Mg}(\text{OH})_2$ and serpentine with olivine as harmful components proceed into further concentration, because they are the main carriers of SiO_2 .

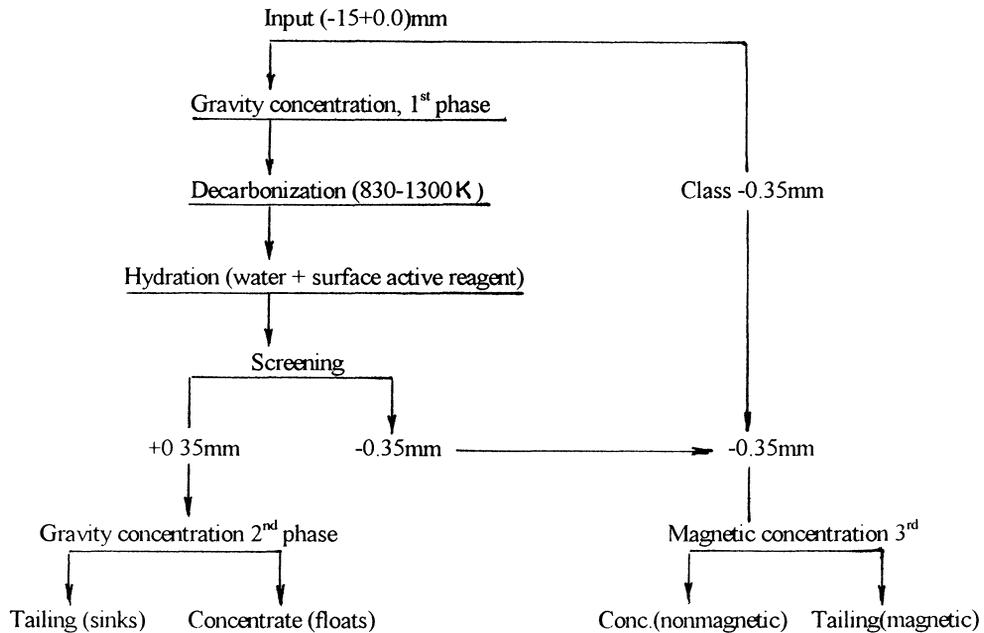


Fig. 2. A flowsheet of the combined gravity–magnetic separation process (the third stage)

EXPERIMENTAL

Gravity Separation

The laboratory experimental results and those from the industrial–scale tests on magnesite ore from Goles were reported in detail in [1, 3, 4, 5, 6]. Final results of gravity concentration in two stages are summarised in Table. 2.

Table 2. The final result of two–stage gravity separation

Size range, mm	Suspension density, kg/m ³	Mass, %	SiO ₂ , %	CaO, %
-15+0.35	<2000	81.26	0.28	0.72
	>2000	18.74	45.26	-

Magnetic Concentration

Series of tests on magnesite ore were carried out at the Institute for Technology of Nuclear and Mineral Raw Materials, Belgrade using the Sala HGMS, model 10–15–20. Schematic diagram of the separator is shown in Fig. 3.

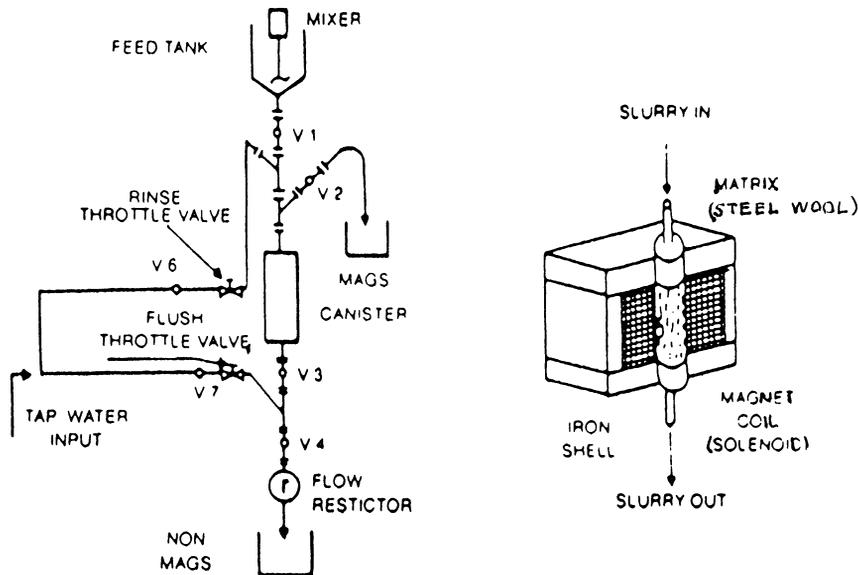


Fig. 3 Schematic diagram of a laboratory cyclic SALA–HGMS magnetic separator

The average magnetic susceptibility of serpentine and olivine that remained in the the class -0.035 mm of the decarbonised products was found to be $\chi = 2200 \times 10^{-9} \text{ m}^3/\text{kg}$. Based on this susceptibility and on the characteristics of the magnetic separator, a minimum particle diameter of particles for magnetic treatment was calculated using the following parameters:

susceptibility of serpentine and olivine	$\chi = 22 \times 10^{-11} \text{ m}^3/\text{kg}$
velocity of water flow	$v = 0.05 \text{ cm/s}$
external magnetic field	$H_0 = 1600 \text{ kA/m}$
magnetisation at 2 T	0.1592 T
surface tension of industrial water	$\gamma = 0.072 \text{ N/m}$
surface tension of water solution of the surface-active reagents	$\gamma' = 0.032 \text{ N/m}$

diameter of matrix element	$a = 0.01 \text{ m}$
angle of wetting	$\theta = 0$
factor of resistance to motion in the fluid	$k = 0.65$

The reagents were used in the hydration process and in the second stage of gravity separation because of very high pH (10–11) of the suspension. In order to overcome flocculation in the process of magnetic concentration, the same reagents were used.

For the wetting angle $\theta = 0$, the minimum particle diameter d which can be held by the matrix, is calculated using expression (1) [7]:

$$d = \sqrt{\frac{9\eta va}{\chi I(H_0 + \frac{8\pi}{3} I)}} k = \sqrt{\frac{9 \times 1 \times 10^{-13} \times 0.05 \times 10^{-2}}{2200 \times 10^{-9} \times 0.1592(2 + \frac{8\pi}{3} \times 0.1592)}} \times 0.65 = 23 \mu\text{m} \quad (1)$$

where $k = 0.65$, taken from earlier experimental work [7].

After desliming (removing classes smaller than -0.023 mm) which cannot be treated at the magnetic field of 2 T the sample is once again treated by the water solution of the surface–active reagents, as a result of the fact that hydration of magnesium has not been completely finished. Subsequently, the tests were carried out. The results obtained in these tests are summarised in Table 3.

Table 3. The results of magnetic separation tests

Size range, mm	Products	Mass, %	SiO ₂ , %	CaO, %
-0.35+0.023	magnetic	31.40	37.14	0.06
	nonmagnetic	68.60	0.16	0.31

It can be seen from Table 3 that the size fraction -0.023 mm which represents more than 14% of the total mass could not be treated by the magnetic separator owing to insufficient magnetic field (maximum 2 T). As a result of the

experimental data which confirmed the theoretical determination of the minimum particle size as a function of the magnetic field strength it can be concluded that the magnetic field up to 5 T is necessary for this type of magnesite. It means that additional 12% of magnesite could be upgraded. It follows from eq.(1) that the minimum particle diameter of 0.008 mm could be separated at 5 T, compared to 0.023 mm from previous HGMS experiments. According to literature, superconducting magnetic separators with magnetic field in excess of 5 T are available and further investigations will be performed in this direction. By introducing such separators to the beneficiation of the magnesite ore it will be possible to recover material rejected from the hydration process of the caustic magnesite and from the gravity concentration process.

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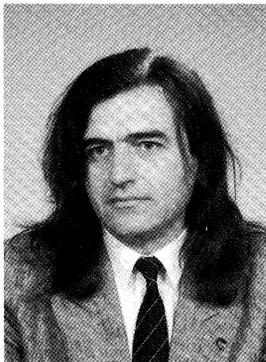
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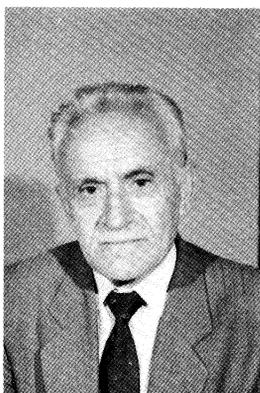
Miroslav R. Ignjatovic was born in 1959. He graduated from the Faculty of Mining and Geology, University of Belgrade. He obtained his M.Sc. degree from the University of Belgrade, Technical Faculty in Bor, in 1991. After graduation he joined the Institute for Technology of Nuclear and Other Mineral Raw Materials in Belgrade and he has worked on projects and studies in gravity and magnetic concentration of mineral raw materials. Mr. Ignjatovic is an author of two monographs, 10 papers in scientific and professional journals. He also participated, with 15 reports, in national and international symposiums and congresses.



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