Investigation of the Fehérvárcsurgó heap

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Abstract

Natural heavy mineral enrichment can be observed in the particle fractions below 250 microns of the Fehérvárcsurgó glass sands. The heavy minerals contain several types of titanium: ilmenite, rutile, and anatase. This titanium-containing mineral is the primary ore of titanium metal and plays a very important role in many areas of industry. The research work aims to extract these minerals by magnetic separation after classification by particle size. The recovery of titanium (ilmenite, Mg-ilmenite) was obtained using a Mechanobr dry cylindrical electromagnetic separator. Materials were fed for magnetic separation by particle size fraction (0-63, 63-125, and 1225-250 µm) at a magnetic flux density of 0.137, 0.310, 0.430, and 0.657 T. After the magnetic enrichment, the magnetic products of the fractions were sent for chemical analysis, during which X-ray crystallography determined their mineral content. Based on mineralogical analysis at low magnetic flux density (0.14 T), about 9/10 of the ilmenite and 2/10 of the rutile and anatase can be recovered due to agglomeration.

1 Introduction

The topic of this research is the enrichment of heavy minerals, including ilmenite recovery from the mine waste, in the glass sands of Fehérvárcsurgó. The ilmenite ($FeTiO_3$) is a titanium-containing mineral, the primary ore mineral of the titanium metal, and plays a significant role in many areas of industry.

The Fehérvárcsurgó glass sands occur in the Mór Trough separating the Bakony and Vértes mountains, in the Iszkaszentgyörgy-Fehérvárcsurgó-Magyaralmás-Csákberény arc [1]. Clean, white sand with a grain size of 0.1-0.5 mm is suitable for glass production [2], but the raw glass sand contains several heavy minerals, including ilmenite. The heavy minerals in the glass sands usually have smaller particle sizes than the main component (quartz), as higher-density minerals settle together with the larger but less dense quartz grains [3].

The Institute of Raw Material Preparation and Environmental Processing, within the framework of the “CRITICEL project”, has previously analyzed the mineralogical and chemical composition of the glass sands of Fehérvárcsurgó. Studies on the waste minerals containing heavy minerals from the mining and cleaning of glass sands have shown that they are rich in ilmenite, which is well enriched in the waste minerals under study. Therefore, the research work aims to extract the glass sands' titanium content primarily by magnetic methods.

2 Material and methods

2.1 Material

The starting raw material was flotation waste product from a glass sand processing plant (Üveg-Ásvány Kft, Fehérvárcsurgó). The XRD measurement (Table 1) shows that titanium is present in the following mineral phases: rutile, anatase, brookite, ilmenite, and Mg-ilmenite.

The initial moisture content was 16.07 wt% and the particle density was 3.64 kg/dm3. The results of the particle distribution analysis and the density of particle size fractions are shown in Figure 1. The particles in the sample are less than 1000 µm, with a median size of 105 µm. The higher density values indicated the enrichment of heavy minerals. As expected, this agrees with the findings of other researchers [4] [5]. Therefore, fractions below 250 µm were processed in the research. Preliminary physical and chemical analysis of the sample, and similar studies [6] [7], indicated that ilmenite content can be obtained by particle size classification and magnetic and conductivity enrichment.

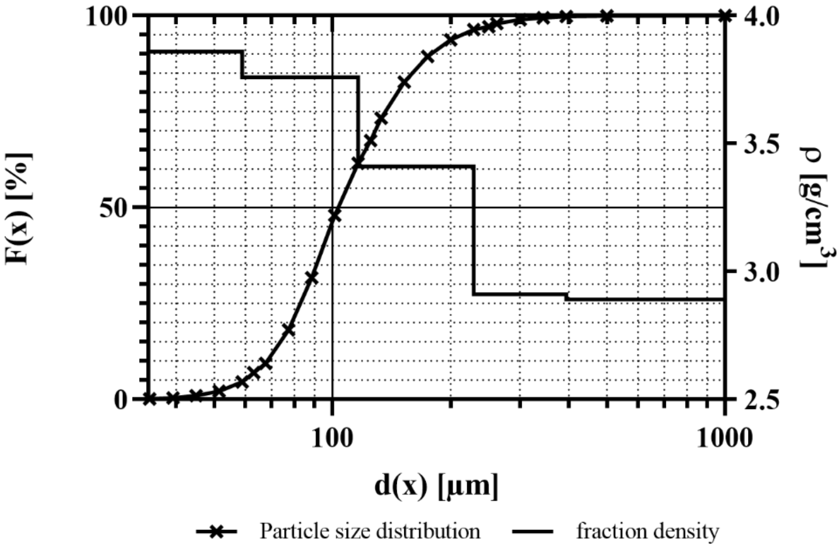

Figure 1. Particle size and density distribution of the raw material

2.2 Methods

The recovery of titanium (ilmenite, Mg-ilmenite) was obtained using a Mechanobr dry cylindrical electromagnetic separator. Materials for magnetic separation by particle size fraction (0-63, 63-125, and 1225-250 µm) were fed at a magnetic flux density of 0.137, 0.310, 0.430, and 0.657 T.

The raw material dispersity was determined with sieve analysis and a Horiba-La-950V2 laser particle size analyzer under wet conditions using distilled water as dispersing media. For better dispersion of fine particles, before the measurement, sodium pyrophosphate was added to the sample material, and the sample material was ultrasonic stirred for one minute before measurement. The particle size distributions (PSD) were estimated by Fraunhofer's approximate method from the measured data.

Electron microscopy and energy dispersive spectrometry were carried out on the flotation waste product. The measurement was performed with a Phenom ProX scanning electron microscope equipped with an EDS detector. The measurement conditions include an accelerating voltage of 10 and 15 kV in point analysis mode with a spectrum collection time of 60 s. The images were taken with variable zoom.

XRD was used to identify and characterize the raw material and the products of the magnetic separation, with a Bruker D8 Advance diffractometer using Cu K-alpha radiation (40 kV, 40mA) in parallel beam geometry obtained with Göbel mirror in the 2-70° (2Theta) range with a 0.007° (2Theta) step interval and a 24 s step counting time. The Bruker DiffracPlus software package identified the crystalline phases in its EVA module ICDD PDF-2 (2005) database for the search/ matching of phases. The quantitative evaluation was carried out by Rietveld-refinement in TOPAS4 software, where the amorphous content was determined by the amorphous hump method.

2.3 Characterization

Before starting the magnetic enrichment, the mineral content with XRD measurement of the froth waste material and the morphology of the particles constituting the sample with optical and electron microscopy were examined.

Figure 2 shows the microscopic image of the mining raw material (3/1) and the flotation gangue (3/2-4). The XRD measurement (Table 1) shows that the raw sand contains white translucent quartz particles. The proportion of quartz in the barren waste is reduced and replaced by different colored minerals. The columnar, prismatic minerals with brown and brownish-orange color are possibly dravite and schorl of the tourmaline group. The black metallic luminous particles are the ilmenite. Sample 0-63 μm shows a prismatic red particle, possibly rutile.

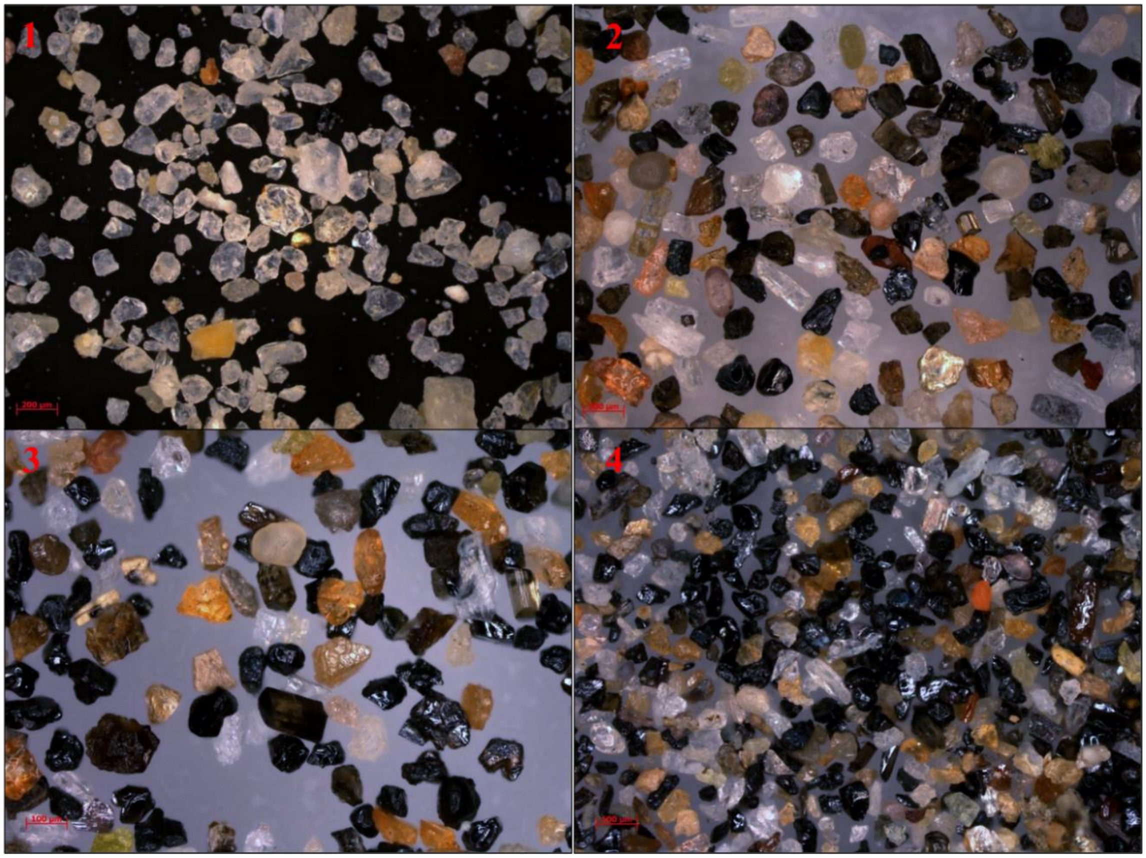

Figure 2. Microscope image of the glass sand (1: glass sand, 2: fraction 125-250 μm, 3: fraction 63-125 μm, 4: fraction 0-63 μm)

Table 1 shows the result of the mineral composition of the raw and classified by particle size materials. The raw material from the mine has ~0.82 wt% titanium-containing minerals: rutile, anatase, brookite, ilmenite, and Mg-ilmenite. Below 63-µm fraction has the highest titanium content (~ 52 wt%), but this particle size fraction makes up only 6 wt.% of the raw material. However, most titanium is recovered from the 125-65 µm fraction, containing 65 wt% of the ore minerals. In the study, the extraction of titanium was magnetically based, so this primarily meant the extraction of ilmenite.

Table 1. The results of the quantitative evaluation of XRD on glass sands classified by particle size

Mineral phase	**Chemical Formula**	**Particle Size Fraction [µm]**			
		Raw	**250-125**	**125-63**	**63-0**
Quartz	SiO_2	95,8	7,68	7,62	6,46
Rutile	TiO_2	0,054	7,00	11,23	12,02
Anatase	TiO_2	0,251	1,65	2,52	2,66
Dravite	$NaMg_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$	-	27,06	14,72	11,05
Staurolite	$(Fe^{2+},Mg)_2Al_9(Si,Al)_4O_{20}(O,OH)_4$	-	16,96	17,94	11,41
Kyanite	Al_2SiO_5	0,648	9,31	7,98	4,67
Zircon	$ZrSiO_4$	0,117	0,62	1,01	5,22
Andalusite	Al_2SiO_5	-	1,56	0,96	0,34
Calcite	$CaCO_3$	-	1,58	0,56	0,41
Clinozoisite	$Ca_2Al_3(SiO_4)_3(OH)$	-	4,94	3,47	4,82
Dolomite	$CaMg(CO_3)_2$	-	1,53	0,78	0,73
Brookite	TiO_2	0,207	1,27	1,36	2,70
Ilmenite	$Fe^{2+}TiO_3$	0,309	3,02	10,14	13,35
Zoisite	$Ca_2Al_3(SiO_4)_3(OH)$	-	5,52	2,63	2,22
Annite	$KFe^{2+}_3AlSi_3O_{10}(OH,F)_2$	-	0,70	0,59	0,52
Ilemnite (Mg)	$(Fe^{2+},Mg)TiO_3$	-	6,85	14,30	20,31
Hematite	Fe_2O_3	-	0,12	0,63	0,70
Ankerite	$Ca(Fe^{2+},Mg,Mn)(CO_3)_2$	-	0,79	0,07	0,00
Almandine	$Fe^{2+}_3Al_2(SiO_4)_3$	-	0,13	0,10	0,11
Schorl	$NaFe^{2+}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$	-	1,71	1,38	0,37

3 Result and discussion

Figure 3 shows the results of the magnetic separation. On a magnetic basis, only the ilmenite can be extracted from the titanic minerals. Still, non-magnetizable titanic minerals can also be transferred to the magnetic product due to grain agglomeration.

Based on the results, it can be concluded that ~90% of the total ilmenite content can be extracted at 0.43 T. Thus, the ilmenite content of the product can be increased from 20-25 wt% to 40-45 wt%. As a by-product (due to agglomeration), 20 wt% of the non-magnetic titanium can be recovered, giving a total ore content of around 50 wt%. As the magnetic flux increased, the recovery improved moderately from this point onwards, while the separation efficiency decreased sharply. This trend is observed for all samples with a particle size above 0.63 μm. Below 0.63 microns, the maximum ilmenite content (~30 wt%) measured in the extracted product occurs at 0.31 T, but the extraction of magnetic titanium is still only ~70 wt%, with non-magnetic only ~20 wt%.

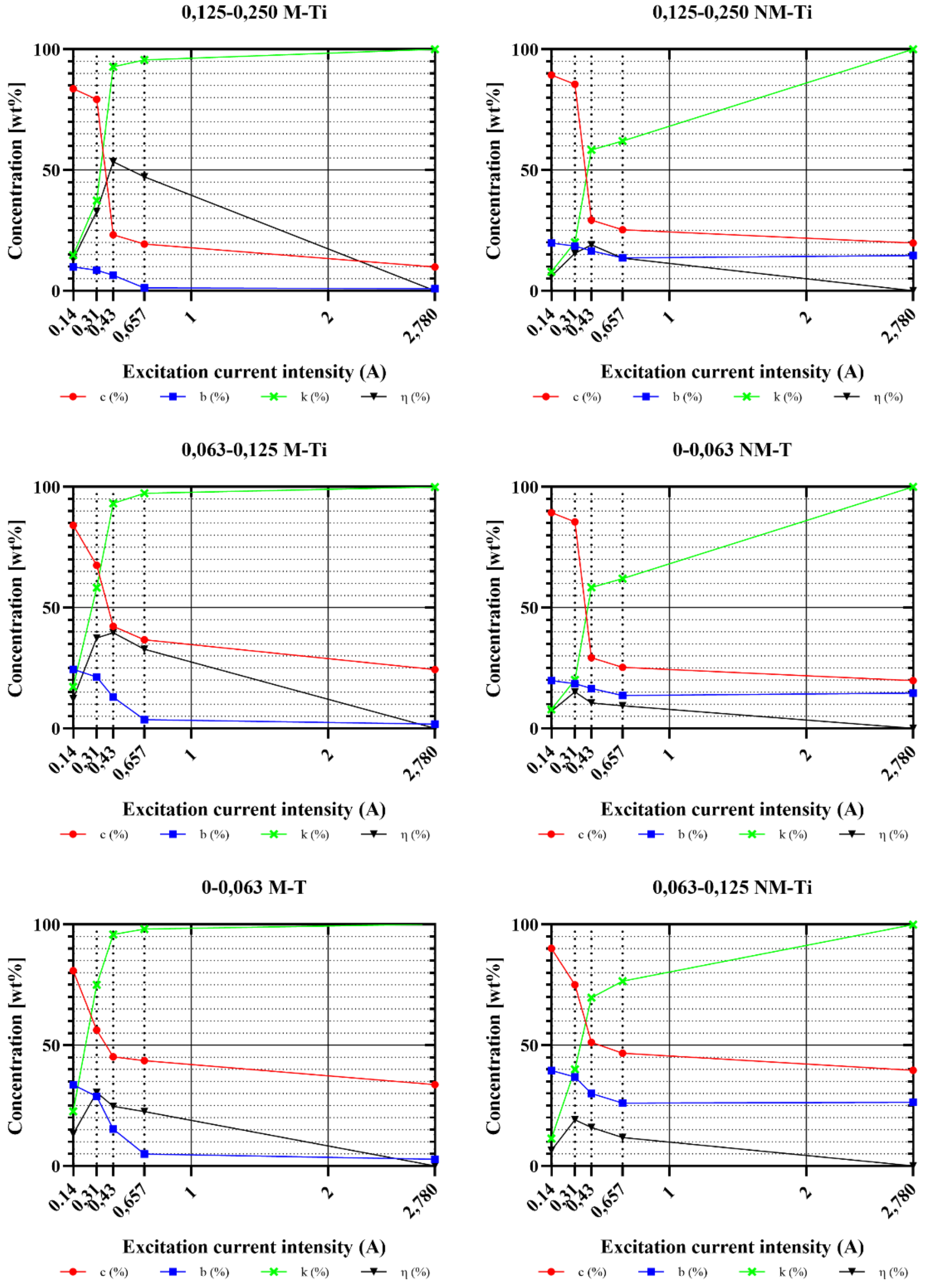

Figure 3. Extraction curves after magnetic separation (M: magnetic titanium ore, NM: all titanium ore; c: concentrate curve, b: gangue curve, k, component extraction curve η: separation efficiency)

After magnetic separation (Figure 4), the concentrate contained the highest amount of ilmenite (2. 4. 5. 6. 7. 8. and 11. particles). The image shows a few quartz particles (3, 10). It is ankerite based on the composition of particle Nr. 1 (iron, calcium, oxygen, carbon).

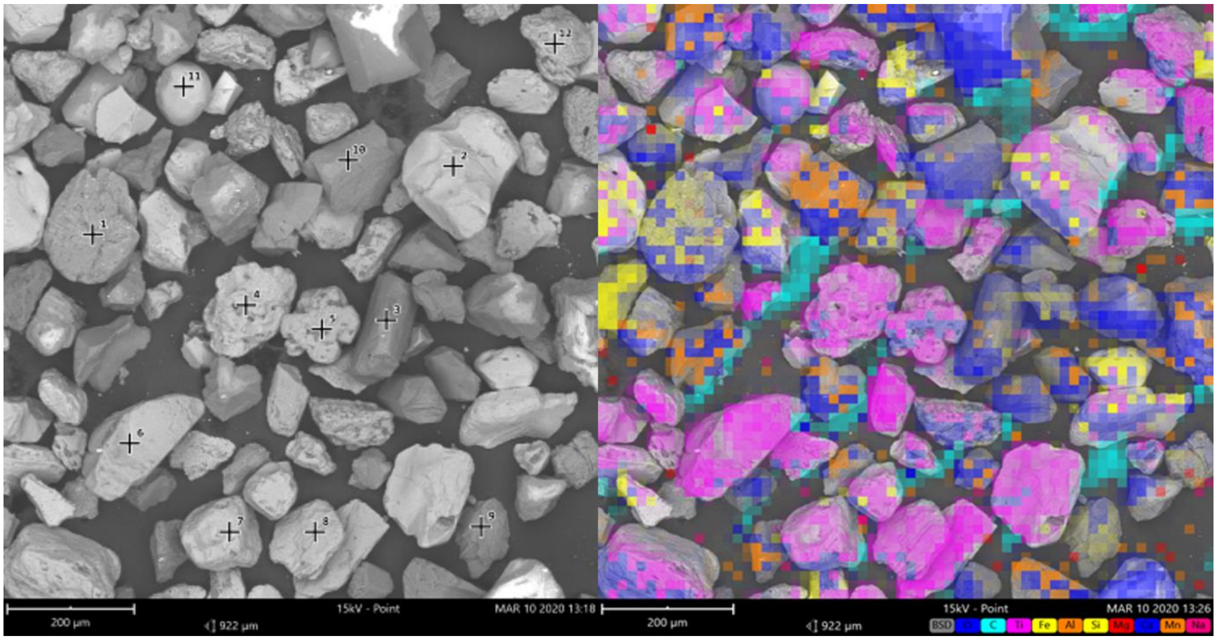

Figure 4. The morphology of the after magnetic separation of the product below 63 µm, numbers with dots indicate the EDX measurement site

4 Conclusion

The study aimed to recover titanium, which is present in the sample as 3/1000 ilmenite, 1/2000 rutile, and anatase minerals. The heavy minerals in Fehérvárcsurgó glass sands are naturally enriched in finer fractions according to grain size. For this reason, they can be classified by particle size and enriched by magnetic or conductivity methods. We used a magnetic method for the measurements. Only ilmenite and the particles that have grown with it can be obtained.

At low magnetic flux density (0.14 T), about 9/10 of the ilmenite and 2/10 of the rutile and anatase can be recovered due to agglomeration. The titanium content can thus be increased from 7/2000 to 1/2. Increasing the magnetic field strength only slightly improved the titanium yield but significantly degraded the metal ore content of the concentrate.

5 Acknowledgements

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