RECUPERATION OF ULTRA-FINE IRON ORE FROM TAILING PONDS AS AN ECONOMICALLY AND TECHNICALLY FEASIBLE AND ENVIRONMENTALLY CORRECT ALTERNATIVE METHOD [1]

José Eustáquio Vieira[2]
Augusto Nogueira Ramos Neto[3]

Abstract

The present report documents the results of industrial-scale utilization of ultra-fine iron ore stored in tailing ponds during previous years of productions. The tailings were studied and technically evaluated in pilot plant scale by high intensity magnetic separation with the aim to segregate quartz from hematite. The declared aim of the project was the recovery of a concentrate product with the SiO_2 content limited to a maximum of 3.0 % and a grain size range dictated by the process. The philosophy of the company was to effectuate the idea of utilizing technically and economically the available raw material by an environmentally sound method.
Key words: Mining; Iron Ore; Concentrate; Tailings; Ultra-Fine Magnetic separation from Waste Dumps.

1 *Technical contribution to the 2nd International Symposium on Iron Ore, September 22 – 26, 2008, São Luís City – Maranhão State – Brazil*
2 *Student of Production Enginier – General Development Manager of Ferro + Mineração S/A.*
3 *Mining Enginier Genral Manager of Ferro + Mineração S/A*

1 INTRODUCTION

The - here discussed - iron ore mining company is an enterprise with an installed production capacity of 1.6 million tons of products per annum comprising lump ore, sinter feed and pellet feed.
It is located close to kilometer 593 of the federal road number BR-040 within the city region of Ouro Preto in the state of Minas Gerais, Brazil.
Until 2002 the company was focused on just producing rich lump ore.
The material smaller than 8 mm which was considered being tailings was stockpiled in the near neighborhood of the enterprise.
From 2002 onward a gravity method process plant to produce sinter feed has been established to treat the fraction between 2.0 mm and 0.074 mm.
The fraction between 8.0 mm and 2.0 mm did not require any upgrading.
From 2006 onward a project has been commissioned for the upgrading of the tailings which had been deposited in tailing ponds applying high intensity magnetic separation producing a concentrate with a silica-content lower than 3.0%.
Besides of reducing environmental problems this solution became necessary because the crude ore consists predominantly of specular hematite and friable itabirite with a high portion of ultra-fine particles.
This phenomenon required the utilization of these ultra-fines as a product thus increasing the total recovery of the plants.
The studies with the aim to utilize the ultra-fines of the tailing ponds started in 2004 applying high intensity magnetic separation in two successive stages.
In these tests various grades of magnetic field strength and various widths of separation gaps have been studied to define the operational conditions of an eventual industrial plant.
The test results confirmed the feasibility of an industrial plant for upgrading ultra-fine iron ores using WHC separators in the first stage with ripple plate distances of 2.5 mm width of separation gaps and using the same separators in the second stage – however – with a gap width of just 1.5 mm to treat the tailings and the middlings of the first stage.
Besides of the reduction of the environmental impact this possibilty to utilize the ultra-fine iron ore sedimented in the tailing ponds as a commercial product created an important positive economical factor for the company.

2 DEVELOPMENT - DESCRIPTION OF THE VARIOUS STEPS - RESULTS

The following paper concentrates on the results of the industrial beneficiation process for ultra-fines, being the main subject of this study.
The company treats in the beneficiation plant run of mine ore blended with ultra-fines from the tailing ponds in various proportions in function of the market requirements.
The recovery of the fines from the tailing ponds does not present any problems as this material is dry and does not create any difficulties for the shovels.
The transport on trucks and the handling through the intermediate stockpile and day bins also is easy.
The various intermediate stockpiles are piled by stackers.
They are controlled in their proportions of the different types of feed ore to ensure for the process a recommended blend for the envisaged rate and quality of each product.

Of essential importance for the control of the process are the protection screens before the high intensity magnetic separators which have to avoid any coarse particles enter into the ripple plates and causing there obstructions.
The magnetic separation is always operated at the utmost highest magnetic field strength in order to recover most of the ultra-fines smaller than 0.045 mm, i.e. of that fraction which is predominantly present in the feed material.
Another important process parameter for the magnetic separation is the pulp density of the slurry feed.
The upper limits the pulp density are well defined.
The operators therefore are strictly monitoring the pulp density to ensure the optimum process conditions.
The recovery of concentrate is directly related to the pressure of the wash water.
Therefore there are manometers in all branches of the washing system.
In addition there are filters provided in the system to maintain control over the process.
Every 15 minutes the process flows are automatically sampled and collected for a composite eight-hour-shift sample for each type of product.
The magnetic concentrates are individually analyzed in order to detect eventual deviations in any of the process steps.
The laboratory furnishes the analytical results to the plant thus enabling a close control of the equipment.
The following tables present the results of the daily chemical and physical analyses of the magnetic separation over the period of six months production, that is, from January to June 2008.

Table 1: Feed of Magnetic Separation first stage

	Chemical Composition [%]					
	Fe	SiO_2	P	Mn	Al_2O_3	PPC
Average	46,68	30,77	0,045	0,03	0,94	1,19
Stand Desviation	2,79	4,12	0,015	0,01	0,18	0,26
Max.	52,93	41,08	0,055	0,04	1,53	2,32
Mín.	39,64	21,27	0,035	0,03	0,53	0,62

Table 2: Feed screen of Magnetic Separation first stage

	Screen Composition [mm]											
	1,00	0,50	0,30	0,212	0,150	0,106	0,075	0,045	0,025	Pass.	Abaixo 0,150	Abaixo 0,106
Average	0,1	1,2	1,3	1,2	2,4	4,3	6,6	20,4	16,2	46,3	93,8	89,4
Stand Desviation	0,1	0,8	0,6	0,5	0,9	1,1	1,3	2,2	3,5	5,7	2,4	3,1
Max.	0,7	5,0	4,4	3,6	6,3	7,1	10,3	25,9	22,4	62,3	98,3	95,8
Mín.	0,0	0,1	0,3	0,3	0,8	1,9	3,5	14,4	8,2	34,5	84,9	79,8

Table 3: Feed of Magnetic Separation Second Stage

	Chemical Composition [%]					
	Fe	SiO_2	P	Mn	Al_2O_3	PPC
Average	28,93	55,50	0,045	0,03	1,16	1,39
Stand Desviation	4,13	6,28	0,015	0,01	0,28	0,29
Max.	38,95	68,75	0,055	0,04	2,18	2,75
Mín.	20,39	35,45	0,035	0,03	0,47	0,85

Table 4. Chemical Composition [%] of Magnetic Concentrate

	Chemical Composition [%]					
	Fe	SiO_2	P	Mn	Al_2O_3	PPC
Average	66,94	2,60	0,045	0,03	0,61	0,71
Stand Desviation	0,40	0,53	0,015	0,01	0,10	0,16
Max.	67,75	3,91	0,055	0,04	1,20	1,65
Mín.	65,98	1,62	0,035	0,03	0,35	0,35

Table 5: Chemical Composition [%] of Magnetic Tailings

	Chemical Composition [%]					
	Fe	SiO_2	P	Mn	Al_2O_3	PPC
Average	11,00	81,04	0,045	0,030	1,36	1,50
Stand Desviation	2,05	3,16	0,015	0,010	0,42	0,28
Max.	15,9	87,8	0,055	0,040	3,7	2,2
Mín.	6,8	73,0	0,035	0,025	0,7	0,8

The established quality aims to guarantee for certain clients a maximum silica-content of 3 % for the concentrate is 2.9% SiO_2.
The iron content of the tailings is also controlled to less than 12% Fe in order to keep the Fe-recovery above 85%.
Another matter which is also studied in this process is the potential utilization of the high-silica tailings as a raw material , for example as an aggregate for concrete, for ceramics or for other applications:
This - of course – could be offered at an attractive price.
This utilization of tailings would also lead to utmost clean products.
The Figure 1 shows the development of the recovery of the process plant in relation to the various steps of modifications.

Step 01: Wash Lump Ore Production until 2002 June.
Step 02: Wash Lump Ore Production + *Sinter feed* – before 2002 June.
Step 03: Wash Lump Ore Production + *Sinter feed* + *Pellet feed* since 2007 June.

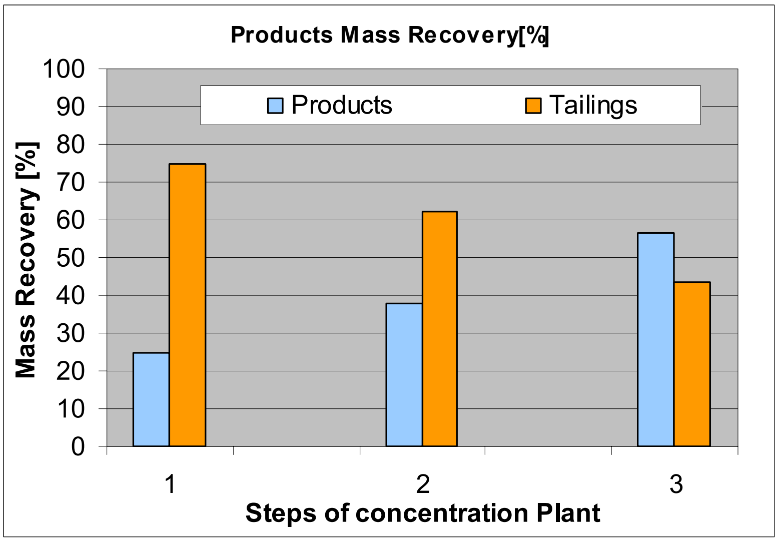


Figure 1: Production Evolution of Concentration Plant

Table 6 shows the average chemical composition of the products and the distribution of the mass recovery.
Presently there exists the tendency to lower the output of lump ore and sinter feed and to increase stepwise the production of ultra-fine concentrate by magnetic separation.

Table 6: Products Mass Recovery and Chemical Composition

Products	Fraccion - mm	Recovery [%]	Fe	SIO_2	AL_2O_3	P	Mn	PPC
WLO	31,0 – 6,35	7	62,00	8,00	1,80	0,035	0,08	1,40
Sinterfeed	6,35 - 0,105	25	64,50	3,70	1,60	0,025	0,07	1,80
Pellet feed	< 0,105	30	66,94	2,60	0,045	0,03	0,61	0,71
Tailings	< 0,105	38	11,00	81,04	0,045	0,030	1,36	1,50
Total		100	43,78	34,62	1,39	0,0394	0,42	1,26

The Figure 2 shows the size distribution of the products in the various steps of the magnetic separation process revealing that the concentrates of both stages of separation are well finer than the final tailings.
The ultra-fine size distribution and the high specific surface of the concentrate differ remarkably from the products of other mines.
This fact will influence the grinding costs for the production of pellet feed quite positively.
The analyses of the specific surface are not shown here; but occasional tests revealed data in turn of 1,100 cm^2 / gram.

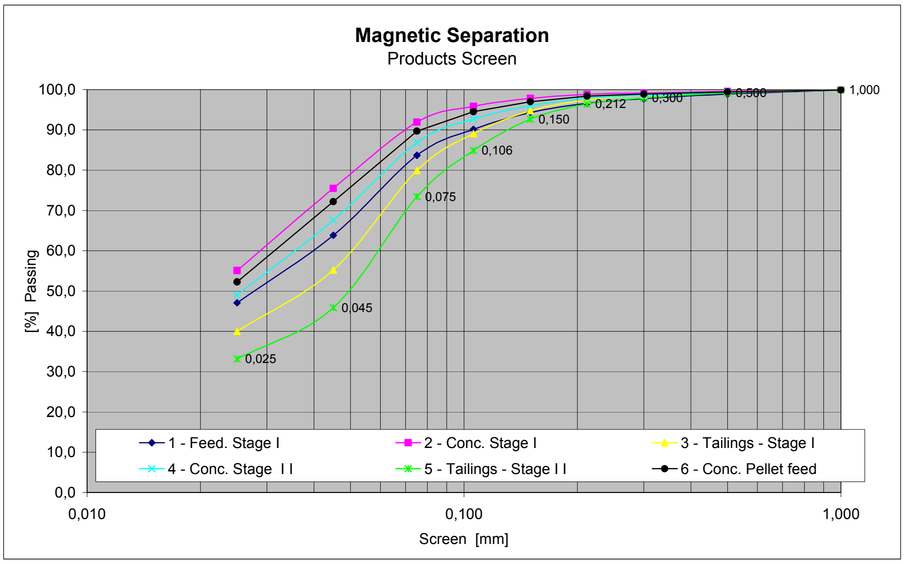


Figure 2: Screen Products Analisys of Magnetic Concentration

The Fe-recovery is a factor of high importance as it guarantees that operation and process are well controlled.
The Figure 3 demonstrates the consistency of the results over the total report period.

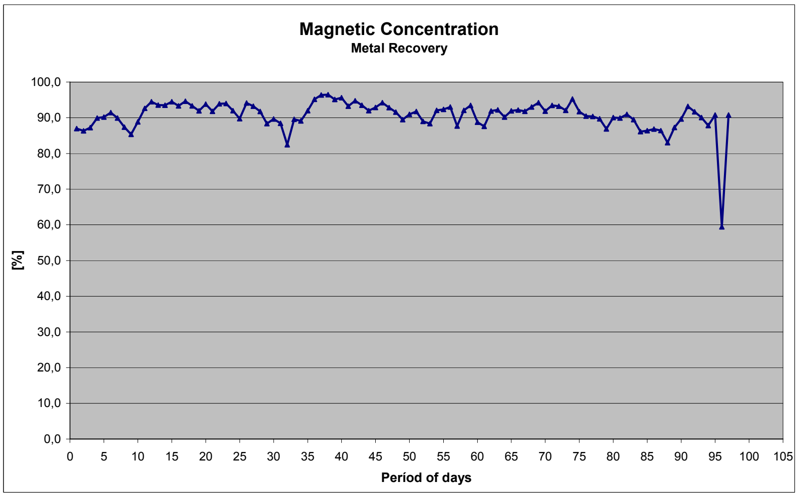


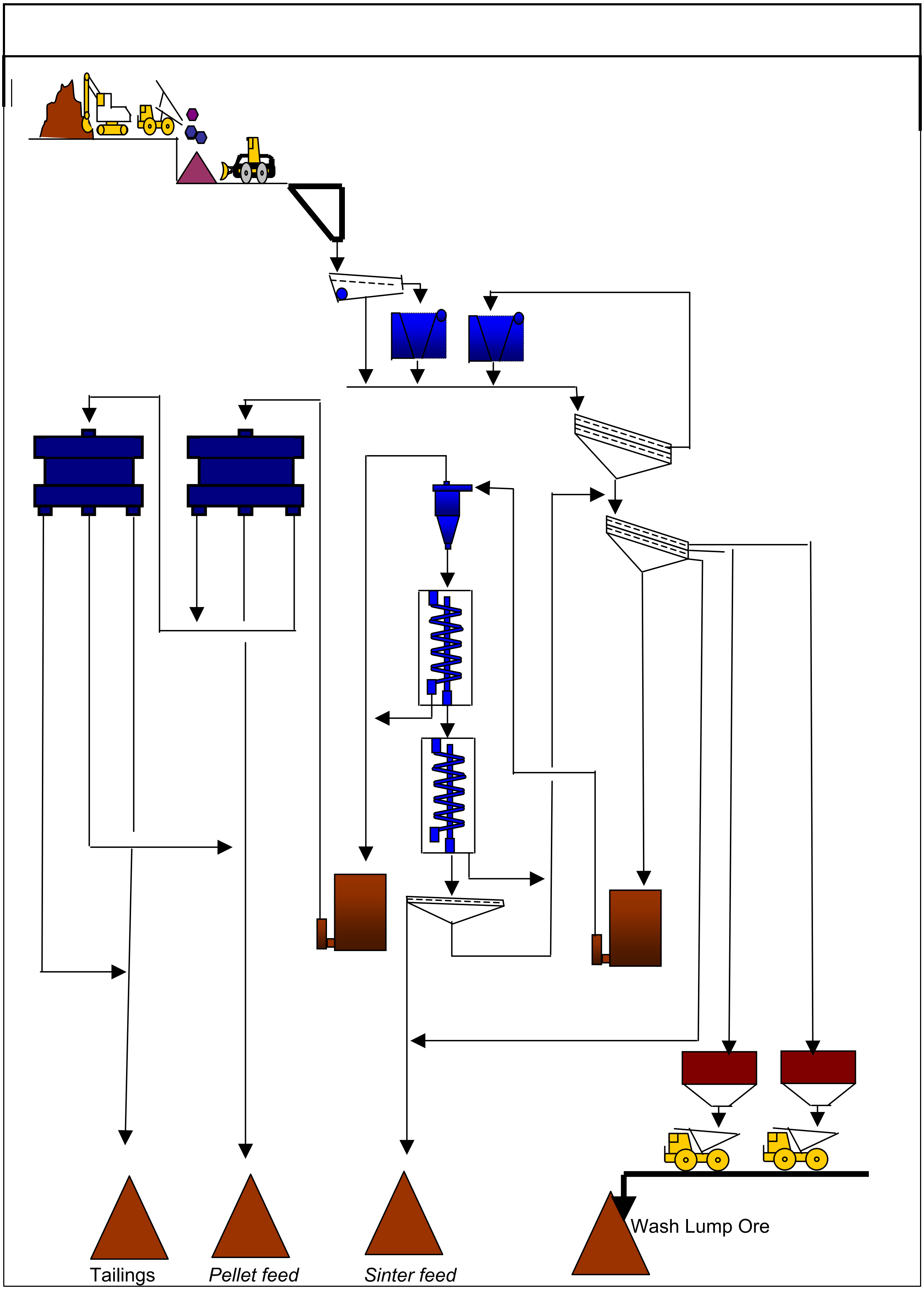
Figure 3: Fe - Recovery of Magnetic Concentrate

Figures 4 e 5 show the contrast between the two basic products of the magnetic separation.

Figure 4: Concentrate

Figure 5: Tailings

2.1 Process Flowsheet of Ferro + Mineração S/A



3 CONCLUSIONS

The results in industrial scale confirm the viability of the magnetic separation in two stages for the solution of the environmental problem of high quantities of ultra-fine deposited in tailing ponds as well as for the creation of a new product (pellet feed concentrate) with a considerable economical value for our enterprise.
The screen concentrate is very fine material 75% smaller then 0,045mm and specific surface about 1.100 cm^2/g. However this concentrate quality is much better and low energy consumption
of balls Mill process.
The chemical composition of concentrate has 80% lass than 2,9% of Sílica in the periodo.
The Fe-recovery lies above 85 % and the iron-content in the tailings lies in average around 12% Fe.

Acknowledgement

The authors wish to thank especially for the understanding received from the management of Ferro & Mineracao S/A and for the great support during the execution of this project, also for the liberation of these informations for publication
Thanks also to our colleague Adriano Elias Armond, beneficiation technician, for the elaboration of this study.
Further thanks to our colleague Tiago Claret Santiago for his great contribution in the elaboration of this paper.

BIBLIOGRAFIA

VIEIRA, J.E. Report 0076 – 20050316 – 01 - Development of *pellet feed* at Ferro + Mineração S/A.