BENCH-SCALE MICROPELLETIZING TESTS OF SINTERING MIXTURES [1]

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Abstract

The sintering process consists in the agglomeration of iron ore fines (named sinter-feed), fluxes and additives. The product of this process, the sinter – is the main component of the blast furnace burden at ArcelorMittal Monlevade. Micropelletizing performs an important role in the sinter production due to its impact in the main operational parameters of the sintering process and in the sinter quality. Aiming a greater knowledge about the sinter-feed behavior in the micropelletizing process, bench-scale tests were carried out using the sintering mixture usually used at the sinterplant in ArcelorMittal Monlevade, placing emphasis in Andrade sinter-feed. These tests consisted of the following steps: mixture preparation (raw materials proportioning and homogenization), micropelletizing in balling, sintering of the micropellets and the sinter characterization. The tests results provided support to the decision of applying the "Hybrid Pelletized Sinter" process (HPS) at Monlevade Works, representing an important tool for the decision-making.N This paper shows the results obtained in the micropelletizing of the sintering mixture in bench-scale, as well as their reproducibility in the industrial facility at ArcelorMittal Monlevade.

Key words: Sintering; Micropelletizing; Iron ore; Bench-scale tests

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2 *Ironmaking area, ArcelorMittal Monlevade*

1 INTRODUCTION

Since the beginning of its operation, in February 1978, ArcelorMittal's sinterplant has been supplied with iron ore from its own mine, the sinter feed Andrade (SFAN).
From 1999 on, after the start-up of blast furnace A (BF-A), sinter production became a bottleneck. In order to increase sinter production, the use of external sinter-feed was intensified, reaching the level of 55 % of the total iron ore mix.
Aiming at fully using the potential of Andrade mine, some alternatives were evaluated:

- iron ore treatment at the mine – as the bench-scale (laboratory) tests showed, this would not eliminate the external dependence on ore and the required sinter production would not be reached;
- increase of the effective grate area –a technical-economic study for increasing the width and length of the strand was carried out in 1999. This alternative showed that it would not eliminate the external dependence of iron ore and would also be very costly;
- micropelletizing of the mixture – preliminary studies showed that this process should enable the use of 100% of our own iron ore, and also meet the required production level. So, this alternative showed to be interesting, pointing out to a promising solution.

For over 15 years a bench-scale sintering facility was available at Monlevade Works, and several tests were performed, always aiming at providing the necessary technical support to the industrial plant operation. This facility was transferred to Samarco's industrial unit in Ponta Ubu – at that time both companies belonged to the same group, and an agreement between them made it easy for Monlevade team to conduce tests in Ponta Ubu, without costs.
For sustaining the idea of the micropelletizing, bench-scale tests were performed from December 2000 to October 2002. These tests were carried out in the laboratory facilities of Samarco, in Ponta Ubu, Espírito Santo State.
Some advantages of these tests were:

- low costs, due to the agreement between the two companies: the pot grate facilities were transferred from Monlevade Works to Ponta Ubu plant one year before;
- Monlevade's team knowledge in bench-scale tests, due to the large experience in the use of the facilities;
- possibility of expanding the testing program, through exploratory tests;
- the possible contribution of the tests for minimizing the technological risks in the decision-making.

The micropelletizing of the sintering mixture in balling discs was already done in the Japanese steel industry [(1)]. Aiming at a better understanding of the micropelletizing of the mixture containing SFAN, bearing in mind the strong reliance on external ores (for size correction) and making use of the experience acquired in several tests performed in Monlevade as well as the facilities in Samarco (including bench-scale balling discs), the tests hereafter commented were accomplished.
Such tests consisted of the following steps: mixture preparation (raw materials proportioning and homogenization), micropelletizing in discs, sintering of the micropellets and the sinter characterization.
The purpose of this paper is to show the main results obtained in the bench-scale tests, as well to compare them with those reached at the industrial plant.

2 BENCH-SCALE TESTS

The different steps of the sintering process were simulated in the laboratory, from the mixture preparation to the sinter production – for the conventional sintering process and for the micropelletizing process, as follows:

- mixture preparation (raw materials proportioning and homogenization);
- micropelletizing in balling disc;
- sintering of the micropellets;
- handling of the sinter cake.

All the sinter cakes were characterized according to the same standards used in Monlevade. The size distribution analyses were done at Samarco laboratory and the physical and metallurgical tests were done at Monlevade laboratory.
The mixture (with SFAN) used at that time in the industrial plant in the conventional process was taken as reference.
Having the mixture used at the industrial plant as a reference, the following ore mixes were defined:

- conventional process: 45 % SFAN; 30 % ore "A"; 25 % ore "B";
- with micropelletizing: 100 % SFAN.

3.1 Raw Materials

The raw materials used in the tests were collected at Andrade mine (SFAN) and in the sinterplant at ArcelorMittal Monlevade (external sinter feeds, burnt lime, limestone, serpentine, coke fines, manganese ore, internal return fines, return fines from blast furnace and sinter for hearth layer). After prepared for the tests in accordance with the standard procedures for bench-scale tests, the raw materials were packed and sent to Samarco plant.
Table 1 shows the size distribution for the iron ores.

Table 1. Size distribution for iron ores (in %)

Ore	> 6,35 mm	> 1,00 mm	< 0,149 mm	Ratio >1,00/<0,149	Mean size (mm)
SFAN	2,66	30,78	41,59	0,74	1,14
Ore "A"	11,42	71,88	15,86	4,53	2,78
Ore "B"	16,93	63,74	17,62	3,62	3,04

3.2 Equipment

The tests were performed using the bench-scale balling disc and sintering facility available at Samarco laboratory.
Figure 1 shows the flow sheet and equipment used for simulating the different steps of the process. Equipment details are given in Table 2.

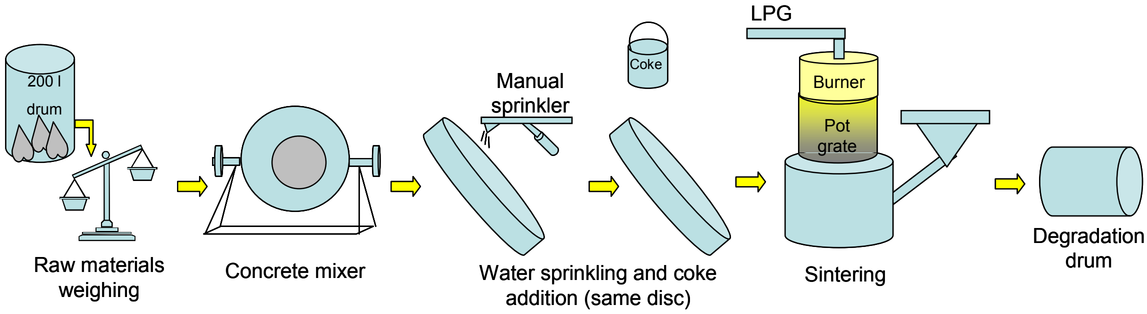

Figure 1. Flow sheet and equipment used in the tests

Table 2. Equipment characteristics

Equipment	Dimension			Slope (°)	Speed (rpm)	Capacity (kg)
	Height (mm)	Diameter (mm)	Area (m^2)			
Concrete mixer	700	685	0,37	-----	24	~ 120
Balling disc	200	1000	0,79	47	15	~ 120
Pot grate	405	285	0,06	-----	-----	~ 52
Tumble drum - ISO 3271 (2)	500	1000	-----	0	25	-----

3.3 Procedures

The operational and sinter quality indexes obtained in bench-scale tests should be of the same order of magnitude of those registered in industrial scale. In the case of the tests with the micropelletizing of the sintering mixture, a greater approximation of productivity and physical quality of sinter with industrial results was sought, in detriment of the fuel consumption.

It was a challenge to simulate de mixture micropelletizing in laboratory, due to:

- high quantity of raw materials – this should contribute for a low repeatability of the tests, leading to doubts about the results;
- few experience of the team in micropelletizing of mixtures containing sinter-feed.

In order to overcome these challenges some factors must be highlighted:

- the experience acquired with the accomplishment of several sintering tests at ArcelorMittal Monlevade;
- the interaction and dedication of the laboratory teams of both companies.

The procedures for the bench-scale micropelletizing of the sintering mixture were based in results of preliminary tests carried out with this purpose.

For the sintering, the simulation of the sinter cake handling and the sinter characterization, the same procedures used in the tests already done at Monlevade were adopted.

Table 3 shows the procedures used for the sinter production and characterization (mixture preparation, sintering, sinter cake handling). The criteria for defining the optimal moisture, the chemical composition of sinter and the approved tests are included in the Table 3.

Procedure		Standards	
		Without micropelletizing	With micropelletizing
Mixture preparation	Sinter-feed size distribution	Full	< 8 mm
	Fuel size distribution	3,0 mm ~ 5,00 mm: 15 % < 3,0 mm: 85 %	100 % < 1,00 mm
	Quantity of dry mixture	45 kg	50 to 80 kg
	Dry mixing time (mixture natural moisture)	3 minutes	1 minute
	Water addition in the concrete mixer	5 minutes	2 minutes
	Total mixing time	8 minutes	3 minutes
	Micropelletizing time (balling disc)	---------------------	Fixed between 8 and 15 minutes (enough to form enough micropellets for charging the pot grate)
	Micropellets coating	---------------------	With coke breeze < 5,00 mm; 3 minutes in the disc
	Optimal moisture definition	One test for each moisture content, varying 0,5 percentual point each mixture. The optimal moisture is defined as the one that showed the higher productivity, the lower fuel consumption and the lowest return fines production (balance)	
Sintering	Ignition time	1 minute	
	Air and gas flow in ignition	Air: 220 Nm^3/h – LPG: 6 Nm^3/h	
	Depression in ignition	500 mmH_2O	
	Depression in sintering	1000 mmH_2O	
	Depression in cooling	700 mmH_2O (after 3 minutes from the end of sintering)	
	Hearth layer	3 kg (35 to 40 mm)	
	Bed height	390 mm	
Handling simulation	Sinter cake degradation in ISO drum	40 turns	
Approval criteria	4 tests for getting data for calculation of operational parameters and sinter for characterization	Return fines balance (< 5,0 mm): 95 to 105 % Maximum difference in sintering time: 1 minute	
Chemical composition of sinter	Definition	Basicity index (CaO/SiO_2) fixed in 1,78. MgO content fixed in 1,24%. (The presented chemical composition is the theoretical, except for FeO content)	
Sinter characterization	"Shatter index"	JIS - M 8711 (3)	
	"Tumble index"	ISO 3271 (2) - ASTM - E 279 (4) and JIS - M 8712 (5)	
	RDI	JIS - M 8720 (6)	
	Reducibility	JIS - M 8713 (7)	

Table 3. Procedures for the tests

3.4 Activities

The developed activities for the bench-scale micropelletizing of the sintering mixture are listed in table 4. Highlight for the quantity of raw materials samples that were handled (approx. 48 tons).

Table 4. Developed activities during the tests

Activity	Quantity
FeO content determination	19
Size distribution analysis	59
Shatter index determination	19
RDI determination	34
Burnt lime reactivity determination	4
Reducibility determination	38
Tumble index determination	27
Number of testing steps	19
Handled raw material	~ 48 ton
Sample preparation for chemical analysis	51
Sintering tests	225
Sinter cake handling simulation	225

3.5 Performed Tests

The main purpose of the performed tests was to compare the performance of the sintering mixture in the conventional process and with micropelletizing. For reaching this target, the following items were evaluated:

- SFAN micropelletizing, separately;
- the burnt lime effect;
- the SFAN composition (type of ores from different mining areas) effect;
- the effect of using bentonite instead of burnt lime.

4 RESULTS

The main results of the bench-scale tests and of the industrial sinterplant are shown in Table 5 and Figures 2 to 8. In order to check the tests reproducibility, the steps “conventional” and “micropelletizing” are compared and the difference between them are pointed out.

For the industrial scale the annual results of 2001 and 2007 were taken, representing the conventional and micropelletizing periods, respectively.

Evolution of sinter production from 1998 to 2007 at ArcelorMittal Monlevade is shown in Figure 9. It must be highlighted that from 2003 on, after the installation of the Hybrid Pelletized Sinter (HPS) process, only Andrade sinter-feed has been used.

It is necessary to say that the tests here described and their results were an important tool for the decision of installing the HPS technology.

Table 5. Results: bench-scale and industrial scale

Scale			Laboratory			Industrial		
Parameter		Unit	Conventional	Micropelletizing	Dif. (%)	Conventional (2001)	Micropelletizing (2007)	Dif. (%)
Ore mix composition	SFAN	%	45	100	--	45	100	--
	Ore "A"	%	30	0	--	30	0	--
	Ore "B"	%	25	0	--	25	0	--
Specific consumption	Fuel	kg/t	72,5	71,2	-1,8	60,9	54,0	-11,4
	Lime	kg/t	30,2	55,2	82,8	26,8	48,6	81,4
Productivity		$t/m^2.24h$	35,3	40,1	13,6	36,8	40,9	11,0
Sinter quality	Mean size	mm	17,7	17,8	0,5	18,8	19,7	4,9
	Shatter Index	%	83,3	83,5	0,2	87,0	86,2	-0,9
	RDI (<2,83mm)	%	25,4	21,1	-16,7	26,1	25,2	-3,4
	R.I.	%	57,2	58,6	2,4	60,1	64,6	7,5

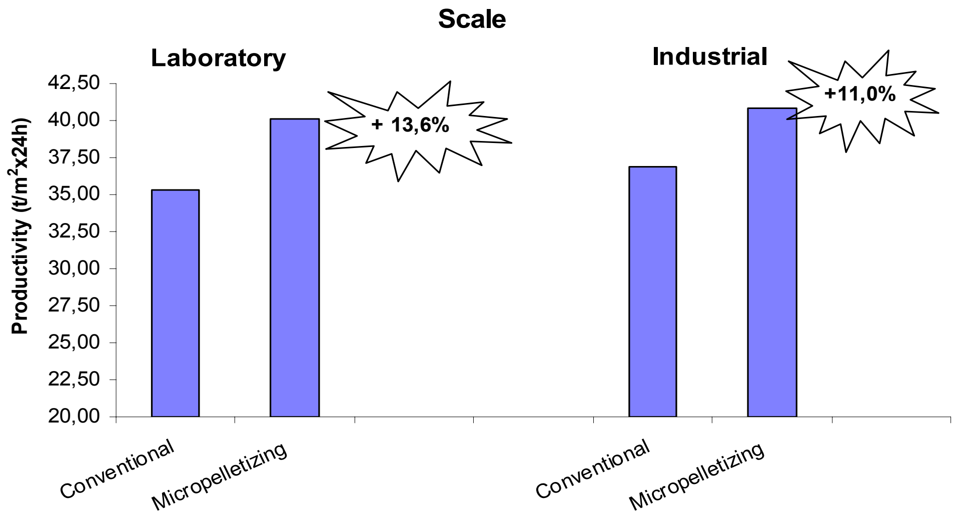

Figure 2. Productivity

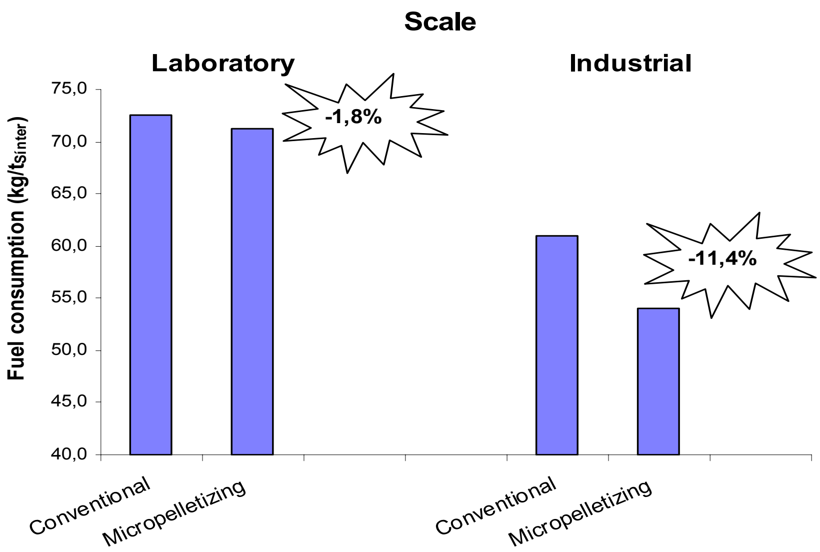

Figure 3. Fuel consumption

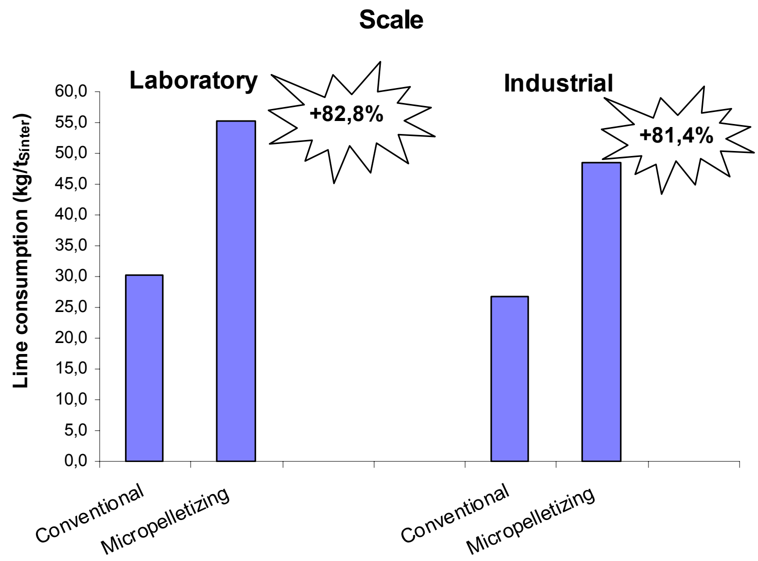

Figure 4. Lime consumption

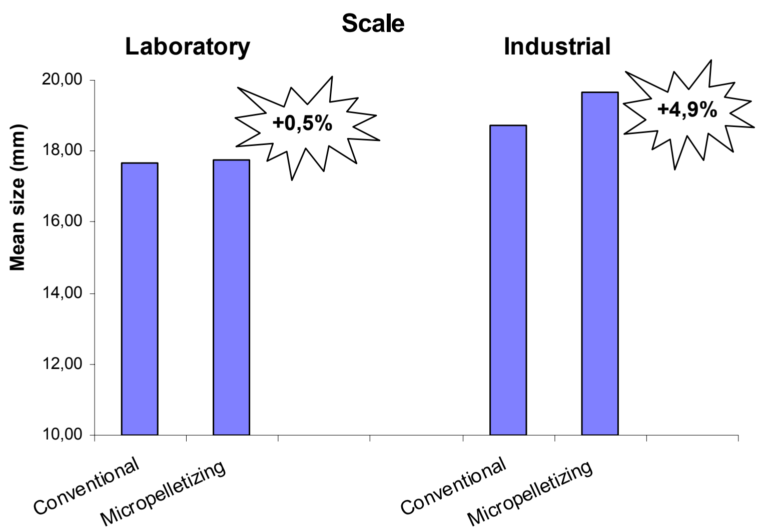

Figure 5. Sinter mean size

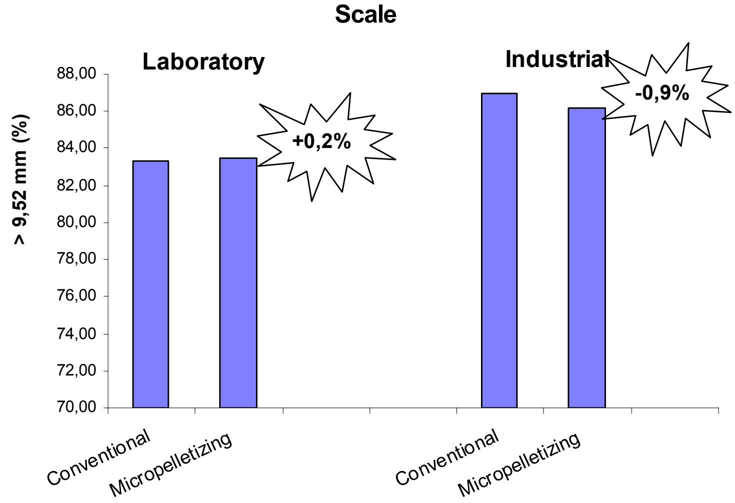

Figure 6. Shatter Index

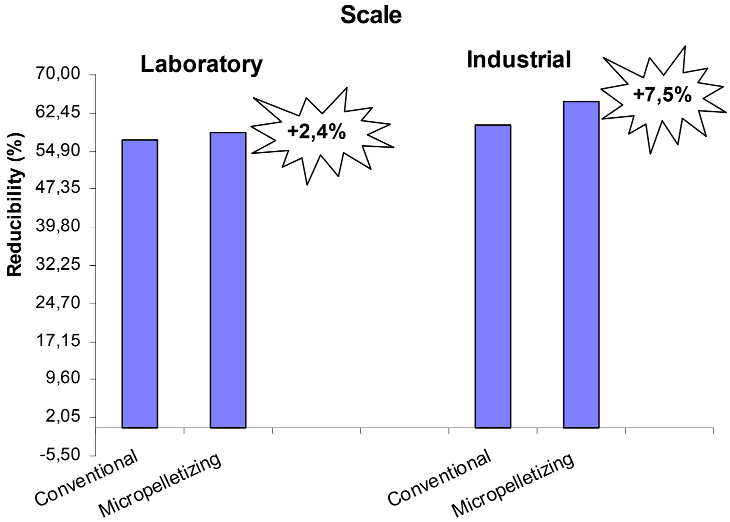

Figure 7. Reducibility

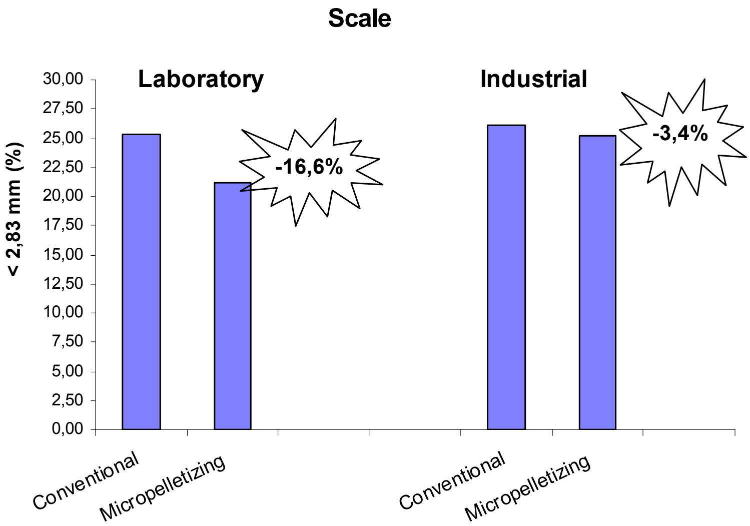

Figure 8. Sinter RDI

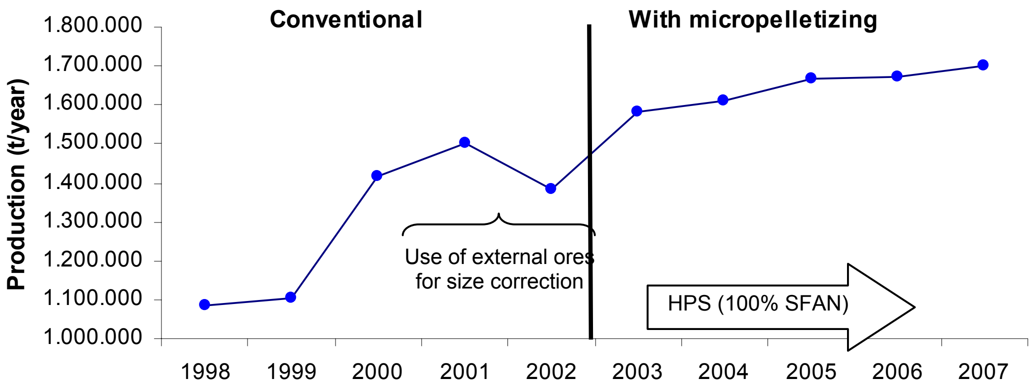

Figure 9. Sinter production

5 ANALYSIS OF RESULTS

According to Figure 2 and considering the tests results, it was foreseen an increase of approximately 13% in the productivity due to the micropelletizing. In the industrial plant the productivity increased by 11%.
The foreseen change in fuel and lime consumptions (Figures 3 and 4) was the same in both scales. The sharp increase in lime consumption in the micropelletizing process is due to the use of this material as a binder for the process. Regarding to the fuel consumption, the decrease in the industrial scale was higher than in the bench-scale; some reasons for this difference are:

- the thermal losses in bench-scale are proportionally higher than in the industrial plant;
- in the industrial sinterplant there is a segregation device in the strand feeding; in bench-scale this facility was not available.

According to Figures 5 and 6, in bench-scale the sinter size distribution was not changed with the micropelletizing, but sinter strength increased. In industrial scale both characteristics were not changed.
The sinter metallurgical quality indexes (Figures 7 and 8) showed a betterment trend in the bench-scale. In the industrial plant this trend was confirmed, but for the RDI the trend was lower than in the laboratory tests.
The increase in sinter production with the micropelletizing of the mixture is clearly seen in Figure 9.
In summary, the main results obtained with the micropelletizing of the sintering mixture in bench-scale showed:

- considerable increase in productivity (13 %);
- the feasibility of using 100% of the own iron ore, SFAN;
- a decreasing trend in fuel consumption (-1,8%);
- sinter quality in the same level, or even better.

The results in the industrial scale show the high reproducibility of the tests, regarding to:

- operational performance: productivity (+11%)
- use of 100% of Andrade ore
- sinter quality in accordance with blast furnace requirements.

6 CONCLUSION

ArcelorMittal Monlevade experience with sintering bench-scale tests was of high value for obtaining a high reproducibility in the industrial scale.
The micropelletizing of the sintering mixture in bench-scale supported the decision of installing the HPS process at Monlevade sinterplant, representing an important tool for the decision-making.
The results in the industrial plant showed a high reproducibility of the tests, indicating that the decision was correct.

Acknowledgement

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6 JIS - M 8720: Iron ores - Determination of low-temperature reduction-disintegration
7 JIS - M 8713: Test methods for determination of reducibility of iron ores