Comparison of Ferrosilicon Powders used in Katanga HMS Plants

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Abstract: ***FeSiis the main reagent used in HMS plant and is consumption is it the key parameter in cost analysis. Optimal choice of this reagent allow management to increase both plant performance andprofitability of operations. In this article, we are going to compare three types of FeSi 270D mainlyused in HMS plant in former Katanga's province.***

Keywords: Heavy density separation, Ferrosilicon; magnetism, density

1. Abbreviations

- HMS: Heavy media separation
- DMS: Dense media separation
- FeSi: Ferrosilicon
- Kg : Kilogram
- t: ton
- m^3: cubic meter
- t/m3: ton per cubic meter
- Ltr: litre
- Km: kilometre
- mm : millimetre
- hr: hour
- min: minute
- ref: reference

2. Introduction

The Republic Democratic of Congo is largely known as a country of minerals and metals. The 20th century have seen diamond, cassiterit and manganese using HMS plant; the beginning of 2000's, saw Copper and Cobalt industry also consuming it.

Companies such as Anvil mining in 2003, Mumi in 2005, Boss mining in 2006, Chemaf in 2008, Kisamfu Mining 2011, Comidesprl2012 and Gécamines 2013, etc. in former Katanga province are leaders in this technology.

During the heavy media separation, minerals are deepen in a fluid having a density between the heavy mineral and the light one. Normally, we should talk about a pseudo density generated by an emulsion of FeSi and water.[1].
Some processes, such as Chemaf, have associate FeSi and magnetite to lower cost and density range of minerals produced.

Ferrosilicon of 14% to 16% silicon has become widely accepted as the most suitable medium for the heavy-medium separation of ores having a specific gravity in the range of approximately 2.5 to 4.0.

Ferrosilicon has many properties essential to a metal or alloy powder that is to be used as a heavy medium, some of the more important being the following:
a) Resistance to abrasion,
b) Resistance to corrosion,
c) High specific gravity,
d) Magnetism, which allows easy magnetic recovery with subsequent easy demagnetization, and
e) Low cost

Ferrosilicon contain between 14% and 16% silicon is found to have the optimum combination of these properties. If the silicon content is lower than 14%, the specific gravity and magnetic properties are improved, but resistance to corrosion decreases rapidly.

Above 16%, the corrosion resistance of the alloy is not significantly improved, but the magnetic properties and specific gravity deteriorate[2].

Two marks of mill FeSi are mainly uses in former Katanga provinces FeSi Powder and Chemet.

The three type of FeSi compared are described below:
- FeSi powder in plastic drums containing 250Kg.
- FeSi powder in big bags: 1ton of FeSienveloped in plastic film inside of the big bags.
- CHEMET : 250Kg FeSi enveloped by plastic film in a metallic drum ;

[1]Robert HOUOT, Robert JOUSSEMET, in technique de l'ingénieur, concentration gravimétrique, A5190, p-10

[2] B. COLLINS, TJ NAPIER-MUNN and M. SCIARONE, The production, proprieties, and selection of ferrosilicon powders for heavy-medium separation, Journal of South African Institute of Mining and Metallurgy, 1974

The Congolaise des Mines et de Développement, Comide, where those studies were done, is one of factories of ERG group, is located in South of Democratic Republic of Congo, in the South of Lwalaba province, between Kolwezi and Likasi at 15 km from Kisanfu village. Comide is producing concentrate from Mashitu mine via two HMS and one spiral plant.

3. Problematic

It is important to select for his process, the best and suitable reagent which will have the lowest specific consumption, make up time, cost, the best recovery and long life time, etc. Changingtypes of FeSi is impacting directly to the process as shown in graphic 1 which confirm field observations; it is appeared a huge consumption of FeSi while using Chemet; in Yellow are months when Chemet was used alone. Months of January, February and August 2015, are having the highest FeSi consumption in Kg of FeSi per ton of ore fed into the DMS. The rest of the months FeSi powder were used alone or mixed with chemetdepending on the available stock.

Type of FeSi is disturbing following plant parameters:
- FeSi consumption,
- Increment of make-up time.

Those two parameters are having such corollaries:
- Increment of downtime due to FeSimakeup;
- Troubling density and tonnage fed into dms,
- Increment of handling operations, etc.

Makeup process is composed with:
- Handling bags or drums,
- Lifting FeSi or bags/drums
- densification process to achieve suitable density,
- Housekeeping of whatever drums/bags, plastic, etc. remaining on the floor.

To understand the difference on FeSi, two parameters have been study in this article: *density* and *magnetic recovery*.

4. Materials and Methods

Magnetism: the FeSi is a ferromagnetic, and the comparison of magnetic susceptibilityis made via a magnachute.

Magna chute is a magnetic separator. It is modifying magnetic field in zone where is used. It induct a magnetic field which react selectively on bodies which gives a high aptitude on magnetism[3].

It is a good simulator for magnetic drums which recover FeSi from effluent flow coming from dilute tank.

In magnetic process separation (concentration or effluent), separation is obtained by applying to all particles in the mix the same magnetic strength.

[3] Gérard GILLET, in technique de l'ingénieur, Séparation magnétique A5220, p5

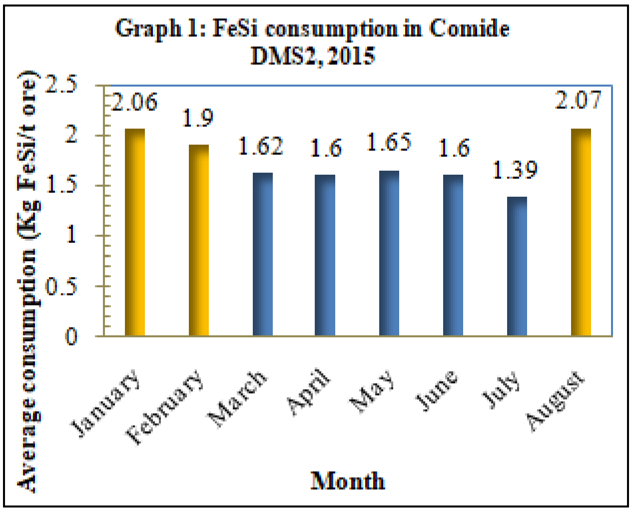


Image 1

Following points are test steps:
- A mass $M_1$of FeSiis diluted in 20ltrs of clear water and fed into the magnachute hopper.
- Let tray lays on magnet, the valve is getting opened to flow the pulp on it.
- 15ltr of clean waterare used through hopper to washed and flush nonmagnetic particles.
- Raised up tray and collect FeSi trappedby the magnet,
- Magnetic FeSi is dried and weighted, M_2.
  The magnetic fraction is $\frac{M_2}{M_1}$%.

Density
- Tare the empty 1ltr glass graduated cylinder;
- Fill up to FeSi in the cylinder up to measure gauge ;
- Weight the cylinder;
- Remove the tare,
- The calculate weight divided 1kg is the *d*density of the FeSi density.

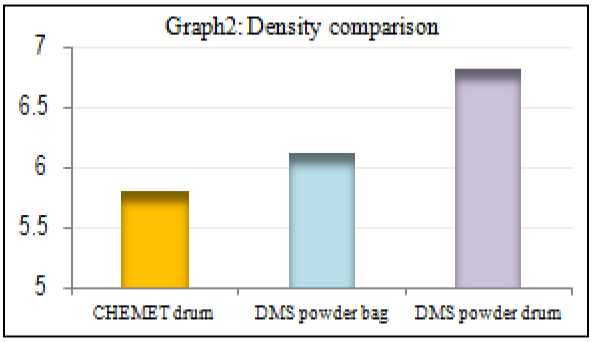
5. Results and discussions

Density measurement

From table 1 is deduced, Chemetis having the lowest density of the three, DMS powder in drums is getting the highest density.

Table 1

FeSi	density
CHEMET drum	5,81
DMS powder bag	6,12
DMS powderdrum	6,82



The immediate consequence of the table 1 will be;

- Increment of fesi consumption for chemetand DMS powder in bags because it will request more quantity to achieve the same density;
- Increment of makeup time;
- Increment of handling time, it will request more drums to achieve the same performance of fesi powder drums.

Two majors' reasons can explain the density difference:

- Corrosion of the fesi,
- Remain graphite in the reagent

Corrosion of reagent may be due to packing mode specially for FeSi powder in big bag because bags are not protecting like drums are doing, piercing material during haulage, handling and stocking may easily cut or pierce both bag and internal plastic.

The chemet which is having wrapped plastics inside of a drum should be infected by high ratio of graphite.

Impact of density differences

Two big incidences of density difference are observed, consumption and handling time increment.

Resulting on plant average parameters, density 2.3 and 25 minutes for batch drum time preparation and base on below mathematic theoretical development, we can calculate table 2.

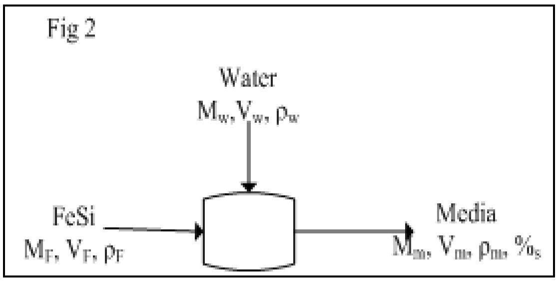


Fig 2

If :
M_w :water mass used to prepare a batch, in this exercise we equal it to $1m^3$=1t.
ρ_w :water volumetric mass, here is equal to $1t/m^3$.
V_w :water volum, here equal to $1m^3$.
M_F : mass of FeSito feed
ρ_F :volumetric mass of FeSi
V_F :Volum of FeSi to feed
M_m :mass of mediato obtain
ρ_m :media volumetric mass
$\%_s$:solid percentage of the media

$$\begin{cases} M_m = M_F + M_w & (1) \\ M_m = V_m \cdot \rho_m & (2) \\ M_F = V_F \cdot \rho_F = V_m \cdot \rho_m \cdot \%_s & (3) \\ \%_s = \dfrac{\rho_F(\rho_m - \rho_e)}{\rho_m(\rho_F - \rho_e)} & (4) \end{cases}$$

Equation (1) can be wrote
$M_m - M_F = M_w \quad (1')$

From (2) in (3):

$$M_F = V_F \cdot \rho_F = M_m \%_s$$

$$\text{So } M_m = \frac{M_F}{\%_s} \qquad (5)$$

(4) into (5)

$$M_m = \frac{M_F}{\frac{\rho_F(\rho_m - \rho_w)}{\rho_m(\rho_F - \rho_w)}} = \frac{M_F \rho_m (\rho_F - \rho_w)}{\rho_F(\rho_m - \rho_w)} \qquad (6)$$

(6) into (1')

$$\frac{M_F \rho_m (\rho_F - \rho_w)}{\rho_F(\rho_m - \rho_w)} - M_F = M_w$$

$$M_F\left[\frac{\rho_m(\rho_F - \rho_w)}{\rho_F(\rho_m - \rho_w)} - 1\right] = M_w$$

$$M_F\left[\frac{\rho_m(\rho_F - \rho_w) - \rho_F(\rho_m - \rho_w)}{\rho_F(\rho_m - \rho_w)}\right] = M_w$$

$$M_F\left[\frac{\rho_m\rho_F - \rho_m\rho_w - \rho_F\rho_m + \rho_F\rho_w}{\rho_F(\rho_m - \rho_w)}\right] = M_w$$

$$M_F\left[\frac{\rho_F\rho_w - \rho_m\rho_w}{\rho_F(\rho_m - \rho_w)}\right] = M_w$$

$$M_F\frac{\rho_w}{\rho_F}\left(\frac{\rho_F - \rho_m}{\rho_m - \rho_w}\right) = M_w$$

$$M_F = M_w\frac{\rho_F}{\rho_w}\left(\frac{\rho_m - \rho_w}{\rho_F - \rho_m}\right) \qquad (7)$$

From equation (7), table 2 is calculated; it is giving FeSi amount to achieve a density of 2.3 in $1m^3$ and FeSibatch time preparation.

Table 2

	density	Mass (t)	ΔMass %	Time (min)
CHEMET drum	5.81	2.152	9.7%	53.796
DMS powder bag	6.12	2.083	6.2%	52.068
DMS powderdrum	6.82	1.962	0%	49.038

Graph3 is showing which quantity is requested to achieve 2.3 density in $1m^3$ of water; clearly FeSi consumption is been challenging by density. Less is de FeSi density high is the demand to get proper density.

The request of DMS Powder drum to achieve density of 2.3 is the lowest of the three, 1.962t while Chemet need 2.152t for.

Due to his lower density DMS powder bag request 6.2%extra and Chemet 9.7% more compare to Dms powder drum.

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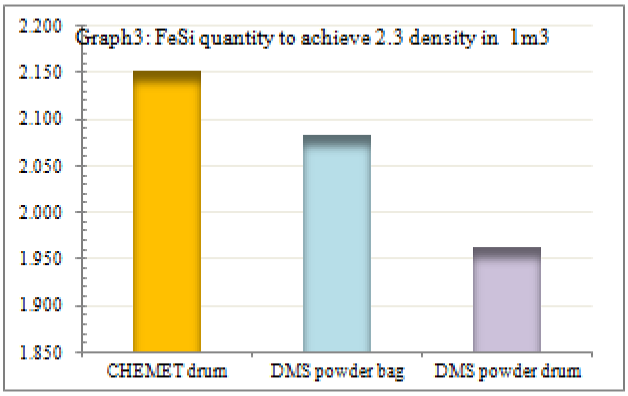
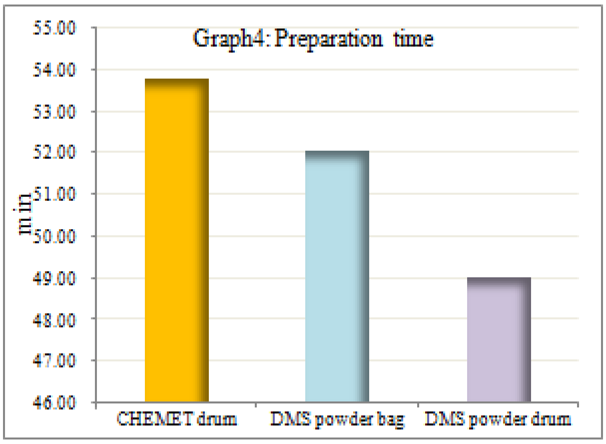


The corollary of mass increment inducts rise up preparation and handling time; extra drums for chemet for example.

Graph 4is reporting how long preparation is delaying 49min for DMS powder drum, 51min for Dms powder bag and 52min chemet.



Magnetic recovery

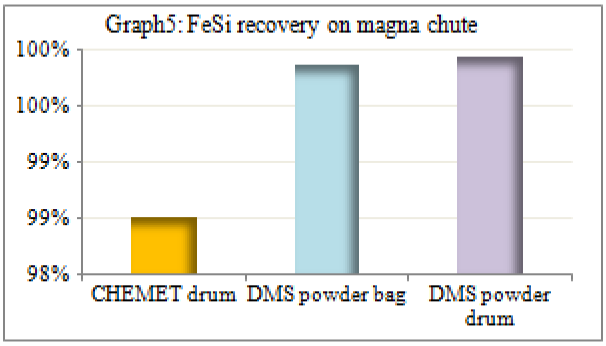
This stage check the magnetic susceptibility of each FeSi powder.

One of the advantage FeSi is a ferromagnetic, the aptitude allow his recovery via magnetic drum. This quality is one of the most tracked in field to reduce overall FeSi consumption and make up.

Tests done on magna chute is report in the table 3:

Table 3

FeSi	Mass tot, gr	Nonmagnetic, gr	Proportion	Δm %
CHEMET drum	294,6	4,4	98,51%	1,43%
DMS powder bag	296,6	0,4	99,87%	0,07%
DMS powder drum	299,7	0,2	99,93%	0,00%



Out of the three FeSi, chemet is having the lowest magnetic susceptibility, his recovery is 98.51% which is 1.45% less compared to Dms powder drum.

The nonmagnetic particles come most probably from oxidized material and graphite coming from melting process which can be observed by black colour while make-up and test chemet.

The difference on magnetic susceptibility between dms powder drum and bag is only 0.07%; 99.87% for dms powder bag and dms powder drum. The proportion of nonmagnetic resultedmostly from oxidized particles.

Global performance

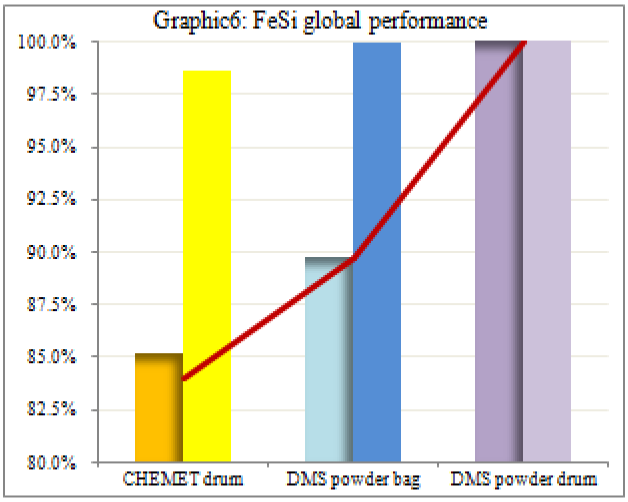
Table 4 is providing a resume of both parameters studydensity and magnetic recovery. We consider the global efficiency as:

$$Eff = \frac{density}{ref\ density} x \frac{magnetic\ recovery}{ref\ magnetic\ recovery}.$$

DMS powder drum has been taken as the FeSi reference.

Table 4

	density	ΔMass %	ΔMagn %	eff
CHEMET drum	5,81	85,2%	98,6%	84,0%
DMS powder bag	6,12	89,7%	99,9%	89,7%
DMS powderdrum	6,82	100,0%	100,0%	100,0%



From efficiency, chemet is giving only 84% of DMS powder drum performance while DMS powder in bag is giving 89.7%.

6. Conclusion

Dms powder in drum, in bag and chemet are the three most used FeSi in former Katanga province by companies. From the parameters used, density and magnetic susceptibility; DMS powder in drum is the best out of those three. It is getting the highest density, magnetic susceptibility and recovery.

Those parameters inducted less reagent consumption, less handling, a reduced make-up and preparation time, minimum density fluctuations.

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