

Pelletization of feldspar solid waste tails and its use as slag coagulator during the remelting of cast iron

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Pelletization of feldspar solid waste tails and its use as slag coagulator during the remelting process of cast iron was studied. The feldspar solid waste tails powder with different concentration of sodium silicate was formed into pellet via pelletizing technique. The produced pellets were characterized by measuring its compressive strength and dropping resistance. It was found that the compressive strength and dropping resistance of the pellet increases with increasing the sodium silicate content. The performance of these pellets as slag coagulator was determined on the basis of the amount of removed slag as a result of its addition during the smelting of cast iron in induction furnaces. The removed slag was characterized by determining its chemical composition and XRD. It was concluded that the amount of slag removed that results from its coagulation decreases with the increase of sodium silicate content up to 6-wt.% then it increases thereafter. These results rationalized by complete coating of the waste grain surface by sodium silicate during its pelletizing leading to decrease the slag components to easily penetrates the pellet. This in turn, decreases the ability of the slag to easily reacts with pellet constituents. However, the increase of sodium silicate content above 6 wt.% doesn't only completely wet the pellet grains but it also goes in the interface through the feldspar grains. Excess sodium silicate through the grain interfaces in turn, facilitates the pellet fusion when it was subjected to the temperature of the remelting process allowing to the slag component to react with the pellet constituents.

Parole chiave: fonderia, fusione e rifusione, ghisa

INTRODUCTION

Electric induction furnaces are either cylindrical or cup shaped refractory lined vessels surrounded by electrical coils that, when energized with high frequency alternating current, produce a fluctuating electromagnetic field to heat the metal charge. For safety reasons, the scrap metal added to the furnace charge is cleaned and heated before being introduced into the furnace. Any oil or moisture on the scrap could cause an explosion in the furnace. The molten metal is tapped by tilt and pours through a hole in the side of the vessel. Induction furnaces are kept closed except when charging, skimming and tapping(1). Therefore, the metallurgical processes that uses induction furnaces aims to produce high purity metal or its alloys with low cost. Cost factors of these processes are summarized under the following headings as follows:

- 1- Refractory lining
- 2- Raw materials
- 3- Additives

The goal of achieving these tasks (low cost operation with high purity product) depends on the mechanism to carry out the refining process with low cost and to maximize refractory service life of the induction furnace. It is well known that the slag consists of the oxide impurities that must be separated from the molten metal because these oxide impurities affects on the metal properties and the furnace lining. At high temperature of the smelting process, these oxides react together to form less dense and low viscous slag, therefore, it floats on the surface of the metal. The lower viscous slag corrodes the

refractory lining, facilitates the penetration of the ambient environment gases that facilitate the oxidation of the metal and increase of the consumption of the energy by increasing the heat transfer. Therefore, the addition of materials is necessary to coagulate the slag i.e. increasing its viscosity to impose a barrier between the metal and the ambient environment gas to prevent or minimize the penetration of gases that oxidize the metal and to conserve the energy by decreasing the heat transfer. On the other hand, the coagulation of the slag makes easy its removal during the smelting process, and decreases the refractory lining by subjecting it to the slag long time i.e. increase the service life of the lining. Consequently, the removal of the slag decreases the drastic effects on the refractory lining of the furnace and facilitates the floating of the impurities that wet the metal to separate by decreasing its concentration on the surface of the metal itself. For these reasons, the successful materials to be added have two advantages; to react with the slag and to increase its viscosity by forming high refractory phase in order to improve its removing during the smelting process.

Many materials have been tested in the last few decades to act as slag coagulators. In this investigation the use of solid waste tails from the beneficiation process of feldspar to be used as slag coagulators have been investigated.

In the feldspar beneficiation process a huge amount of solid waste tails have been produced. This waste has no economic use and has a particle size of less than 0.074 mm. To reuse such materials as slag coagulators, it should be firstly agglomerated before using. The pelletization of such materials is a useful process for agglomerating such very fine particles. The pellet strength should be high enough to withstand transpiration, handling and charging in furnace. To fulfill the requirements of the pellets from the strength point of view, some additives should be used. Sodium silicate is regarded as one of the very useful binder that can develop strength for pellet.

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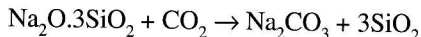
Many investigators had worked on the use of sodium silicate as binder in different foundries.

Sodium silicate (water glass) has been used industrially as a binder and adhesive for foundry sands to deteriorate the introduction of bentonite for at least 120 year(2).

Dwivedi(3), reported that when CO₂ gas reacts with sodium silicate solution, two mechanisms are involved:

- 1) a chemical reaction involving the formation of a silica hydro gel bond
- 2) a physical process in which a glass-like high viscosity sodium silicate bond is formed due to dehydration of the aqueous silicate, where both mechanisms are operating and contributing to the strength developed.

Nicholas(4), suggested that, the chemical reaction between CO₂ gas and sodium silicate is rather complicated but in simple terms it is:



Mc Donald(5), suggested that depending on the gas condition and SiO₂/Na₂O ratio of the sodium silicate employed as binder, the dehydration during storage led to either an increase or decrease in bond strength.

The aim of this investigation is to evaluate the use of the solid waste tails produced during the beneficiation of feldspar, in ore beneficiation plants by pelletization of such very fine materials using sodium silicate as binder. The effects of different percentage of sodium silicate addition (based on the total feed weight) on the properties of green and dried pellets properties were studied. Also, the effect of such an addition on the performance of these pellets to act as slag coagulator was investigated. The total chemical composition with x-ray diffractogram for each pellet type after slag coagulation was performed.

EXPERIMENTAL AND PROCEDURE

Material

The solid waste tails produced from the beneficiation of feldspar were delivered from a beneficiation pilot plant in Central Metallurgical Research and Development Institute, (CMR-DI), Cairo, Egypt. The total chemical composition of solid waste tails was as given in Table 1.

A local type sodium silicate has 56.15%, solid content, SiO₂/Na₂O ratio (2.67/1) and 1.6 gm/cm³ specific gravity was used.

Apparatus and procedure

A laboratory disc pelletizer 40 cm diameter and 10 cm depth

Constituent	(%)
MgO	0.18
SiO ₂	66.88
Al ₂ O ₃	19.79
TiO ₂	0.30
CaO	0.88
Fe ₂ O ₃	0.23
Na ₂ O + K ₂ O	10.86

Table 1: Chemical composition of feldspar tails from spatofluoro beneficiation process.

Tabella 1: Composizione chimica di sterili di spatofluoro dal processo di arricchimento del feldspar.

was used for pelletization of the finely ground, (-0.074 mm) solid waste tails from feldspar beneficiation. The solid waste tails were fed to the pelletizer, and then the predetermined amount of added water was sprayed onto the rolling bed of the material in the pelletizer. At the end, the pellets sample were collected and screened to collect the +4-8 mm pellets [what does + mean?] which was taken as a measure of the productivity of the pellets which was calculated according to the following equation:

$$P = [W_1/W_2] * 100$$

Where

P = productivity of the green pellets (+4-8) mm diameter, %.

W₁ = weight of the produced green pellets (+4-8) mm diameter, gm.

W₂ = weight of the charged materials to the disc pelletizer, gm.

Mechanical properties (compressive strength and drop resistance) are necessary in order to produce green or dry pellets able to resist the compression load in the pellet bed of the belt conveyer, drying grate, and during their handling and storage. The average compressive strength of pellets is measured by compressing at least 10 green or dried pellets sample (+4-8 mm) between parallel steel plates up to their breaking. The mean value of the tested pellets gives their average compressive strength(6).

The drop resistance indicates how often green or dried pellets can be dropped from a height of 46 cm before they show perceptible cracks or crumble. Ten green or dried balls are individually dropped onto a steel plate until their breaking. The mean value of the tested pellets gives their average drop number (7).

Drying of green balls was conducted in air atmosphere for different periods of time, and then the mechanical properties of the dried pellets were determined as was mentioned previously.

After drying different pellets type (containing different sodium silicate contents) they were used for application as a slag coagulator. The same weight of (+4-8) mm pellets from each pellet type was introduced into the induction furnace and then skimmed and weighed again to obtain the percent of slag coagulated on each type. This could be obtained using the following equation:

$$K = (M2 - M1) / M1 * 100$$

Where

K is the weight percent of coagulated slag

M1 is the weight of pellets before being introduced to the induction furnace

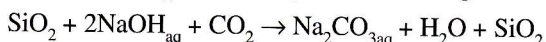
M2 is the weight of pellets after being skimmed from the induction furnace.

RESULTS AND DISCUSSION

Effect of sodium silicate addition on the properties of green pellets

Figure 1 illustrates the effect of sodium silicate addition on the productivity of +4-8 mm green pellets. From this figure it is clear that increasing the amount of sodium silicate addition leads to an increase of the productivity of green pellets till it reached a maximum value at 4% sodium silicate addition whereas it decreased thereafter.

The increase in the productivity of +4-8 mm pellets with increasing the sodium silicate addition up to 4% sodium silicate may be attributed to the fact that sodium silicate contains a liquid fraction, and it reacts with atmospheric CO₂, leads to the formation of H₂O according to the following reaction:



This leads to increase the amount of moisture included in the charge. The moisture content for producing a good quality green pellet is quite critical. The indicated optimum moisture content is that at which water molecules are formed in every surface pore. Insufficient moisture content will result in air inclusions in the ball, which reduce the capillarity effect and cause a lower pellet quantity and quality. Whilst excess moisture will coat the ball with a coherent film of water which

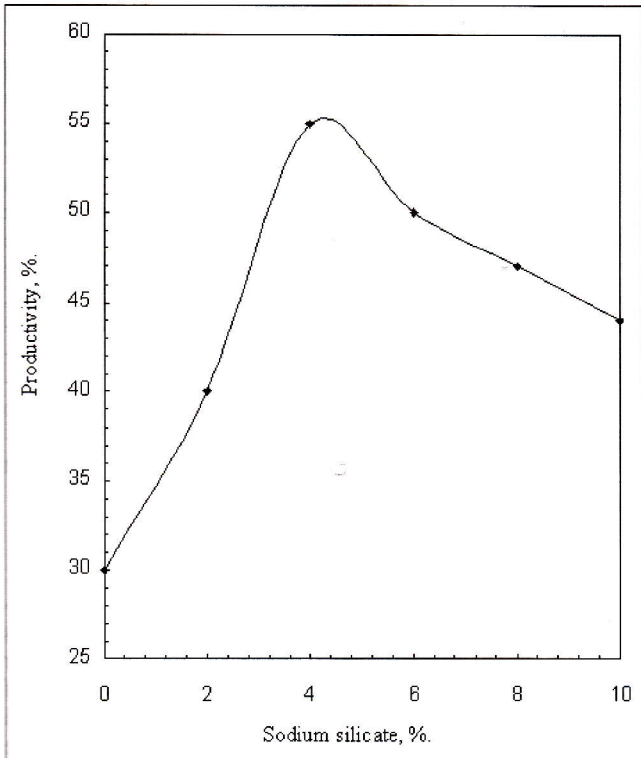


Fig. 1 - Effect of sodium silicate addition on the productivity of +4-8 mm diameter green pellets.

Fig. 1 - Effetto dell'aggiunta di silicato di sodio sulla produzione di pellet verdi del diametro di +4-8 mm.

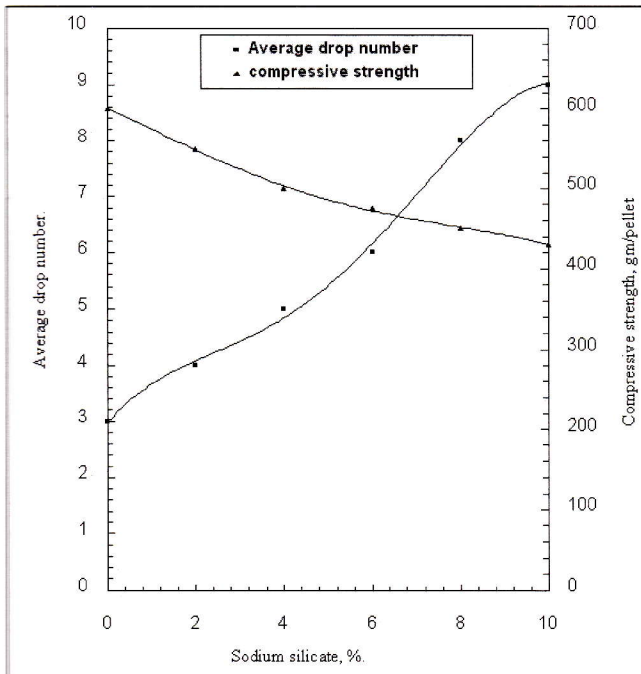


Fig. 2 - Effect of sodium silicate addition on the average drop number and compressive strength of green pellets.

Fig. 2 - Effetto dell'aggiunta di silicato di sodio sul numero medio di gocciolamento e forza di compressione dei pellet verdi.

neutralizes the capillarity effect and leads to the formation of large size ball with low quality(8).

Figure 2 shows the relation between the amount of sodium silicate addition and the mechanical properties of green pellets. It can be found that increasing the sodium silicate addition leads to increase average drop number while the compressive strength decreases with increasing the sodium sili-

cate addition. The increase in average drop number and the decrease in compressive strength with increasing sodium silicate addition may be related to the same phenomena. Thus, increasing sodium silicate addition leads to increase the moisture content in the pellets making it more plastic which leads to increase the average drop number. Whereas the increase in moisture content leads also to increase the capillary diameter inside the pellets which reduces the capillary forces between granules making it easier to be cracked and fail under load(9).

Effect of sodium silicate addition on the properties of dried pellet

Green pellets were subjected to dry over one night and over two nights then the properties of pellets were determined. Figure 3 illustrates the relation between the amount of sodium silicate addition and the properties of dried pellets. It was found that at any period of drying increasing water sodium silicate leads to increase in both the average drop number and compressive strength of the dried pellets.

Also it was found that at any constant sodium silicate addition (> 2%) the increase in drying time leads to the increase in both the average drop number and the compressive strength. The increase in both average drop number and compressive strength of dried pellet with increasing sodium silicate addition at any constant period of drying may be attributed to the fact that sodium silicate reacts with carbon dioxide of air producing silica gel and sodium carbonate, thus the solid waste particles were locked together by silica gel surrounding the particles--(10).

On the other hand increasing of average drop number and

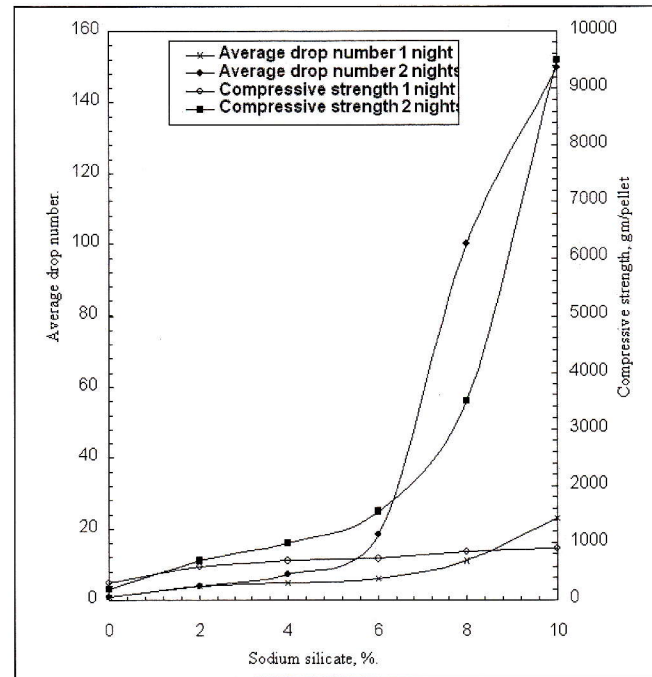


Fig. 3 - Effect of sodium silicate addition on the average drop number and compressive strength of dried pellets.

Fig. 3 - Effetto dell'aggiunta di silicato di sodio sul numero medio di gocciolamento e forza di compressione dei pellet essiccate.

compressive strength with increasing the time of drying at any constant sodium silicate addition may be attributed to the fact that increasing time of drying gives more time for the reaction between sodium silicate and carbon dioxide causing locking the particles. Also, it may be due to the fact that increasing time of drying leads to the deposition of a thin dense crust at the pellet margin(10).

Effect of sodium silicate addition on the efficiency of pellets as slag coagulator

Figure 4 illustrates the relationship between the amount of sodium silicate addition and the amount of slag coagulated with pellet containing different sodium silicate addition. It was found that increasing sodium silicate content in the pellets leads to a decrease in the amount of coagulated slag on such pellets till it reaches minimum at pellet containing 6% sodium silicate addition, then it increases thereafter. This may be attributed to the fact that in the pellets containing a small amount of sodium silicate the grains of feldspar waste are not completely wet with sodium silicate leading to a higher amount of feldspar waste grains in contact with slag. Therefore the ability of the slag components to react with pellets increased leading to a high amount of slag removed. With increasing the percentage of sodium silicate in the feldspar pellets causes a complete wetting of the grains so the surface area of the waste grains that can be subjected to the slag component decreased. Thus, the amount of the removed slag decreased till it reach minimum at pellet containing 6% sodium silicate. Beyond 6% sodium silicate addition, the increase in the amount of slag removed for pellets containing 8 and 10% sodium silicate, may be attributed to the fact that sodium silicate does not only completely wet the grains but it also goes in the interface through the feldspar grains and facilitates its fusion when it is subjected to the furnace temperature. This in turn, leads to increase in the surface area of the feldspar waste grains, which increases its ability to be in contact more and more with the slag components that facilitate its reaction together. Consequently, this contributes to formation of refractory phases, which facilitate the coagulation of the slag and helping its removal.

The decrease in the amount of slag removed with increasing the sodium silicate contents in feldspar pellets till it reaches minimum at 6% sodium silicate and its increasing thereafter, may be also attributed to the fact that the addition of sodium silicate increases the pellet strength, therefore, the ability of the slag to penetrate the pellet decreases, in turn, the reaction

of the slag components with the pellet decreases. Therefore, the amount of the slag removed decreases. However, the increasing of the amount of the removed slag with the pellet of low content of sodium silicate added could be rationalized by the ability of the slag component particularly MnO, and TiO₂ to penetrate the pellet and react forming high viscous refractory phases that facilitate the coagulation of the slag and helps to remove it easily. With increasing sodium silicate content in the pellets, the pellet strength increases and the ability of the slag components that form refractory phases and coagulate the slag, MnO, and TiO₂, decreases as given in table (2). However, the increasing of pellet strength with sodium silicate content above 6 wt.% leads to decrease the softening temperature of the pellet surface and facilitates the slag components to easily react and form refractory phases. This is also clear from the increase of the slag components that form refractory phases like MnO and TiO₂ and help the coagulation of the slag as given in table (2).

Effect of different sodium silicate addition on the mineralogy of pellets after slag coagulation

Figure 5 shows x-ray diffractogram of pellets (containing different sodium silicate) after slag coagulation. Feldspar tails are composed mainly of quartz with small amount of feldspar as it is shown in Figure (5). With increasing the amounts of sodium silicate in the pellets, the quartz content decreases till it reaches minimum at pellet containing 6% sodium silicate addition, then it increases therefore. At the same time feldspar contents increase till it reach maximum at pellet containing 6% sodium silicate addition, then it decreases therefore. It is also noticed that the mineralogy of feldspar changed during the process of slag coagulation. Feldspar in the original tails is composed of sanidine (Na-rich feldspar) while it became microcline (K-rich feldspar) in the coagulator. The results of mineralogy are consistent with the amounts of slag coagulated with pellets and the results of the chemical analysis. The increase of feldspars and change in the mineralogy of feldspar with using the pelletized feldspar tails as a

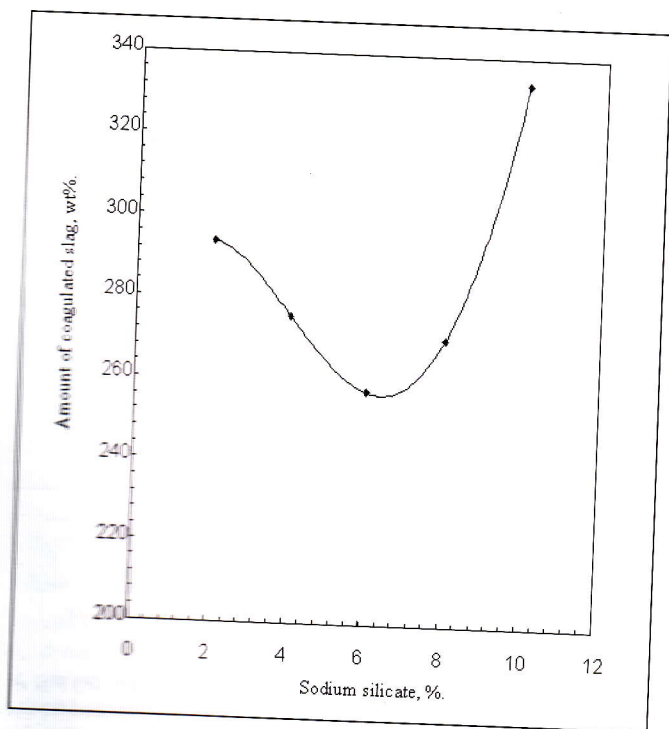


Fig. 4 - Effect of sodium silicate addition on the amount of coagulated slag.

Fig. 4 - Effetto dell'aggiunta di silicato di sodio sulla quantità di loppa coagulata.

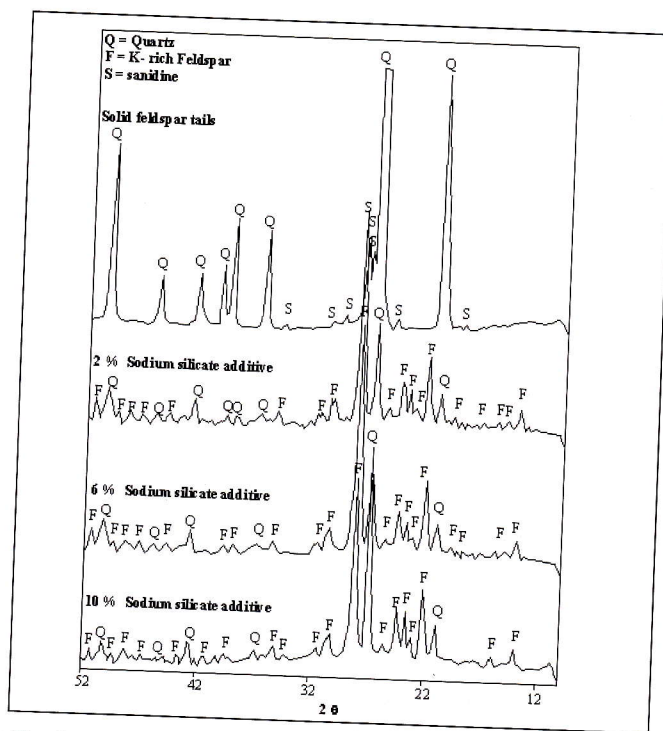


Fig. 5 - X-ray diffractogram of coagulated sample with feldspar pellets containing different percentage of sodium silicate.

Fig. 5 - Diffattogramma raggi x di un campione coagulato con pellet di spatofluoro contenenti diverse percentuali di silicato di sodio.

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Table 2 - Total chemical composition of pellet with slag after coagulation.

Tabella 2 - Composizione chimica totale del pellet con scoria dopo coagulazione.

Constituent	Composition, %.				
	Pellet containing 2% sodium silicate	Pellet containing 4% sodium silicate	Pellet containing 6% sodium silicate	Pellet containing 8% sodium silicate	Pellet containing 10% sodium silicate
MgO	0.62	Nil	0.14	0.19	0.60
SiO ₂	71.00	72.83	67.6	69.88	74.33
Al ₂ O ₃	9.27	12.54	15.45	14.76	10.43
MnO	4.45	2.03	2.49	2.72	5.42
TiO ₂	1.3	1.12	0.85	1.04	1.64
V ₂ O ₅	0.03	0.06	0.06	0.05	0.07
CaO	0.35	0.37	0.51	0.51	0.68
Fe _T	7.5	3.9	2.90	2.80	2.45
FeO	5.18	2.10	1.3	2.02	1.30
Na ₂ O	3.15	5.20	8.35	6.45	2.56
K ₂ O	0.2	0.15	0.22	0.29	1.32

slag coagulator indicate the efficiency of feldspar tails pellets as a slag coagulator where the coagulated elements are incorporated in the structure of feldspar minerals especially Al, Na, Ca, and K.

CONCLUSION

The following conclusions could be derived from this study:-

- 1- The productivity of +4-8 mm diameter green pellets increased with increasing sodium silicate addition till it reaches maximum at 4% addition and then decreased thereafter.
- 2- The averages drop number of green pellets increased with increasing sodium silicate addition while the compressive strength of green pellets decreased.
- 3- Both average drop number and compressive strength of dried pellets increased with increasing the period of drying at any constant sodium silicate addition and also increased with increasing sodium silicate addition at any constant time of drying.
- 4- The performance of feldspar solid waste tails pellets as slag coagulators decreased with increasing sodium silicate pellet content till it reaches minimum at 6% sodium silicate owing to the lower amount of coagulated slag at this percentage while it increase beyond 6% sodium silicate (at 8 and 10% content) owing to fusion and sublimation which occurred to the pellets at this sodium silicate contents.

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A B S T R A C T

PELLETIZZAZIONE DI STERILI SOLIDI DI SPATOFLUORO E LORO IMPIEGO COME COAGULANTE DELLA LOPPA NELLA RIFUSIONE DELLA GHISA

E' stata studiata la pelletizzazione di sterili solidi di e loro impiego come coagulante della loppa nella rifusione della ghisa. Polveri di sterili solidi di spatofluoro con diverse concentrazioni di silicato di sodio sono state trasformate in pellet mediante tecniche di pelletizzazione. I pellet così prodotti sono stati caratterizzati mediante misurazione della forza di compressione e resistenza al gocciolamento. Si è riscontrato che la forza di compressione e resistenza al gocciolamento dei pellet aumentano con l'aumentare del contenuto di silicato di sodio. La prestazione di questi pellet come coagulanti della loppa è stata determinata in base alla quantità di descorificazione come conseguenza della loro aggiunta durante la riduzione della ghisa in forni a induzione. La descorificazione è stata caratterizzata determinando la composizione chimica della loppa e

mediante XRD. Si è concluso che la quantità di descorificazione ottenuta come conseguenza della coagulazione diminuisce aumentando il contenuto di silicato di sodio fino al 6% del peso, mentre aumenta da questo punto in poi. Questi risultati sono stati valutati sistematicamente mediante la ricopertura completa della superficie del grano degli sterili con silicato di sodio durante la pelletizzazione, che porta ad una diminuzione dei componenti degli scarti in modo da penetrare facilmente nei pellet. Ciò a sua volta diminuisce la capacità della loppa di reagire facilmente con i costituenti dei pellet. Tuttavia l'aumento del contenuto di silicato di sodio al di sopra del 6% del peso non bagna completamente i grani di pellet e inoltre si insinua sull'interfaccia attraverso i grani di spatofluoro. Però l'eccessiva presenza di silicato di sodio attraverso l'interfaccia dei grani ha facilitato la fusione dei pellet quando questi sono stati sottoposti alla temperatura del processo di rifusione, in quanto ha permesso ai componenti della loppa di reagire con i costituenti del pellet.

MEMORIE

5/2003