TRIPLE DECK ROLLER FEEDER, A POSITIVE IMPACT ON PELLET PRODUCTION, FIRED PELLET QUALITY AND ENERGY SAVINGS

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SUMMARY

It has been long recognized that conducting a unit operation in closed circuit enhances its efficiency. This concept also applies to the agglomeration of green balls in the iron ore pelletizing industry. Metal7 has relied on classification principles to develop an array of solutions to address some limiting constraint of pelletizing plants. Those principles had conducted more recently to the development of the Triple Deck Roller Feeder, a breakthrough technology in the world of iron ore pelletizing plants. This presentation outlines the theoretical basis for the development of this new screening process and exposes the benefits for the end-user. From increases in production, his positive impact in bed permeability resulting in higher pellet quality, as well as energy savings. This revolutionary technology has been developed in partnership with Corem Research Center and operated with success in one benchmark pelletizing plants. Results of this industrial trial will be shared through the presentation, as well as operating experience.

KEY WORDS

Screening efficiency, roller screens, roller feeder, pellet bed permeability, productivity increase, quality improvement, energy saving, induration process

INTRODUCTION

The typical flowsheet to produce iron ore pellets is composed of:

- Production of the pellet feed
- Agglomeration
- Screening
- Firing

The production of the pellet feed is typically performed by grinding the iron concentrate to reduce the particles size in order to reach the optimum size distribution to allow efficient formation of the green balls in the agglomeration units. Upgrading of the iron ore concentrate could also be performed at this stage of the process to meet client specification regarding the silica content in the final product (fired pellets). The most common process to reduce the particle size is by using wet grinding. Therefore, it is mandatory to filtrate the slurry coming out of the grinding process. The filtration process is used to remove most of the water content in the slurry. The slurry is then transformed ~~to~~ in a filter cake that will be afterwards mixed with some binding agent. This mixed material is used as pellet feed for the agglomeration process. The agglomeration process will take place by using a disc or drum. The green balls produced by those units will have to be screened typically by one or several roller screens to remove the undersize and oversize pellets (out of spec product), and thus recovering the good size pellets that will be fed in the induration furnace or kiln. In this article we will be referring mainly to the induration furnace. At this stage, the green balls will be dry and fired at high temperature to become hard enough to sustain handling and transportation to the iron and steel-making plant.

In this flowsheet, agglomeration, screening and firing processes are strongly link together. And the screening efficiency is a key parameter to achieve optimum pelletizing and induration processes.

SCREENING EFFICIENCY CONCEPT AND ITS IMPACT ON PELLETIZING AND FIRING PROCESS

The screening efficiency is defined by using two important functions:

1- The ability to remove out of specification pellets in terms of size diameter (fines or oversize).

2- And the ability to recover the pellets with the desire product size range.

If the screening device is dedicated to remove let's say fine pellets, the screening efficiency could be illustrated by using a probability curve as presented on Figure 1. This curve is illustrating the proportion of retained pellets according to the gap opening. The efficiency of 100% means that all pellets with a size diameter bigger than the gap opening will be retained (right side of the retained curve). On the opposite, all the pellets having a size diameter smaller than the gap opening will not be retained and will be recirculated to the balling unit. A perfect screening efficiency is not achievable in real industrial pelletizing flowsheet.

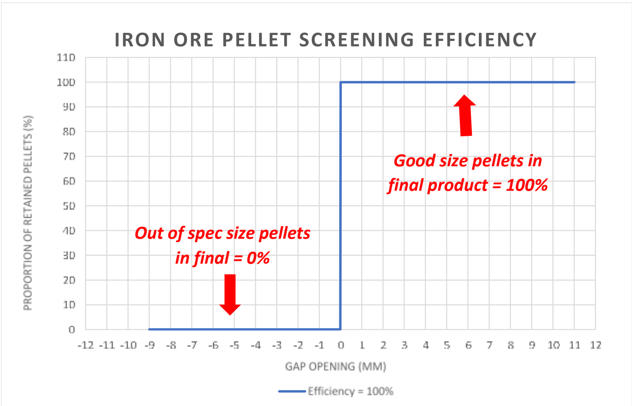

Figure 1: Screening efficiency concept – 100%

A typical screening efficiency will be more in the range of 75% as illustrated in Figure 2. According this retaining curve, an iron pellet with a size diameter exactly the same as the gap opening will have 50% probability to be retained or reject. If the size diameter is bigger by 1 mm, the probability to be retained will be approximately 65%. And more the size diameter of the pellet is bigger than the gap opening, higher will be the probability to be retained. As another example based on Figure 2, a pellet with a size diameter bigger by 3 mm compared to the gap opening will have a probability of 80% to be retained. On the opposite side, more the pellet size diameter is smaller compared to the gap opening, higher will be the probability to be rejected and recirculated.

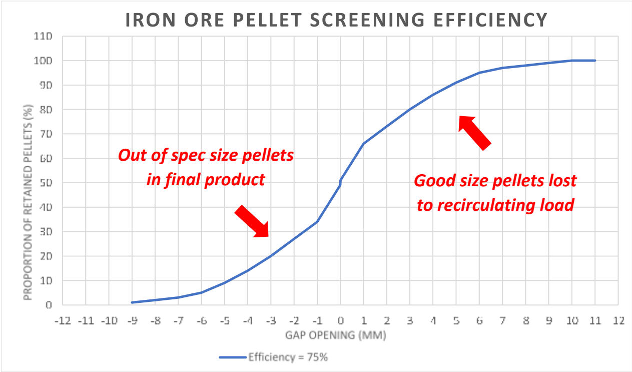

Figure 2: Screening efficiency concept – 75%

Increasing the screening efficiency, from 75 to 85%, will translate to some benefits for the pelletizing plant. Indeed, the probability of retaining good size pellets will be increased as shown on Figure 3. On this figure, the probability to retain good size pellet with a size diameter 3 mm bigger than the gap opening will move from 80% to 93% if the screening efficiency is improved from 75 to 85%. This is resulting directly to a productivity increase of good size pellets feeding to the induration furnace.

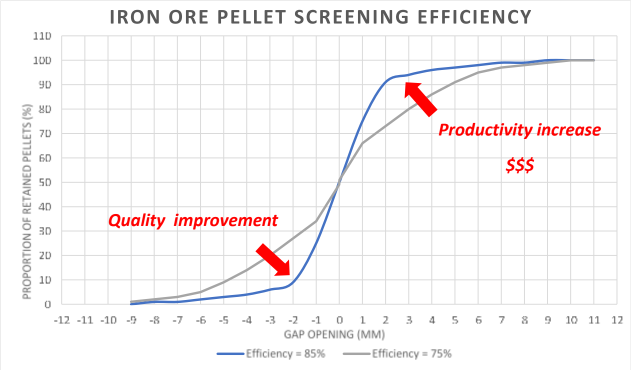

Figure 3: Screening efficiency concept – 85%

On the opposite, the proportion of fines that will be retained will also decreased with a screening efficiency increase. As an example, on Figure 3, fine pellets having a size diameter 3 mm smaller than the gap opening will be retained with a probability of 20% when the screening efficiency is at 75%. When the efficiency is increasing at 85%, the probability to retain those fines pellet will be at 5%. So, this means less fines retained and feeding the induration furnace. This will translate directly to a quality improvement in terms of sizing. For the induration furnace, less fines also translated to a better bed permeability and will lead to more efficient firing process.

HOW TO INCREASE THE SCREENING EFFICIENCY

The screening efficiency in a pelletizing plant can be improved by different ways. First, this could be achieved by increasing the screening area. For a screening process using rollers, the effective area can be increased using more rolls and/or increasing the length of the rolls. If there is some limitation regarding the space available, the screening area can be increased by reducing the diameter of the rolls. No matter which way is used, more rolls and/or longer rolls will result in more gaps to perform the screening process, thus screening efficiency will be improved.
A typical way to put some number on the screening area is to use the screening ratio. The screening ratio could be defined by the total tonnage feed on a roller screen, reported on the total length of the gap. As for an example, a process flowsheet using a screen with 40 gaps opening, with rolls of 4 m length, and feed tonnage of 600 tph, the screening ratio will be 3,75 t/m (600 tph / (40 gaps * 4 m)). By increase the number of gaps for the same feed tonnage, this will decrease the screening ratio and thus the screening efficiency will be improved. In the same way, if the feed tonnage is decreasing for the screening area, the screening ratio will also decrease and thus the screening efficiency will be better.

Some other ways can be used to improve the efficiency of this process. Among those, the gap opening uniformity and rolls straightness are critical. The reach high screening efficiency, the goal here is to have a gap opening as uniform as possible from one gap to another, and also by using rolls as straight as possible. Finally, screen deck angles, linear speed and transportation of the green pellets form one rolls to another could also have some impact on the screening efficiency.

TDRF (TRIPLE DECK ROLLER FEEDER) AND ITS IMPACT ON THE SCREENING EFFICIENCY

For most of the actual pellet plant, the space available to add more equipment is limited. As an example, for a pelletizing plant using a Double Deck Roller Feeder to screen pellets prior the induration furnace, most of the time there is no space available upstream as there is some conveyer belt arrangement to feed pellets from pelletizing units to the roller feeder. And downstream, space is also limited as the induration furnace is generally located just right after the feeder.

The concept of the Triple Deck Roller Feeder (TDRF) technology is to design a three decks screen that will fit in the same physical space as a two decks or single deck. The figure 4 is illustrating this concept.

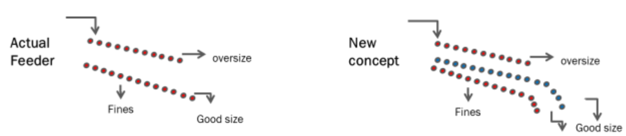

Figure 4: Concept of using an intermediate deck to increase screening area for the same physical space of the double deck

In this example, the feed tonnage will be split in three decks instead of two. This decreases the screening ratio. In other words, there is less feed tonnage per unit of screening area. The result is an improvement of the screening efficiency. Some simulations were performed to evaluate the impact of this new flowsheet on a benchmark pellet plant using 5 balling disks with a feed tonnage of 200 tph per disk and

using a double deck roller feeder with 24 gap on the upper deck and 35 on the lower deck. The use of TDRF for this flowsheet allow the introduction of an intermediate deck between the upper and lower deck, with the addition of 38 more gaps. The simulation results suggested a productivity increase of 7,5% more good size pellets feeding the induration furnace.

The Figure 5 is presenting view of the TDRF concept.

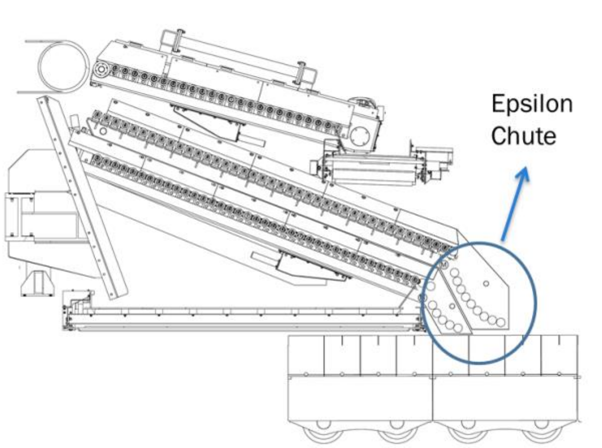

Figure 5: Plan view of Triple Deck Feeder

TDRF AND ITS IMPACT INDURATION PROCESS

The development of TDRF concept is also allowing the feeding of the induration furnace with the segregation concept.

The Figure 6 is illustrating this concept. Typical Single or Double Deck Feeder allow the feeding of the induration furnace with pellets size randomly distributed on the bed depth. By using a proper setup like TDRF, it's possible to feed the induration to form a 2-layer bed pattern with smaller size pellets at the bottom layer and bigger pellets on the top layer.

The first benefit of 2-Layers pellet bed is to allow with better permeability compared to single layer pellet bed. Secondly, during induration process, the hot descendant air will transfer the biggest amount of heat on the big pellets, more difficult to fire. When the heat front is reaching the bottom layer, there is less energy available, but the small pellets are much easier to fire. This segregation concept allows a smarter use of the energy.

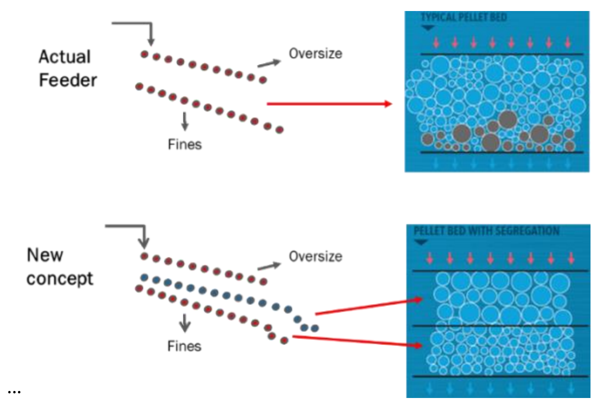

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Figure 6: Pellet bed segregation concept

During the development of the TDRF concept, it was found in the first design that the drop height from the intermediate deck to the pallet car was over 1000 mm. This is far from best practice as the green pellets can be deform or even crack or destroyed while falling of this height. To overcome this issue, a ''banana'' shape chute was designed to reduce the drop height and to reduce the impact force while the green pellets are reaching the bed. By calculation, this shape design can reduce the impact force by 20%. The commercial name of this design is named **Epsilon Chute™** as illustrated in the Figure 5.

As the green balls can deform while reaching the pellet bed, the reduction of the impact force will reduce the bed compaction and thus improve the bed

permeability. This can be appreciated through the equation proposed by Ergun (1) that is describing the pressure drop through a porous bed:

$$\Delta P = \left[\frac{150(1-\varepsilon)^2 \mu_g}{\phi^2 d^2 \varepsilon^3 \rho_g} G + \frac{1.75(1-\varepsilon)}{\phi d \varepsilon^3 \rho_g} G^2 \right] \Delta Z$$

Equation (1)

Where :

- ΔP = Pressure differential through the bed
- ε = Void fraction
- μg = Gas viscosity
- ϕ = Pellets sphericity
- d = Pellets mean diameter
- ρg = Gas density
- G = Gas flowrate
- ΔZ = Bed height

Indeed, when the green pellets are feeding the induration furnace bed with less impact, there is less deformation and thus less compaction. This will improve (increase) the void fraction ε and sphericity ϕ. Those two variables are at the power 2 or 3 in the Ergun Law, and are inversely related to the pressure drop. So that mean that a small reduction of deformation (thus increase of ε and ϕ) is having a huge impact on the reduction of the pressure drop through the bed. In other words, the reduction of the bed compaction is a significant key parameter to improve the bed permeability. During the firing process, a better permeability allows the process gas to flow through the bed with less restriction, providing more efficient heat transfer to the pellets. At the end of the day, this could translate into higher capacity of the induration furnace and/or a reduction of energy consumption and/or a quality improvement.

PILOT SCALE TESTING

During the development of TDRF technology, some pilot scale testing was performed at Corem Research Center based in Quebec, Canada.

More specifically, some pot grate testing was conducted to evaluate if the use of segregated 2-layers bed could represent some issue during total firing process. By using smaller pellets at the bottom layer of the pellet bed, it was suspected that the updraft drying stage becomes less efficient. If it is the case, some of the water could remain in the pellets after drying zones and will evaporate quickly in the firing zone at high temperature. If so, the quick evaporation of the remaining water will generate cracks and broken pellets. By performing pot grate testing at Corem, it was possible to confirm that it was not a real concern, and pellet bed degradation via slower drying should not happen in the real industrial furnace.

Corem also performed Discreet Element Monitoring (DEM) analyzing to evaluate the distribution of the green pellets in a 3-decks configuration in comparison of a 2-decks. This to confirm in-house simulation results regarding the screening efficiency. The results from those DEM analysis confirm that the use of a TDRF is increasing the screening efficiency and this will translate to a productivity increase of good size pellets feeding the induration furnace. The expected productivity increased of 7,5% evaluated in-house was confirmed by Corem, and even more productivity should expect.

OPERATION WITH TDRF – PLANT RESULT

After its development, the first TDRF unit was tested in operation at the benchmark pellet plant of ArcelorMittal located in Port-Cartier, Canada.

The first plant trial started on June 18, 2018. But after 14 days of operation, the test had to stop due to mechanical issues. The total operating hours during this first trial was 225 hours.

The preliminary observations of this trial are:

- A good behaviour of pelletizing and induration processes.
- A positive impact on productivity and quality.

This period of operation with TDRF was very short, so it was difficult to conclude with a high level of confidence.

After fixing the mechanical issue, the TDRF was installed on October 22, 2018 in the same pellet plant for a second trial. With this second installation, it was possible to operate without any issue for several months.

The following plant results are for 5 months of operation following the second installation (from October 2018 to March 2019). The reference period used for the comparison was for the same production line and for the same pellet chemistry (Self Fluxed), but with the operation with the previous screening technology (Double Deck Feeder). This reference period is from January 2018 to October 2018. The results are presented on a relative basis (%). More specifically for quality results, it was chosen to use results from the shipments according to the same periods.

The Figure 7 is presenting of productivity level with the TDRF (right part of the trend) in comparison to the reference period (left part of the trend). According to those data, the productivity increased by 2,7% with the use of TDRF. According to the internal analysis performed by process team of this pellet plant, the bottle neck moved from pelletizing-induration processes to pellet feed area. With higher capacity for the pellet feed production, productivity increase obtained with the use of TDRF could be potentially even higher.

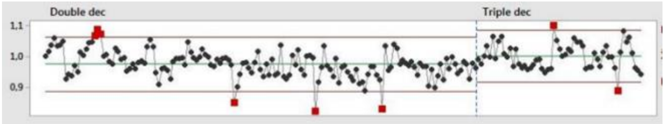

Figure 7: Impact of the use of TDRF on productivity (Results are courtesy of ArcelorMittal Mines Canada – Pellet Plant)

The Figure 8 is presenting the results regarding the impact of the use of TDRF in operation on the Abrasion Index, one of the key quality parameters performed on the fired pellets. The results are showing an improvement of 18% of this quality parameter.

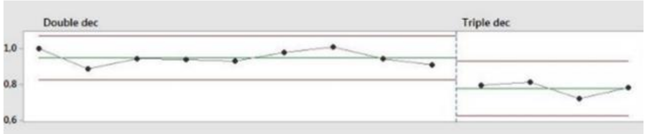

Figure 8: Impact of the use of TDRF on Abrasion Index (Results are courtesy of ArcelorMittal Mines Canada – Pellet Plant)

The next results are for the good size range of fired pellets. At this pellet plant, the pellets in the good size range are those with a diameter between 9 and 16 mm. With the use of TDRF, it was expected to improve the screening efficiency that should translate to more size uniform pellets feeding the induration furnace. For the 5 months operation with the TDRF, the proportion of good size pellets improved by 2%. The results are presented in the figure 9.

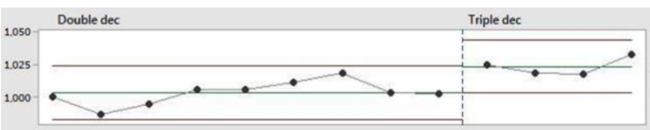

Figure 9: Impact of the use of TDRF on pellets good size range (Results are courtesy of ArcelorMittal Mines Canada – Pellet Plant)

Regarding the metallurgical properties of the fired pellets, the use of TDRF in operation also provided some improvement. Indeed, the Low Temperature Disintegration (LTD) improved by 3%, and the reducibility R40 also improved, but by 5%. The figures 10 and 11 are presenting those results.

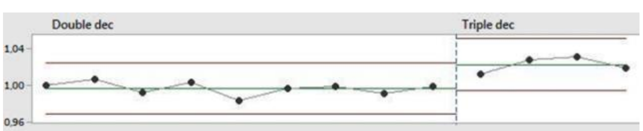

Figure 10: Impact of the use of TDRF on LTD (Results are courtesy of ArcelorMittal Mines Canada – Pellet Plant)

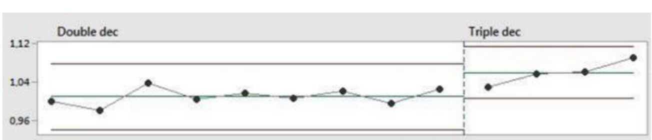

Figure 11: Impact of the use of TDRF on R40 (Results are courtesy of ArcelorMittal Mines Canada – Pellet Plant)

As mentioned previously, the Epsilon Chute was developed to reduce the drop height of the green pellets and thus reduce the pellet bed compaction inside the induration furnace. No measurement was performed to evaluate specifically this aspect. But visually, it was possible to appreciate an improvement of the pellet's sphericity. The left picture of Figure 12 is showing a fired pellets sample collected during the production with the use of TDRF, so with the use of Epsilon Chute. In comparison, the picture on the right showing pellets collected during the production of the previous screening technology, so without the special chute. As it can be appreciated on Figure 12, the use of Epsilon Chute is improving the pellets sphericity.

Figure 12: Impact of the use of TDRF on pellets sphericity (Results are courtesy of ArcelorMittal Mines Canada – Pellet Plant)

One of the side benefits of the sphericity improvement was the elimination of the bed fluidization in the cooling zones of the induration process. Indeed, before the use of TDRF, the productivity of the induration furnace had to be reduced when this issue was observed. By using the TDRF in operation, and also with the use of Epsilon Chute, the bed permeability is improved, and this could explain why this bed fluidization disappeared.

CONCLUSION

During the development of TDRF, it was expected to:

- Significantly increase screening efficiency;
- Improve bed permeability through the use of Epsilon Chute (Lower bed compaction);
- Allow Segregation concept.

This was confirmed through a plant trial in the benchmark pellet plant. Those expected benefits translated to plant results showing:

- Productivity increase of 2,7% (even more without bottlenecks on the pellet feed)
- Quality improvement of 2 to 18%, depending on quality index
- Energy: in development…
- Better overall operation: less deterioration of recirculating load over time and elimination of pellet bed fluidization phenomena in the induration process cooling zones of the induration process.

ACKNOWLEDGMENTS

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