

The impact of new technologies on the iron ore screening flowsheet

Alexandre Gonçalves Andrade^{1,*} , Steve Beaudin¹, Eric Tremblay¹, and Václav Šmilauer²

¹ Metal 7 Inc, 285, des Pionniers, CP 1590, G4R 4X9, Sept-Îles, Québec, Canada

² WooDEM, Květoslava Mašity 291 CZ-25231 Všenory, Czech

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Abstract. The iron ore screening process plays a pivotal role in determining the dimensions of pellets that enter the firing process of a pelletizing plant. The particle size distribution resulting from this process significantly influences the gas flow permeability within the induration furnace. This paper investigates the latest developments in screening technology, highlighting advancements that contribute to elevated levels of screening efficiency and enhanced plant productivity. The discussion turns around how these technological innovations pave the way for achieving the objective of producing high-quality iron ore pellets with minimal energy consumption, thereby improving the overall performance of the plant. The paper offers a comprehensive overview of the screening process flowsheet, encompassing these cutting-edge technologies, associated process parameters, and benefits quantified through DEM simulations. Moreover, it examines the consequential impact on greenhouse gas (GHG) emissions, providing a holistic perspective on the environmental implications of these advancements.

Keywords: Roller screen / roller feeder / iron ore pellets quality / plant productivity / innovation / screening technology / screening efficiency

Highlights

- Double Deck Roller Screen (DDRS) is a new technology allowing increase on plant capacity for both disk and drum pelletizing circuits.
- Triple Deck Roller Feeder (TDRF) and Double Deck Roller Feeder – Segregation (DDRF-S) allows the creation of segregated pellet bed inside furnace.
- Improvements on screening efficiency and the use of a segregated pellet bed profile provides benefits in plant throughput or energy savings, depending on the plant strategy.

1 Introduction

The iron ore pellet holds a pivotal role in the ironmaking process, enabling the utilization of high-grade ore and the upgrading of low-grade deposits [1]. This process involves several steps, including fragmentation, size separation, concentration, and dewatering to refine the ore. Achieving the right pellet size is crucial for its suitability in counterflow reactors, which involves considering factors such as moisture levels, addition of essential elements (like limestone, coal/coke, dolomite, and binders), and ensuring the proper chemical composition for an effective firing

process [2]. Central to this refining process is the roller screen, an indispensable equipment used to adjust the sizing of green pellets, ensuring they meet the requirements for iron burden in steelmaking plants [2–4]. Initially, pelletizing plants employed vibrating screen technology, resulting in high pellet degradation rates, which diminished process efficiency. However, the evolution of roller conveyor technology in 1958, eventually advancing into roller screening technology in the 1960s and 1970s, addressed these inefficiencies by subjecting pellets to lower stress, thereby enhancing screening efficiency [5]. The roller screen, consisting of rotating rollers maintaining specific gaps, effectively separates material flows into retained and passing groups [6]. Studies by Meyer [5] highlighted a 25% increase in screening efficiency using roller screening technology compared to vibrating screens, with minimal damage to pellets. Further comparisons by Goncharenko, Balandin [7] illustrated the benefits of roller screens, including reduced recirculating load, improved pellet homogeneity, and increased production potential. Currently, some plants employ roller screens post-disk/drum systems or just before the induration furnace entrance, underscoring the significance of correct green pellet classification. Proper screening enhances gas flow during the firing process, reducing energy consumption, dust generation, and enhancing pellet quality [8]. A successful screening process involves eliminating undersized and oversized particles to avoid adverse impacts on furnace and balling productivity [3]. Notably, pelletizing units using

* e-mail: agandrade@metal7.com

drum technology encounter higher recirculating loads, necessitating efficient screening to maintain productivity [9,10]. Ensuring pellet homogeneity through effective screening positively impacts furnace energy consumption and the performance of the pellet bed in the induration furnace [11,12]. The role of screening, particularly through roller screens, is fundamental to ensuring the production of high-quality iron ore pellets by managing size distributions, enhancing furnace performance, and ultimately impacting the economic viability of pelletizing processes. Williams [13] explored the segregation of granular mixtures based on particle size, involving trajectory segregation, percolation of fine particles, and the rise of coarse particles during vibrational movement. Drahn and Bridgwater [14] conducted a quantitative study on segregation in granular materials, particularly focusing on free surface segregation, more pronounced with different particle sizes and densities, showcasing the movement and rearrangement of green balls, percolation of fine particles, and the floating of larger particles, potentially leading to undersized pellets reaching the gap opening for classification. Moreover, Goncharenko, Balandin [7] demonstrated that the feed position on the screen deck significantly influences fine particle recovery, corroborating the findings of previous segregation studies. Additionally, investigations with iron ore stockpiles, as noted by Zhang, Zhou [15], confirmed segregation and stratification phenomena. Hogg [16] explored segregation processes in hoppers and bins. Particle shape significantly affects screening performance in roller screening, serving as indicators of moisture content, particle fineness, and binder agent dosage, as identified by various researchers [2,17-20].

The roller screening process is probabilistic, influenced by various factors such as the movement of pellets, screen deck inclination, particle orientation, size distribution, shape, gap opening, and residence time on the screen. The efficiency of a roller screening process is significantly impacted by several key factors that influence the screening ratio (ton/m^2), the quantity of rolls, rolls' diameter, rolls' length, and the feed tonnage [21]. The number of rolls directly affects the screening ratio. More rolls for the same feed tonnage result in a lower screening ratio, enhancing the screening surface area and improving the probability of particles reaching the gap opening for classification. However, a higher quantity of rolls can increase the plant footprint, leading to elevated capital expenditures (CAPEX) and operational costs (OPEX) [21]. Additionally, an excessive number of rolls may cause issues with pellet transportability, creating a "cigarette effect" where pellets get stuck, altering their shape and obstructing the screening gaps [21].

Decreasing roll diameter and increasing their quantity within the same footprint considerably boosts the open screen area, leading to increased screening efficiency. Research by Silva, Cunha [22] demonstrated that reducing the roll diameter increased the screening efficiency, mainly by improving undersized particle removal. The length of rolls impacts the total screening width and consequently the screening area, allowing for more efficient particle classification. The amount of material fed into the roller screening process is critical. If the quantity of material exceeds the screening surface's capacity, the screening ratio

increases, and some particles may not reach the gap openings of the screening device, reducing the overall screening efficiency. Yang, Zhao [23] observed that a higher feed rate leads to a lower screening efficiency due to an excessive quantity of material overloading the screen, resulting in an increased proportion of undersized and oversized pellets in the final product. The particle size distribution of green pellets feeding the roller screening process significantly impacts screening efficiency. According to studies by Goncharenko, Balandin [7], moisture content in the pellet charge affects pellet aggregation on screens. Dias, Guimarães [11] emphasize the importance of uniform pellet size for quality and homogeneity. Different strategies in pellet diameter adjustment impact plant productivity. Uniformity in the gap opening between rolls affects screening efficiency. According to Silva [6], maintenance, wear, and wear-resistant coatings play crucial roles in the screening performance. Irregular wear increases recirculation, impacting production and pellet size distribution [21]. The straightness of rolls affects the screening process. Silva [6] notes that bending due to poor-quality rolls or wear impacts gap settings, affecting efficiency and productivity. A well-distributed pellet bed enhances screening efficiency. Silva [6] explains that proper distribution techniques and equipment help maintain an even load on rolls, preventing irregular wear and improving efficiency. The ability to transport pellets across the screen is affected by roll surface roughness, velocity, and tonnage load. According to Silva [6], roughness impacts iron ore buildup, affecting transport and productivity. The screen's angle impacts throughput and efficiency. Goncharenko, Balandin [7] performed tests showing that varying angles affect available gap openings and the removal of undersized and oversized pellets. Rolls' speed impacts the residence time of pellets in the equipment, affecting throughput. Silva, Cunha [24] explains how different speeds influence the efficiency of undersized and good-sized pellets. Yang, Zhao [23] also studied the effect of the rotational speed on the screening efficiency using a specific screening configuration.

Andrade, Beaudin [21] presented a deep explanation about the parameters impacting the performance of the screening process on the general iron ore pelletizing process and also the different screening devices available on the market. The SDRS (Single Deck Roller Screen) is the equipment used at the discharge of the balling units and it is composed by a single deck. Depending on the gap opening strategy, the device can remove fines in the first zone remove goodsize product as the final product and retain the oversized particles, the fines and oversized pellets returns to the agglomeration units while the goodsize pellets are destined to the firing process. Otherwise, this machine can be configured to remove fines and retain goodsize product as final product. The DDRF (Double Deck Roller Feeder) is a machine composed by 2 roller screening decks, whereas the top deck is responsible to remove oversized pellets and the lower deck is responsible to remove fines and retain the goodsize product as the final product. The TDRF (Triple Deck roller Feeder) machine is a Metal7's patented solution composed by three rollers screening decks, whereas the top deck is responsible to remove oversized pellets, the middle deck is responsible to retain goodsize pellets bigger

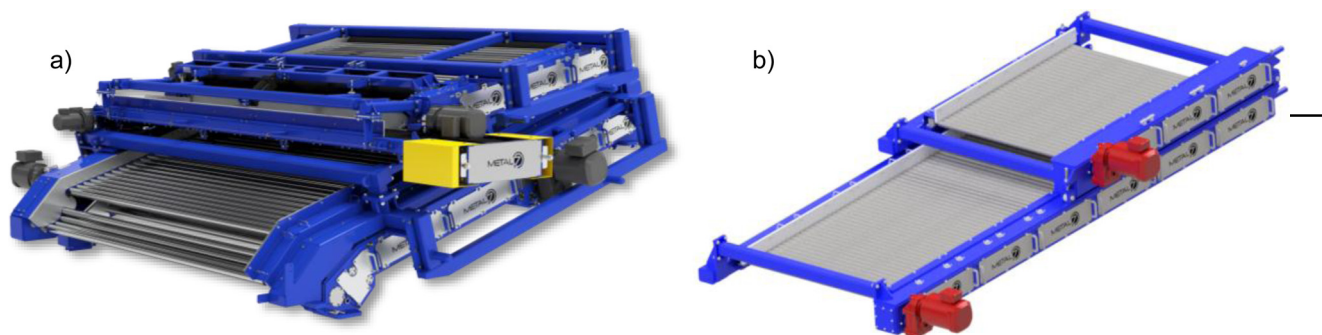


Fig. 1. (a) Triple Deck Roller Feeder (TDRF); (b) Double Deck Roller Screen (DDRS).

in diameter as the final product, while the lower deck is responsible to remove fines and retain goodsize particles lower in diameter in the final product, this way the pellet bed profile produced by this type of machine is a segregated pellet bed, which improves the gas flow inside the induration furnace [25]. Ergun [26], Kozeny [27] defines the pressure drop over a compacted bed of solids particles, presenting the parameters impacting its performance. More recently, Carvalho, Thomazini [28] studied the possibility to promote a segregated pellet bed formation by the use of a conventional Double Deck Roller Feeder, removing the conveyors to collect oversized pellets. The DDRF-S (Double Deck Roller Feeder – Segregation) is basically the same technology of the TDRF, but without the use of the top deck, responsible to remove oversized pellets. It is used for the flowsheets that removes oversized pellets on the balling screens.

The DDRS (Double Deck Roller Screen) device is a screening machine to be used at the discharge of the balling units composed by two decks, which the top deck is responsible for reducing the load of particles in the lower deck, differently than the typical DDRF technology whereas the top deck is used to remove oversized particles. The benefits of reducing the load of particles in the lower deck comes from the fact that screening devices at the discharge of balling units has normally less screening area compared to feeders, presenting a high screening ratio (tons per hours/m² of screening), it means that part of the load of pellets doesn't touch properly the gap openings of the screening device, reducing the screening efficiency of the machine, increasing the proportion of goodsize pellets in the recirculating load (removed as fines in the screening device) and increasing the proportion of fines in the final product. With the use of the DDRS technology, part of the load of pellets is retained in the top deck of the machine to reduce the amount of material in the zone responsible to remove fines, this was, the load is reduced, and the screening efficiency is increased. The retained material on the top deck is then transported to the lower deck to finish the screening of fines particles, flowing the goodsize zone on the lower deck.

The improvements on the screening flowsheet for the iron ore pelletizing plants consists of using the DDRS technology at the discharge of balling units and the TDRF or the DDRF-S technology at the entrance of the induration furnaces. It increases drastically the screening efficiency and provide extra benefits for the use of a segregated pellet bed profile in

the induration furnace, improving the gas flow on the different steps on the firing process (drying, pre-firing, firing, post-firing and cooling zones). Figure 1 represents the TDRF and DDRS technologies.

The paper offers insights into significantly improving the screening efficiency of iron ore pelletizing plants by comparing the performance of the operational unit using a standard screening flowsheet versus the proposed one.

2 Experimental

Simulations using the discrete element method (DEM) were conducted using an open-source code from woodem.org. The roller screen module was developed by Woodem company (www.woodem.eu). Simulations were run in a Lenovo – Thinkstation P620-1X AMD Ryzen Threadripper PRO – Hexadeca-core (16 cores) – 3955WX 3.90 GHz – 32 GO DDR4 SDRAM – 1 TO SSD memory. Given their nearly spherical shapes, pellets were modeled as spheres. Pellet contact is simulated using custom-developed pellet model which features contact-level plastic dissipation (both normal and tangential) and adhesion. The pellets themselves carry irreversible plastic deformation induced by confinement; this is done by reducing the sphere radius (but not mass) – as a compromise between simulating non-spherical shapes and disregarding plastic deformation. The computing PSD on outlets, it is the original pellet diameter which is considered. The pellet contact model is completely rate independent. This was a design decision when developing the model for pellets since pellet deformation is primarily elasto-plastic. Sidestepping viscosity (rate-dependent stiffness) avoided problematic areas in both calibration and simulation (time-stepping); and allowed for easy stiffness and time scaling, with important favorable impact on simulation speed. Several studies considering DEM were conducted to simulate roller screening performance [6, 15, 18, 20, 22–24, 29–32]. Figure 2 shows simulation results versus the real data collected in a real industrial screening operation. The mass balance was collected at different feeding rates (750, 800, 850, 900 and 950 tph) and at different points on the screen machine (feeding point of the equipment, discharge of goodsize product and discharge of undersize). As it can be seen, the results of DEM module after calibration were similar to the real data collected in a pelletizing plant operation.

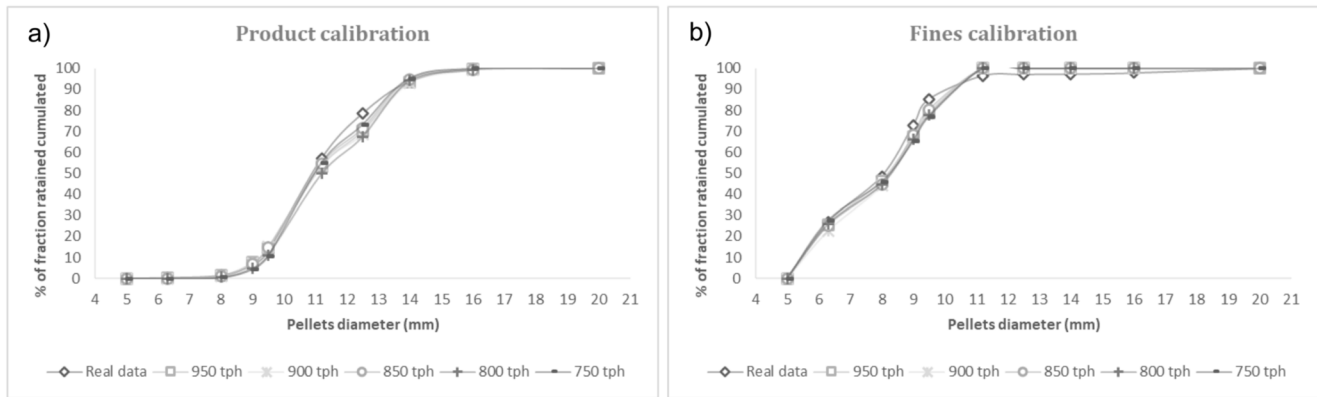


Fig. 2. Comparison of simulation results versus real operational data operation. (a) Calibration of “Product” fraction. (b) Calibration of “Fines” fraction.

Table 1. Global Warming Potential (GWP) factors [34].

Gas	PRG 100 YEARS – GIEC 2013
CO ₂	1
CH ₄	28
N ₂ O	265
R22	1760
R410a	1725
R134a	1300
SF ₆	22800
NF ₃	17200

To simulate the pellet bed permeability, it is used a simulator developed by Corem Research Center. The simulator was created by using different blends of particle size distribution (PSD) from a specific iron ore pelletizing plant and then running pot grate testing to evaluate de pressure drop for each blend of material. It considers factors like the PSD, pellet mean diameter, pellet bed high. As results, the simulator delivers the pellet bed void fraction and the pressure drop for a specific flowrate of 95 Nm³/min m² [33].

The Global Warming Potential (GWP) and the greenhouse gas emission factors used in the calculations are presented in Table 1 and Table 2.

The simulations are done comparing the scenarios described in Table 3, being three different scenarios for a typical iron ore pelletizing flowsheet using disks as agglomeration units and three scenarios for a typical iron ore pelletizing flowsheet using drums as agglomeration units.

The paper describes the benefits of using the TDRF/DDRFS and DDRS in two different case flowsheets and present the improvements on plant throughput and energy savings on the firing process.

3 Results and discussions

The results and discussions will be discussed separately considering the two different iron ore pelletizing flowsheets described in session 2.

3.1 Case study 1–6 MTPY Pellet plant using disk pelletizers

In this context, the prevailing process constitutes a pelletizing operation with an annual capacity of 6 million tons of pellets per year. The chosen technology for iron ore pellet production involves the utilization of disk pelletizers. Figure 3 delineates the flowsheet employed in this specific scenario. The screening component of the flowsheet comprises Single Deck Roller Screens (SDRS) positioned at the discharge of the disks, complemented by a Double Deck Roller Feeder (DDRFS) placed at the entrance of the induration furnace.

The parameters used in each scenario composed in the case study 1 are schematically represented in Figure 4 and it is detailed in Table 4.

The particle size distribution used in the case study 1 is represented in Figure 5, representing a typical particle size distribution produced in iron ore pelletizing plant using balling disks as agglomeration technology.

The enhanced configuration (SDRS + DDRFS) demonstrated a 7.4% improvement in plant throughput compared to the baseline scenario (SDRS + DDRF). It's noteworthy that the simulations do not account for the advantages stemming from the segregated pellet bed profile within the induration furnace. In the subsequent evolutionary scenario (DDRS + DDRFS), there is an 11.0% increase in plant throughput relative to the base case scenario (SDRS + DDRF).

For operations experiencing bottlenecks in the pellet feed area (e.g., grinding and filtering) or prioritizing energy savings over plant throughput, a screening gap strategy adjustment is implemented. This adjustment aims to eliminate more undersized and oversized pellets, thereby enhancing the particle size distribution of the pellets fed into the furnace. Consequently, this optimization results in a reduction in heavy oil or coke/coal consumption, attributed to the improved particle size distribution and the utilization of a segregated pellet bed formation, allowing for a decreased energy input in the furnace. This strategic adjustment leads to a reduction in greenhouse gas emissions. The results are presented in Figure 6 and Table 5.

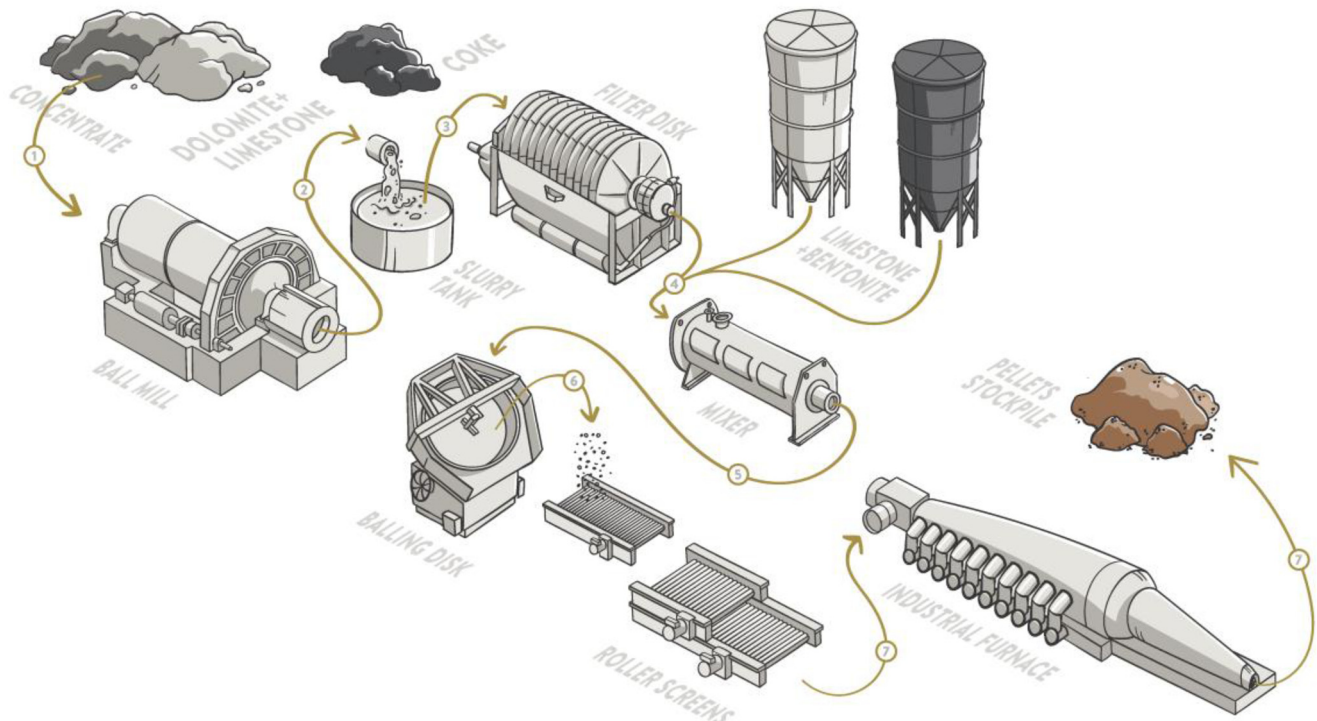
Table 2. Greenhouse gas emission factors.

SOURCE	EMISSION FACTORS				REFERENCE
	t CO ₂	t CH ₄	t N ₂ O	t CO ₂ -eq.	
Anthracite (ton GHG/kg)	0.002340	0.000000030	0.000000020	0.002346	[35]
Petroleum coke (ton GHG/liter)	0.003494	0.00000012	0.000024	0.00986	[36]
Bentonite (ton GHG/kg)	0.0000183			0.0000183	*Calculated, based on the percentage of carbon, reference not found
Limestone (ton GHG/kg)	0.0004436			0.0004436	
Dolomite (ton GHG/kg)	0.0004766			0.0004766	
Heavy oil (ton GHG/liter)	0.003156	0.00000012	0.000000064	0.003176	[36]
Natural gas (ton GHG/m ³)	0.001926	0.000000037	0.000000033	0.001936	[36]
Electric energy quebec – base hydroelectricity (ton GHG/kwh)				0.0000019	[36]

Table 3. Scenarios simulated in the study.

#	DESCRIPTION	IDENTIFICATION
1	6 MTPY Pellet plant using disks + 10 SDRS + DDRF	Base case scenario 1
2	6 MTPY Pellet plant using disks + 10 SDRS + DDRF-S	Improved scenario 1
3	6 MTPY pellet plant using disks + 10 DDRS + DDRF-S	Next generation 1
4	3 MTPY pellet plant using drums + 6 SDRS + SDRF	Base case scenario 2
5	3 MTPY pellet plant using drums + 6 SDRS + DDRF-S	Improved scenario 2
6	3 MTPY pellet plant using drums + 6 DDRS + DDRF-S	Next generation 2

MTPY = million tons per year; DDRF = double deck roller feeder; TDRF = triple deck roller feeder; DDRS = double deck roller screen; SDRS = single deck roller screen; SDRF = Single Deck Roller Feeder.

**Fig. 3.** Iron ore pelletizing flow sheet used on the base case scenario 1.

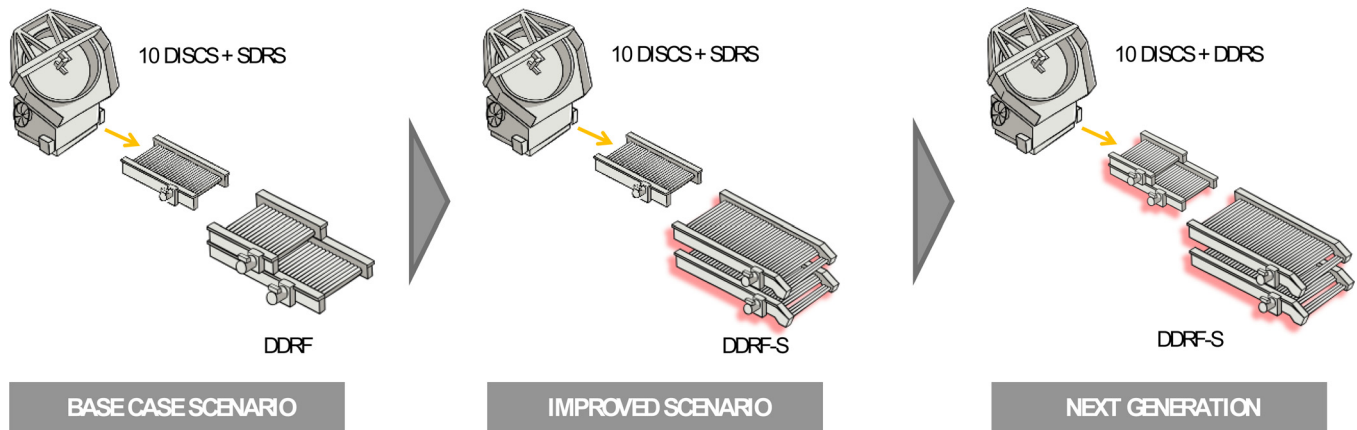


Fig. 4. Scenarios studied in the case study 1.

Table 4. Parameters used on simulations at case study 1–Base case, Improved and Next generation scenario.

PARAMETERS	BASE CASE	IMPROVED SCENARIO	NEXT GENERATION
Agglomeration technology	Disks	Disks	Disks
Quantity of agglomeration units	10	10	10
Production by agglomeration unit	150 tph	150 tph	150 tph
Roller screen configuration			
• Quantity of rollers on top deck	–	–	20
• Gap opening on top deck (mm)	–	–	11
• Quantity of rollers to remove fines	45	45	45
• Gap opening to remove fines (mm)	8	7.8	7.7
• Quantity of rollers to remove oversized	15	15	15
• Gap opening to remove oversized (mm)	16	16	15.8
• Rollers length (mm)	1800	1800	1800
• Rollers diameter (mm)	75	75	75
• Rollers rotation speed (rpm)	120	120	120
• Screen inclination angle (C)	13	13	13
Roller feeder configuration			
• Quantity of rollers to remove oversized (top deck)	20	–	20
• Gap opening to remove oversized (mm)	16	–	16
• Quantity of rollers in the middle deck	–	43	43
• Gap opening in the middle deck (mm)	–	10.5	10.5
• Quantity of rollers to remove fines (lower deck)	40	40	40
• Gap opening to remove fines (mm)	8	8	8
• Rollers length (mm)	4000	4000	4000
• Rollers diameter (mm)	89	89	89
• Rollers rotation speed (rpm)	100	100	100
• Screen inclination angle in the middle and lower decks (C)	21	21	21

To calculate the benefits of a better particle size distribution inside furnace, a pellets permeability simulator developed by Corem Research Center is used [33]. The calculations are presented in Table 6.

Environmental benefits are quantified by translating the improvements in pellet bed permeability into savings in solid fuel consumption. This improvement in permeability results from optimizing the particle size distribution of pellets fed into the furnace, coupled with the use of a segregated pellet bed profile. Each iron ore pelletizing plant selects a strategy based on technology-derived benefits,

which can be applied to reduce greenhouse gas (GHG) emissions through either electric energy or solid fuel reduction. In this study, the emphasis is placed on anthracite consumption savings.

Considering the improvements in Particle Size Distribution and pellets sphericity provided by a Double Deck Roller Feeder-Segregation in an iron ore pelletizing plant in Asia, a correlation was defined with Corem Permeability Model, showing that 10% improvement in pellet bed permeability provided by Corem simulator represents approximately 5% energy savings in the induration

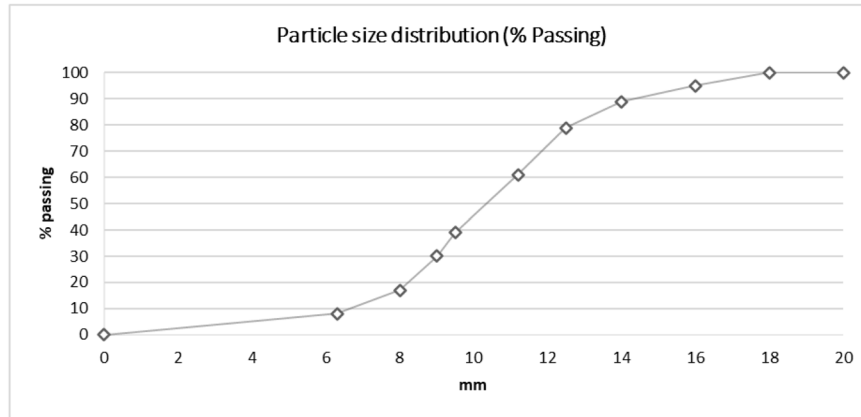


Fig. 5. Particle size distribution at discharge of agglomeration units used on case study 1.

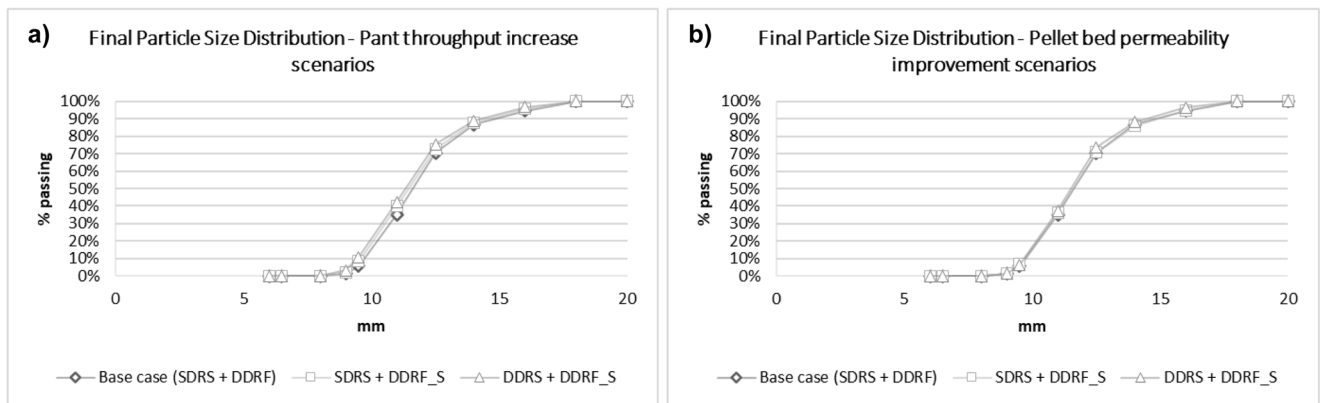


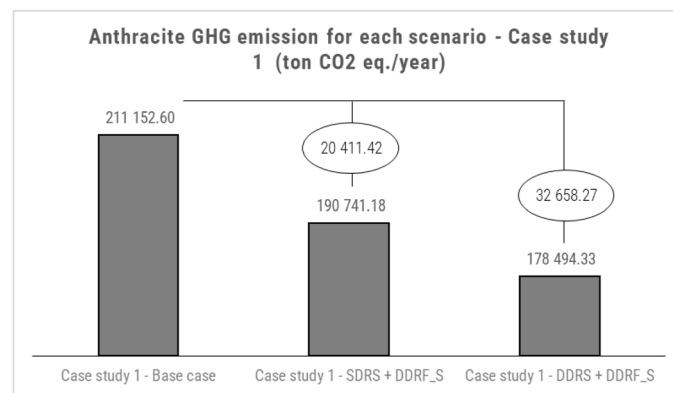
Fig. 6. Particle size distribution at the entrance of furnace on case study 1. (a) PSD representing scenarios for plant capacity increase. (b) PSD representing scenarios of pellet bed permeability improvement. Results from the DEM simulations.

Table 5. Results from DEM simulations of case study 1.

PARAMETERS	BASE CASE (SDRS + DDRF)	IMPROVED SCENARIO (SDRS + DDRF-S)	NEXT GENERATION (DDRS + DDRF-S)
BALLING SCREENING OUTPUT			
Production / disk (tph)	95.7	101.4	106.0
Fines removal / disk (tph)	54.3	48.6	44.0
Fines – 8 mm (%)	0.09%	0.13%	0.29%
Onsize + 8 – 16 mm (%)	94.10%	95.19%	96.53%
Override + 16 mm (%)	5.81%	4.68%	3.18%
FEEDER SCREENING OUTPUT			
Production (tph)	917.1	985.1	1018.0
Fines removal (tph)	40.1	28.9	42.0
Fines – 8 mm (%)	0.01%	0.02%	0.06%
Onsize + 8–16 mm (%)	94.53%	95.65%	96.78%
Override + 16 mm (%)	5.46%	4.33%	3.17%
PRODUCTION INCREASE (%)		7.4%	11.0%

Table 6. Results from the Permeability Simulator developed by Corem for case study 1.

PARAMETERS	BASE CASE (SDRS + DDRF)	IMPROVED SCENARIO (SDRS + DDRF-S)	NEXT GENERATION (DDRS + DDRF-S)
Pellets mean diameter (mm)	11.1	11.2	11.2
Improvement on pellets sphericity (%)	–	11%	15%
Void fraction in pellet bed (%)	31.3	32.2	32.6
$\Delta P@ 95 \text{ nm}^3/\text{min m}^2$ (pa)	4449.0	4059.4	3913.9
% ΔP REDUCTION		10.1%	13.3%

**Fig. 7.** Greenhouse gas emissions for anthracite consumption in each scenario of case study 1.

furnace. In the scenario employing SDRS + DDRF-S technologies, a 5% energy savings is considered. Conversely, for the scenario using DDRS + DDRF-S technologies, an 8% energy savings is factored in. The total reduction in megajoules (MJ) per ton of pellets is then translated into a reduction in anthracite consumption. For the calculations in case study 1, it is assumed that an iron ore pelletizing plant consumes 800 MJ per ton of pellets. Results are found in Figure 7.

The substitution of the conventional DDRF technology with DDRF-S (Improved scenario) has the potential to yield a reduction of 20,411.42 tons of CO₂ equivalent per year. Simultaneously, replacing the standard SDRS technology with DDRS technology at the discharge of balling units and substituting the standard DDRF with DDRF-S at the entrance of the furnace offers a greater reduction, amounting to 32,658.27 tons of CO₂ equivalent per year.

3.2 Case study 2 – 3 MTPY Pellet plant using drum pelletizers

In this case study, the pelletizing operation is configured with a capacity of 3.0 million tons of pellets per year. Drum pelletizers serve as the selected technology to produce iron ore pellets. The screening flowsheet is structured with

Single Deck Roller Screens (SDRS) positioned at the discharge of the drums, complemented by a Single Deck Roller Feeder (SDRF) situated at the entrance of the induration furnace.

The parameters used in each scenario composed in the case study 2 are schematically represented in Figure 8 and detailed in Table 7.

The particle size distribution used in the case study 2 is represented in Figure 9, representing a typical particle size distribution produced in iron ore pelletizing using balling drums as agglomeration technology.

The enhanced scenario (SDRS + DDRF-S) exhibits a notable improvement of 9.2% in plant throughput when compared to the base case scenario (SDRS + SDRF). The subsequent evolutionary scenario, denoted as Next Generation (DDRS + DDRF-S), demonstrates a substantial 19.2% increase in plant throughput relative to the base case scenario (SDRS + SDRF). The benefits derived from these scenarios are particularly pronounced for circuits employing drums as agglomeration units. Typically, these flowsheets exhibit recirculating loads (undersized and oversized pellets) ranging between 200% and 350%. The proposed technologies enhance screening efficiency, reducing the percentage of good-sized pellets within the recirculating load. This, in turn, ensures their inclusion in the final product, elucidating the significant benefits in plant throughput.

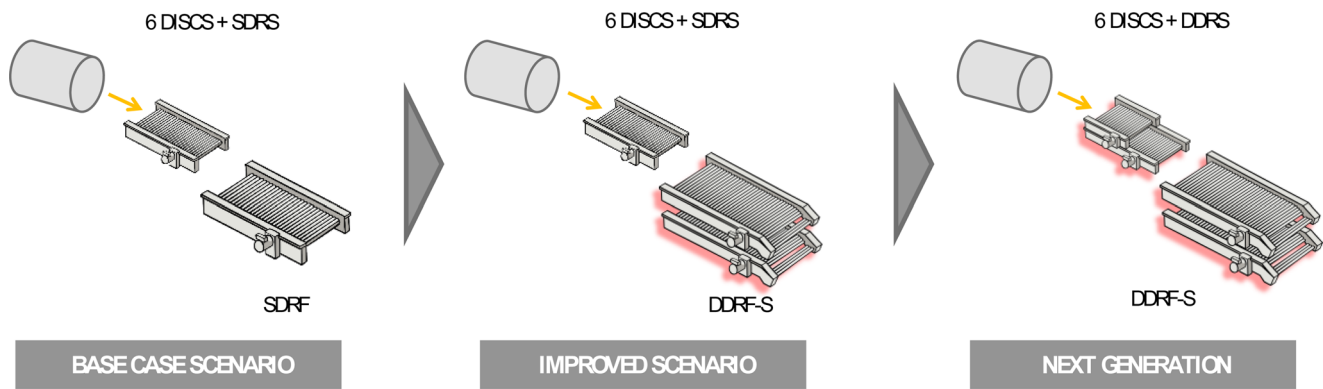


Fig. 8. Scenarios studied in the case study 2.

Table 7. Parameters used on simulations at case study 2–Base case, improved and next generation scenario.

PARAMETERS	BASE CASE	IMPROVED SCENARIO	NEXT GENERATION
Agglomeration technology	Drums	Drums	Drums
Quantity of agglomeration units	6	6	6
Production by agglomeration unit	400 tph	400 tph	400 tph
Roller screen configuration			
• Quantity of rollers on top deck	–	–	27
• Gap opening on top deck (mm)	–	–	9
• Quantity of rollers to remove fines	54	54	54
• Gap opening to remove fines (mm)	8	8	7.9
• Quantity of rollers to remove oversized	8	8	8
• Gap opening to remove oversized (mm)	15	15	15
• Rollers length (mm)	2200	2200	2200
• Rollers diameter (mm)	75	75	75
• Rollers rotation speed (rpm)	120	120	120
• Screen inclination angle (C)	13	13	13
Roller feeder configuration			
• Quantity of rollers to remove oversized (top deck)	–	–	–
• Gap opening to remove oversized (mm)	–	–	–
• Quantity of rollers in the middle deck	–	34	34
• Gap opening in the middle deck (mm)	–	10.5	10.5
• Quantity of rollers to remove fines (lower deck)	30	30	30
• Gap opening to remove fines (mm)	9	8.8	8.8
• Rollers length (mm)	4000	4000	4000
• Rollers diameter (mm)	89	89	89
• Rollers rotation speed (rpm)	100	100	100
• Screen inclination angle in the middle and lower decks (C)	21	21	21

In the context of Case Study 2, the benefits can also be translated into an enhancement of the particle size distribution of pellets feeding the induration furnace, the results are represented in Figure 10. This improvement is coupled with the adoption of a segregated pellet bed, particularly advantageous for cases exhibiting bottlenecks or restrictions in the pellet feed area, such as grinding, balling, filtering, or mixing areas. The results are presented in Table 8 and Table 9.

In accordance with Case Study 1, the quantification of the benefits associated with an improved particle size distribution within the furnace utilizes the simulator developed by the Corem Research Center [33]. The detailed calculations are outlined in Table 9. It's noteworthy that in comparison to Case Study 1, the benefits in this instance are marginally diminished. This diminution is attributed to the fact that the pelletizing process employing drums as agglomeration units inherently generates pellets characterized by a more

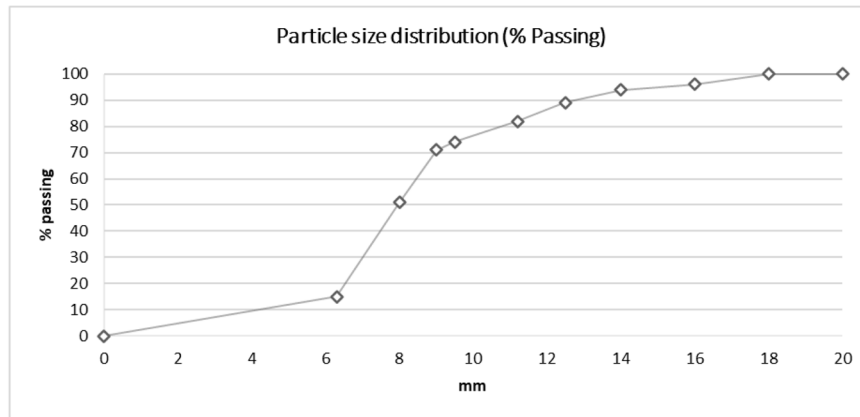


Fig. 9. Particle size distribution at discharge of agglomeration units used on case study 2.

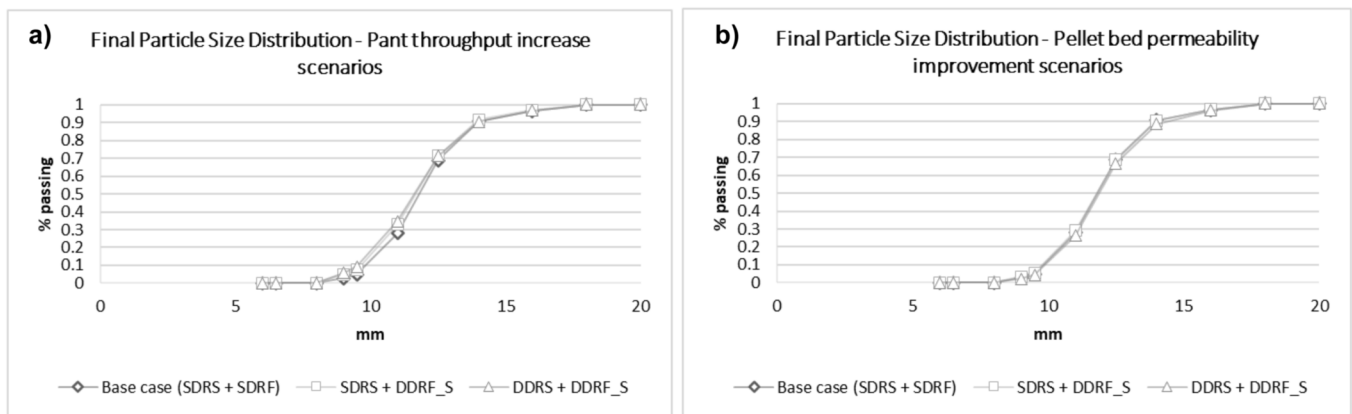


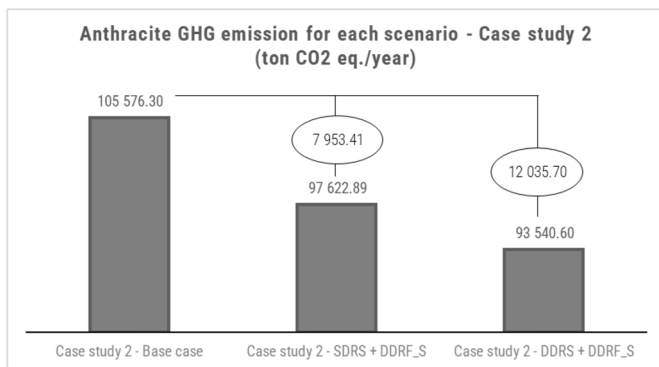
Fig. 10. Particle size distribution at the entrance of furnace on case study 2. (a) PSD representing scenarios for plant capacity increase. (b) PSD representing scenarios of pellet bed permeability improvement. Results from the DEM simulations.

Table 8. Results from DEM simulations of case study 2.

PARAMETERS	BASE CASE (SDRS + DDRF)	IMPROVED SCENARIO (SDRS + DDRF-S)	NEXT GENERATION (DDRS + DDRF-S)
BALLING SCREEN OUTPUT			
Production / disk (tph)	97.4	97.4	107.3
Fines removal / disk (tph)	285.4	285.4	283.1
Override removal / disk (tph)	17.2	17.2	9.5
Fines – 8 mm (%)	2.41%	2.41%	3.20%
Onsize + 8–16 mm (%)	94.97%	94.97%	93.93%
Override + 16 mm (%)	2.61%	2.61%	2.88%
FEEDER SCREEN OUTPUT			
Production (tph)	443.5	484.1	528.7
Fines removal (tph)	140.7	99.9	136.3
Fines – 8 mm (%)	0.05%	0.11%	0.19%
Onsize + 8–16 mm (%)	96.55%	96.97%	96.67%
Override + 16 mm (%)	3.40%	2.92%	3.14%
PRODUCTION INCREASE (%)		9.2%	19.2%

Table 9. Results from the Permeability Simulator developed by Corem for case study 2.

PARAMETERS	BASE CASE (SDRS + SDRF)	IMPROVED SCENARIO (SDRS + DDRF-S)	NEXT GENERATION (DDRS + DDRF-S)
Pellets mean diameter (mm)	11.1	11.2	11.1
Improvement on pellets sphericity (%)	–	11%	15%
Void fraction in pellet bed (%)	31.2	32.1	32.5
$\Delta P @ 95 \text{ nm}^3/\text{min m}^2$ (pa)	4513.6	4162.2	3992.0
% ΔP REDUCTION		7.8%	11.6%

**Fig. 11.** Greenhouse gas emissions for anthracite consumption in each scenario of case study 2.

favorable particle size distribution, as evidenced by a steady PSD (Particle Size Distribution) curve. Consequently, the potential gains from enhancing particle size distribution are somewhat reduced in this scenario.

Environmental benefits in this case study are determined by translating the improvement in pellet bed permeability into savings in solid fuel consumption. Each iron ore pelletizing plant adopts an optimal strategy to mitigate greenhouse gas (GHG) emissions based on the technology-derived benefits, which may manifest through reductions in either electric energy or solid fuel consumption. In this analysis, the focus is on the benefits associated with anthracite savings.

Considering the improvements in Particle Size Distribution and pellets sphericity provided by a Double Deck Roller Feeder-Segregation in an iron ore pelletizing plant in Asia, a correlation was defined with Corem Permeability Model, showing that 10% improvement in pellet bed permeability provided by Corem simulator represents approximately 5% energy savings in the induration furnace. For the scenario employing SDRS + DDRF-S technologies, a 7.8% improvement in pressure drop is considered, translating to an estimated 3.9% energy savings. Conversely, for the scenario utilizing DDRS + DDRF-S technologies, a 5.9% improvement in energy savings is accounted for. The overall reduction in megajoules (MJ) per ton of pellets is then

converted into a reduction in anthracite consumption. In the calculations for Case Study 2, it is assumed that an iron ore pelletizing plant consumes 800 MJ per ton of pellets. The results are shown in Figure 11.

The replacement of conventional SDRF technology with DDRF-S (Improved scenario) has the potential to yield a reduction of 7,953.41 tons of CO₂ equivalent per year. Additionally, replacing the standard SDRS technology with DDRS technology at the discharge of balling units and substituting the standard SDRF with DDRF-S at the entrance of the furnace could result in a more substantial reduction, amounting to 12,035.70 tons of CO₂ equivalent per year.

4 Conclusion

The calibrated Discrete Element Method (DEM) module demonstrates a strong correlation with results obtained from an industrial iron ore pelletizing screening operation across various feeding tonnages. Subsequently, leveraging this calibration, simulations were conducted to assess the potential advantages of implementing two novel technologies: the DDRS (Double Deck Roller Screen) and the TDRF/DDRF-S (Triple Deck Roller Feeder/Double Deck Roller Feeder – Segregation). These simulations were applied to two distinct iron ore pelletizing flowsheets, one using disks as agglomeration units and the other employing drums. The findings derived from the DEM simulations robustly establish the individual and combined benefits of these technologies, underscoring their cumulative advantages.

In the case of the circuit employing disks as agglomeration units, the potential boost in production throughput is 11.0% with the screening flowsheet incorporating DDRS + DDRF-S technologies. Pressure drop simulation across the pellet bed profile uses Corem Permeability calculator, revealing a 13.3% reduction in benefits. This reduction corresponds to a reduction of 32,658.27 tons of CO₂ equivalent per year, based on an annual plant production of 6.0 million metric tons of pellets per year.

For the circuit using drums as agglomeration units, simulations indicate 19.2% increase in plant throughput with the screening flowsheet incorporating DDRS + DDRF-S. The simulated pressure drop is 11.6% lower in

this scenario compared to the base case scenario (SDRS + SDRF). It corresponds to a reduction of 12,035.70 tons of CO₂ equivalent per year, considering an annual plant production of 3.0 million metric tons of pellets per year.

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On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Author contribution statement

The contribution of the author and the co-authors are described as follows.
Alexandre Gonçalves Andrade

- Conceived and designed the analysis
- Collected the data
- Performed the analysis and simulations
- Correlation with industrial results
- Support on the development of the technologies proposed in the paper
- Wrote the paper

Steve Beaudin

- Support to the main author to conceived and designed the analysis
- Support on the development of the technologies proposed in the paper
- Analysis of results and correlation with industrial results
- Paper review

Eric Tremblay

- Development of the new technologies proposed in the paper
- Details on the technologies (3D pictures, machine configuration, etc)
- Paper review

Václav Šmilauer

- Development of the simulator DEM (discrete element method)
- Paper review

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