EXAMINING ROLLER SCREEN PERFORMANCE TO CATEGORIZE IRON ORE GREEN PELLETS TO OPTIMIZE PELLET INDURATION

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Abstract Within the iron ore mining industry, roller screens are used to segregate on-size green iron ore pellets. This is done by depositing the raw pellet stream onto a roller screen consisting of several sections of rolls with different gaps to remove undersized pellets, segregate on-size pellets and allow oversized pellets to run off the end of the screen. The on-size pellets are hardened in an indurating furnace prior to transport. The permeability of the on-size pellet bed allows a ready flow of hot gases through the pellets reducing fuel consumption of the indurating furnace, increasing productivity and improving the quality and uniformity of hardened pellets. Oversized and undersized pellets are returned to pelletizing drums or discs for reprocessing (disc return rate). Optimizing the screening process to reduce the disc return rate and contamination of the on-sized pellet stream by oversized and undersized pellets can further increase the productivity and reduce costs of the pellet induration process. As it is cost prohibitive to experimentally examine the factors affecting roller screen performance, we use the discrete element method to do that.

1 INTRODUCTION

Roller screens are a widely used method for raw material preparation in the iron ore mining industry (Figure 1). And, it is one of the standard solutions for size grading that is an important point for lean manufacturing. Typically, Roller screens consist of several sections of rolls with different gaps between them. The distance between gaps increase in the direction of the flow.

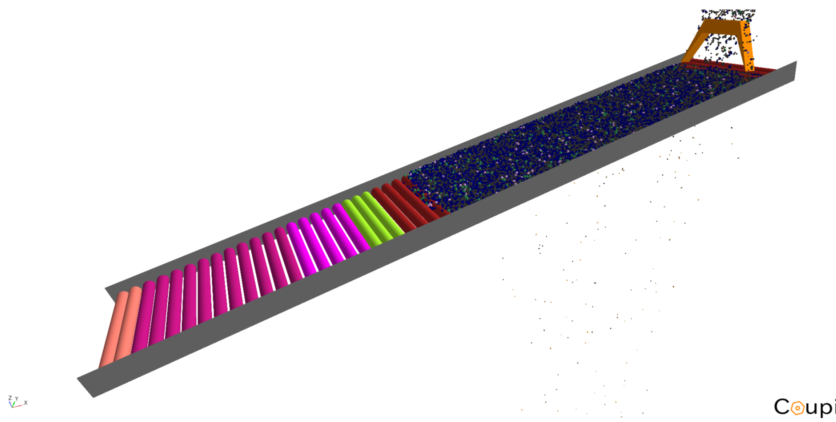

Figure 1: A roller screen after 20 seconds from the start of the simulation. Iron ore colorized by groups respond to the diameter range.

The first section should remove from the flow undersized pellets. The next section/sections remove pellets that fit the required size range (on-size pellets) with oversized pellets running off the end of the roller screen. The oversized and undersized pellets are returned to pelletizing drums or discs for reprocessing (disc return rate). And the on-size pellets are hardened in an induration furnace.

The permeability of the on-size pellet bed allows the ready flow of hot gases through the pellets reducing fuel consumption, increased productivity and improved the quality and uniformity of hardened pellets. Optimizing the screening process to reduce the disc return rate and contamination of the on-sized pellet stream by oversized and undersized pellets can further increase the productivity and reduce costs of the pellet induration process.

The efficiency of screening depends on many factors that include the geometry of rollers and pellets, moisture content of the pellets, angle of the roller screen, flow rate of the pellets, and others. During operations, pellets can stick to parts of the screen and block the sieve.

Conducting full-scale experiments to examine roller screen performance is extremely difficult and cost prohibitive. As an alternative to full-scale tests, roller screen performance can be examined using the discrete element method (DEM). Silva et al. (2018) constructed a detailed DEM model of a roller screen, conducted experiments to estimate green iron ore pellet properties, used input data from a full-scale operating screen, and compared the measured pellet disk return rate with simulation of the operating roller screen for validation. Silva et al. also did a parameter study to determine how the roller screen performance changed with different pellet properties. As part of their study Silva et al. identified factors affecting roller screen performance that should be analyzed to determine the optimal screen design. This include roll length and diameter, rotation frequency, screen angle, total screen length and the length of each set of rollers used to segregate pellets by size. The purpose of the current effort is to set up the basic roller screen DEM simulation to replicate Silva et al.'s results and extend their work to examine roller screen performance as a function of different roller screen and pellet properties. We report on our initial simulation results to generate base line roller screen performance data.

2 MATERIALS AND METHODS

2.1 Setup

The simulation consists of a hopper, sifter and a roller screen. The hopper is a buffer of pellets with sloped sides that provides a constant flow rate. The sifter separates the flow into three particle streams to cover the whole top surface of the roller screen. And the roller screen is a set of rollers with gaps between them that is by the width ends with walls.

Each roll of roller screen is a cylinder with diameter equal to 75 mm and height equal to 900 mm. All rolls are collected in groups with the same gap between rolls. The first group of rolls (in the flow direction) is is designed to remove undersized pellets and consists of 38 rolls with a gap between rolls 8.8 mm. The second group of rolls is a transport section that consists of 3 rolls with a gap equal to 2 mm. The third group consists of 5 rollers with a gap equal to 14 mm. And the fourth group consists of 11 rolls with the gap 17 mm. The two sets of rolls with gaps of 14 mm and 17 mm are used to separate on-size pellets from the particle flow. The last group consists of 2 rolls with a gap equal to 2 mm and is used to transport oversized particles off the end of the roller screen. All rolls rotate with the same frequency equal to 80 rpm, in the same direction and create a screen angle equal to 15 degrees.

2.2 Materials

We are using two types of materials in the our simulation. First one is pellet and the second one is steel. The roller screen and sifter are made of steel. Pellets are made of pellet material. Material properties and contact properties of the pellet material are given in Table 1 and Table 2 respectively. The contact properties are calibrated to be in agreement with experimental data [1].

Table 1: Material properties

Property	Pellet	Steel
Shear modulus [MPa]	1.8	7720
Bulk density, [g/cm^3]	3.15 ± 0.48	7.8
Poison's ratio [1]	0.25	0.25
Coefficient of restitution [1]	0.1	0.7

Table 2: Contact properties of pellet material

Property	Pellet	Steel
Friction coefficient [1]	0.3	0.35
Surface energy [J/m^2]	1.5	0.5

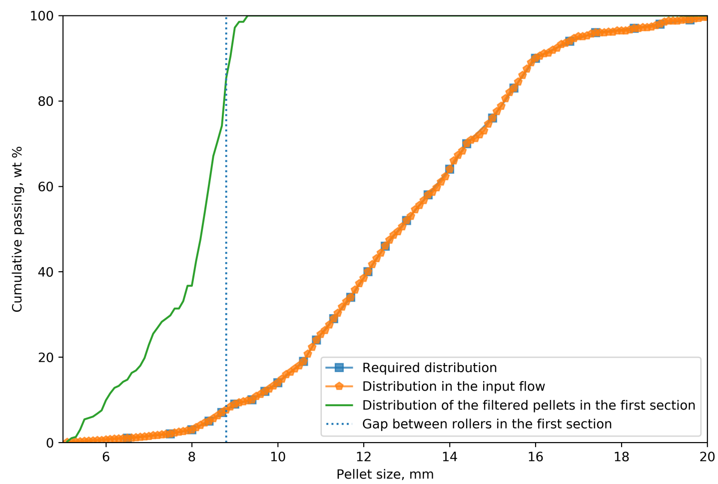

Figure 2: Particles size distributions. Required from the Silva et al. paper [1]; measured in the input flow; distribution of pellets passed the gaps in the first section of the roller screen.

2.3 Pellets

We assume that a pellet is an unbreakable spherical particle made of a pellet material. The range of sizes for the simulated pellet flow stream is from 5 mm up to 20 mm. The pellet size range of interest is from 8 mm up to 18 mm. The purpose of the roller screen simulation is to divide the aggregate of pellets into three main groups: under 8 mm (”undersized” pellets); above 18 mm (”oversized” pellets); and ”on-size” pellets. We are controlling the bulk density of pellets in the hopper and the particles size distribution.

2.4 Particles size distribution

The pellets in our simulation distributed continuously by diameter from the 5 mm up to 20 mm following the measured particle size distribution (PSD) from [1] (Figure 2). We are keeping the PSD on the same level and control it each second of simulation. Also, we are able to check the particles size distribution in each stream (undersized, on-size and oversized).

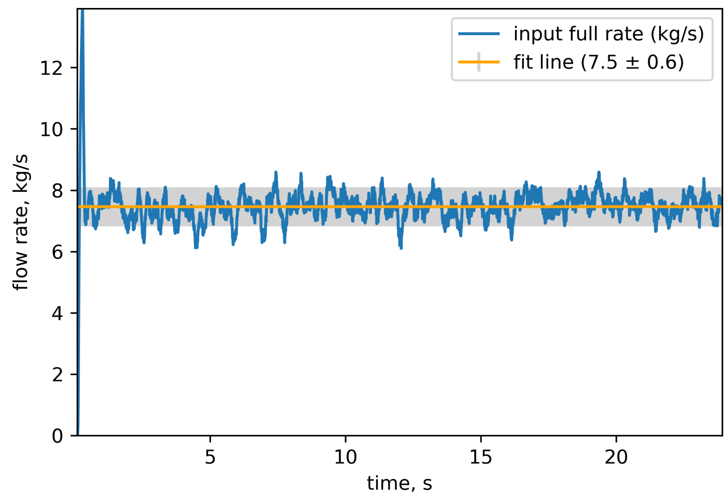

Figure 3: A feed rate of input flow as a function of simulation time

2.5 Feed rate

We use a hopper with previously settled particles to provide a constant feed rate on the roller screen. The real feed rate is monitored at each step of simulation and it fits good in a horizontal line on level 7.5 kg per second with a standard deviation equal to 0.6 kg/s (Figure 3).

2.6 Parameters for analysis

We classify all pellets into 36 groups (like Silva et. al. [1] did) by diameter. And, for each size class index i we calculate the following parameters (following Silva et al.'s nomenclature):

F_i [kg/s], is the feed rate out of the feed hopper. A pellet is out of the hopper when its center lower than the hopper's lowest point.

U_i [kg/s], is the flow rate through undersized section rolls into the undersized flow stream to be returned to the balling drums or disks. The undersized flow stream can contain undersized, on-size, and oversized pellets if those pellets fall through the gaps in the first section of the roller screen.

O_i [kg/s], is the flow rate of particles transported over all of the screen rolls to fall off the end of the screen into the oversize flow stream to be returned to the balling drums or disks.

P_i [kg/s], is the on-size flow rate of particles that are transported over the first section of rolls and transport rolls and fall through the gaps in the second or third section of rolls. A pellet is considered to have fallen through the gap when its top point is lower than the line between centers of the rolls (to avoid including stuck particles that are blocking the sieve).

$c_i^{[1]}$ [1] (first partition curve equation for first classification zone), is the sum of pellets retained on the section 1 rolls as a percentage of the feed rate.

$$c_i^{[1]} = \frac{P_i + O_i}{F_i} \tag{1}$$

$c_i^{[2]}$ [1] (second partition curve equation for first classification zone), is the partition of pellets that report to the oversize stream from the on-size rolls as a percentage of the pellets that report to the on-size screens.

$$c_i^{[2]} = \frac{O_i}{P_i + O_i} \tag{2}$$

For all pellets in the system we also calculate the following parameters:

F [kg] (full mass), is the total mass of all pellets passed hopper.

UO [kg] (undersized mass), total mass of all pellets returned to the pelletizing or reprocessing.

U^T [%] (loss in the undersized flow), is the total percentage of pellets with size greater than 8 mm those are lost in section for undersized.

$$U^T = 100 \frac{\sum^{i(D>=8mm)} U_i}{F} \tag{3}$$

O^T [%] (loss in oversized flow), is the total percentage of pellets with size less or equal to 18 mm those are lost by traversing the complete length of the roller screen and falling of the end into the oversize bin.

$$O^T = 100 \frac{\sum^{i(D<=18mm)} O_i}{F} \tag{4}$$

OS^T [%] (total loss of on-size (8-18 mm) pellets), is the total loss of on-size pellets lost to the undersized particle flow (undersized screening rolls) or to the oversized flow. On-size pellets traversing over the screen to be deposited to the oversized flow.

$$OS^T = 100 \frac{\sum_{i(D>=8mm)}^{i(D<=18mm)} (U_i + O_i)}{\sum_{i(D>=8mm)}^{i(D<=18mm)} F_i} \tag{5}$$

DR^T [%] (discs return rate), is the percent flow rate of pellets of all sizes that are returned to the pelletizing drums or discs for reprocessing.

$$DR^T = 100 \frac{UO}{F} \tag{6}$$

OCS^T [%] (on-size contamination), is the rate of flow of undersized and oversized particles that are included in the on-size particle stream.

$$OCS^T = 100 \frac{\sum_{i(D>=5mm)}^{i(D<8mm)} P_i + \sum_{i(D>18mm)}^{i(D<=20mm)} P_i}{\sum_{i(D>=5mm)}^{i(D<=20mm)} P_i} \tag{7}$$

3 CONCLUSION AND DISCUSSION

A numerical DEM model of a roller screen for sorting of green ore pellets was created to determine the parameters to optimize roller screen performance. We first replicate the simulation of Sliva et al. [1] to validate our approach and provide a baseline performance. We will then extend Silva et al.'s work to examine roller screen performance as a function of different roller screen and pellet properties to determine the optimal screen design. These properties include roll length and diameter, rotation frequency, screen angle, total screen length and the length of each set of rollers used to segregate pellets by size.

We report on our model development and initial simulation results to generate bas line roller screen performance data. The model uses the Hertz-Mindlin contact model with Johnson-Kendall-Roberts adhesion model that takes into account particles moisture and electrostatic forces for pellets sticking. The simulation has been conducted, to compare the initial state of the model with the industrial data. Additional simulations will be conducted to investigate the influence of the screen dimensions and rotational speeds on the sorting performance and accuracy.

The fragility of pellets and their moisture could be a good point for the next investigations and model improvement. Also, the problem of pellets sticking and sieve blocking will be quantified. Future work will examine the distribution of the pellets along the roller's length. This will be useful to take into account the feed rate on roller screen's ability to segregate particles to on-size, undersize, and oversize bins. These determine the percentage of on-size particles lost to reprocessing drums or disks.

REFERENCES

[1] Benito Barbabela e Silva, Emerson R. da Cunha, Rodrigo M. de Carvalho, Lus Marcelo Tavares. (2018). Modeling and simulation of green iron ore pellet classification in a single deck roller screen using the discrete element method. *Powder Technology* 332 (2018), 359–370.