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SIMULATING BACKFILL OPERATIONS FOR UNDERGROUND MINING

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ABSTRACT

This case study focusses on the simulation model that was developed for Sibanye-Stillwater's underground platinum mining operations in Nye, MT. Sibanye-Stillwater is a global mining company based in South Africa with Platinum Group Metals (PGM) and Gold mines in the Americas and Africa. One of their US mines in Montana, Stillwater Mining Company, owns and operates underground mines for PGM ore and a Concentrator plant. The process involves mining, transporting the muck (ore and waste) to the surface, milling ore into powder and backfilling the mined out cavities in the underground with tailings from milling operation. The circular dependency between mining and backfilling operations, along with variability for each task, makes it difficult to develop a realistic short-term schedule, and efficiently deploy equipment and people to various tasks. This presentation will review the simulation model used to help the mining company understand how the bottleneck shifts every week, understand which resource is constraining underground mining from increasing production and understand where capital investments are needed in backfill operations.

1 OVERVIEW

As of August 20, 2021, Sibanye's operations in the Americas consist of Stillwater and East Boulder mines in Montana, where they extract and process PGM ore from the J-M Reef, the only known significant source of PGMs in the US and the highest grade PGM deposit known in the world. These operations primarily produce palladium and platinum, which are referred to as 2E PGMs. They also own and operate the Columbus Metallurgical Complex, also situated in Montana, which smelts material mined to produce PGM-rich filter cake and recycles automobile catalysts to recover PGMs.

Sibanye currently develops a high-level annual mine plan for budgeting purposes followed by a detailed monthly plan for executing operations. The detailed plans include all the constraints related to equipment, staffing, and ore body. The mine plan organizes the underground three-dimensional ore-body into a number of blocks. Each block comprises multiple 'headings', which are linear cavities at specific depths. Once a heading has been mined out, the void created is backfilled with paste (sand & cement mix), sand only, or cemented rock-fill (broken rock and cement mix).

Sibanye's immediate goal for the process digital twin is to understand the interdependencies between underground mine operations, backfill plant capability, and related logistical operations. Additionally, understand ability of multiple backfill plants to keep up with mining schedule (quantity and timing for delivering broken-rock backfill or cement-paste backfill to active faces).

2 CHALLENGE

A typical short-term mine plan is a series of 8 feet 'rounds' that make up a heading, with estimates for start date and quantity of ore & waste muck generated as a result. The mine plan also provides a precedence

relationship between rounds. Each round goes through a series of drill-blast-haul cycles. The expected start date for a round is calculated in mine planning software using average durations for various steps like mining, muck hauling, and backfilling. These duration estimates include results from historic performance and contingency buffers. Since the delay times applied are a combination of multiple averages and do not take into account the constraints of the backfill system, they do not reflect the actual function of the mining system. This causes continual schedule drift once mining starts.

The backfilling operations (BFO) works as a shared service catering to requests from many headings being mined concurrently across the underground mines. BFO constantly prioritizes requests and relies on accurate fill start dates from the mining teams. The BFO analyst has to constantly monitor the progress of all the headings to re-prioritize fill requests. Once the pumping of backfill at a heading starts, it cannot be preempted without impacting the structural soundness and stability of the filled void. In addition, set up and break down of backfill delivery incurs man hours, so additional delay and cost is introduced if multiple backfill events have to occur for a heading.

The overall challenge that the backfill system faces is that it depends on availability of tailings from the mill, which in turn depend on rate of mining activities, which depends on how quickly BFO can complete fill requests. The milling operations, due to its nature, requires frequent downtimes for preventative maintenance and unplanned failures. This interrupts the steady supply of tailings for BFO. The backfill system can maintain a limited inventory of tailings which quickly deplete once filling starts. In addition, periodic maintenance and exceptional mechanical failure of the backfill system is not considered in planning. This leads to unexpected down time for the backfill system and further schedule drift. The bottom-line is that if BF cannot keep up with the mining rates, then mining activities cannot generate sufficient ore for tailings causing BF to stall, resulting in a downward spiral.

3 SOLUTION

MOSIMTEC designed and developed a flexible, AnyLogic-based discrete-event simulation model to allow Sibanye engineers to generate a backfill schedule (with start & end dates for each heading) given different round-level mine plans. The model allowed engineers to test the impact of daily changes in tailings supply rate on the ability of the BFO to keep up with requests. The model contained objects that represented mining, backfilling, milling and logistics operations. The AnyLogic flow library was used to model the flow of tailings, sand and paste through a network of pipes in the underground. Preliminary analysis indicated that the flow representation in the model closely matched real-world flow behavior.

The model can be run via an Excel user interface. This Excel user interface allowed engineers to change mine plans, processing times, monthly resource schedules, and backfill types to use. The Excel front-end also included data ETL (extract-transform-load) to generate a heading-level inputs from round-level mine plans. The interface also allowed engineers to understand key model outputs in the Excel environment.

4 BENEFITS

The weekly fill schedule that would have take 2-3 days to develop can now be turned around in a few hours. The direct input of mine round data for planning, which decreased data translation and work load on the department as a whole. Periodic maintenance can now be planned based on plant run time hours and be accounted for in the schedule. Since the constrains and real world operation is accounted for in a sitewide perspective, Stillwater can plan distribution of tailings from the mill to each backfill area. This is a level of planning that was not done in a realistic fashion previously and serves to take the guess work out of operation of the tails distribution system. Replacing average estimates for backfilling a heading with real values and constraints from BFO provided mining teams with more accurate heading completion estimates.