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IMPLEMENTATION OF ADVANCED TRANSFER CHUTE DESIGNS[1]

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Abstract

Frequently materials handling operations are compromised by transfer chute problems ranging from high wear rates, blockages and ineffective loading of the downstream conveyor. This paper will present the design flow implemented to overcome problems in two case studies utilising Discrete Element Modelling incorporating material characterisation. Material testing is relevant in achieving a valid DEM simulation model and subsequently a valuable design tool for transfer chute assessment and design. It is well recognised that in the current growth and demand for mineral resources, leading to ever increasing conveyor capacities associated with export terminals and mineral processing facilities that transfer chutes are a key focus point. The successful performance of the transfer chute is also dependent on operating with a “robust range” of material flowability and handling characteristics. This requirement is crucial in accommodating minerals ores from developing resources which are often more friable and stickier than in past decades. This paper will include details of chute installations associated with iron ore and coking coal, from the DEM simulations through to the performance of the installed and commissioned plant.

Key words: Discrete element modeling; Transfer chute.

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1 INTRODUCTION

The ability to model and investigate chute designs utilising computer aided design utilising 3D models and Descrete Element Modeling is gaining wider acceptance in the industry.
Additionally, benefits in the utilisation of a "soft" loading chutes consisting of a profiled upper deflector operating in conjuction with "spoon" to load the receiving conveyor is gaining a range of acceptance as compared to the more traditional rock box and vertical impact plate style chutes. To confirm the chute performance prior to fabrication and certainly installation stages (and subsequent redesign costs), validation utilising DEM modeling is justified.
Set out in the subsequent sections are case studies of two chute installations, utilising the key elements of engineering design flow within a multidiscpilinary design team, and associated with the upgrade of the respective operations.

2 CASE STUDY 1; IRON ORE EXPORT TERMINAL DYNAMIC CHUTE

Transnet's iron ore export terminal at Saldanha, South Africa, has undergone a series of phased expansions to a capacity of 60Mtpa from pre-2006 to 2011. The terminal's stockyard consists of four stacker reclaimers and related stockyard conveyors, designed for capacities of up to 10,000tph. The terminal handles thirteen grades of iron ore with varying properties, some of which have high fines and clay content and are highly abrasive.
Various problems were, however, experienced with some of the new equipment from the upgrades. One such problem was the stockyard conveyor discharge chutes, which experienced regular blockages and spillage, resulting in excessive plant downtime. Hatch, in a JV, developed the concept redesign of the two stockyard conveyor discharge chutes which were subsequently implemented to the new ceramic lined dynamic or free flow chute configuration [1].

2.1 Previous Rock Box Design Chute

Due to the highly abrasive nature of the ore, initial terminal upgrade chute designs were based on mini-rock box type chutes in order to minimize wear and incorporated into low height shuttling head systems. However, this reduced height compromised the chute design so that chute angles were insufficient to maintain ore velocity through the restricted cross sectional area causing blockages at peak capacities. Also, the limited height did not allow centralised flow on the downstream conveyor resulting in off centre loading and spillage. Design checks based on material test work data indicated that the current chute capacities could be limited to as little as 75% of the required peak capacity.
Figures 1a and 1b depict the experienced problems in regard to off centre loading of the receival belt and skirting damage resulting from the belt mistracking. In an attempt to centralise the flow profile plates were added to the outlets, but were found to be ineffective, further reduced the chute cross sectional area, and a source of additional maintenance due to excessive wear.

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Figure 1. (a) Off centre loading of receival conveyor (b) Damaged skirting.

Flow through the rock box chute was simulated for improved visualisaton of the chute performance problems. The simulation, refer to Figure 2, confirmed the site observations of low discharge velocities, limited cross sectional area (and choking at peak capacity) and off centre loading and burden discharge direction onto the downstream belt.

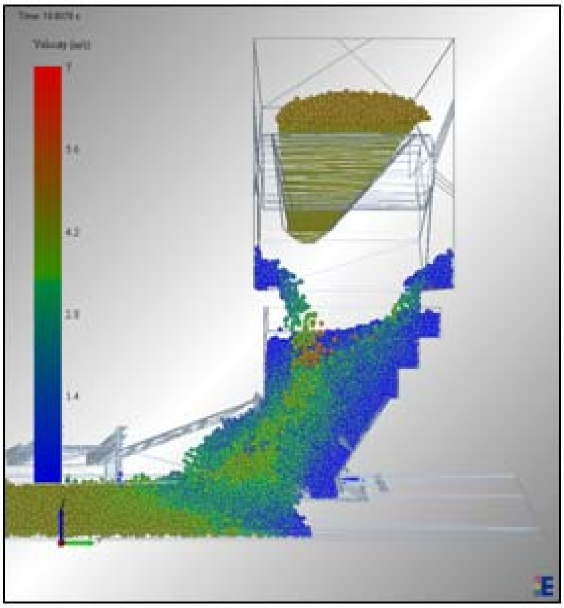

Figure 2. DEM simulation of Rock Box Chute, highlighting choking and low velocity loading.

2.2 Development of the Dynamic Chute Design

As the future expansions were to be based on a similar stockyard arrangements it was critical to Transnet that the performance of the discharge chute improve. Rather than rebuilding stockyard conveyor head ends to increase transfer height (which would have been very costly, requiring extensive downtime and resulting in a reduced stockpile area), the project endeavoured to design a new chute that would address the problems.

Hatch integrated flow and wear test work and concept design provided by Jenike & Johanson (J&J), for the layout, detail design, execution and commissioning of the new chute. The software EDEM (DEM Solutions) was utilised for discrete element

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modelling for flow simulations during development of the conceptual design to better visualize the flow patterns through the chute, and to optimise the design, as shown in Figure 3 and Figure 4.
It was clear that the new design provided more than sufficient cross sectional area that could accommodate larger surges. It showed the effectiveness of the new design in directing flow, as required, while maintaining velocity, so that the discharge flow matched the downstream belt speed and direction with very little impact.

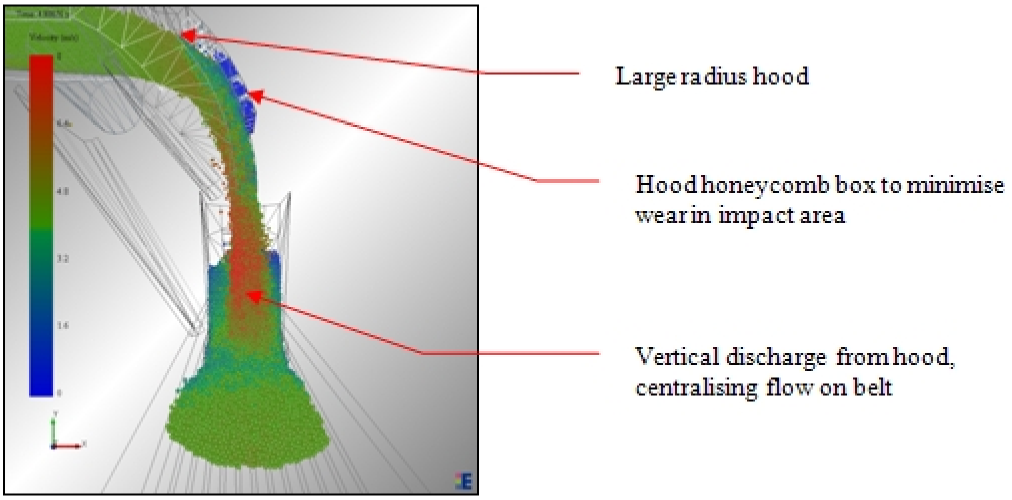

Figure 3. DEM simulation of new Hood and Spoon Chute (front view).

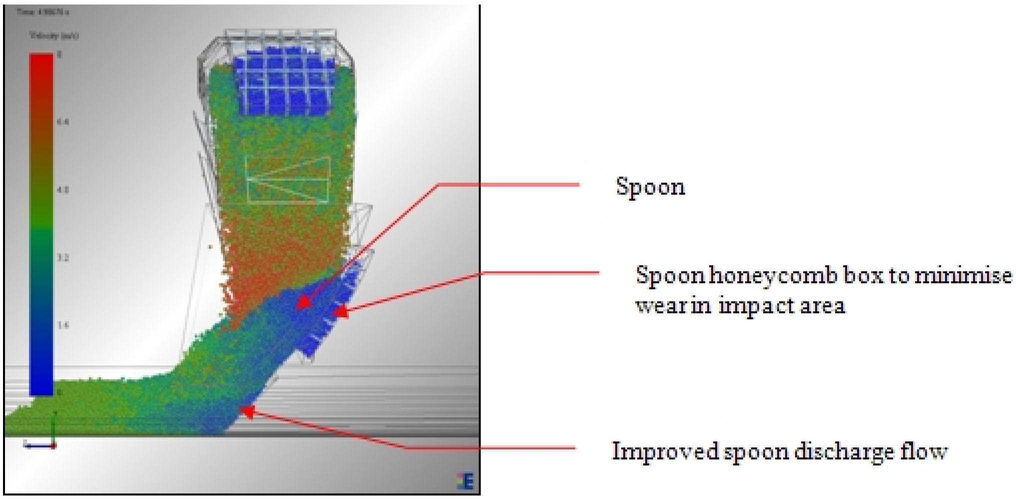

Figure 4. DEM simulation of the new Hood and Spoon Chute (Side View).

2.3 Installation and Evaluation

At the end of 2010, after being in operation for 16 months, a total cumulative capacity of 15Mt, there had been no significant wear in the spoon sections and they had not required any maintenance. Figure 5 depicts the spoon liner configuration, and operational performance, with minimal loading turbulence, no skirting and on centre loading.

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Figure 5. (a) Spoon liner installation, (b) Spoon discharge in operating position.

The high impact areas in the hood honeycomb have also performed well. Small patches of localised wear occurred at the outer edges of the impact area in the hood, just outside the honeycomb. The rate of wear in these patches relative to that in the main honeycomb impact area proves the effectiveness of the honeycomb design in reducing wear. Refer Figure 6 depicting the hood in operation and wear liner fillet refurbishment for life extension before complete hood replacement.

Figure 6. (a) Hood installation with honeycomb (b) Hood wear performance with liner plate fillet. refurbishment at 3 Mt throughput

Due to the research and development that went into this new chute design the project cost was slightly high compared to a more off the shelf solutions that various companies provide. The project cost was approximately US $320,000.00 for material test work conceptual designs and fabrication. With the initial investment already made, any similar chutes, in future, would be a cost effective investment.

3 CASE STUDY 2; COKING COAL, TWO STREAM DEFLECTOR CHUTE

This project was part of an upgrade to an existing coal preparation plant to accommodate increased washed coal production to a peak of 1200tph. Although the product coal conveyor to the truck loading bins is relatively modest, at 1200 tph, it is a critical component to ensure constant product throughput and washery operation. The existing chute at times plugged as a result of material build-up and surges in flow rate. The redesign of the transfer chute was undertaken with a calibrated DEM

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material model and utilising the EDEM software. The simulations provides some insight into the challenging area of modelling WSO (*Wet and Sticky Ores*) in DEM simulations.
The transfer chute was designed to direct coarse product coal and de-watered filter cake to either of two paths, downwards into a product bin or forward onto a second conveyor. The product coal is loaded onto the conveyor belt first and then at an intermediate loading station filter cake (conveyed from horizontal vacuum belt filters) is layered on top of the product coal.

3.1 Development of Chute Design

A key concern was the sticky characteristic of the filtercake, and the deflector performance due to the first impact from this material due to being layered on top of the product coal burden. Figure 7 depicts the nature of the filtercake.

Figure 7. Filtercake appearance (24% wb moisture content).

Coal samples were collected from the operating plant for both the product coal and filtercake and tested by BMEA to determine appropriate material model parameters for DEM simulation, refer [2]. This calibration is considered relevant for bulk materials where there has not been an established experience, or where chute performance is critical under difficult material characteristics.
Figures 8a and 8b depict the chute configuration and the two positions of the deflector plate respectively. As indicated the deflector is a profiled curve lined with stainless steel, and with an upper pivot. In the through loading arrangement the coal stream is directed onto a loading spoon for controlled feed of the collection conveyor.

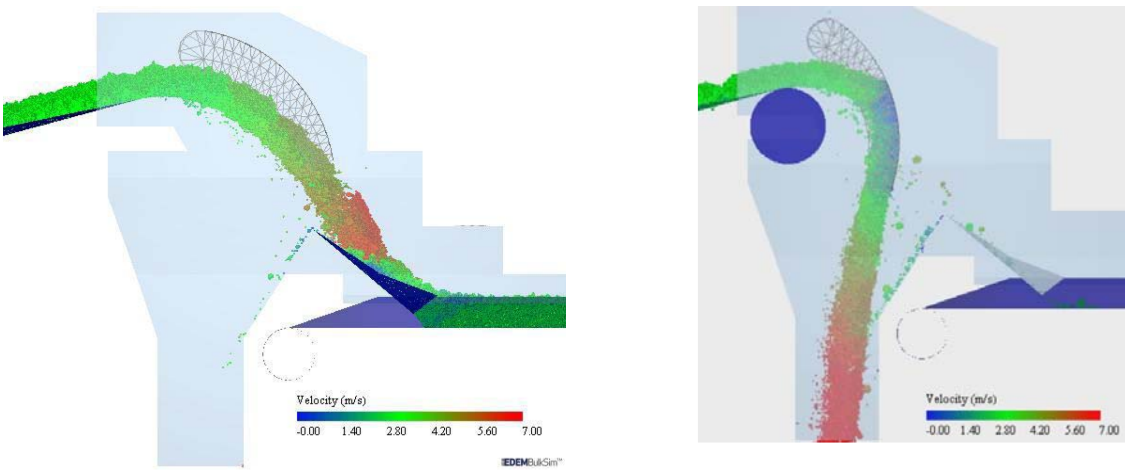

Figure 8. (a) Deflector up for through loading onto collection conveyor, (b) Deflector down for discharge into bin below.

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Figure 9 presents a detail of the coal stream separation from the DEM modelling and represents the clumping nature of the filtercake layer as compared to the underlying burden of sized product coal. For comparison Figure 9b with the chute in operation, indicates reasonable agreement with the DEM model, with the clumping and distinct coal layers apparent.

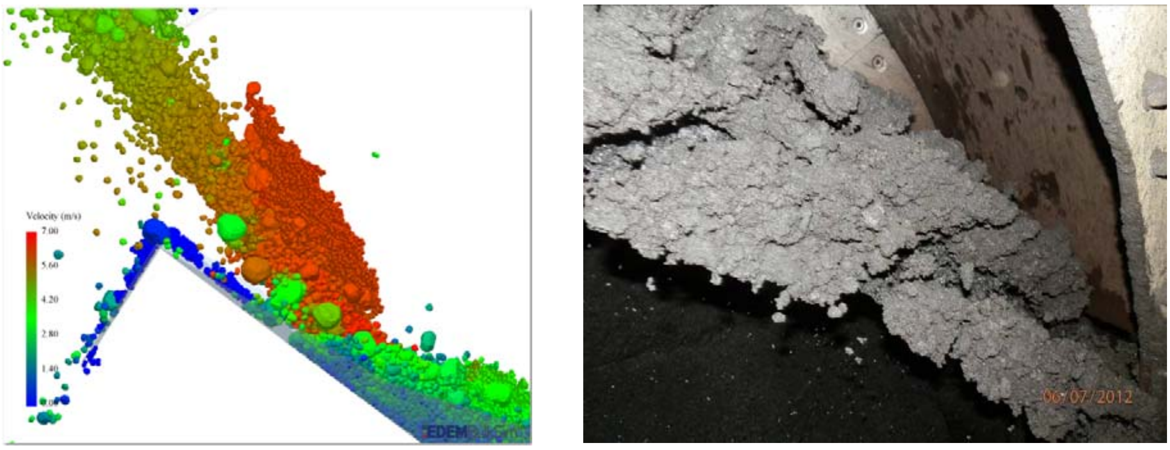

Figure 9. (a) Detail of filtercake clumping within trajectory, (b) Coal production trajectory detail adjacent deflector chute.

Operationally the transfer chute performs well for the deflector contact and discharge into the bin below. Figures 10a and 10b presents detail of the two deflector positions and the respective trajectories. The full “bore” exit discharge from the deflector (Figure 11b) is pleasing and without problem. The forward trajectory has not been as effective due to construction tolerances, and coal buildup on sections of the chute wall away from the main trajectory. This has necessitated hose out the coal buildup and “exercising” of the deflector gate to disrupt the buildup.

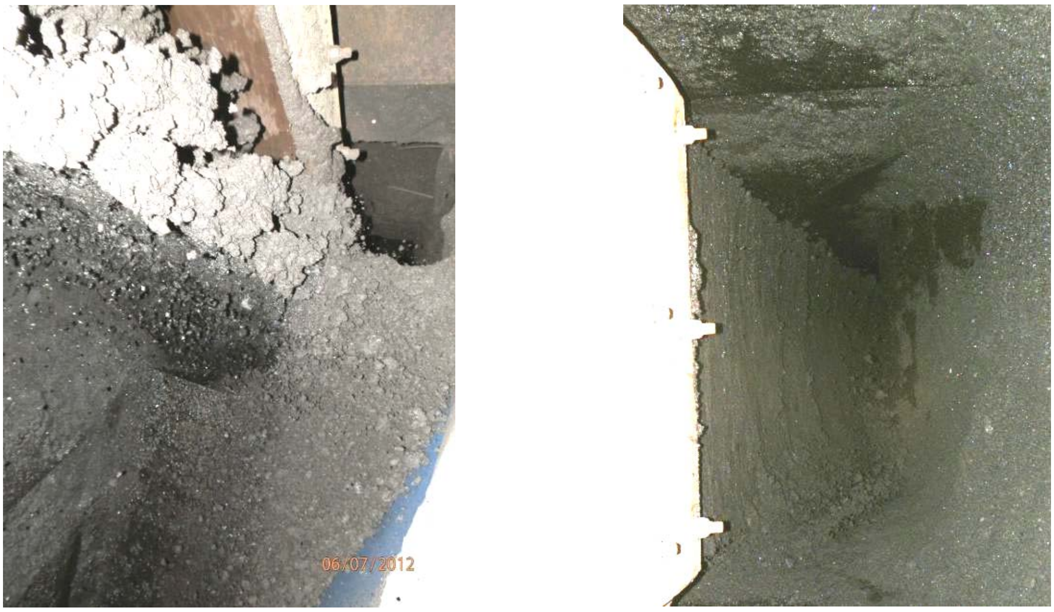

Figure 10. (a) Detail of trajectory, through loading, (b) Detail of trajectory in contact with deflector, and discharge into bin.

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A learning from the DEM modelling and subsequent operation of the redesigned chute relates to the interpretation of the DEM results. As shown in Figures 10a and 11, the inside of the chute head box is coated over time with fine coal adhering to the surface. This buildup can become problematic. Referring to Figure 9a the DEM model indicated this tendency or "risk" with the separated particle "spatter" from the underside of the main trajectory.

Figure 11. Detail of through loading spoon and fine coal buildup directly adjacent the primary trajectory stream.

4 CONCLUSIONS

Two chute design and installation case studies have been presented on quite different but challenging materials due to the parameters of high capacity, material abrasiveness, and highly cohesive material (as in the coal filtercake). The engineering design flow included the key steps of:

- Physical testing of relevant material parameters in order to verify the material model parameters for the DEM desktop simulations.
- DEM simulation of the material flows and design cases, including worst case situations, for example capacity surges, higher moisture content and consequently increased material cohesion levels to test the "robustness" of the design concepts.
- Closing the design process by site investigation of the transfer chute once in production, and comparison with the design DEM modelling .

The challenge for industrial application of DEM Modelling is that of WSO bulk materials, and correct determination of the adhesion / buildup features. Due to the slow rate of adhesive buildup, (and possibly significant computation times required), the need for perhaps a *risk based* assessment would be beneficial, in identifying secondary operational issues of the DEM simulation results.

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