# Discrete Element Modelling – Predictable Transfers at Last

*By: Edmond O'Donovan*
*Principal, E. J. O'DONOVAN & Associates*
*Consulting Engineers*
*Brisbane, Australia*

"Despite being able to put a man on the moon, it remains impossible to transfer material from one conveyor to another!" This quote is from a recent conference where the speaker, a retiring senior construction manager, was talking about intractable engineering issues he had experienced during his career. This article deals with Discrete Element Modeling (DEM), a new analysis tool that has the capability of removing this problem from the "intractable" list. Problems like those shown in Figure 1 are very common.


**Figure 1 Common Chute Problems**

Transfer points have traditionally been a problem area for the materials handling industry. A chute that transferred most of the material, and did not block too often, was acceptable. In times past it was common in the mining industry to have a person permanently stationed at a transfer point to clean up spillage. Issues such as chute wear, belt wear, dust and material degradation were mostly too hard to consider as part of the transfer issue. Design of transfers was at best an evolutionary process of trial and error, with no science beyond tracing trajectories, or was simply not done at all.

In recent years, the cost of cleanup, wear, dust mitigation etc have meant that considerably more emphasis has been placed on transfers than in the past. This has lead to significant improvements. Hood and spoon type soft loading chutes such as shown in Figure 2 have been very successful, particularly in the coal industry where the material is relatively non-abrasive. However in hard rock applications where there are very high impact loads, and rock boxes are the only protection against significant wear, the progress has not been nearly as good.

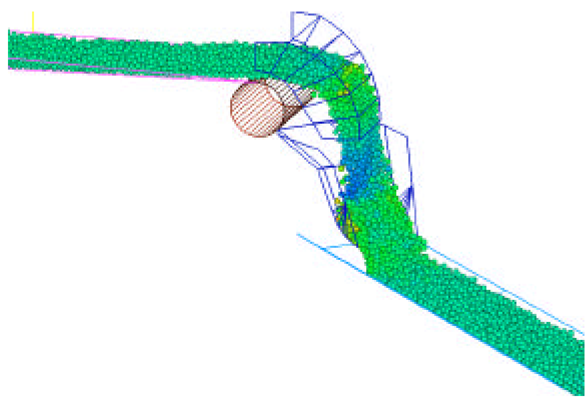


**Figure 2 Example of a Hood and Spoon Chute**

Substantial effort has been put into the design of hood and spoon type chutes. Since in this application the flow is not too complicated, progress has been quite good. However, most of the "design" tools developed for these chutes are in reality automated drafting techniques. They still rely on tracing trajectories and making empirical assumptions on how material will slide, once it has contacted a surface. These techniques are limited to simple flows, and cannot usefully predict anything except the initial impact point in complicated, rock box type transfers.

Though chute designers could be criticised for not applying more scientific techniques, one of the problems chute designers have had is that there was simply no relevant scientific techniques available to model the complex flow in a transfer chute. Some applications of fluid mechanics were trialled, but they were also limited to simple, relatively smooth geometries.

Enter DEM. Discrete Element Modeling is a technique where the mechanics of thousands of interacting, individual elements are computed. Any geometry can be configured and the properties of the Particle-Particle and Particle-Boundary collisions can be adjusted to suit the materials.

In essence, the technique is multiple applications of the standard billiard-ball collision studied in high school physics. The main challenge is the huge book keeping exercise required to keep track of all the collisions. It is also very computationally intensive! The technique has been around in academic circles for a couple of decades, but the computer power required to make any practical use of it has only been available in the last few years. It has been used for a variety of applications including milling and sub-level caving problems. With increased computer power it would be expected that it will be used in other areas in the near future. Figure 3 shows two examples of its application.

The idea of applying DEM to transfer chutes was first tackled by Dr Andrew Hustrulid from the Colorado School of Mines in the Mid 1990s. His initial work showed great promise for the technique with accurate prediction of complicated transfer behaviour. It also showed for the first time that it is possible to quantify the material impact loads on the chute boundaries, and the material acceleration wear on the belt. Access to quantified values of these parameters meant that it was now possible to evaluate changes to chute geometry on a computer, rather than when the chute went into service.

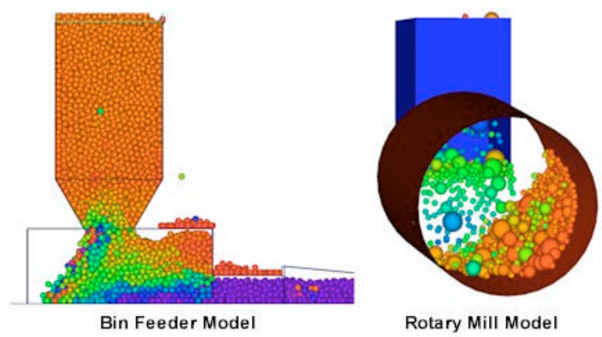



**Figure 3 Examples of the Application of DEM**

A typical Rock Box Type transfer could now be confidently modeled as shown in Figure 4

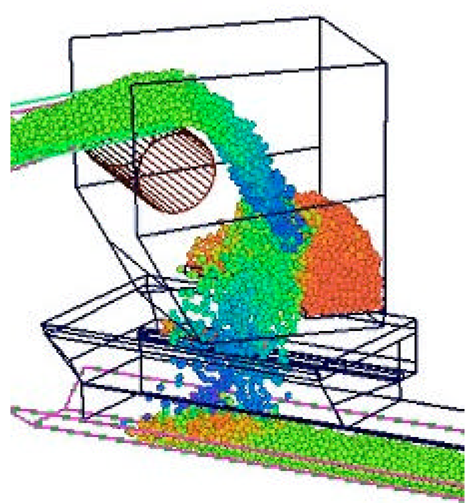


**Figure 4 Model of Rock Box Type Transfer**

Evolution of the Transfer Chute

Application of DEM was slow during the late 1990s. This was partly due to computational limitations and partly due to market resistance. People were understandably reluctant to commit to an expensive analysis technique that, while showing great promise, did not have a significant, proven track record.

This reluctance has slowly been eroded in some markets where the value of DEM in producing a functional transfer chute has been clearly definable. The first step in this direction was from conveyor belt manufacturers who were able to appreciate the value of the technique. While a belt supplier has control, or at least knowledge of most of a conveyor's operating parameters when they supply the belt, they have had no way of assessing the performance of a chute. While it is known that most of the belt wear on a conveyor occurs at the transfer, until DEM came along there had been no way of evaluating chutes to determine which were "good" and which were "bad". For a number of major installations, the belt manufacturers began to offer extended warranty if the transfers were designed using DEM. The extended warranty more than justified the cost of the analysis.

Soon operators with "intractable" problems which were costing a small fortune, were prepared to try anything to get a solution. Arch Coal's West Elk Mine in the USA had a complicated chute that was guaranteed to block every time even a small, over tonnage slug passed through it. DEM analysis of the existing geometry accurately simulated the problem. A number of minor changes to the chute geometry, resulting from further DEM analysis on modified geometry, eliminated the problem altogether. The operation can now run continuously at higher tonnage if necessary. Before and after examples are shown in Figure 5.

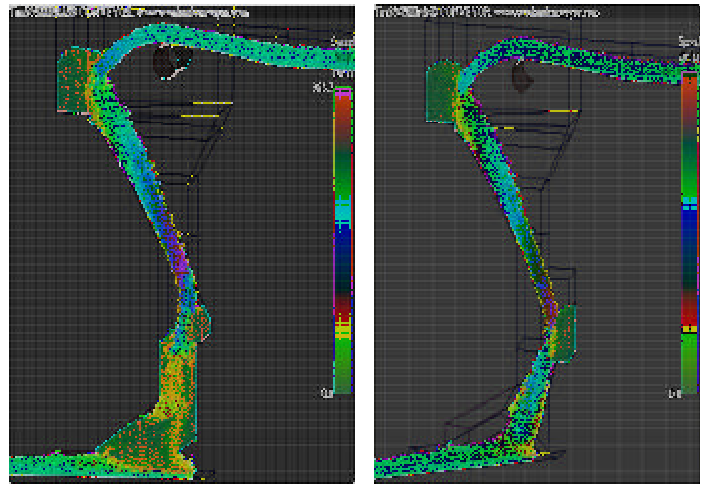
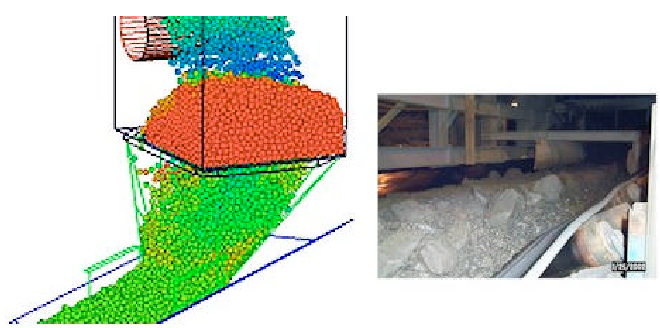


**Figure 5 Complex Transfer Solution**

Another operation was changing a short, plant belt every couple of months. The cost of the belt, while significant, was small compared to the downtime required to change it. The effort to solve the problem had for some time concentrated solely on getting a better belt. While stronger, thicker more expensive belt gave some small improvements, the life was still poor. A completely different chute designed using DEM has now been installed, and in 18 months the belt has not been changed. The life prediction for the belt is now around five years. The actual transfer and its model are shown in Figure 6.



DEM of Final Design        New Chute In-Action

**Figure 6 Transfer and Model**

Apart from standard transfers, special areas where DEM has been successfully applied include bifurcated or flop gate transfers, dust minimisation, transfers that must work at multiple speeds and/or transfer angles. If the same chute can be used in multiple applications at the same operation, it saves on spares and simplifies maintenance. The chute shown if Figure 2 is designed to work at two speeds and two transfer angles.

With greater confidence in the technique, usage of DEM for transfer design has steadily increased. There have now been over 150 transfers designed using DEM, and more than 80 of them are in service.

There are of course some transfer issues that DEM cannot solve. Attempting to pass product with the consistency of wet cement through a transfer designed for lumps still not work. Attempting to pass metre long surf boards through a transfer designed for 200mm lumps is also likely to cause problems. Interestingly, DEM has shown that for some transfers, the speed, width, height parameters are such that it is impossible to get material from one belt to the next. Fortunately this is uncommon. However, as long as the basic geometry is workable and the material is not too far from specification, then the word intractable should be able to removed from all discussions about transfer issues. Since as one operator said after the installation of his first DEM designed transfer, “Actual performance is so close to the modeling it’s almost scary!”