The Use of Parametric Modelling to Design Transfer Chutes and Other Key Components

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Introduction

Many companies and individuals working on conveyor system maintenance, have long recognised that one of the major sources of maintenance and risk is through mis-adventure in conveyor maintenance is poorly designed transfer chutes. In 1988, Gulf teamed up with Tasman Engineers to work on developing the transfer technologies being utilised at the Clinton Coal Loader at Gladstone Australia as a means of substantially addressing these transfer design issues. The transfer technology is based on fluid mechanics wherein by accurately predicating the material flow from a head pulley, the material can be turned, at a low angle of incidence, in the vertical direction. This vertical flow is then be picked up, also at a low angle of incidence and directed smoothly, with zero to low impact onto the receiving conveyor.

While the variations to the theme are endless, most transfers resulted in a collecting section at the top, which is termed a 'hood' (figure 1), and a receiving section at the bottom termed a 'spoon' (figure 2) The optimising of the design and positioning of the hood and spoon type of transfer has been subjected to a great deal of research and development. Also through the simplicity of the concept, many similar designs have been developed by others with the result this type of transfer would be arguably the most popular type of transfer design in the Australian bulk materials handling industry today.

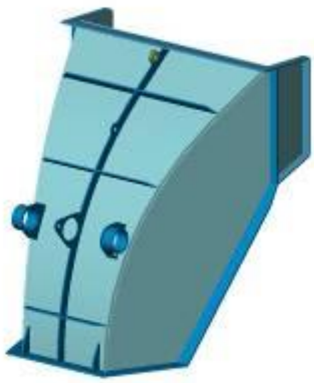


Figure 1 ~ Hood

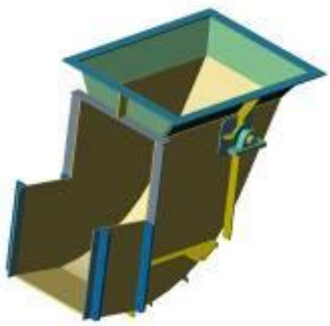
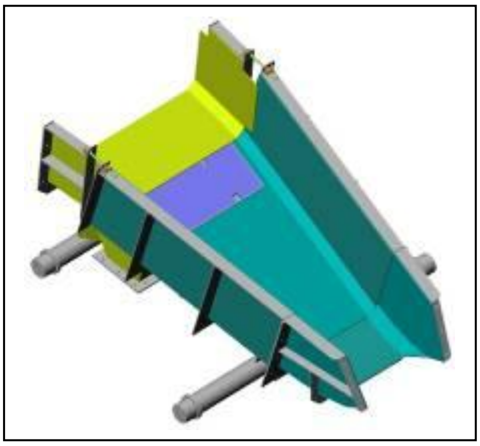


Figure 2 ~ Spoon

The technology has been further advanced to create in line transfers where the hood section of the transfer is eliminated and a dewatering type transfer utilised. The design also features soft loading on to the receiving belt.
Dewatering is achieved through a design that is based on accurate calculations of the differential trajectories of water-laden slurries and normal coarse ore where water is continuously removed from the material stream. There have been many papers Gulf and others have presented on this technology some of which is referenced at the end of this paper.



Figures ~ 3 Dewatering chute

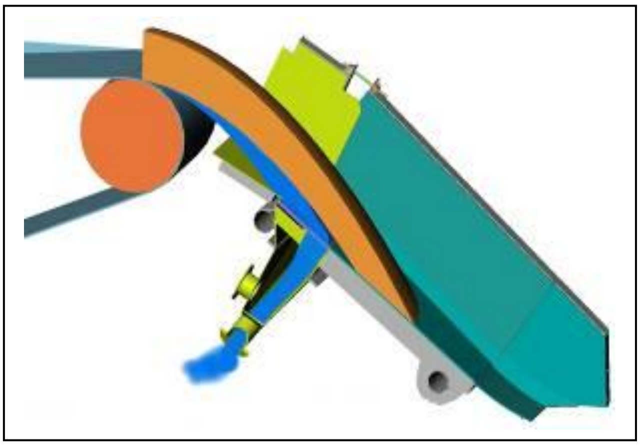


Figure 4 ~ Dewatering using differential trajectories

This paper focuses not only on the transfer chute design principles necessary to competently design a transfer chute, it also discusses the research and development undertaken to speed up the design process to enable the output design to be translate into the finished product efficiently and effectively. These principles can also be used quite broadly in engineering design with some examples presented toward the end of this paper

Design inputs

To produce an effective design, it is essential that accurate input data be obtained regarding the particular application. It is imperative at this time that the reader is cautioned that no two applications are identical and it is a very dangerous assumption that a transfer design can be simply copied to a different location.

There are up to 46 different input requirements with 19 of theses being absolutely critical to the success of the design (see figure 5) it only takes one of these change to render significant design changes to be made. It needs to be understood that the input requirements mentioned results in over 220 design permutations within the design process with each permutation influencing the final design output.

Principally however, designing transfer chutes is based on the flow characteristics of the material and this requires:

- Accurate mathematical models to project the material flow
- The design criteria for the key elements, the 'hood' and 'spoon', that accommodate the variations in material properties, flow volumes and material size
- The design criteria to accommodate variations in belt to belt height (or material drop)

Feed Conveyor	
Belt speed	m/s
Belt width	mm
Belt width	mm
Jib/Head pulley dia	mm
Pulley width	mm
Angle to horizontal at the head pulley	degrees
Troughing angle	degrees

Site Height Data	
Feed conveyor top of belt to roof	mm
Drop height	mm
Receiving conveyor top of belt to floor	mm

Receiving Conveyor	
Belt speed	mm
Belt width	mm
Belt thickness	mm
Angle of intersection	degrees
Angle to horizontal	degrees
Troughing angle	degrees

Material properties	
Max. oversize lump (on top)	mm
Max. oversize lump (on top)	degrees

Note; Other information is desired but the above provides the minimum necessary to complete preliminary design

Figure 5 ~ Design input data requirements

In combination with the transfer chute itself, the design must then incorporate structural elements that support the transfer chute, head pulley, fines tray and scrapers. Further design may also be required to accommodate the various thrust and compression forces created by the conveyor system dynamics.

As mentioned previously, for a standard belt to belt transfer station there are about 220 design parameters and integrating the above process even with the aid of the latest CAD programs is time consuming and prone to inaccuracies as designers needs to interact with the customer, drawing office and ultimately project engineers/construction engineers who build and install the transfer chute.

The difficulty encountered utilising the conventional (2-D CAD) methodology proved to be a very time consuming and often frustrating exercise for all involved. This was principally due to the design/communication limitations as depicted in figure 6

Process	Comment
Initial contact with the customer	Usually through marketing efforts or reputation in the market place
Project brief and obtain design input data	Sometimes a difficult task as projects can be ill defined or in early concept
Develop a design concept to secure the contract	This can be a time consuming and costly exercise, sometimes without the promise of an order
Develop preliminary design concept	This can involve much engineering time & effort with constant interaction with the customer
Translate preliminary design concept to 2-D drawing	Involves communicating the design requirements to the drafting personnel with constant interaction as the drawings progress
Present design to customer for draft concept approval	Present the drawings to the customer with sufficient detail and development to achieve customers commitment to the design
Amend concept drawings as seek customer acceptance	Involves more interaction with the drafting personnel and the customer possibly resulting in many time consuming changes
Commence detailed design	Determine all of the required design parameters in order to arrive at the correct design. This process involves much research and design data verification.
Validate the design, physical modeling if possible	Validate the design using necessary tools to ensure that the final design will perform to specification. When using 2-D drafting methods, this may even involve costly model making
Commence detailed drafting , fabrication, installation & GA drawings	Many drafting hours are applied to bring the project to a detailed design stage, This also involves continued interaction with the design engineer and the customer.
Check drawings	This usually involves passing the drawings to an independent person with the appropriate checking skills. The checker needs to be through briefed to confidently complete this task
Release for fabrication	It is prudent to thoroughly brief the fabricator with the job and it can some times be difficult to communicate the end product requirements particularly if they have not previously done the type of work.

Figure 6 ~ Flow-chart showing the typical 2-D design process, initial concept through to finished product

In order to remain competitive in an ever demanding the market place, it was necessary to critically review the efficiencies of the entire transfer design process. This resulted in the eventual adoption of a Parametric 3-D Design package which was to form the base platform onto which a custom designed transfer chute design package was researched and developed.

To achieve improved design efficiency and productivity, it was necessary to turn to parametric design technology as distinct from parametric drafting because it promised to deliver exactly what was required to keep pace with the demands of the market place. The logic of parametric design has been around for quite some time but has, to our knowledge had been applied in creating one off designs. The technical philosophy underpinning this approach is one that creates mathematical models linking the design process to how structural elements must be re-configured to accommodate changes in the base model.

When one considers the 220 different design permutations of the transfer chute, creating such an interactive model had some monumental difficulties. This was partially overcome by integrating the:

- The Customers expressed and implied needs.
- The Design process.
- The modelling of key elements.
- And a commercial 3D CAD program.

Combined with a database of previously successful designs it was possible to establish a base modelling process from which assessments could be made of the design process capabilities thus validating the new design process. Refer figure 7

Process	**Comment**
Initial contact with the customer	Usually through marketing efforts or reputation in the market place
Project brief and obtain design input data	Sometimes a difficult task as projects can be ill defined or in early concept
Develop a design concept to secure the contract	This is modeled directly in the parametric 3-D environment with some added benefit being the rendered 3-D images as seen in this document. This step also involves modeling the preliminary design concept as part of the process
Present design to customer for draft concept approval	Present the rendered outputs to the customer which in most circumstances provides sufficient detail and development to achieve customers commitment to the design
Amend concept drawings as seek customer acceptance	This is usually a simple task as the base information is built into the basic model - Making changes is where the 3-D parametric modeling process excels over 2-D drafting
Commence detailed design & validate the design	The model already contains most of the base information and due to the intelligence of the modeling tool, it is a simple task to finish the detailed design and to validate the design with the built-in simulation tools & "what if" scenarios
Produce detailed drafting , fabrication, installation & GA drawings	One of the benefits of the parametric design environment is that the detailed drafting is taken directly from the model itself. This means that the design engineer is directly involved in the production of the drawings, eliminating the need to translate via a time consuming manual 2-D drafting process
Check drawings	The parametric 3-D environment, it is possible for the checker to operate within the regime that created the design and the drawings. This provides the checker with the means to not only check the output result but also to trace their origins for a better result
Release for fabrication	It has been proven many times over that a better result is achived if the people involved can visualise the ouput prior to starting. The rendered images produced by the parametric modeling process allows this to happen.

Figure 7 ~ The improved and more efficient process using parametric 3-D modelling

Through the adoption of this new design methodology, it is now possible to accommodate new design elements and to test the product as simulated modes within the software program without the added expense of physical modelling or the more risky approach of trialing following installation of the finished product.

Some of the major benefits of this approach are:

(1) Seeing is believing: The output of the design process produces a faithful rendered view of the final design, offering much more than a 2-D drawing.

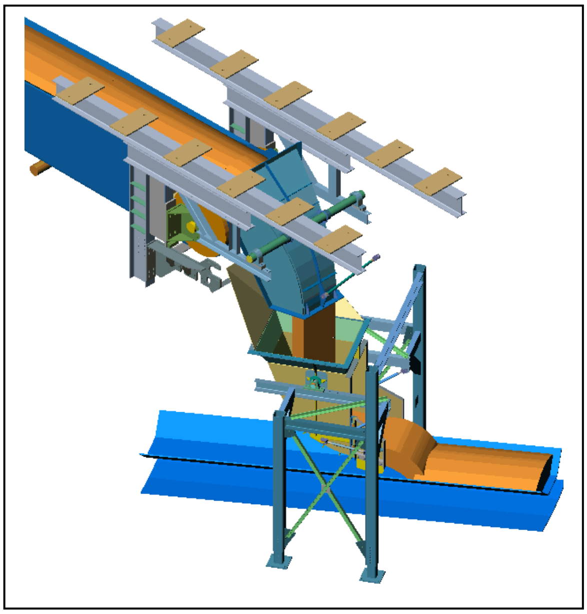


Figure 8 ~ Transfer Station for an Underground Application

(2) Creates Certainty: You can integrate the model by doing cut aways and rotating it.

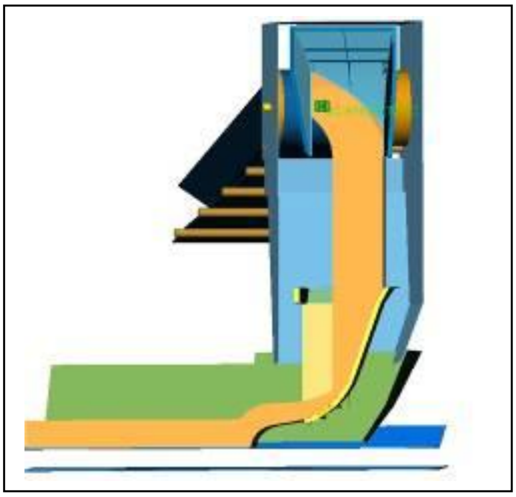


Figure 9 ~ Confirmation of material flow characteristics through cross sectional views of material flow

(3) What If? Can create dynamic models that examine "what if" scenarios.

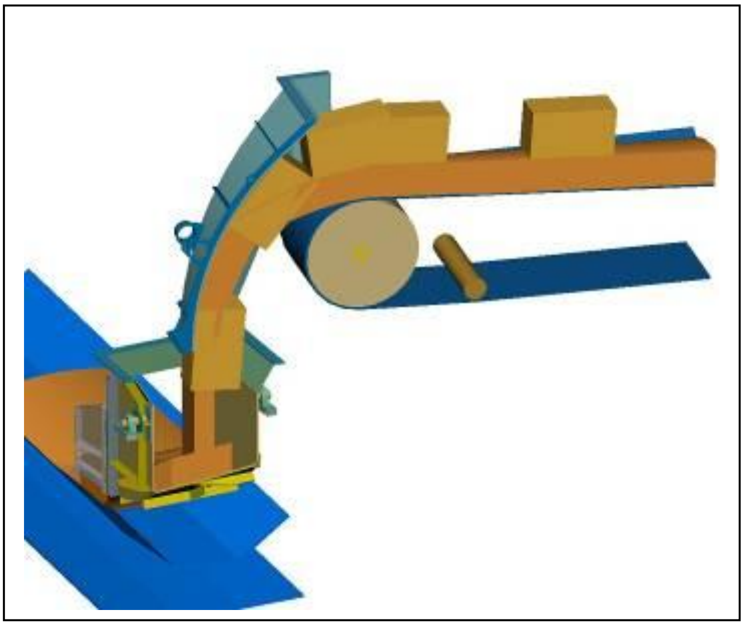


Figure 10 ~ "What if" Analysis of Large Lumps Through the Transfer Chute

(4) Changes are quick: You can change the model to accommodate changes in design including flow rates in minutes.

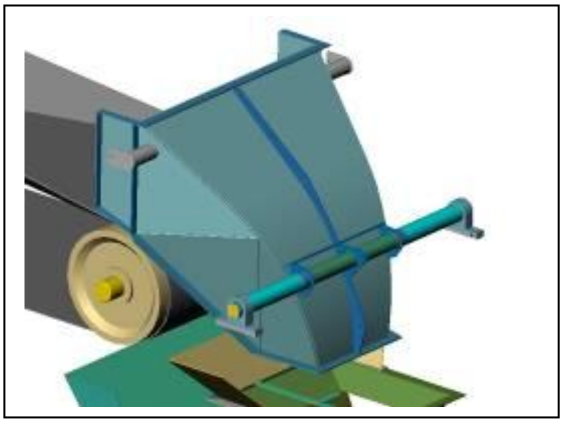


Figure 11 ~ Normal duty hood with side plates

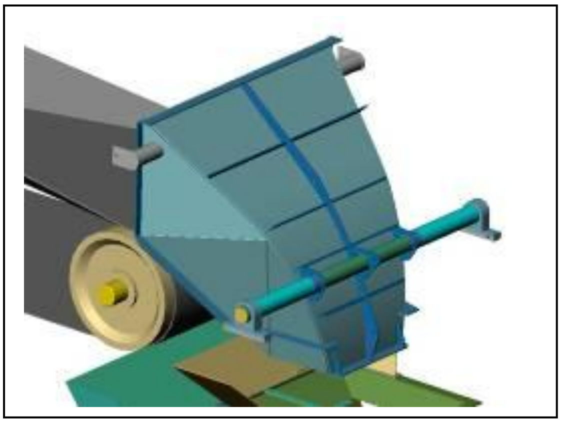


Figure 12 ~ Heavy duty hood without side plates and additional stiffeners

Due the parametric design capabilities, these and other changes are simple to implement with the added advantage that the changes made flow automatically through the design process including the automatic updating of the respective drawings.

(5) Less errors: The model generates the design and installation drawings – no drafting interface

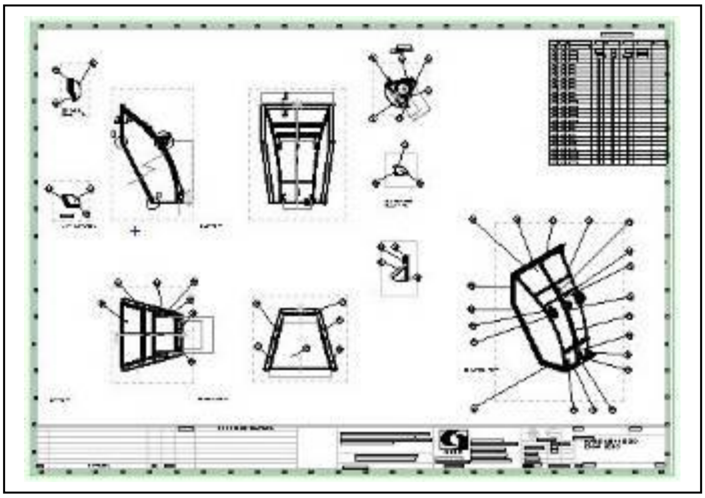


Figure 13 ~ Typical Drawing from the Parametric Design Process

(6) Quick

The basic model providing it is not a new transfer concept can be developed in a day

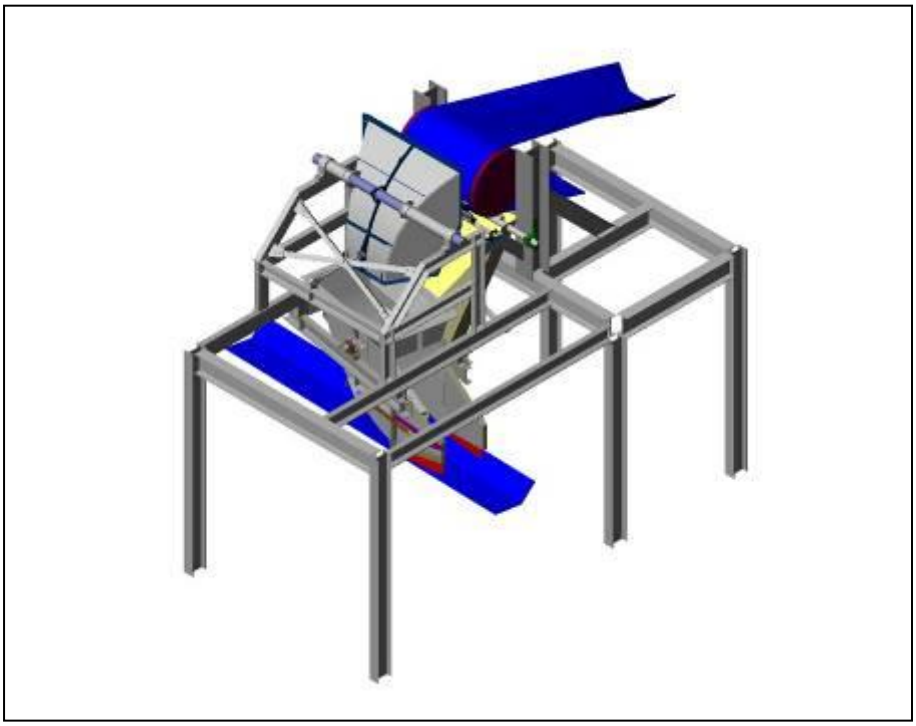


Figure 14 ~ Typical Above Ground Transfer Station

The constraints. With transfer chutes, given that most clients want a complete transfer plus structural assembly drawings, will require some detailing of the structural components by conventional drafting. In time this may be able to be taken off the database but as at the moment such detailing can take a few days. The process however is still extremely quick and by its nature prone to a lot less errors. (Doing this work rigorously by conventional means can take up to six (6) weeks).

Having taken the time to develop this parametric design methodology it is now used to do many other engineering designs. For instance it is used to:

- Develop installation and sizing drawings for proprietary scrapers

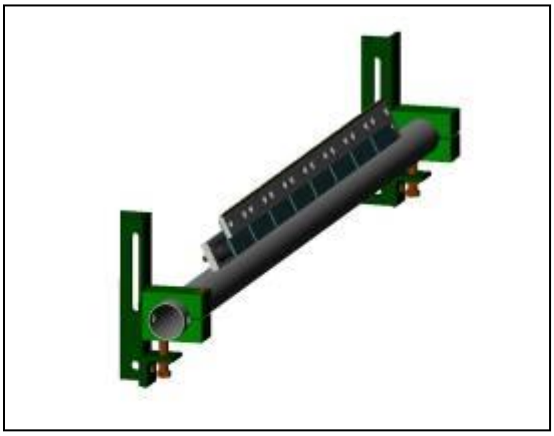


Figure 15 ~ Belle Banne P Type Scraper

What this effectively translates into for those effectively adopting the new design methodology is a means to remain competitive in the market place compared with an organisation that does not use parametric modelling techniques.

- To design simple stockpile structure and to examine implications & design features

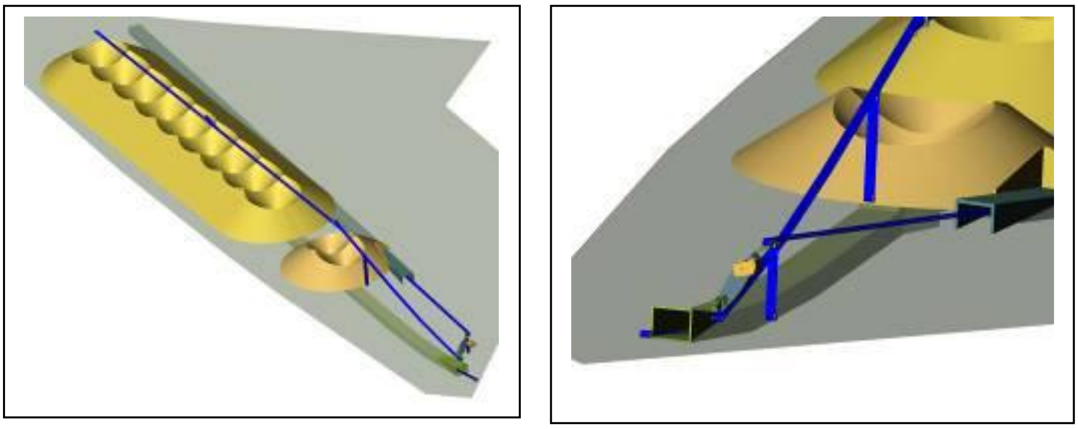


Figure 16 a & b ~ Examples of stockpile configuration design and analysis

To design new applications for existing technology (patented dustless transfers utilising Passive Dust Enclosure Conveyor System – "PECS" technology)

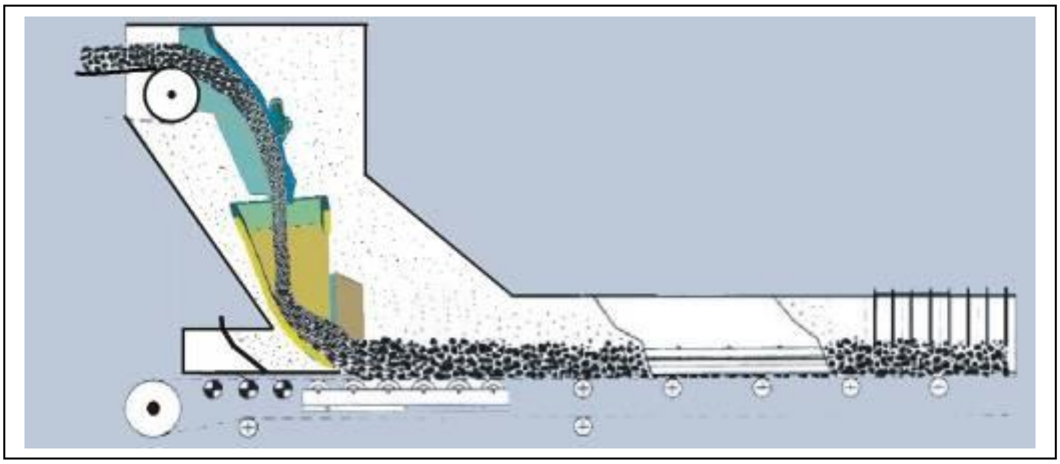


Figure 17 ~ Patented passive dust control technology incorporating the hood & spoon transfer design

New opportunities such as our working with the Newcastle University (NSW Australia) in developing a comprehensive design model for bins and silos.

Eventually the methodology and process will be extended to most of our engineering designs because the benefits are many i.e. less errors, once the model is developed as it is much quicker and empowers engineers to be more creative by allowing them to test options more quickly.

Finally it creates a very accurate and intimate communication between the designer and the project engineer as the model can develop its own installation drawings and any fabrication drawings are comprehensive.

This technology is an exciting way to use computers creatively to both save time and improve engineering processes and engineering outcomes. Eventually it is believed that it will replace the conventional GA approach to engineering concept designs.

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