THE PERILS & PITFALLS OF INTELLIGENT CONVEYING

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SYNOPSIS

Variable Speed Conveyors are commonly used in conveying applications with the major benefit being that of ramping the conveyor in an acceptable linear controlled manner to offer a non aggressive start minimising tension spikes by means of maintaining a low Drive Start Factor.

It however also offers the secondary benefit of running the conveyor at a speed suitable to optimising the belt loading. These savings in running the conveyor at a lower speed are difficult to quantify, but we do know that there will be a saving with respect to all system components. This process is generally known as “Intelligent Conveying”

There are many grey areas applicable to “Intelligent Conveying”, as we do not always administer sufficient or any intelligence into the system. The lack thereof causes secondary problems. These problem areas need to be highlighted such that designers and users are aware and understand the ramifications thereof.

The other associated issue that needs to be addressed is the material transfer as a result of a varying trajectory. This is a major problem associated with Variable Speed Conveyors.

The paper highlights the associated benefits and problems applicable to the application of intelligence, or lack thereof, and creates an awareness of the misapplication of Intelligence in Belt Conveyors.

BACKGROUND

Intelligent conveying was first discussed and presented within the conveying industry in South Africa in a hypothetical paper presented by Phillip Venter at Beltcon 8 in 1995, now 10 years on.

The content of this paper highlighted the benefits that can be realised through the implementation of applying intelligence to a conveyor system.

The emphasis was particularly with reference to underground mining within the coal industry where Run of Mine, ROM, product was being mined.

This was followed up with a paper by Louis Botha in August 2001 at Beltcon 10 with the topic, “Intelligent Conveyor Drives – For Underground Conveyors” This paper was particular to the drive technology used when applying Intelligence through Variable Speed or Variable Frequency Drives as used at Secunda Collieries.

INTRODUCTION

Fundamentally, “Intelligent Conveying” can be defined as altering the speed of the belt to suit the loaded profile as applied to the conveyor at the point of loading. It is therefore only of benefit to apply intelligence to conveyors in ROM applications where the belt loading is erratic and non continuous. There would thus be no or little benefit to applying intelligence through varying the belt speed to a conveyor which is loaded by means of a feeder from a silo or bunker.

ROM coal is generally difficult to convey due to the non continuous flow of material as a result of the mining methods being practised. Coal, being the biggest conveyed commodity by volume, is mined by means of various methods each producing a different requirement and belt loading to the conveyor. This is further complicated by one section’s ROM coal being added to that of another section's ROM coal on the same belt. In addition we are faced with varying lump sizes of different basic shapes and densities caused through the mining of stone bands within the coal seam.

From previous designs and applying the principles of Intelligent Conveying, a lot has been learnt to the benefit and detriment of the Bulk Materials Handling Industry.

FACTORS AFFECTING CONVEYOR CAPACITY

Of all the reasons applicable to the speed of the conveyor, the most important factor is:

Belt Tension is Indirectly Proportional to the Belt Speed.

In the case of Run of Mine product, generally known as ROM, the following is applicable:

- For a constant speed conveyor as the loading is varied, the tension will vary accordingly as the load is increased or reduced. - ***The operational tension in the belt is thus lower than that of "Intelligent" conveyors***.

- For an intelligent conveyor the belt loading is constant with the speed being varied to suit the load. This option allows the induced tension to remain constant. - ***The operational cycle per tonne conveyed is lower thus resulting in decreased wear.***

As "Intelligent" conveying involves maximising the capacity of a conveyor, we need to firstly know what factors affect capacity.

There are four major factors that have an effect on the capacity of a conveyor system for a material with known characteristics as follows:

- Belt Width
- Belt Speed
- Belt Profile – (Troughing Angle and Shape of Loaded Area).
- Slope Factor – Maximum Angle of Inclination

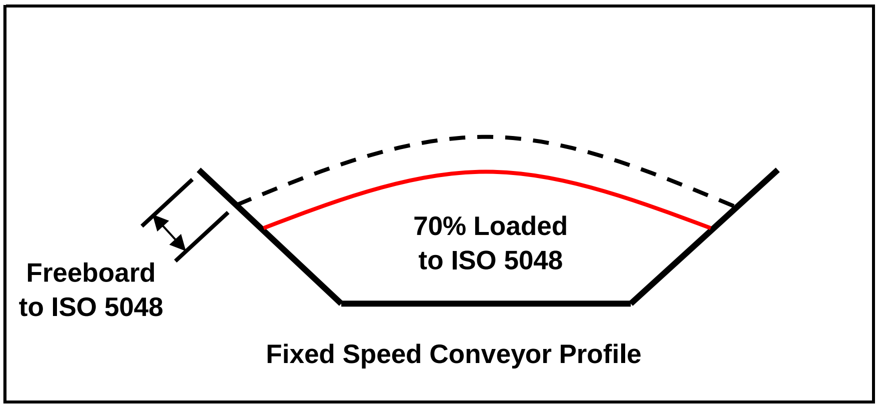
The capacity can be calculated to various international standards, or from first principles.

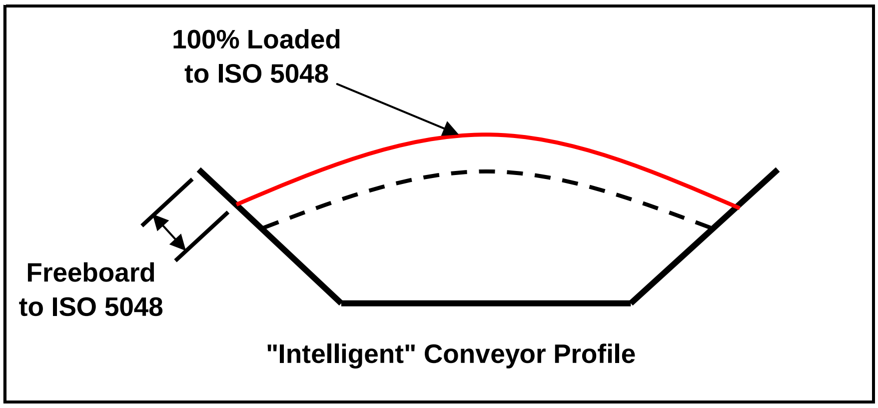
PHILOSOPHY OF "INTELLIGENT CONVEYING"

The philosophy pertaining to "Intelligent Conveying" is fundamentally to maximise the utilisation through maximising the loading on the belt in order to run the conveyor as slowly as possible without spillage. It is also deemed to be beneficial to reduce the cycle time of the conveyor and thereby reduce the resultant wear on the mechanical components and the belting.

This philosophy requires "Intelligence" to be programmed into the conveyor such that an increase in loading can be anticipated or measured in advance and communicated to the drive such that the belt speed can be accelerated whilst applying an acceptable differential DSF, (Drive Start Factor). The converse applies when the loading is decreased to slow the belt down in order to re-gain the benefits of "Intelligent Conveying"

This measurement is conducted by placing field devices at strategic points on the conveyors and returning the belt profile to a PLC in order to compute and hence control the loading through varying the speed of the belt.





CONSIDERATIONS

Conceptually fixed speed conveyors are designed for a given transfer rate in TPH with a known topography against a suitable calculated belt speed and for a given class and type of belt. This design will have an influence on the following areas of the conveyor:

Idlers & Stringers: When designing a conveyor we generally design for a throughput rate of material being conveyed and measured in TPH. With a fixed speed conveyor the material characteristics will yield a belt loading expressed as a percentage of the allowable loading in accordance with a particular standard. This loading can be stated as a mass per metre value, which will induce a given deflection in the stringers and idlers and will subject the idler bearings to a given loading.

On the other hand, when the conveyor is designed to operate with “Intelligence”, the structure needs to be designed to accommodate the maximum loading as the objective is to maximise the belt loading in order to minimise the number of cycles. The conveyor will thus see the maximum loading being applied during operation.

This issue needs to be considered in a serious light when upgrading a conveyor from that of being “fixed speed” to being “Intelligent”. Conveyors that have a light loading percentage, such as incline conveyors that are handling ROM material need to be considered very carefully for possible overloading of the structure.

From the experiences of current users of “Intelligent Conveying”, the life of idlers is increased drastically provided the design was applied to the worst case loading scenario. The life of the idler shell is however also considerably better.

Deflection & Bearing Life Calculation Summary

Sample Conveyor Specs	U o M	"Normal"	"Intelligent"
Belt Width	mm	1650	1650
Capacity	TPH	3000	3000
Belt Speed	m/sec.	3.8	2.65
Loading on Centre Idler	kg	220	316
Material Mass / Idler Set	kg/lin. Mtr.	328.5	471
T1 Tension	kN	215	283
Rotational Speed	rev/min.	477	333
Idler Spacing	m	1.5	1.5
Deflection	Minutes of 1°	**5.97**	**8.22**
L10/B10 bearing Life	Hrs.	**287,037**	**157,654**

For "Intelligent" Conveying	
% Increase in Deflection	**38**
% Decrease in Bearing Life	**45**

Structural Steelwork: For the reasons given above particular attention needs to be given to trestles, gantries and towers. These need to be designed to withstand the maximum loading applicable and not the rated system tonnage per hour.

It is normal for pit head conveyors to discharge onto a stockpile or onto another conveyor through a transfer point. Gantries are also equipped with walkways on both sides, doghouse sheeting, under guards etc. Should the speed of the conveyor ever be too slow to accommodate the load, then the conveyor will be overloaded considerably to the extent that spillage will occur.

This spillage accumulates on the walkways and on the under guards which in turn will place extreme loading on the gantries and trestles. The delivery tower steelwork is also subjected to the excessive loading which was not considered in the design phase. This could induce permanent deformation in the steel structure and could possibly collapse the supporting structure.

Under normal circumstances this damage will not occur. The cause can normally be attributed to the incorrect application, direct programming or incorrect communication from field devices. Defective blocked chute detection at the head end will add to the possibility of a failure.

Safety: Often underground conveyors that are roof suspended at a reasonable height and particularly incline shaft conveyors on a gantry require an acceptably low belt loading. This needs to be maintained in order to eliminate spillage such as to provide for an acceptable level of safety. For these purposes the percentage loading can be as low as 8% and up to 60%. Overloading of gantries to the extent that spillage is experienced is potentially dangerous.

Excessive Spillage will cause high loads on the Gantry and Trestles – Note the Relative increase in system width as a result of the wide walkways.

Gearboxes:

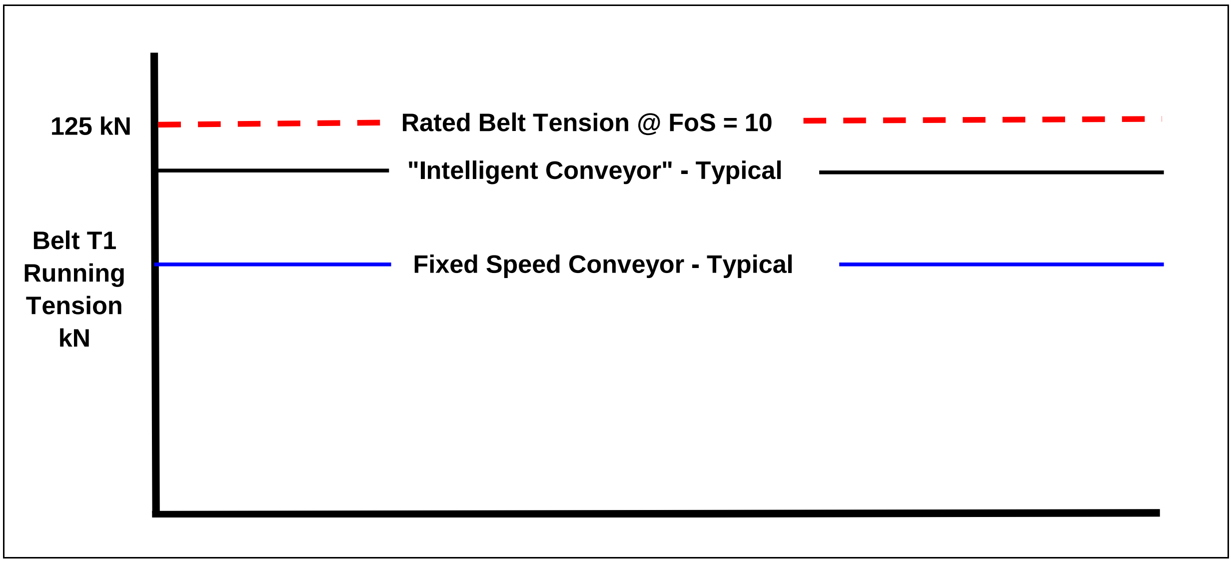
- **Thermal:** Due to the nature of conveyors the duty rating extends over long periods and therefore some form of cooling is required for the gearbox. This is normally done with a bi directional fan fitted to the input shaft which channels the air flow over the gearbox from the input shaft end by means of a cowling or ducting. Bi-directional fans are only efficient at their rated speed. If the conveyor is run slower than this rated speed, then a reduced air flow is present and insufficient cooling is provided.

- **Lubrication:** Gearboxes are often lubricated by means of internal "Splash Lubrication" to raise the gear oil to the upper parts of the gearbox such that the oil can then gravitate within the gearbox for lubricating the bearings and gears. If the rotational speed is not sufficiently high, then insufficient lubrication could be problematic.

Motor Cooling: Similarly motors are air cooled against an optimal cooling design usually at a given speed rating. If, however the speed of the conveyor is varied by means of varying the motor speed, then usually additional cooling is required by means of an external forced cooling fan which is fitted to the non drive end of the motor replacing the normal bi directional axial flow fan.

Belting: "Intelligent" conveying will have the following effect on the belting:

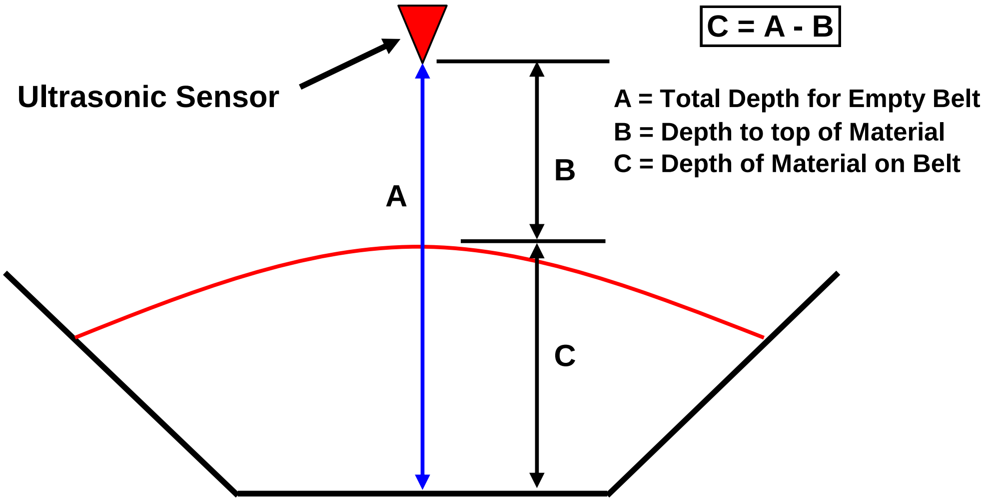
- Due to the reduction in cycle time, the average operating tension in the belting will be higher, but not to the detriment of the belting provided the initial belt class was selected correctly.
- Again, provided the belt class is correctly selected, there will be no detrimental effect on the belting and the belt life expressed in wear vs. tonnes conveyed will be better.
- The belting must be selected using the absolute maximum induced tension within the system. If selected on tonnage and speed, the induced tensions may exceed the requirements of the belt class as selected. On incline conveyors the operating tensions would result in the selection of a higher belt class as a direct result of the increase in the slope tension.



Pulleys: The conveyor pulleys will need to accommodate the higher induced tensions as a result of the lower belt speed and the increased belt loading. The fatigue life of the pulley would be affected as a result of the magnitude of tension being higher, but will see a lower cycle frequency.

Field Devices: In order to apply "Intelligence", data needs to be obtained and processed through the PLC before being applied to the conveyor. The method of collecting the data pertaining to the belt loading is generally done by means of detecting the average height of the ROM material on the belt. This height, together with the belt speed is then computed within the PLC to indicate the belt loading. This rate is then processed by the PLC to increase or decrease the belt speed.

In the event of a failure being detected in a field device by the PLC, it is advisable to have the system programmed to increase the belt speed to a maximum in order to prevent any chance of gross overloading.



Field Device
to Determine Belt Loading

Programming & Software Changes: "Intelligent Conveying" is normally employed on ROM conveyors as stated earlier and not on conveyors which are loaded by means of a feeder at a fixed rate.

Due to the changes in mining operations in the sections and the "Intelligent Conveyor" normally not being in isolation, but being a part of a string of conveyors, the continual programming maintenance and re-programming of the system is on going.

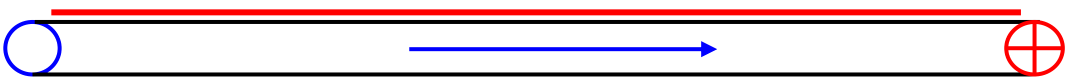
Whilst the conveyors within the string are loaded from various mining sections as a result of the mining operations, the programming logic requirements are continually changing. This necessitates the need to continually alter the programming to suit the changing operational aspects.

Under normal logic, if a field device becomes faulty, the fault is flagged up and if necessary the system is shut down for rectification. With "Intelligent Conveying", if a belt loading detection device fails, the belt and the string ahead of the faulty belt is taken up to full speed in order to prevent excessive overloading, spillage, and allowing the next start to be done on an empty belt.

Staffing Levels: Due to the continual changes required to the programming of the conveyors, the skills levels, understanding and expertise of the programming personnel needs to be understood and addressed. The general level of expertise of the PLC maintenance staff needs to be at an acceptable level.

Bunkering: Insufficient bunkering is not an uncommon problem in an underground mining operation. With "Intelligent Conveying", a relatively large quantity of coal can be stored on the belt once the existing bunker has reached capacity, thus allowing the mining operation to continue for a longer period thus increasing the effective production time.
The effect of bunkering can be seen in the following slides:

Bunkering Capacity = 548 Tonnes - (219 kg/m)



Conveyor Specifications:

Belt Width	**=**	**1650mm**	**ISO 5048 Loading = 70%**
Belt Speed	**=**	**3.8 m/s**	
Troughing Angle	**=**	**45°**	
Belt Length	**=**	**2500 meters**	
Bulk Density	**=**	**900 kg/m^3**	
Belt Loading	**=**	**70 % to ISO 5048**	

Bunkering Capacity = 786 Tonnes - (314 kg/m) - Increase of 43%

Conveyor Specifications:

Belt Width	**=**	**1650mm**	**ISO 5048 Loading = 100%**
Belt Speed	**=**	**2.65 m/s**	
Troughing Angle	**=**	**45°**	
Belt Length	**=**	**2500 meters**	
Bulk Density	**=**	**900 kg/m^3**	
Belt Loading	**=**	**100 % to ISO 5048**	

Power Requirements: The power consumed in "Intelligent Conveying" when using VSD's will provide a saving in energy consumed and with a string of conveyors within the backbye system could constitute a considerable saving.
The negative side is however that when the conveyor is fully loaded and has been shut down for a period of time, the torque required to ramp the belt to full speed is higher and the installed power and drive technology needs to be adequate to accommodate the ramping to the pre-determined speed.

Belt Speed: Belt speeds, when applying "Intelligent Conveying", will generally operate better through the range at lower speeds with wider belts than at higher speeds with narrower belts.

Experience has shown that the minimum speed for the conveyor will be around 40% of the rated belt speed. Experience has also been gained where a fixed number of speed steps are used rather than to apply an infinitely variable speed. Practically a number of chosen set speeds are used in the programming logic. (Rated Belt Speed is the speed of the conveyor at 50Hz)

MATERIAL TRANSFERS

Introduction: Chutes are used to direct the flow of bulk solids from a given discharge point to a desired receiving point within certain design parameters. Impact angles; impact pressures; material velocities and critical chute angles are just some of the constraints that exist when designing a chute.

Of recent times one the most important design criteria parameters has changed from being a fixed entity to one that varies. This is the initial velocity that the bulk material has when leaving the conveyor discharge point. The use of variable speed conveyor belts has had a negative impact on the complexity of chute design.

The degree of difficulty in chute design is directly proportional to the complexity of the transfer path that must be designed for; the order of difficulty in which various chutes find themselves remains the same however the complexity of design is increased.

The single most difficult factor to contend with when designing a chute for a variable speed belt is to match the bulk material speed with the receiving conveyor belt speed. Usually by doing so, the spillage, noise, material degradation and top cover wear is significantly reduced.

Material trajectory from a conveyor into a silo or bunker:

The material trajectory paths can easily be plotted from off the head pulley and into the bunker, remembering that the preferred point of impact is in the exact centre of the bunker.

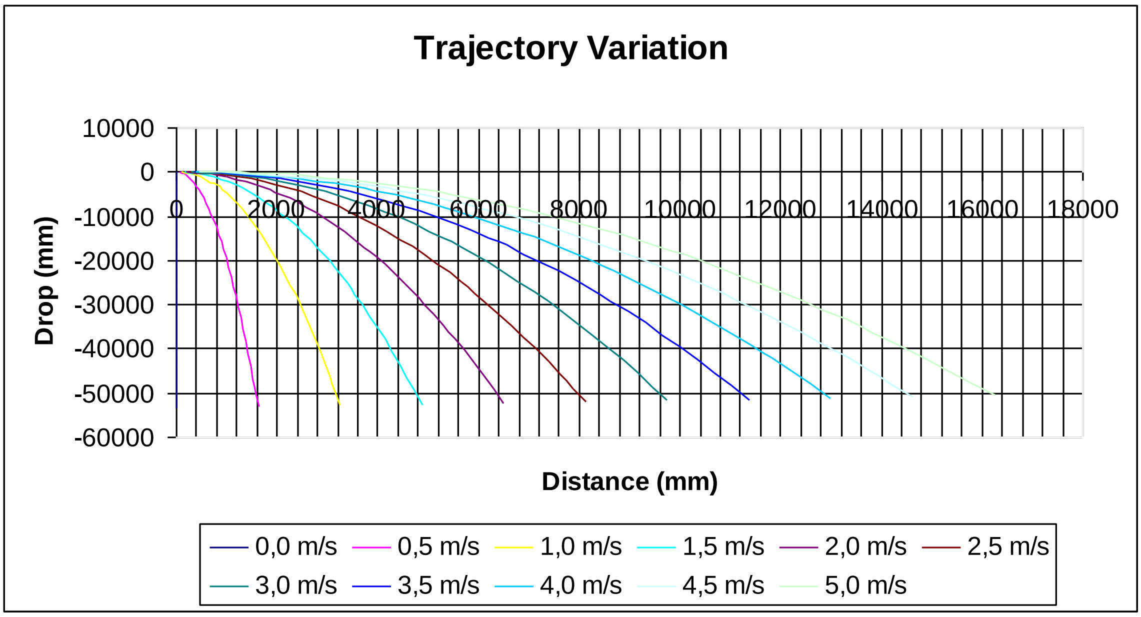


Fig 1 (Trajectory Variation in a Bunker or Silo)

From this simple sketch we see that the drop point of material varies greatly. The parabolic geometry has a 13m range through the belt speeds for a silo that is 60m deep. In most cases material will clash with the bunker or silo wall.

Two possible methods of controlling the drop point of the bulk material are by introducing a deflector chute or by the construction of a retractable jib. The deflector chute is possibly the easiest and cheapest method of obtaining control however maintenance is required. The retractable jib is a highly expensive exercise that requires precision and a high level of control.

Inline Transfer, Belt to Belt: This type of transfer typically uses a Langlaagte chute to assist with the centralized loading of material onto the receiving belt.

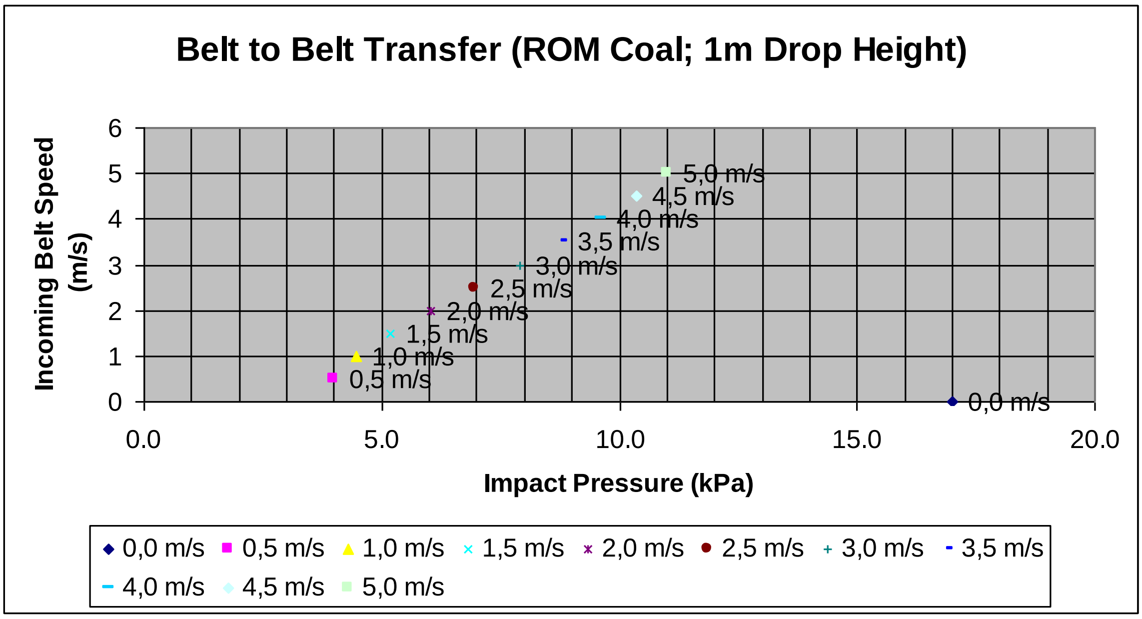


Fig 2 (Belt to Belt Transfer (ROM Coal; 1m Drop Height)

The graph shows the linear change of impact pressure of the bulk material onto the receiving conveyor with relation to the incoming belt speed. This is achieved even though there is a reduction of impact angle for higher incoming belt speeds. The very high impact pressure at 0m/s is due to the impact angle being 90º over a drop height of 1m, in reality this would be the start up and slow down of bulk material.

Conveyor belt manufactures prefer the impact pressure of the bulk solid on the conveyor belt to remain under 18 kPa. Incorrectly designed transfers are the principal cause of top cover wear.

Material Deflection with a Hood Type Chute: Hood and Spoon chutes are successfully used at transfer stations when transferring bulk material. They are particularly successful when transferring at 90° and 180°. The control of the flow is greatly minimized when trying to transfer the material in any other direction and the wear on the chute will increase accordingly.

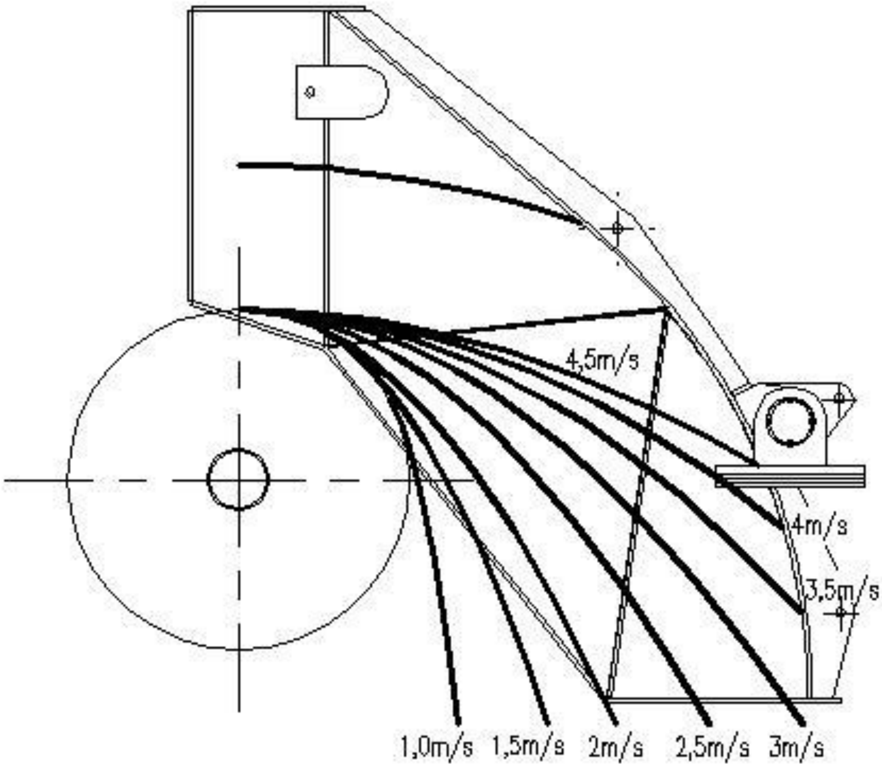


Fig 3 (Hood Type Deflector through a Range of Incoming Belt Speeds)

The above sketch illustrates a simple hood deflector operating through a range of belt speeds. The start up material only comes into contact with the chute’s surface at 3,0m/s and can be seen to have a high impact angle; therefore one would expect the impact pressure to also be high.

The chute only seems to be successful through a small range of incoming belt speeds. If an existing conveyor with a hood and spoon type chute is to be modified to a variable speed conveyor, then this is the typical scenario that can be expected. The chute would only be able to accommodate a selection of belt speeds.

The hood can be designed so that its position can be controlled, using hydraulics or pneumatics, accommodating for varying belt speeds. However the same has to be done to the spoon section of the transfer. A risk of wedging or blocking exists if the hood moves too close to the discharge pulley, narrowing the material passage, due to slow belt speeds and large lump sizes.

Dead Box Chute: The Dead box is probably the most successful transfer chute for variable speed conveyors. The material is stopped inside the chute in the Dead box portion and then allowed to slide down onto the receiving conveyor. Through the range of incoming belt speeds the commencement of the sliding starts at 0m/s, so the material falling onto the receiving conveyor is constant.

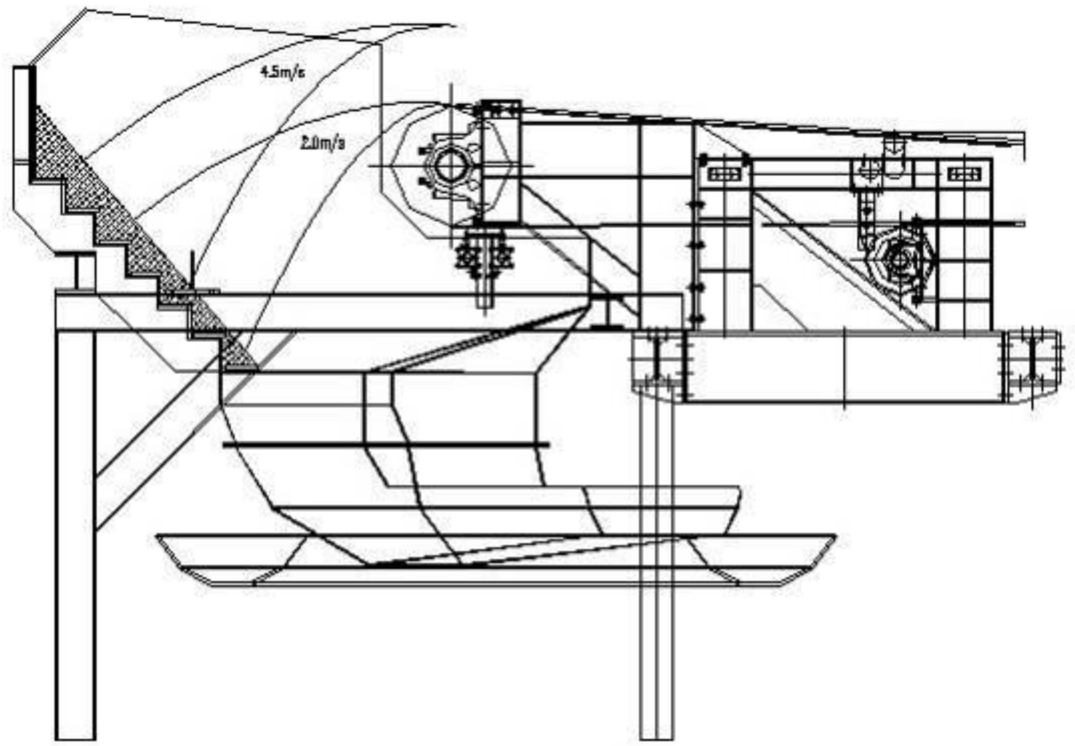


Fig 4 (Dead Box Type Deflector through a Range of Incoming Belt Speeds)

Fines management in a Dead box chute is difficult; this is due to the inability of having enough space for a high angled fines tray. A high drop height will assist but only if this is possible. The amount of dust generated by a Dead box chute is also high and as a result these types of chutes are problematic with the environment.

The biggest problem with a Dead box chute is the amount of degradation that takes place. This is due to the initial impact angle in the chute.

CONCLUSION FOR TRANSFERS

The design of chutes at transfer points has to be done thoroughly and methodically so that the best results are obtained, more importantly is that the chute correctly selected for the application.

Chutes on existing conveyor belts which are to be upgraded to variable speed must be carefully looked at and replaced if they do not meet the desired design criteria. A chute that is operating poorly is always a financial constraint on the operation.

GENERAL CONCLUSIONS PERTAINING TO "INTELLIGENT" CONVEYING

"Intelligent" Conveying presents the following:

Advantages:

- Belt Life when measured in tonnes conveyed is improved.
- Expected life of mechanical components is improved provided that the initial design is correct.

Disadvantages:

- Initial Capital costs are considerably higher.
- Transfer of Material from one belt to another is considered problematic due the varying trajectory.
- Staffing Skills levels need to be considered carefully as the levels of competency are considerably higher than for fixed speed conveyors.
- The structural integrity of the system must be designed for a fully loaded belt under all conditions.

Other Considerations:

- Should an existing conveyor need to be upgraded from “Fixed Speed” to “Intelligent Speed”, the conveyor needs to be totally upgraded so as to incorporate the considerations mentioned in this paper.

AUTHORS CV – A T EXTON

The author of this paper has been involved in the mining industry since 1969 where he commenced his training West Rand Consolidated Mines Ltd as an apprenticed Fitter & Turner. During his Apprenticeship he obtained a National Technical Diploma in Mechanical Design. After 7 years employment in the mines, he joined the private sector in the Mining Division of Dowson & Dobson (Pty) Ltd. as a design engineer. He was involved in the design field of both coal & hard rock mining equipment for various companies until 1990.

In July 1995 Nepean Conveyors (Pty) Ltd. was formed in South Africa and the author was appointed as the founding Managing Director, which position he still holds.

RELEVANT AFFILIATIONS

- Director of Companies
- Member of the South African Institution of Mechanical Engineers.
- Professional Member of South African Institute of Materials Handling.
- Past Chairman of the Conveyor Manufacturers Association of South Africa Ltd.
- Past Member of Beltcon 8, 9, 10, 11 & 12 Committees.
- Member of Beltcon 13 Committee.

CO-AUTHORS CV – CARLOS ANDRADE

The co-author joined the bulk materials industry after obtaining his BEng Mechanical degree from the Rand Afrikaans University. Employed by Nepean Conveyors (Pty) Ltd., as a project engineer, he managed a number of projects including turnkey projects before heading up a new business division dealing with the design of chutes and transfers called Nepean Transfer Technologies. He is actively involved with projects through the CMA and is a member of the Beltcon 13 committee.