VSD CONTROLLED CONVEYOR DRIVES AS A METHOD FOR SAVING POWER

R Bawden[1] and J van Niekerk[2]

[1]Read Swatman and Voigt
[2]Zest Electric Motors and Drives

1. INTRODUCTION

The purpose of this paper is to do a theoretical investigation into Variable Speed Drive (VSD) controlled conveyors to ascertain whether this is a feasible method of saving power.

There are certain conveyor applications where conveyors run for long periods of time at reduced or empty loads. This is particularly relevant in underground mining applications where conveyors are frequently used to convey rock to underground silos, to surface or to the rock hoisting skips. The feed to these conveyors is often sporadic, providing the opportunity for running long, lightly loaded conveyors at reduced speeds, where the potential for power saving exists. The process of running conveyors at lower speeds to generate power savings is generally known as 'intelligent conveying'. In this paper, the potential power savings for a typical underground hard rock application will be quantified and the technical issues in installing VSDs to save power will be discussed.

2. 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. The content of this paper highlighted the benefits that can be realized through the implementation of applying intelligence to a conveyor system with particular emphasis on underground mining in the coal industry.

This was followed up with a paper by Louis Botha at Beltcon 10 with the topic 'Intelligent Conveyor Drives – For Underground Conveyors'. This paper referred particularly to the drive technology used when applying intelligence through variable speed or variable frequency drives as used at Secunda Collieries.

'Intelligent conveying' was discussed further with a paper by Alan Exton and Jose Andrade of Nepean Conveyors at Beltcon 13 entitled 'The Perils and Pitfalls of Intelligent Conveying'. In this paper, the authors discussed the factors and philosophy behind 'intelligent conveying' and the technical issues that arise when trying to operate conveyors at varying belt speeds.

3. THEORY

3.1 Conveyor Power Requirements

The power required to convey bulk material is required to overcome several resistances to motion. The resistances may be classified into five groups, namely:

Main resistances	F_H
Secondary resistances	F_N
Special main resistances	F_{sl}
Special secondary resistances	F_{s2}
Slope resistance	$F_{st.}$

The total resistance F_U is the sum of the resistances

Where $$F_U = F_H + F_N + F_{sl} + F_{s2} + F_{st} \qquad (1)$$

The absorbed power (P) is the product of the total resistance (F_U) and the velocity (V).

Where $P = F_U V$

(2)

3.2 Belt Conveyors Main Resistances

The main resistances of belt conveyors are:

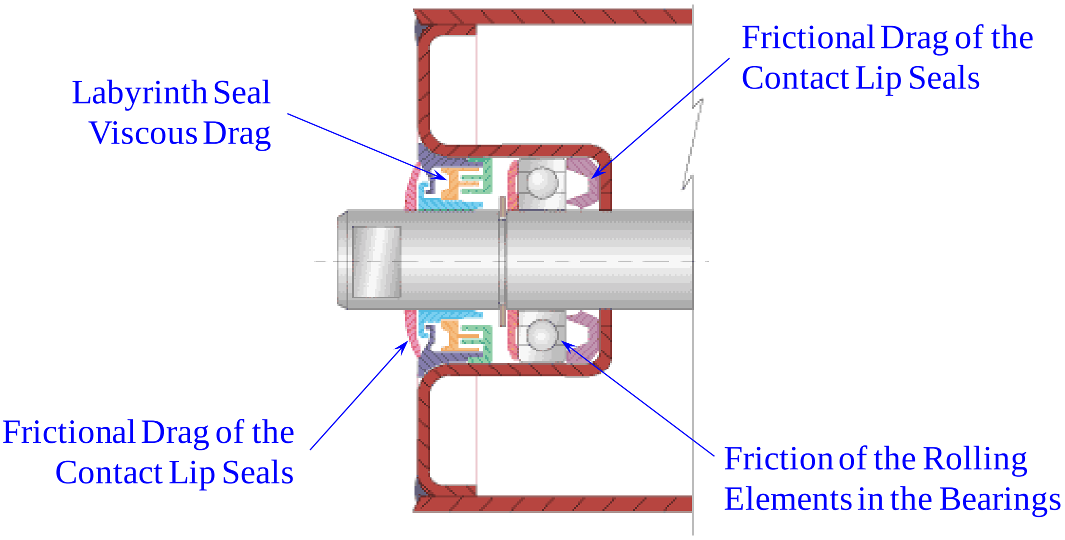
- Idler roll rotating resistance
- Indentation rolling resistance
- Bulk solid and belt flexure resistance.

Where the influence of key conveyor variables on conveyor resistances include:

- Bulk solid properties
- Belt speed and sag
- Idler roll diameter and spacing.

3.2.1 Rotating resistance of idler rolls

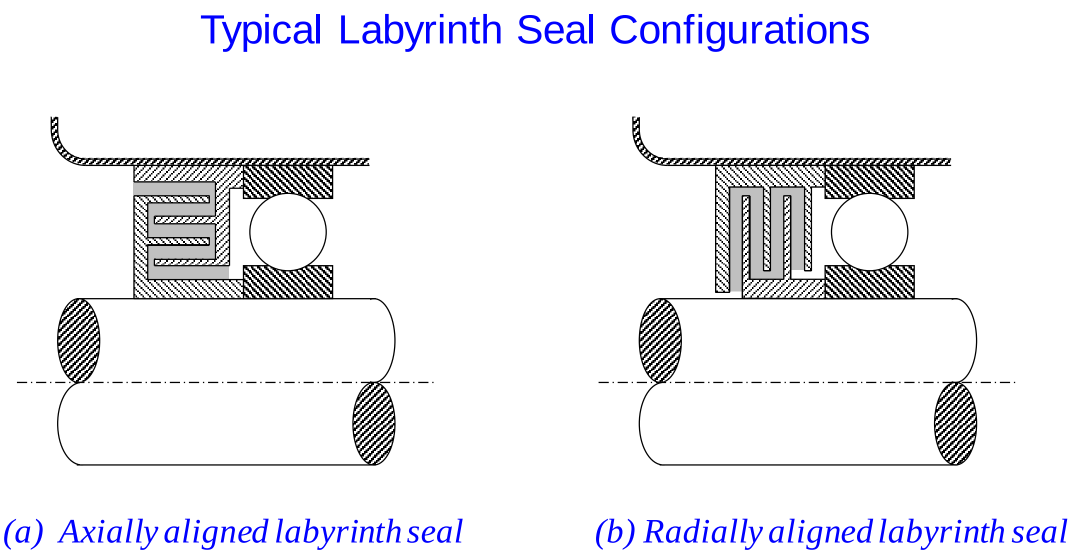
3.2.1.1 Components of idler roll rotating resistance



Reference: Mesco Idlers 2004

Figure 1. Components of idler roll rotating resistance

3.2.1.2 Labyrinth seal resistance drag



Typical Labyrinth Seal Configurations

(a) Axially aligned labyrinth seal

(b) Radially aligned labyrinth seal

Figure 2. Typical labyrinth seal viscous drag

The labyrinth seal moment ($M_{labyrinth}$) is proportional to the rotational velocity (Ω) if it is assumed that the dynamic viscosity ($\acute{\omega}$) of the rotating grease remains constant.

Thus $$M_{labyrinth} \alpha \, \Omega \tag{3}$$

Where the resistance force ($F_{labyrinth}$) per roll of diameter (D) due to the labyrinth seal is:

$$F_{labyrinth} = 4M_{labyrinth}/D \tag{4}$$

3.2.1.3 Bearing friction

The total friction moment of each bearing (M_{brg}) may be obtained by adding the no load moment (M_0) and the load dependent component (M_1).

Thus $$M_{brg} = M_0 + M_1 \tag{5}$$

According to SKF, the no load component is proportional to the product of dynamic viscosity ($\acute{\omega}$) and the rotational velocity (Ω) to the power of two thirds.

Thus $$M_0 \alpha \, (\acute{\omega} \, \Omega)^{2/3} \tag{6}$$

And the load dependent component (M_1) is independent of the rotational velocity.

Where $$F_{brg} = 4M_{brg}/D \tag{7}$$

3.2.1.4 Idler roll rotating resistance

The idler roll rotating resistance (F_{idler}) is a function of belt speed (V), idler roll diameter (D), radial load (P_r), mean bearing diameter (d_m), and the grease temperature (T_g).

Thus $$F_{idler} = f(V,D, P_r,d_m,T_{g\ldots}) \tag{8}$$

Thus a **decrease in idler roll resistance can be expected for a decrease in belt speed** for a particular conveyor system where the idler roll diameter, radial load, mean bearing diameter and grease temperature is fixed.

3.2.2 Indentation rolling resistance

3.2.2.1 Belt indentation rolling resistance mechanism

Conveyor belting is a viscoelastic material which as it rolls over an idler shell, generates an asymmetric pressure distribution on the idler shell opposing the roller rotation. This is illustrated in Figure 3.

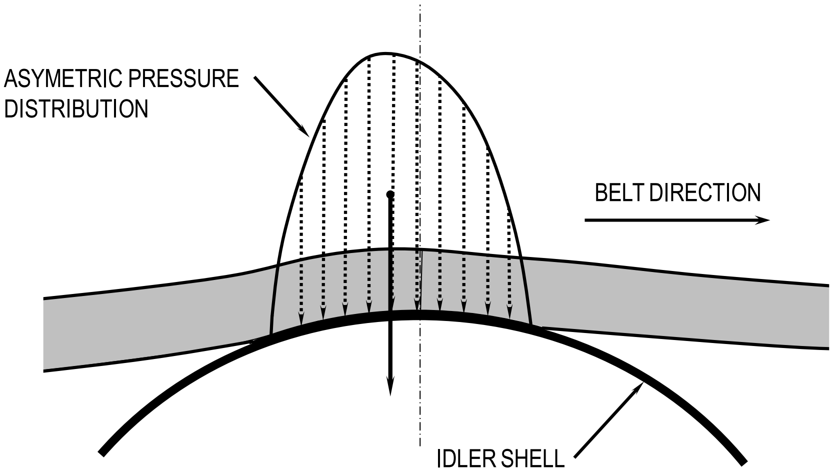


Figure 3. Belt indentation rolling resistance

3.2.2.2 Viscoelastic deformation of the belt drag

The tension drag increase (ΔT_{bin}) from the viscoelastic deformation of the belt cover is proportional to the viscoelastic characteristic of the belt cover rubber (K_{biR}), the cover indentation parameter (P_{jn}), the belt weight (W_b), the material weight (W_m), the load distribution factor (W_i), and the length of the roller (L_n).

Where $\Delta T_{bin} = K_{biR} \times P_{jn} \times (W_b+W_m) \times W_i \times L_n$ *(9)*

And $K_{biR} \propto \log V$ *(10)*

3.2.2.3 Belt indentation rolling resistance

The belt indentation rolling resistance (F_{ind}) is a function of belt speed (V), idler roll diameter (D), and the normal load (P_n).

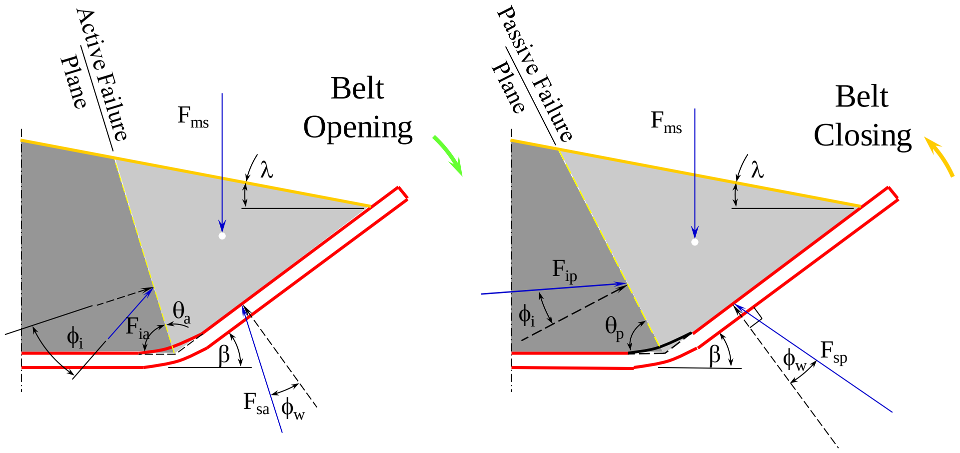
Where $F_{ind} = f(V, D, P_n)$ *(11)*

Thus a decrease in belt indentation rolling resistance can be expected for a decrease in belt speed and the normal load for a particular conveyor system where the idler roll diameter is fixed.

3.2.3 Belt and bulk solid flexure resistance

3.2.3.1 Belt and bulk solid flexure mechanism

The belt and conveyed bulk solids flex open and then close as it moves between idler sets. This belt and bulk solid flexure generates an energy loss or a resistance to the forward motion. The bulk solid flexure sets up an outer active and inner passive stress state as the belt opens. Conversely, bulk solid flexure sets up an inner active and outer passive stress state as the belt closes. The active and passive stress planes are separated by a failure plane. This is illustrated in Figure 4.



Active Stress State **Passive Stress State**

Figure 4. Belt and solid flexure resistance

3.2.3.2 Belt and bulk solid flexure resistance

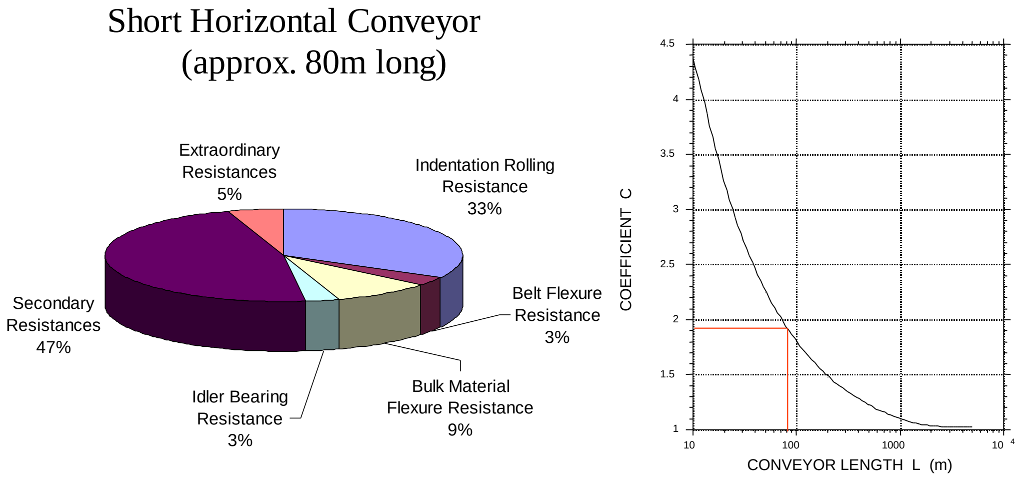
The belt and bulk solid flexure resistance (F_{bs}) is a function of belt speed (V), belt width (B), sag ratio (S), idler roll spacing (a_c), bulk density (ρ), and the internal friction of the bulk solids ($Ø_i$).

Where $$F_{bs} = f(V, B, S, a_c, \rho, Ø_i) \quad (12)$$

Thus a **decrease in belt and solid flexure resistance can be expected with a decrease in belt speed** for a particular conveyor system where the belt width, sag ratio, idler roll spacing, bulk density, and internal friction of bulk solid is fixed.

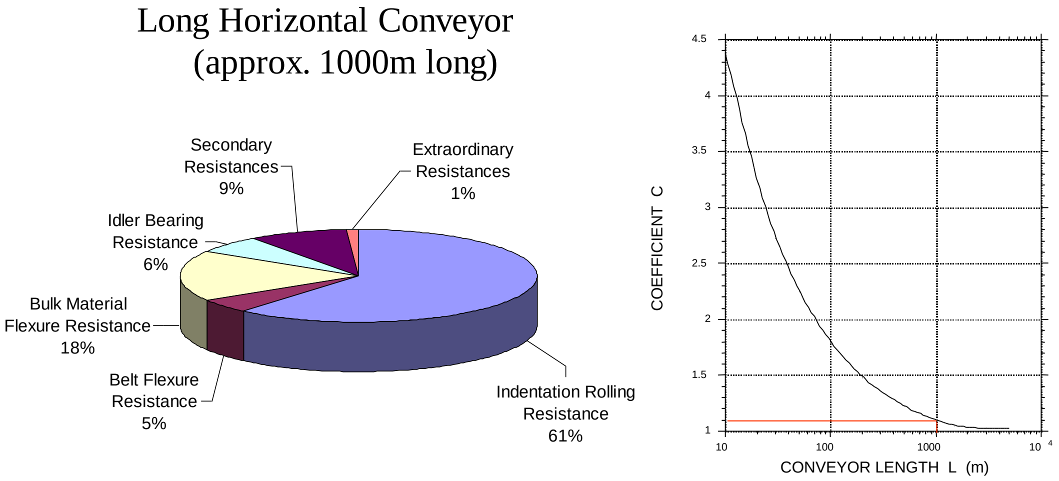
3.2.4 Distribution of motion resistances

The contribution of each motion resistances to the overall belt motion resistance varies according to the length of the conveyor. In short conveyors, approximately 80 m long, the secondary resistances of material acceleration, scraper, skirt, loading bed and plough drag dominate. However in long conveyors, approximately 1 000 m long, the main resistances, such as the belt indentation rolling resistance, dominate. Thus, long conveyors provide a better opportunity for saving power. This is illustrated in Figure 5 and Figure 6.



Reference: Hager and Hintz, *The Energy Saving Design of Belts for Long Conveyor Systems*, BSH pp. 172 1993.

Figure 4. Distribution of motion resistances for a short conveyor



Reference: Hager and Hintz, *The Energy Saving Design of Belts for Long Conveyor Systems*, BSH pp. 172 1993.

Figure 5. Distribution of motion resistances for a long conveyor

3.3 VSDs

VSDs are the most efficient method to control the speed of induction motors. Within a VSD the normal (Eskom) supply voltage is first converted to DC. This DC voltage is smoothed by a large capacitor bank. Thereafter this DC is converted to a controlled AC voltage. Generally the method for this is known a Pulse Width Modulation (PWM). (Figure 7). As a result, the constant 50 Hz supply voltage can be controlled, thereby controlling the speed of the motor.

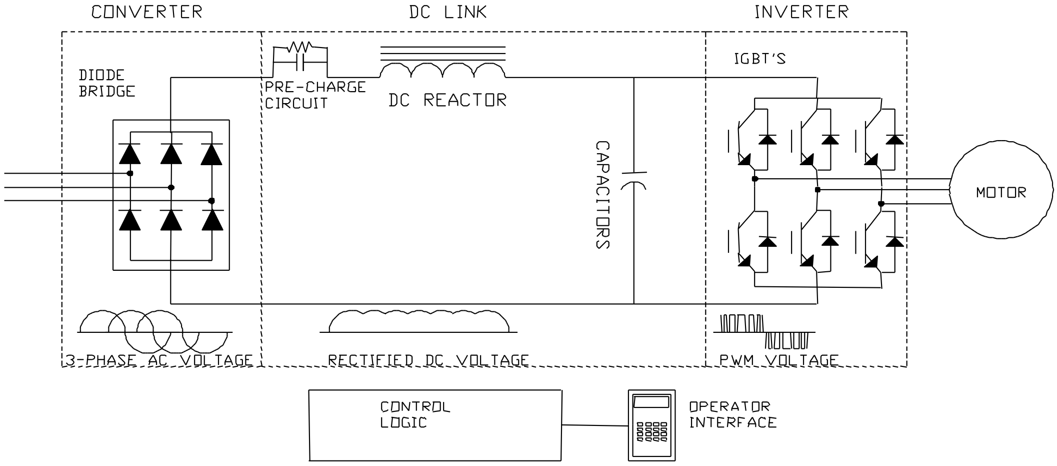


Figure 6. Pulse width modulation

The various components in the VSD have electrical losses. A typical VSD efficiency is equal to or greater than 97%. VSD losses are of the order of 3%.

Load (%)	Efficiency (%)
100%	97%
75%	97%
50%	96%
25%	94%

Table 1. Motor load versus VSD efficiency

The VSD efficiency will thus remain the same for a 75% load and drop to 96% and 94% for a 50% and 25 % load.

4. POWER SAVING IN VSD CONTROLLED CONVEYOR DRIVES

4.1 Basis of Discussion

In many underground hard rock mining conveyer layouts, for example, platinum mines, strike conveyors on the levels feed a decline or incline conveyor system. The decline conveyor will either convey the ore directly to surface or feed an underground storage silo or ore pass system.

The conveyors discussed in this section are hypothetical, but based on actual installations and can be considered typical for most underground hard rock applications.

The conveyors' technical specifications are listed in Appendix 2. The conveyor calculations are in line with CEMA 5.

4.2 Strike and Decline Conveyors

This section is based on a typical platinum type operation. The mining parameters and design criteria used to quantify power savings are shown in Table 2. These parameters are in line with underground conveyor design criteria used by most South African mining houses.

Description	Units	Qty
Mining monthly capacity	t/m	135,000
Mining days per month	d/m	21
Mining daily capacity	t/d	6,429
Shifts per day	s/d	3
Mining shift capacity	t/s	2,143
No of levels	No	5
No of half levels	No	10
ROM lump size	mm	300
Strike conveyor capacity	t/h	180
Strike conveyor belt width	mm	1,200
Strike conveyor belt speed	m/s	1.5
Strike conveyor belt type		fabric
Decline conveyor capacity	t/h	600
Decline conveyor belt width	mm	1,200
Decline conveyor belt speed	m/s	2.5
Decline conveyor belt type		fabric
Decline conveyor maximum leg length	m	600
Decline conveyor legs	No	3
Mining electrical cost	R/kWh	0.5

Table 2. Typical underground mining design criteria

4.2.1 Strike conveyor

The strike conveyor is installed on the level to convey ore from the stopes to the decline.

The most likely method of feeding a strike conveyor with ROM from the stopes is by load haul dumpers (LHDs) at the strike conveyor tip point. The conveyor may have one or more tip points depending on the mining layout. In general, as the mining advances, the conveyor is extended and the tip point is moved. The most common tip point will consist of a fixed grizzly where the undersize rock feeds the strike conveyor and the oversize is broken manually or by means of a pecker. In some instances tip points have vibrating feeders.

A strike conveyor with a fixed grizzly tip arrangement must theoretically remove the bucket load at the same rate at which it was dumped to avoid spillage. The strike conveyor belt width and speed is designed to match the LHD discharge rate, (calculations in Appendix 1) while the absorbed power is determined by the strike conveyor capacity. The strike conveyor will therefore need to run at maximum speed to avoid spillage even when lightly loaded. The only practical time the conveyor can operate at reduced speeds is when it is running empty.

4.2.1.1 Reduced belt speed operation power savings

The reduction of the strike conveyor belt speed for a fixed load system introduces the potential for power saving. (Table 3).

The VSD controlled strike conveyor must operate at maximum belt speed of 1.5 m/s to avoid spillage. (Operational block, Table 3).

		Absorbed Power	
Capacity (t/h)	**Units**	**Belt Speed 0.5 m/s**	**Belt Speed 1.5 m/s**
Empty belt	kW	5	15
100 t/h	kW	8	17
180 t/h	kW	10	20

Table 3. Belt loading for capacity versus belt speed

The strike conveyor **shift** absorbed power with VSD control is shown in Table 4. The strike conveyor operating at the design 'fixed belt speed' of 1.5 m/s is shown in Table 5.

Capacity (t/h)	**Belt Speed (m/s)**	**Percentage Time**	**Time (hours)**	**kW**	**η_{VSD}**	**η_{motor}**	**η_{gbox}**	**kWh**
0	0	38	3.0	0	0	0	0	0
100	1.5	48	3.8	17	0.96	0.93	0.96	75.4
300	1.5	14	1.2	20	0.96	0.94	0.96	27.7
							TOTAL P_{vbs}	103.1

Table 4. Strike conveyor absorbed power with variable belt speed

Capacity (t/h)	**Belt Speed (m/s)**	**Percentage Time**	**Time (% of 8 hours)**	**kW**	**η_{VSD}**	**η_{motor}**	**η_{gbox}**	**kWh**
0	1.5	38	3.0	15	1	0.93	0.96	50.4
100	1.5	48	3.8	17	1	0.93	0.96	72.4
300	1.5	14	1.2	20	1	0.94	0.96	26.6
							TOTAL P_{fbs}	149.4

Table 5. Strike conveyor absorbed power for a fixed belt speed

Theoretical analysis shows that it is possible to save up to 31% in power by introducing a variable speed drive on the strike conveyors to switch the belt off when it is running empty.

The strike conveyor annual power (P_{ast}) savings by introducing a VSD control is the product of the saved power per shift ($P_{fbs} - P_{vbs}$), number of shifts per day (N_{sd}), number of strike conveyors (N_{st}) and the number of working days per year (N_{dy}).

Thus

$$P_{ast} = (P_{fbs} - P_{vbs}) \times N_{sd} \times N_{st} \times N_{dy} \qquad (13)$$

$$P_{ast} = (149.9 - 103.1) \times 3 \times 10 \times 252$$

$$P_{ast} = 353{,}808 \text{ kWh}$$

Thus the annual power money savings at 50 c per kWh is R 176,904.00

Where the VSDs retrofit cost of units plus installation is R 750,000.00

The payback period at present value is 4.2 years.

4.2.1.2 Technical issues

- The introduction of a VSD allows for controlled start-ups with increased belt life and reduced risk of belt tear
- The VSD can be used to sense when the strike conveyor is running empty and switch the conveyor off. The signal to restart the conveyor will be provided by the LHD entering the tip area. A VSD fitted with an analogue or profibus system provides the facility to reset the empty belt load limit remotely once the strike conveyor has been extended.

4.2.2 Decline conveyor system

Strike conveyors from each of the ten half levels feed the decline conveyors in one of the following ways:

- Option 1: Direct strike conveyor feed via a transfer chute onto the decline conveyor requiring 'intelligent conveying' Intelligence is applied to the decline conveyor by detecting the average height of ROM material on the belt and the belt speed. The average material height is measured between each levels and the belt speed adjusted accordingly.
- Option 2: The strike conveyors feed an ore pass which feeds the decline conveyor at a controlled rate via a vibrating feeder. It is assumed that each ore pass has sufficient holding capacity so that the decline conveyor can be fed at the minimum rate of 300 t/h to operate the decline conveyors at optimum efficiency.

Operational times

Data taken from a decline conveyor system capacity study is shown in Table 6. The data was collected by taking average belt weigher readings at hourly intervals over a shift. Readings were taken over 19 shifts covering day, afternoon and night shifts. This data can be considered typical for a five level mining operation where strike conveyors feed a decline conveyor system.

Capacity (t/h)		Hourly Units	% Time
Empty	0 to 19	11	10
Low	20 to 199	36	32
Medium	200 to 399	38	33
Average	400 to 499	10	9
High	500 to 699	18	16
Peak	700 to 799	0	0
High Peak	800 to 900	1	<1

Table 6. Conveyor monitored shift capacities

4.2.2.1 Reduced belt speed operation power savings

The installation of a variable speed drive on the decline conveyor system shows that the potential exists for power saving as the power absorbed for a fixed capacity reduces as the belt speed is lowered. (Table 7).

The effect of reducing the belt speed for a fixed capacity reduces the belt safety factor and increases the take up load required. The decline conveyor maximum operational line for capacity and belt speed at which the belt safety factor and take up load remains within design limits is shown in Figure 8. This is used to calculate the absorbed power in Table 7.

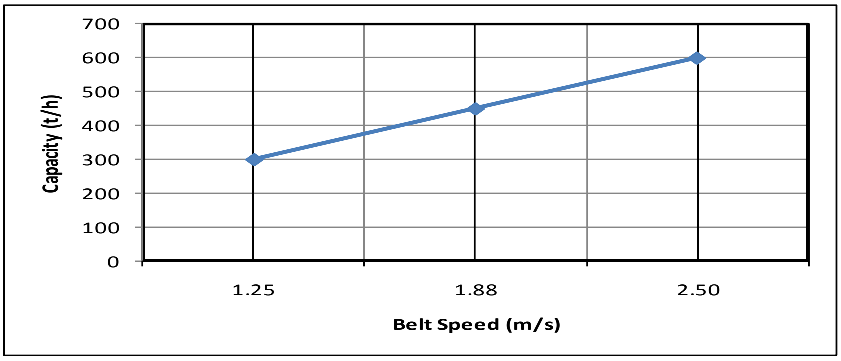


Figure 7. Decline conveyor operational line

			Absorbed Power		
Capacity (t/h)	**Units**	**Belt Speed 0.5 m/s**	***Belt Speed 1.5 m/s**	**Belt Speed 1.88 m/s**	**Belt Speed 2.5 m/s**
Empty belt	kW	12	36	42	60
100 t/h	kW	39	63	72	87
300 t/h	kW	92	117	126	141
450 t/h	kW	133	157	166	182
600 t/h	kW	174	197	206	222

Table 7. Absorbed power for capacity versus belt speed

***Note: The minimum operational belt speed is set at 1.5 m/s to match the strike conveyor belt speed to avoid excessive spillage on the decline conveyor system.**

4.2.2.2 Reduced belt speed operation power savings

The decline conveyor **shift** absorbed power with VSD control for Option 1 and Option 2 is shown in Table 8 and Table 9. The decline conveyor operating at the design fixed belt speed of 2.5 m/s is shown in Table 10.

Capacity (t/h)	**Belt Speed (m/s)**	**% Time***	**Time (hours)**	**kW**	**η_{VSD}**	**η_{motor}**	**η_{gbox}**	**kWh**
Empty Belt	0	10	0.8	0	0	0	0	0
100	1.5	32	2.6	63	0.96	0.92	0.96	193.2
300	1.5	33	2.6	117	0.97	0.95	0.96	343.9
450	1.88	9	0.7	166	0.97	0.96	0.96	129.9
600	2.5	16	1.3	222	0.97	0.97	0.96	319.5
*See Table 6							**TOTAL P_{vbs1}**	986.5

Table 8. Option 1: Decline conveyor absorbed power with variable belt speed

Capacity (t/h)	**Belt Speed (m/s)**	**Percentage Time**	**Time (hours)**	**kW**	**η_{VSD}**	**η_{motor}**	**η_{gbox}**	**kWh**
300	1.5	100	7.1	117	0.97	0.95	0.96	939.0
							TOTAL P_{vbs2}	939.0

Table 9. Option 2: Decline conveyor absorbed power with variable belt speed

Capacity (t/h)	Belt Speed (m/s)	% Time*	Time (hours)	kW	η_{VSD}	η_{motor}	η_{gbox}	kWh
Empty Belt	2.5	10	0.8	60	1	0.78	0.96	64.1
100	2.5	32	2.6	87	1	0.92	0.96	256.1
300	2.5	33	2.6	141	1	0.95	0.96	402.0
450	2.5	9	0.7	182	1	0.96	0.96	138.2
600	2.5	16	1.3	222	1	0.97	0.96	309.9
							TOTAL P_{fbs}	1,170.3

*See Table 6.

Table 10. Decline conveyor absorbed power with a fixed belt speed

Theoretical analysis shows that it is possible to save up to 16% in power by introducing Option 1 intelligent conveying over the fixed belt speed operation.

Similarly, it is possible to save up to 20% by introducing Option 2 fixed reduced load and belt speed operation over the fixed belt speed operation.

It is possible to save up to 5% by switching the fixed belt speed off using a VSD when the belt is running empty.

4.2.2.3 VSD Installation returns

Option 1

The decline conveyor annual power (P_{ast}) savings by introducing intelligent conveying of Option 1 is the product of the saved power per shift ($P_{fbs} – P_{vbs1}$), number of shifts per day (N_{sd}), number of decline conveyors (N_{de}) and the number of working days per year (N_{dy}).

Thus $P_{ast} = (P_{fbs} – P_{vbs1}) \times N_{sd} \times N_{de} \times N_{dy}$ (14)

$P_{ast} = (1{,}170.3 – 986.5) \times 3 \times 3 \times 252$

$P_{ast} = 416{,}858$ kWh

Thus the annual power money savings at 50 c per kWh is R 208,429.00

Where the VSDs retrofit cost of units plus installation is R 880,000.00

The payback period at present value is 4.2 years.

Option 2

The decline conveyor annual power (P_{ast}) savings by introducing Option 2 is the product of the saved power per shift ($P_{fbs} – P_{vbs2}$), number of shifts per day (N_{sd}), number of decline conveyors (N_{de}) and the number of working days per year (N_{dy}).

Thus $P_{ast} = (P_{fbs} – P_{vbs2}) \times N_{sd} \times N_{de} \times N_{dy}$ (15)

$P_{ast} = (1{,}170.3 – 939.0) \times 3 \times 3 \times 252$

$P_{ast} = 524{,}588$ kWh

Thus the annual power money savings at 50 c per kWh is R 262,294.00

Where the VSDs retrofit cost of units plus installation is R 880,000.00

The payback period at present value is 3.4 years.

Decline Conveyor System Switched Off When the Belt is Running Empty

The decline conveyor annual power (P_{ast}) savings by switching the decline conveyor system off when the belt is running empty is the product of the saved power per shift ($P_{fbs} – P_{empty}$), number of shifts per day (N_{sd}), number of decline conveyors (N_{de}) and the number of working days per year (N_{dy}).

Thus $P_{ast} = (P_{fbs} – P_{empty}) \times N_{sd} \times N_{de} \times N_{dy}$ *(16)*

$P_{ast} = 64.1 \times 3 \times 3 \times 252$

$P_{ast} = 145{,}379$ kWh

Thus the annual power money savings at 50 c per kWh is R 72,689.00

Where the VSDs retrofit cost of units plus installation is R 880,000.00

The payback period at present value is 12.1 years.

4.2.2.4 Technical issues

Option 1

- The individual strike conveyor feed onto the decline conveyor is in discrete elements relying on the overall randomness of the system to even out the flow. 'Intelligence' applied to the decline conveyor will not solve any of the existing spillage problems
- Varying feed rates and trajectories through the transfer points will require innovative solutions to avoid spillage. Movable chutes could be considered
- In new installations, a single flight steel cord belt for the full length of the decline may solve the problem. However, this will require the South African mining industry to move away from a deeply entrenched view that with modern conveying technology a decline conveyor leg fed by strike conveyors must be limited to a 600 m length with fabric belting
- The 'intelligent' decline conveyor can be switched off or run at a reduced belt speed when the system is running empty
- The theoretical power saving of 16% is optimistic as the belt speeds will need to be increased at times to avoid spillage.
- The calculated present payback period of 4.2 years will reduce as South African electrical power costs are set to increase by 25% per year for three years starting in 2011
- The risk exists of increasing the frequency of belt tracking misalignment with varying belt speeds
- In intelligent conveying, the belt loading is kept constant with the speed being varied to suit the load. This option allows the induced tension to be kept constant. The operational cycle per tonne conveyed is lower, thus resulting in decreased belt wear
- The drive gearbox is splash lubricated. The lubrication effectiveness could thus be an issue at reduced rotational speeds
- The drive electrical motors are air cooled at an optimal air design for a given speed. Additional forced fan cooling may be required.

Option 2

- Spillage problems, compared to Option 1, will be reduced by having a controlled feed onto the decline conveyor
- A fixed load at constant belt speed will reduce the complexity of trying to solve transfer points varying speed issues
- The decline conveyor system can be switched off or run at a reduced belt speed when the system is running empty
- The theoretical power saving of 20% is optimistic as no allowance for ore pass change over or belt clearing times have been allowed
- The calculated present payback period of 3.4 years will reduce as South African electrical power costs are set to increase by 25% per year for three years starting in 2011
- Option 2 belt tracking will not be an issue as the system will operate at a fixed speed.

5. CONCLUSION

- In operating a strike conveyor it is possible to save up to 31% in power by introducing a variable speed drive on the conveyor to switch the belt off when it is running empty
- There is limited opportunity to run strike conveyors at reduced speeds to save power as the belt must be run at full speed to avoid spillage irrespective of the load
- A strike conveyor retrofitted with a VSD can be paid back within 4.2 years in present terms
- In a decline conveyor system it is possible to save up to 16% in power by introducing intelligent conveying (Option 1) over the fixed belt speed operation
- A decline conveyor intelligent conveying system VSDs can be paid back within 4.2 years in present terms
- In a decline conveyor system it is possible to save up to 20% in power by introducing a reduced fixed load and belt speed operation (Option 2) if sufficient ore pass capacity exists between the levels and the decline.
- A decline conveyor fixed load and belt system conveying system VSDs can be paid back within 3.4 years in present terms
- In a decline conveyor system it is possible to save up to 5% in power by introducing a VSD to switch the conveyor off when the belt is running empty
- A decline conveyor system VSD which is used to switch off the belt when it is empty can be paid back within 12.1 years in present terms
- Power savings achieved in practice will be lower than the theoretical savings calculated in this paper as the issues of increasing belt speeds to avoid spillage (Option 1), ore pass change over times, (Option 2), start-up loads and start-up times have not been taken into account
- The modifications required to an existing decline conveyor installation to install VSD control to save power may be too onerous to implement
- Power saving is possible in new decline conveyor systems where the necessary upfront design has been done to implement VSD control to save power. However, a shift in the industry thinking to consider concepts outside the accepted norm, for instance, single flight steel cord belt, is required.
- Power can be saved by introducing VSD control to switch strike and decline conveyors off or run at a reduced belt speed when they are running empty. There is a risk involved in stopping an operational belt as personnel may assume that the live system is locked out.
- The savings realised in this paper are indicative only. Each installation would have to be investigated as a stand-alone entity to determine what savings are possible.

REFERENCES

1. Philip C Venter. Intelligent Conveyors: Dynamic Adjustment of Conveyor Speed Under Variable Load Conditions. Beltcon 8. 1995.
2. Louis Botha. Intelligent Conveyor Drives for Underground Conveyors. Beltcon 10. 1999.
3. Alan Exton. The Perils and Pitfalls of Intelligent Conveying. Beltcon 13. 2005.
4. Dr Craig Wheeler. Bulk Solids Research: The University of Newcastle, Australia. Conveying, Storage and Handling of Bulk Solids Course, November 2010. Belt Conveying of Bulk Solids pp. 1 to 52. (Figures 1 to 6 supplied by Dr Craig Wheeler

ABOUT THE AUTHORS

RONNIE BAWDEN

The author of this paper is a Professional BSc Mechanical Engineer who graduated from the University of the Witwatersrand in 1978. He commenced work on the Samancor Hotazel Mine in the North Western Cape as a junior engineer. He spent 12 years with Boart Longyear. In 1996 he joined Read Swatman and Voigt, where he is still presently employed in EPCM type projects. He has completed numerous pre-feasibility and feasibility studies for both Impala and Anglo Platinum. He was involved in the Associated Manganese Black Rock Nchwaning No 3 Project from feasibility study stage to final implementation.

Ronnie Bawden

Chief Mechanical Engineer
Engineering & Technology Cluster Office
Read Swatman and Voigt
Tel: +27 11 498 6173
Fax: +27 11 429 8683
Mobile: (082) 903 7102
Email: ronnieb@rsv.co.za

JOHAN VAN NIEKERK

Johan van Niekerk has worked in the drives industry for 20 years. First gaining practical experience as a technician involved hands on with installations and applications. Thereafter as a project engineer, business development manager and drives manager. He is currently drives and automation manager for Zest Electric Motors and Drives.

Johan van Niekerk

Manager
Zest Electric Motors and Drives
47 Galaxy Avenue, Linbro Business Park,
Johannesburg, South Africa
Direct: +27 11 723 6157
Fax: +27 86 630 6661
Mobile: +27 83 326 6863
Email: JohanvN@zest.co.za

APPENDIX 1: STRIKE CONVEYOR BELT CAPACITY CALCULATIONS

1. Inputs

1.1. LHD	Aardmajor MK 2
1.2. Bucket capacity (B_c)	2.2 m^3
1.3. Broken density (ρ)	2,400 kg/m^3
1.4. Lump size	300 mm
1.5. Bucket length (B_w)	2.6 m
1.6. Bucket fill factor (B_{ff})	0.9
1.7. Belt width (W_b)	1 200
1.8. Belt speed (V)	1.5 m/s
1.9. Bucket discharge time (B_{dt})	7 secs

2. Calculations

1.1 Bucket Discharge Load (B_1)

$$B_1 = (B_c \times \rho \times B_{ff})/B_w \qquad (1)$$

$$B_1 = (2.2 \times 2{,}400 \times 0.9)/2.6$$

$$\underline{B_1 = 1{,}827 \text{ kg/m}}$$

Conveyor Travel Length During Bucket Discharge (S_c)

$$S_c = V \times B_{dt} \qquad (2)$$

$$S_c = 1.5 \times 7$$

$$\underline{S_C = 10.5 \text{ m}}$$

Conveyor Loading (L_c)

$$L_c = B_1 \times B_w / S_c \times V \times 3.6 \qquad (3)$$

$$L_C = 1{,}827 \times 2.6/10.5 \times 1.5 \times 3.6$$

$$\underline{L_c = 2{,}443 \text{ t/h}}$$

See Belt fill diagram below

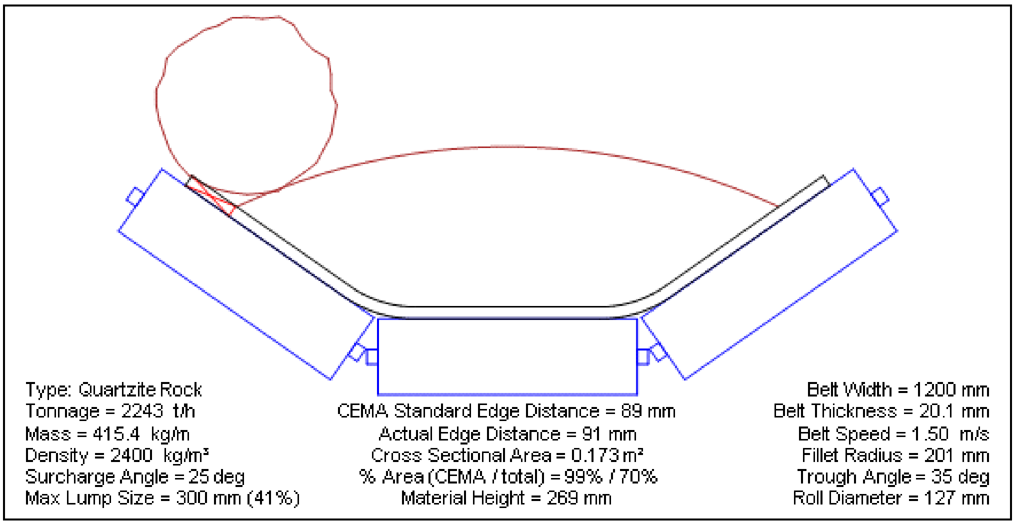


Figure 1. Belt fill diagram

Conclusion: Spillage can be expected for a 1 200 belt running at 1.5 m/s loaded by a LHD.

APPENDIX 2. CONVEYOR TECHNICAL SPECIFICATIONS

Strike Conveyor Technical Specifications

Item	Units	Qty	Comment
Design capacity	t/h	180	
Ore density		2.4	
Maximum lump size	mm	300	
Horizontal distance	m	500	
Lift	m	0	
Belt width	mm	1,200	
Belt class	kN/m	630	Fabric
Belt top cover thickness	mm	8	
Belt bottom cover thickness	mm	4	
Motor	kW	30	1,500 rpm, 525V, 3 ph, 50 Hz
Gear box	ratio	31	Bevel helical
Start/ speed control		1	DOL

Decline Conveyor Technical Specifications

Item	Units	Qty	Comment
Design capacity	t/h	500	
Ore density		2.4	
Maximum lump size	mm	300	
Horizontal distance	m	600	
Lift	m	87	
Belt width	mm	1,200	
Belt class	kN/m	800	Fabric
Belt top cover thickness	mm	10	
Belt bottom cover thickness	mm	3	
Motor	kW	250	1,500 rpm, 525V, 3 ph, 50 Hz
Gear box	ratio	25	Bevel helical
Start/ speed control		1	VSD