# HIGH SPEED CONVEYING – ITS ADVANTAGES, DISADVANTAGES AND SOME PROPOSED SOLUTIONS

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## 1.0 INTRODUCTION

The aim of this paper is to take a look at the contentious issue of high speed belt conveying, its advantages, its disadvantages and some proposed solutions. Under advantages the paper will cover the magnitude of capital saving available should high speed conveying be opted for in the current market conditions. The disadvantages associated with high speed conveying will be discussed, finally leading into some proposed solutions on conveyor structure and transfer points.

It is not the scope or intention of this paper to address the actual design of high speed conveying. However for completion sake, some of the more important factors highlighted by previous work, will be touched on to give a more complete scenario on high speed conveying.

## 2.0 ADVANTAGES

The obvious advantage of conveying bulk ore or material at higher belt speeds is the lower capital cost of the conveyor system. The capital savings are due to lighter material loads, narrower belts and lower belt tensions. It is fair to say that high speed conveying is generally not suited to in plant type of conveyors and probably never will be for reasons of safety and material transfer points. Therefore the focus will be only on the longer 'overland' type of belt installations.

To have a better understanding and to illustrate the capital savings and consequent effects of conveying at higher speeds assume a typical conveyor of 6000m long with an overall elevation of 60m carrying coal at 4000t/h. In order to do a fair comparison the design parameters shown in Table 1 have been through some basic optimisation. A comparison based on ISO 5048 between 4m/s, 6m/s, 8m/s, 10m/s and 12.5 m/s has been done using the design parameters and the results are shown in the calculated values of Table 1 below.

| **DESIGN PARAMETERS** | | | | | | |
|---|---|---|---|---|---|---|
| Belt speed | m/s | 4 | 6 | 8 | 10 | 12.5 |
| Capacity | t/h | 4000 | 4000 | 4000 | 4000 | 4000 |
| Belt S.F on steady state | | min 6 | min 6 | min 6 | min 6 | min 6 |
| Carry Idler spacing | m | 2.5 (7.5) | 2.5 (7.5) | 2.5 (7.5) | 2.5 (7.5) | 2.5 (7.5) |
| Carry idler trough angle | deg | 45 | 45 | 45 | 45 | 45 |
| Idler rolls | # | 5 | 3 | 3 | 3 | 3 |
| Idler roll diam | mm | 152 | 152 | 152 | 152 | 152 |
| Sag percentage | % | 2 | 2 | 1 | 0.5 | 0.5 |
| Minimum L10 idler life | hrs | 60000 | 60000 | 60000 | 60000 | 60000 |
| Friction factor | | 0.016 | 0.016 | 0.0165 | 0.017 | 0.0175 |

**Table 1: Design parameters**

| CALCULATED VALUES | | | | | | |
|---|---|---|---|---|---|---|
| For belt speed | m/s | 4 | 6 | 8 | 10 | 12.5 |
| T1 | kN | 700 | 496 | 409 | 368 | 321 |
| Belt width | mm | 1800 | 1500 | 1350 | 1200 | 1050 |
| % belt fill | % | 85 | 83 | 78 | 79 | 84 |
| Belt class | | ST2500 | ST2000 | ST2000 | ST2000 | ST2000 |
| Idler speed | rpm | 503 | 754 | 1005 | 1256 | 1570 |
| Carry idler series (shaft dia) | | 40 | 40 | 40 | 40 | 40 |
| Return idler series (shaft dia) | | 40/30 | 35/30 | 30 | 30 | 30 |
| L10 carry idler life | hrs | 90000 | 81659 | 84556 | 77727 | 66451 |
| L10 return idler life | hrs | 133134 | 210783 | 215736 | 236522 | 279027 |
| Carry idler bearing | | 6308 | 6308 | 6308 | 6308 | 6308 |
| Return idler bearing | | 6306 | 6306 | 6306 | 6306 | 6306 |
| Load on centre roll | N | 5879 | 5305 | 4765 | 4549 | 4449 |
| Absorbed power | kW | 2274 | 2390 | 2609 | 2789 | 3008 |
| Diff. compared to 4m/s | kW | | 116 | 335 | 515 | 734 |

**Table 2: Calculated design values**

| Cost comparison of capital cost vs. belt speed (cost in R1000's) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Capital Equipment** | **Belt Speed [m/s]** | | | | | | | | | |
| | **4m/s (1800mm belt)** | | **6m/s (1500mm belt)** | | **8m/s (1350mm belt)** | | **10m/s (1200mm belt)** | | **12.5m/s (1050mm belt)** | |
| | R 1000's | % of total | R 1000's | % of total | R 1000's | % of total | R 1000's | % of total | R 1000's | % of total |
| Idlers | 8,511 | 13% | 6,243 | 11% | 5,678 | 11% | 5,298 | 11% | 5,006 | 11% |
| Belting | 32,688 | 48% | 26,352 | 47% | 24,852 | 47% | 23,484 | 48% | 21,996 | 47% |
| Drive | 6,559 | 10% | 5,712 | 10% | 5,333 | 10% | 4,887 | 10% | 4,643 | 10% |
| Pulleys | 3,249 | 5% | 3,281 | 6% | 2,279 | 4% | 1,582 | 3% | 1,431 | 3% |
| Electricals (VSD's) | 5,200 | 8% | 5,200 | 9% | 5,800 | 11% | 5,800 | 12% | 6,800 | 15% |
| Support Structure | 11,310 | 17% | 9,570 | 17% | 8,700 | 17% | 7,830 | 16% | 6,960 | 15% |
| | **67,518** | 100% | **56,358** | 100% | **52,643** | 100% | **48,880** | 100% | **46,837** | 100% |

**Table 3: Capital cost comparison for various belt speeds**

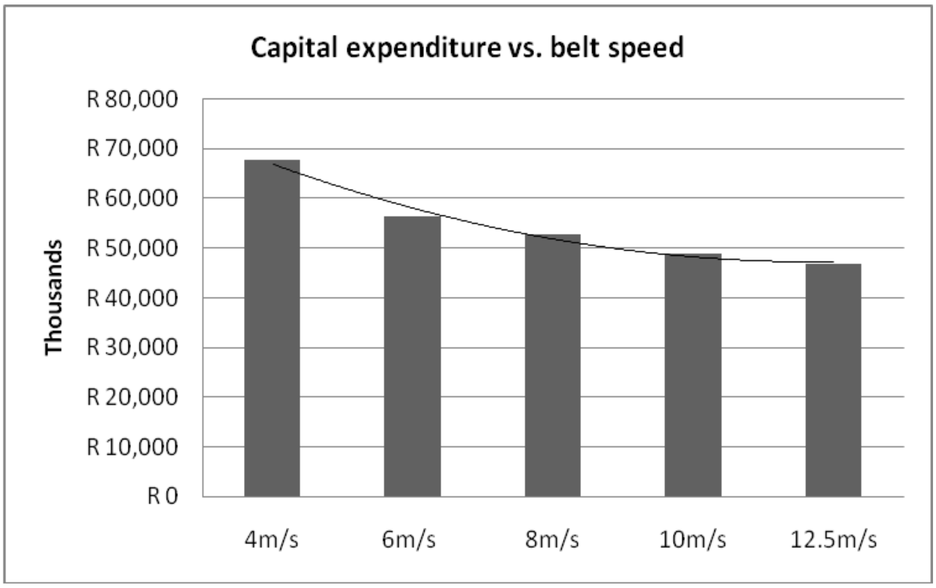


**Figure 1: Graph showing capital expenditure vs. belt width for a given throughput**

Figure 1 shows the general trend from a capital expenditure point of view when considering a wider, slower belt to a narrower, faster belt conveying the same tonnage. There are however also a few other factors that should be considered to ensure a complete comparison can be done between these two options. Factors such as equipment replacement costs (maintenance costs), finance costs and operational costs. Operational costs will be addressed under Section 3.

To illustrate the cumulative effect of all the influencing factors a more detailed comparison has been done between the 1800mm wide belt at 4m/s against the 1200mm wide belt at 10m/s based on the following assumptions:

- The two options have been looked at over a twenty year period.
- All equipment, labour and power costs have been escalated at 8% per annum.
- The high speed belt has an expected life of 5 years against that of 7 years for the slower belt.
- Idlers have a life of 7 years.
- Drives have a life of 10 years.
- Pulleys, VSD's and the steel structure have a life of 20 years.
- Finance costs have been based on Johannesburg Inter Bank Overnight Rate (JIBOR) of 8.3% plus a 4% premium for a total of 12.3%. (June 2009 based)
- Initial capital expenditure is 50% financed over a period of 10 years, thereafter all re-capitalisation is paid in cash.
- Mechanical and structural installation has been ignored as they are assumed similar, however in reality there is probably an additional saving for the narrower belt.
- Civil work has been ignored as the costs are assumed similar, however in reality there is probably an additional saving for the narrower belt.
- Plant operating hours are 335 days per year 12 hrs per day giving a total of 4020 hrs per year.
- Electricity cost is R0.32 per kWhr.

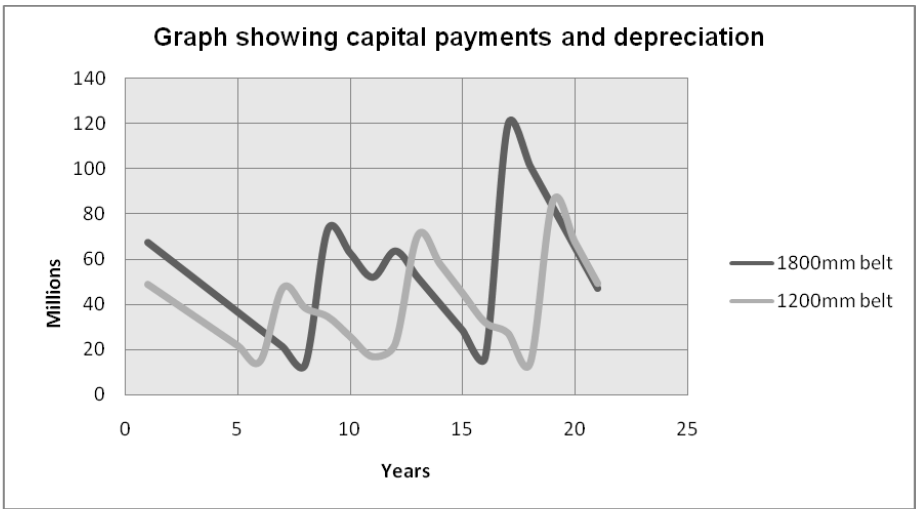


**Figure 2: Capital expenditure (initial and recapitalization) vs. equipment life span**

This graph also gives some idea of future cash flow requirements as the major items are replaced on the conveyors. The major influencing factor is that of belt replacement. The costs of replacing the wider belt are significantly more than those to replace the narrower belt. The cost difference between the two plants indicates that the wider belt remains substantially more expensive throughout the life of the conveyor.

## 3.0 DISADVANTAGES

### 3.1 IDLERS

Idlers are one of the most affected components when belt speeds are increased. Based on previous work done on high speed idlers let us accept that the additional considerations and requirements, when designing higher speed belts, on idlers and their related support structures are:

- Overall conveyor structural alignment, vertical and horizontal, becomes critical.
- Structural rigidity to ensure minimal vibration of the structure as well as to rigidly support the idler frames also becomes critical [2].
- The installation of idler frames becomes critical, both from an alignment point of view as well as to ensure the frames are securely and properly tightened to the structure. It has been noted previously that loose idler frames can play a major part in idler bearing failure due to the vibration [2].
- Idler frames need to be of rigid design [2].
- Idler bearing L10 life is decreased with increasing bearing rpm but is at the same time the L10 life is also increased with the reduced load on the bearings [6].

$$L_{10h} = \frac{1\,000\,000(C/P)^{p}}{60n}$$

- Idler total indicated runout (TIR) and idler mass unbalance at high speeds is another cause of premature idler bearing failure (expand on this) [1].
- Overall higher idler costs as a result of tighter tolerances.
- Forward tilt? – Should well aligned belt conveyors have forward tilting idlers – Possibly not as especially for high speed conveyors this adds additional unwanted resistance and increased belt wear due to scuffing at the higher speeds. Belts that are properly aligned should not require forward tilting idlers, particularly not on the straight sections.
- Design should incorporate optimal idler spacing, belt tensions, belt sag and control as these affect power consumption [1].

### 3.2 BELTING

On higher speed applications, any defect in the belt may be magnified due to the belt speed, thus belts need to be accurately manufactured with high quality splice joints.

Belt wear, due to scuffing on idler rolls if badly aligned, or if idler bases have forward tilting rollers will increase. Belt wear at loading points, if not properly designed to match the material and belt speed along the axis of belt travel, will also increase significantly.

From previous work done on indentation rolling resistance [3] the following is noted:

- Indentation rolling resistance is dependent on the vertical load on the belt (belt plus material), the size of the idler rolls, the visco-elastic properties and thickness of the belt’s bottom cover.
- The most significant influencing factor on indentation rolling resistance is the vertical load.

The use of faster narrower belt results in a lower vertical load. This is an advantage to higher speed conveyors, however it is purely covered here as it falls within the belting section.

## 3.3 MECHANICAL COMPONENTS

For the sake of this paper items such as pulleys and drive systems are referred to as mechanical components, basically those components other than idlers and belting. Without having explored fully the implications on pulley bearings they should not be a major issue. Pulley bearing sizes are usually more dependent on the shaft size after a certain allowed turn down of the pulley shaft. The pulley shaft is generally governed by deflection resulting in comfortable sizing of the pulley bearings. The same scenario is applicable here as was applied to idler bearings – the L10 life will reduce due to increased bearing rpm but the load on the bearing is reduced, while conveying the same load, thus again increasing L10 life to some degree.

As belt speed increases, while conveying the same load, tensions and therefore belt class are reduced. The lower tensions (due to lower resistances) mean a lower gearbox output torque is required. Although this generally reduces initial capital costs starting the belt with lower reduction gearbox may bring some difficulties of its own. Starting requirements after dynamic analysis may also involve more costly equipment in the form of couplings, coolers,VSD's etc.

Power consumption generally increases with an increase in speed. The basic power required comes down to [4] :

$$P=Fv$$

As the velocity increases so does the power consumption. However with narrower belts the F decreases for a given conveyor but typically proportionally not more than the effect of the increased v. This highlights one of the main disadvantages of conveying at high speeds, increased power consumption. For high speed conveying to be an attractive option there will need to be a point reached where the capital savings are substantial enough to off-set the increased power consumption cost.

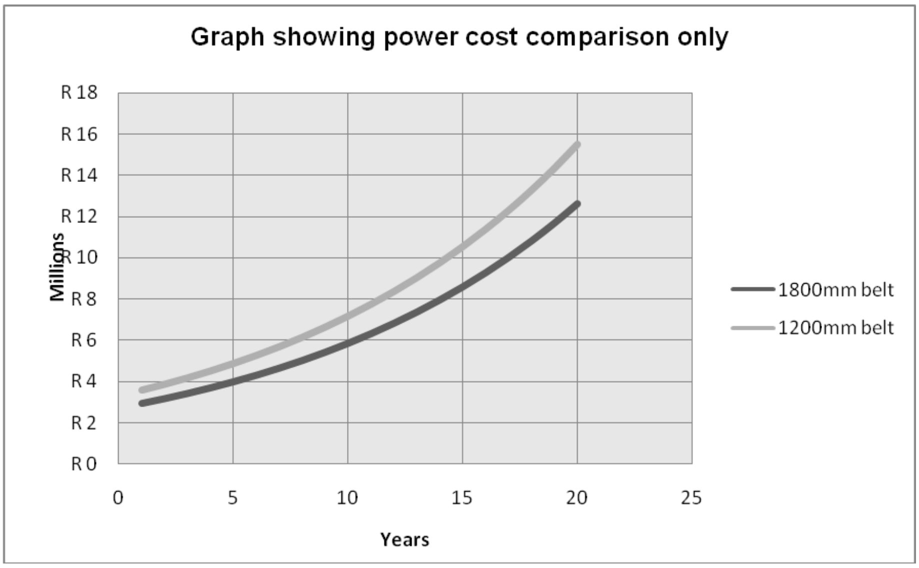


**Figure 3: Graph showing power cost vs. time**

## 3.4 SUPPORT STRUCTURE AND THE INSTALLATION THEREOF

The support structure on high speed conveyors will be subject to a higher excitation frequency and as such may vibrate close to their natural frequency.

Support structures need to be structurally rigid to ensure minimal vibration. It has been shown previously that vibration due to inadequately stiff structures, loose idler frames, flexible idler frames, TIR and mass unbalance of rolls are the major factors in idler failure. It is also understandable that at higher belt speeds areas of misalignment will pose much more of a problem and as such better installations are required for high speed belts.

## 3.5 TRANSFER AND LOADING POINTS

Transfer points can be problem areas even when conveying at low speeds. The transfer of material when using high speed conveying should not be under estimated as it can very easily tarnish all the good design work that may have gone into designing the high speed belt. Typically material degradation, dust generation and chute wear are the major players but don't forget the importance of loading the belt correctly as well.

Material degradation is usually caused in chutes in areas of impact where the particle has a significant and sudden change in speed or direction.

Chute wear also occurs predominantly in these same areas of impact or impact zones. Typically large amounts of money are spent on expensive liner materials to line these zones. Furthermore there is the damage a dislodged worn liner plate can do to a belt and downstream equipment.

Dust generation with certain types of material both while conveying and at transfer points is an area which also must be given the due attention it deserves.

Conveyors should be loaded with the material discharging from the feed chute so that the material and belt speed along the axis of belt travel, are as close as possible. This will assist in reducing dust generation, belt wear, material degradation and power required to accelerate the material to belt speed. Naturally the higher the belt speed the more difficult it is going to be to feed material onto the belt at belt speed. Larger drop heights will be required if gravity is going to be used to do the accelerating, otherwise possibly accelerator belts may be used.

## 4.0 SUMMARY OF ADVANTAGES AND DISADVANTAGES

Therefore high speed conveyors require:

- low TIR and mass unbalance [1]
- Good starting and stopping procedures [1]
- Optimal idler spacing, belt tensions, belts sag control as this affects power consumption [1]
- Well designed transfer points
- Well installed rigid structure and idler support with properly secured idler frames
- More installed power
- Less initial capital and subsequent re-capitalization expenses

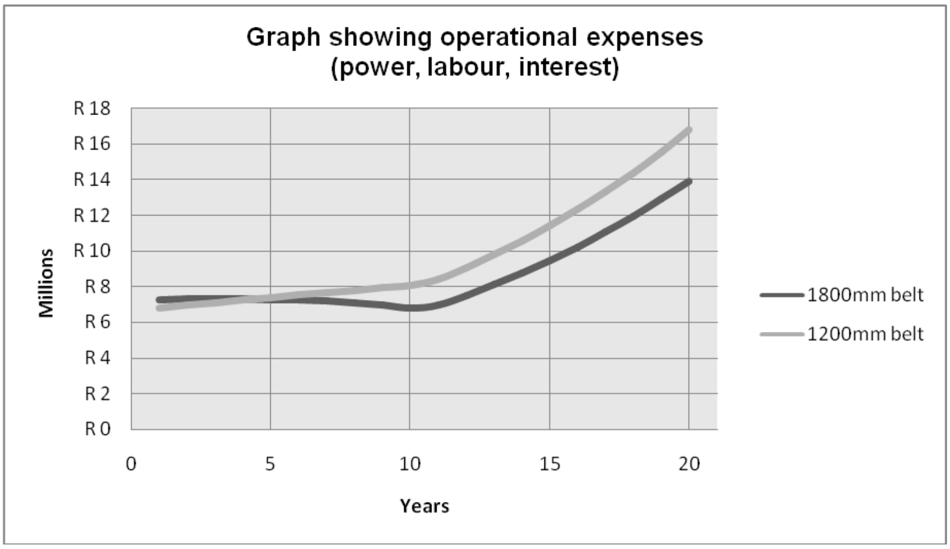


**Figure 4: Graph showing operational cost vs. time**

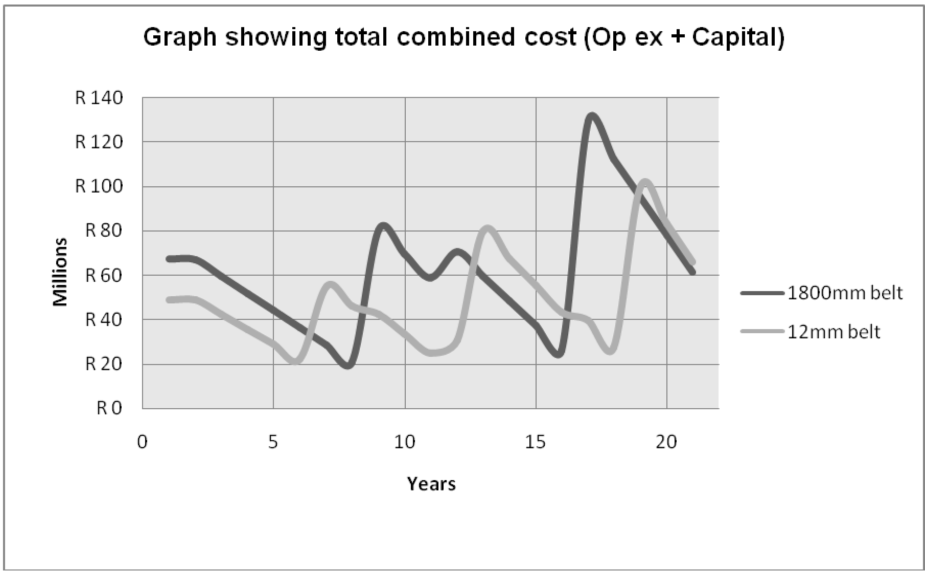


**Figure 5: Graph showing total combined cost**

As a final approach to analysing these different costs, and possibly the most simple but effective way to get a feeling for the magnitude of saving in today's money, is to bring these costs (from figure 5) back to a net present value (NPV).

The approximate net present value (NPV) of the 1200mm wide belt = R162.5 mil over the twenty year period.

The approximate net present value (NPV) of the 1800mm wide belt = R175.8 mil over the twenty year period.

Saving of R13.3 mil. (13.3/175.8 = 7.6%)

As the belt costs are the most significant factor, cost savings are very dependent on belt replacement assumptions.

## 5 SOME PROPOSED SOLUTIONS

Being aware of the advantages and disadvantages of high speed conveying, solutions that enhance the benefits and minimise the problems should be developed. Assuming the design of an overland based on examples already looked at is:

Length: 6000 m
Lift: 60 m
Coal at 4000 t/h at 10 m/s

| **Design parameters** | | | |
|---|---|---|---|
| Belt speed | m/s | 10 | |
| Capacity | t/h | 4000 | |
| Belt S.F on steady state | | min 6 | |
| Carry Idler spacing | m | 2.5 (7.5) | Consider belt flap – addressed in Section |
| Carry idler series | | 40 | |
| Return idler series | | 30 | |
| Carry idler trough angle | deg | 45 | Should well aligned belt conveyors have forward tilting idlers – Possibly not, especially on the 'straight' sections as this adds additional unwanted resistance and increased belt wear due to scuffing at the higher speeds. |
| Idler roll diam | mm | 152 | Selecting a larger idler diameter does not have a significant enough effect on idler rpm. 152 to 180mm diameter gives 15% reduction in idler rpm but then will increase the system inertia. A suitable bearing can usually be selected if required to retain the required L10 life, however as can be seen from the data above if the calculated L10 life was reduced by 15% the idlers would still achieve their design L10 life of around 60000 hrs. L10 life reduced by 15% can still be selected to be better than grease expectancy life. |
| Sag percentage | % | 0.5 | |
| Minimum L10 idler life required | hrs | 60000 | It is certainly my opinion that bearings designed for hours above say 60 000 is practically of little use as the useful grease life is well below that. |
| Friction factor | | 0.017 | |
| **Calculated values** | | | |
| T1 | kN | 368 | |
| Belt width | mm | 1200 | |
| % belt fill | % | 79 | |
| Belt class | | ST2000 | |
| Idler speed | rpm | 1256 | |
| L10 carry idler life | hrs | 77727 | More than adequate as grease life will be well below this. |
| L10 return idler life | hrs | 236522 | Same comment as above |
| Carry idler bearing | | 6308 | |
| Return idler bearing | | 6306 | |
| Load on centre roll | N | 4549 | |
| Absorbed power | kW | 2789 | |

**Table 4: Design parameters, calculated design values and reasons for selection**

Assuming that the design issues around idlers can be overcome and designed out, which is possible, and assuming that the belting bottom cover is suitably designed for minimal resistance due to indentation rolling resistance. Assuming that resistance due to sag has been minimised by limiting sag to 0.5%. Furthermore assuming the conveyor has been dynamically analysed and the appropriate drive and brake systems are selected together with good starting and stopping procedures. Finally accept that a good installation with well aligned structure is achievable with the correct quality checks in place, it still leaves two areas that still can cause significant problems. These areas being the conveyor support structure to eliminate or reduce vibrations and the transfer points.

### 5.1 PRE-CAST MODULE FOR OVERLAND AND HIGH SPEED APPLICATIONS

The Bateman pre-cast module (Patent application number 2008/03573) for overland and high speed applications.

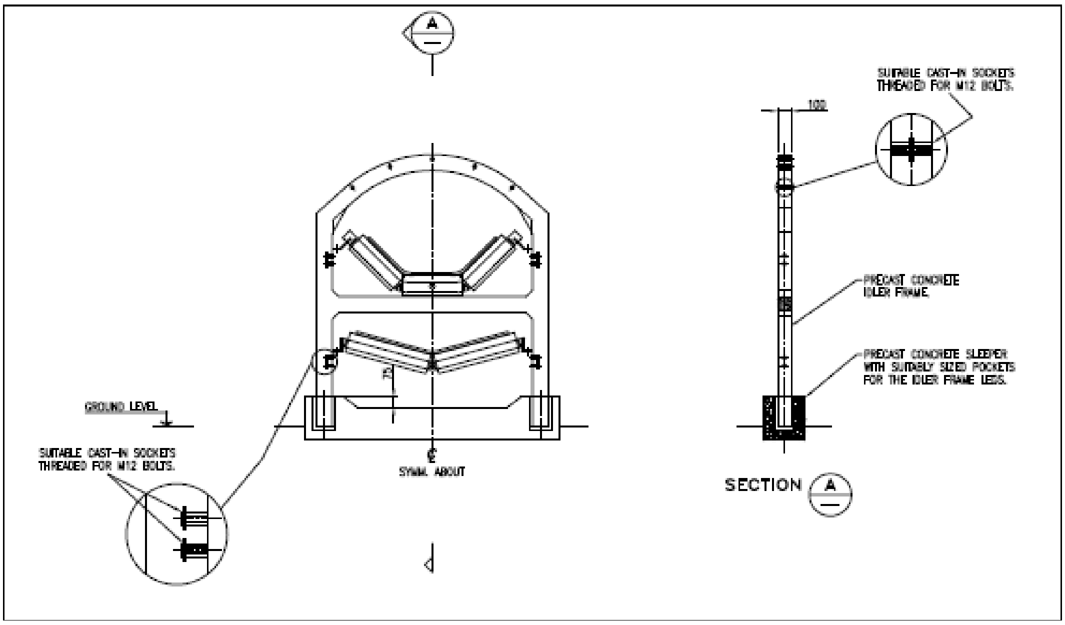


**Figure 6: Pre-Cast Module for 1200mm wide belts**

The overland section of long conveyors typically presents the greatest opportunity for structural savings and to reduce the effect of vibration as it contains the vast majority of the idlers and structural steel. Therefore development work in this area has led to the design of a pre-cast concrete module for a 1200 mm belt. The intension of the module is two fold. Firstly, to attempt to reduce cost with steel prices going where they were and secondly, to provide a stiff structure to reduce the effect of vibration due to belt flap and idler un-balance. As mentioned before, previous work has shown that idler vibration is a major cause of idler bearing failure and this structure should contribute to reducing those failures.

Looking briefly at belt flap for these two conveyors. Belt flap, particularly on the return side must be considered. However as can be seen from Figure 7 below, the natural frequencies of the different belts for the particular belt profiles considered remain fairly constant without much variation. The excitation or idler induced frequency continually increases as the belt speed increases.

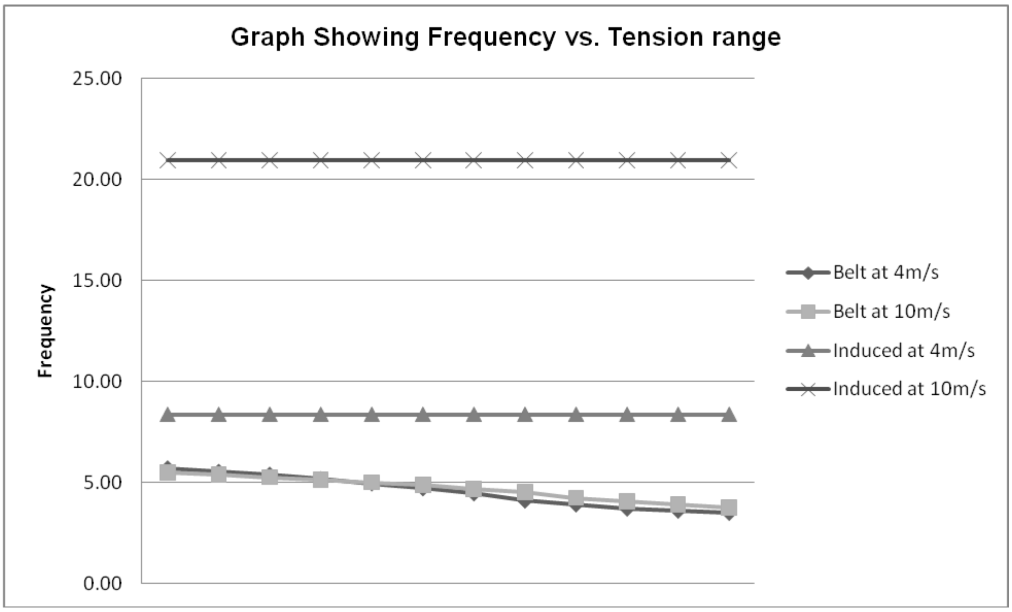


**Figure 7: Graph showing belt natural frequency vs. idler induced frequency**

Although a situation may occur where the third or four mode of the belt will coincide with the idler excitation frequency, these higher modes are usually of far less of a concern, with only the first or second mode really posing a potential problem.

Comparing a fairly standard overland conveyor using ground line type modules for a 1200mm wide belt at 45kg/m, for argument sake, the concrete module can offer substantial savings on the structural cost while providing a rigid structure.

| **Capital cost of 1200mm belt at 10m/s (cost in R1000's)** | | |
|---|---|---|
| **Capital Equipment** | | |
| | **10m/s** | |
| | **(1200mm belt)** | |
| | R 1000's | % of total |
| Idlers | 5,298 | 11% |
| Belting | 23,484 | 48% |
| Drive | 4,887 | 10% |
| Pulleys | 1,582 | 3% |
| Electricals (VSD's) | 5,800 | 12% |
| Support Structure | 7,830 | 16% |
| | **R 48,880** | 100% |

**Table 5: Table showing an extract from Table 3 highlighting the 10m/s 1200mm belt capital breakdown**

## 5.2 CYCLO-CHUTE FOR HIGH SPEED APPLICATIONS

Taking a look at transfer points and introducing the Bateman Cyclo-Chute (Provisional Patent number 2009/02591).

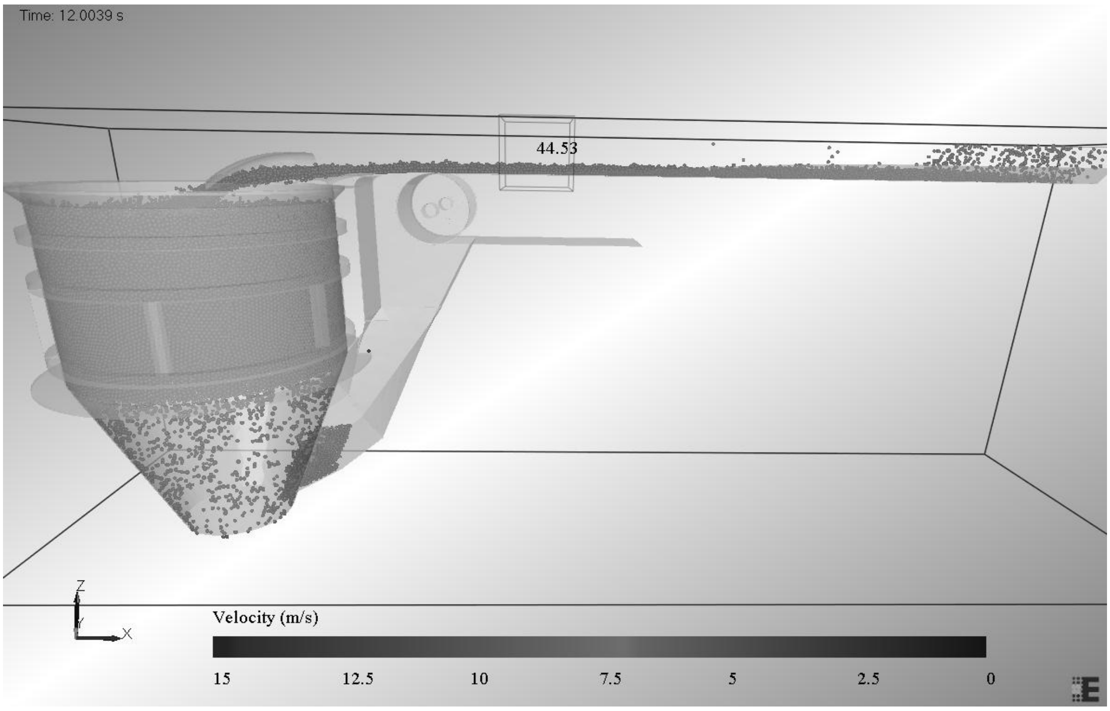


**Figure 8: Cyclo-Chute**

The ‘Cyclo-Chute’ is intended to function as a low wearing transfer chute from one or more high speed conveyor(s) to the next or from one or more high speed conveyor(s) to a slower conveyor or from one or more high speed conveyor(s) to a storage facility (bin, silo, stockpile etc.).

The chute is specifically designed to work on the principal of reducing chute wear, material degradation and dust generation by matching the tangential velocity of the chute wall to that of the incoming material as closely as possible in the most cost effective way possible. The cylindrical portion of the chute is the rotating part with the conical discharge section stationary. The cylindrical portion is driven by some form of drive system before conveyor start-up to ensure the drum is rotating at the correct angular velocity to accept material from the conveyor. This drive system may be able to be disengaged once the system is running using the momentum of the incoming material to maintain the required angular velocity. If not, the drive will remain engaged.

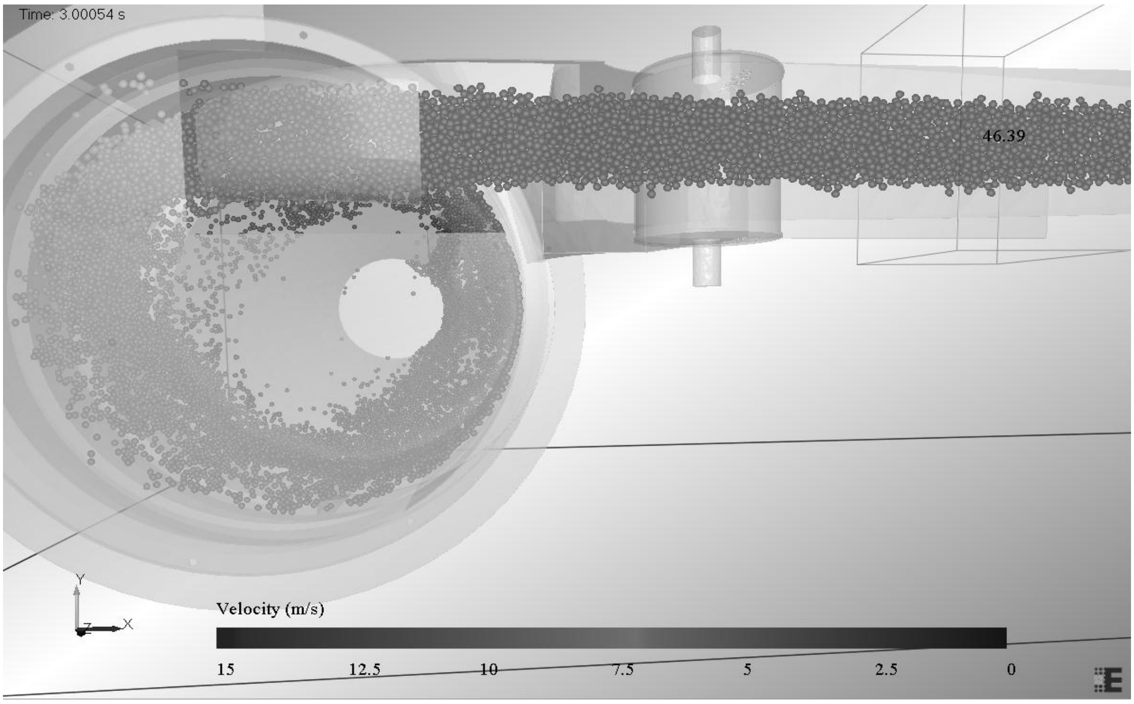


**Figure 9: Figure showing revolving cylindrical portion to reduce wear**

During normal operation the material enters the chute and the angular velocity and associated centrifugal forces cause the material to remain suspended on the vertical chute wall. As more material is added to the chute a vertical bed of material is formed in the same way.

The bed depth builds up to a point where the radius of rotation becomes reduced, thus reducing the outward centrifugal forces to a point where gravity becomes dominant and the material falls down into the conical section in a controlled fashion and at a greatly reduced velocity. This material is then discharged out of the conical section in any direction.

The incoming velocity and the tangential speed can be clearly seen in Figure 9. Figure 10, shows the chute later in time when full and clearly shows the reduction in speed from the incoming to the outgoing material. The outgoing material is in the region of 2.5m/s.

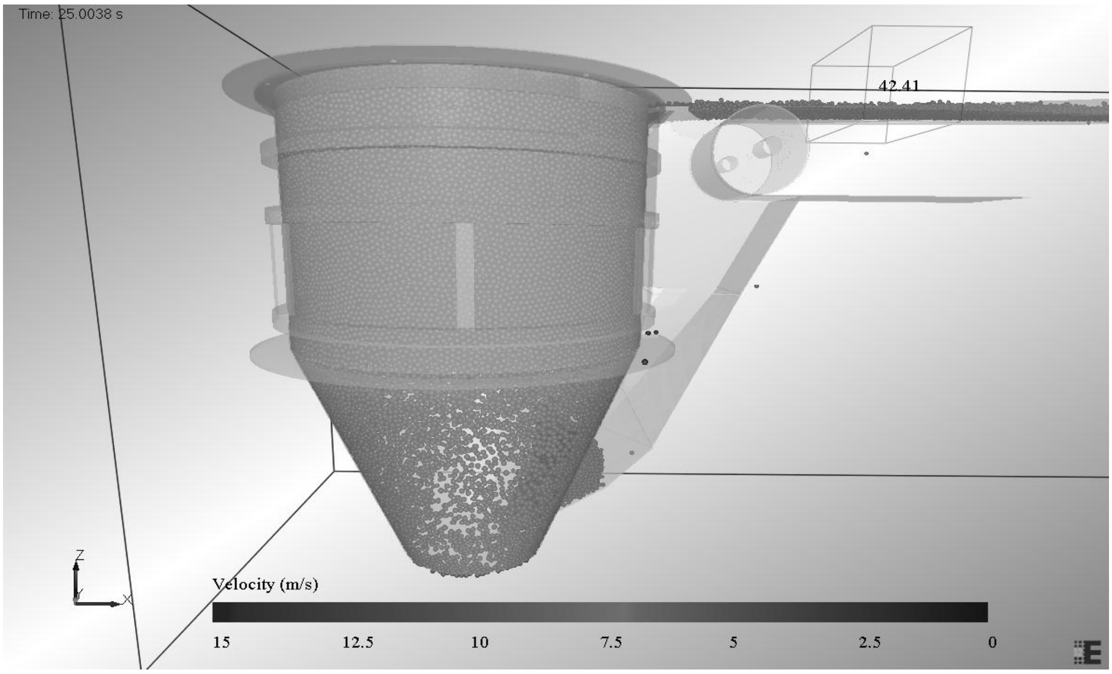


**Figure 10: Figure showing material beginning to discharge**

Furthermore with the bed of material held against the side of the chute by centrifugal forces there is the added protection of material on material. Due to this fact of low or no relative velocities and small angles of incidence where the two material streams come in contact with one another, there will be very little material degradation. Should dust control be an issue this chute lends itself well to the installation of a hood structure on top of the cylindrical section with the dust dropping back into the chute or being extracted completely.

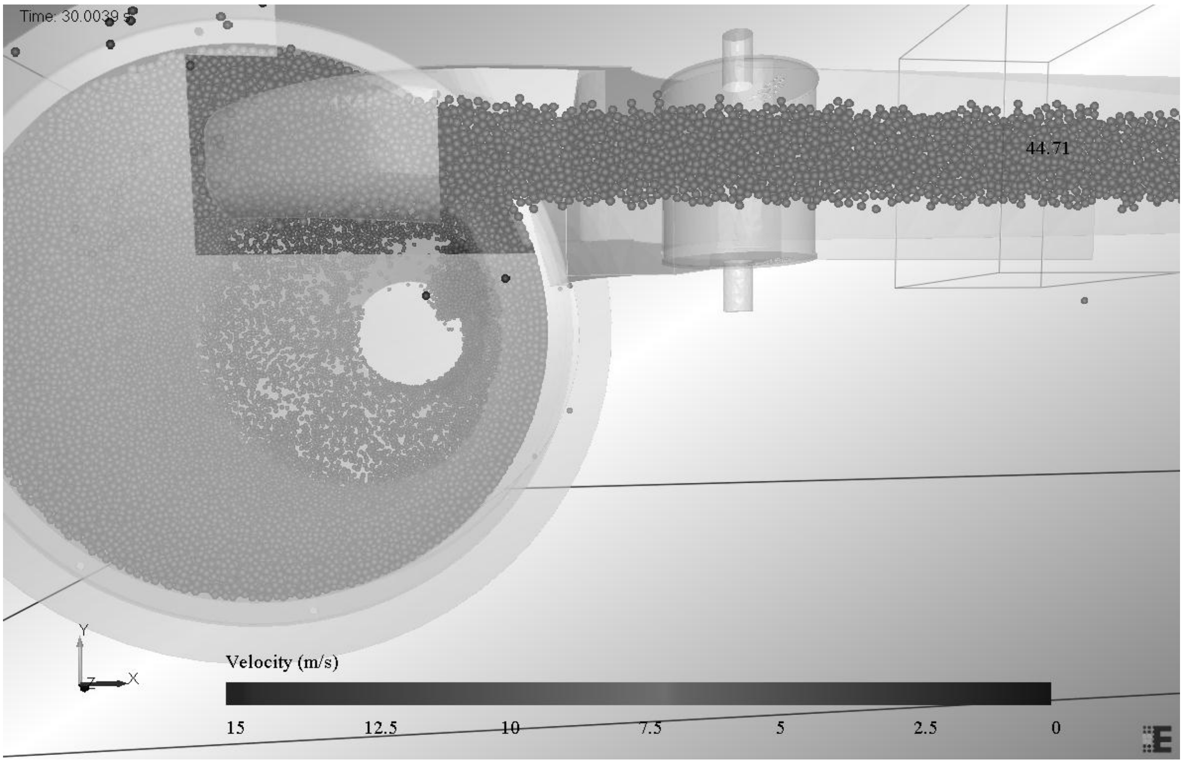


**Figure 11: Figure showing bed of material to eliminate wear and reduce degradation**

## 6 CONCLUSION

Sooner or later we will reach a practical optimised maximum belt speed, which seems to be around the 10m/s mark. But one thing is for sure that more and more high speed conveyors will be installed around the world.

It has been shown that there are ways and means to get around the issues of high speed conveying. There is a need, which can only grow over time, for formalising requirements for high speed idlers and incorporating them into our industry standards.

Furthermore, given the fact that indentation rolling resistance still forms a significant portion of belt resistance, there is room for further development or investigation into the use of larger diameter idler rolls and possible further development of a conveyor belt bottom cover grade of rubber for the overland type of belt where the additional belt cost may be well worth it in the longer term as it would further reduce the power consumption.

High speed conveying is shown to be a more cost effective solution over a twenty year period. However the analysis is very dependent on belt life. Belt replacements are the most significant costs in maintaining the conveyors so all attempts and measures that are put in place, be they in the form of monitoring equipment or in the form of operational attitudes will be well worth the effort.

## 7 REFERENCES


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## 8 ACKNOWLEDGEMENTS

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## 10 APPENDIX 1 – Graph data

| | | |
|---|---|---|
| Hours/yr | 4,020 | |
| Ave Cost | 0.32 | R/kWh |
| | Capital expenses | |

| 1800mm WIDE BELT AT 4m/s | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Idlers | Belting | Drives | Pulleys | Electrical (VSD's etc) | Steel | Sub total | Book value | Labour | Oportunity / Interest cost | Electricity | Total | Op Ex | Op Ex + Book |
| Life span | | 7 | 7 | 10 | 10 | 20 | 20 | | | | | | | | |
| Initial capital | | 8,511,200 | 32,688,000 | 6,559,364 | 3,249,341 | 5,200,000 | 11,310,000 | 67,517,905 | 67,517,905 | | | | 67,517,905 | | 67,517,905 |
| Year 1 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 59,825,935 | 300,000 | 4,051,398 | 2,925,274 | 7,276,672 | 7,276,672 | 67,102,606 |
| Year 2 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 52,133,964 | 324,000 | 3,813,020 | 3,159,295 | 7,296,316 | 7,296,316 | 59,430,280 |
| Year 3 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 44,441,994 | 349,920 | 3,543,611 | 3,412,039 | 7,305,570 | 7,305,570 | 51,747,564 |
| Year 4 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 36,750,023 | 377,914 | 3,239,131 | 3,685,002 | 7,302,047 | 7,302,047 | 44,052,070 |
| Year 5 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 29,058,053 | 408,147 | 2,895,015 | 3,979,802 | 7,282,965 | 7,282,965 | 36,341,017 |
| Year 6 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 21,366,082 | 440,798 | 2,506,104 | 4,298,187 | 7,245,089 | 7,245,089 | 28,611,171 |
| Year 7 | | -1,215,886 | -4,669,714 | -655,936 | -324,934 | -260,000 | -565,500 | -7,691,971 | 13,674,112 | 476,062 | 2,066,564 | 4,642,042 | 7,184,668 | 7,184,668 | 20,858,780 |
| Year 8 | | 5,415,685 | 56,021,488 | -655,936 | -324,934 | -260,000 | -565,500 | 59,630,802 | 73,304,913 | 514,147 | 1,569,808 | 5,013,405 | 68,534,532 | 7,097,360 | 80,402,273 |
| Year 9 | | -773,669 | -8,003,070 | -655,936 | -324,934 | -260,000 | -565,500 | -10,583,109 | 62,721,804 | 555,279 | 1,008,385 | 5,414,477 | 6,978,141 | 6,978,141 | 69,699,945 |
| Year 10 | | -773,669 | -8,003,070 | -655,936 | -324,934 | -260,000 | -565,500 | -10,583,109 | 52,138,695 | 599,701 | 373,878 | 5,847,635 | 6,821,215 | 6,821,215 | 58,959,909 |
| Year 11 | | -773,669 | -8,003,070 | 14,161,175 | 7,015,084 | -260,000 | -565,500 | 11,574,020 | 63,712,714 | 647,677 | | 6,315,446 | 28,139,382 | 6,963,124 | 70,675,838 |
| Year 12 | | -773,669 | -8,003,070 | -1,416,117 | -701,508 | -260,000 | -565,500 | -11,719,865 | 51,992,849 | 699,492 | | 6,820,682 | 7,520,174 | 7,520,174 | 59,513,023 |
| Year 13 | | -773,669 | -8,003,070 | -1,416,117 | -701,508 | -260,000 | -565,500 | -11,719,865 | 40,272,985 | 755,451 | | 7,366,337 | 8,121,788 | 8,121,788 | 48,394,772 |
| Year 14 | | -773,669 | -8,003,070 | -1,416,117 | -701,508 | -260,000 | -565,500 | -11,719,865 | 28,553,120 | 815,887 | | 7,955,643 | 8,771,531 | 8,771,531 | 37,324,650 |
| Year 15 | | -773,669 | -8,003,070 | -1,416,117 | -701,508 | -260,000 | -565,500 | -11,719,865 | 16,833,255 | 881,158 | | 8,592,095 | 9,473,253 | 9,473,253 | 26,306,508 |
| Year 16 | | 9,281,532 | 96,010,985 | -1,416,117 | -701,508 | -260,000 | -565,500 | 102,349,391 | 119,182,646 | 951,651 | | 9,279,463 | 115,523,630 | 10,231,113 | 129,413,760 |
| Year 17 | | -1,325,933 | -13,715,855 | -1,416,117 | -701,508 | -260,000 | -565,500 | -17,984,914 | 101,197,732 | 1,027,783 | | 10,021,820 | 11,049,602 | 11,049,602 | 112,247,335 |
| Year 18 | | -1,325,933 | -13,715,855 | -1,416,117 | -701,508 | -260,000 | -565,500 | -17,984,914 | 83,212,818 | 1,110,005 | | 10,823,565 | 11,933,571 | 11,933,571 | 95,146,389 |
| Year 19 | | -1,325,933 | -13,715,855 | -1,416,117 | -701,508 | -260,000 | -565,500 | -17,984,914 | 65,227,904 | 1,198,806 | | 11,689,450 | 12,888,256 | 12,888,256 | 78,116,160 |
| Year 20 | | -1,325,933 | -13,715,855 | -1,416,117 | -701,508 | -260,000 | -565,500 | -17,984,914 | 47,242,990 | 1,294,710 | | 12,624,606 | 13,919,317 | 13,919,317 | 61,162,307 |
| | | | | | | | | | | | | | 428,085,623 | 172,661,771 | |
| NPV | | | | | | | | | | | | | 175,762,075 | | |

| 1200mm WIDE BELT AT 10m/s | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Idlers | Belting | Drives | Pulleys | Electrical (VSD's etc) | Steel | Sub total | Book value | Labour | Oportunity / Interest cost | Electricity | Total | Op Ex | Op Ex + Book |
| Life span | | 7 | 5 | 10 | 10 | 20 | 20 | | | | | | | | |
| Initial capital | | 5,297,600 | 23,484,000 | 4,886,576 | 1,581,775 | 5,800,000 | 7,830,000 | 48,879,951 | 48,879,951 | | | | 48,879,951 | | 48,879,951 |
| Year 1 | | -756,800 | -4,696,800 | -488,658 | -158,178 | -290,000 | -391,500 | -6,781,935 | 42,098,016 | 300,000 | 2,933,032 | 3,587,770 | 6,820,801 | 6,820,801 | 48,918,817 |
| Year 2 | | -756,800 | -4,696,800 | -488,658 | -158,178 | -290,000 | -391,500 | -6,781,935 | 35,316,081 | 324,000 | 2,760,457 | 3,874,791 | 6,959,248 | 6,959,248 | 42,275,329 |
| Year 3 | | -756,800 | -4,696,800 | -488,658 | -158,178 | -290,000 | -391,500 | -6,781,935 | 28,534,146 | 349,920 | 2,565,417 | 4,184,774 | 7,100,111 | 7,100,111 | 35,634,257 |
| Year 4 | | -756,800 | -4,696,800 | -488,658 | -158,178 | -290,000 | -391,500 | -6,781,935 | 21,752,211 | 377,914 | 2,344,987 | 4,519,556 | 7,242,457 | 7,242,457 | 28,994,667 |
| Year 5 | | -756,800 | -4,696,800 | -488,658 | -158,178 | -290,000 | -391,500 | -6,781,935 | 14,970,276 | 408,147 | 2,095,862 | 4,881,121 | 7,385,130 | 7,385,130 | 22,355,405 |
| Year 6 | | -756,800 | 34,505,701 | -488,658 | -158,178 | -290,000 | -391,500 | 32,420,565 | 47,390,841 | 440,798 | 1,814,307 | 5,271,611 | 42,032,417 | 7,526,716 | 54,917,557 |
| Year 7 | | -756,800 | -6,901,140 | -488,658 | -158,178 | -290,000 | -391,500 | -8,986,275 | 38,404,566 | 476,062 | 1,496,100 | 5,693,339 | 7,665,502 | 7,665,502 | 46,070,068 |
| Year 8 | | 4,414,811 | -6,901,140 | -488,658 | -158,178 | -290,000 | -391,500 | -3,814,664 | 34,589,902 | 514,147 | 1,136,471 | 6,148,807 | 12,214,236 | 7,799,425 | 42,389,326 |
| Year 9 | | -630,687 | -6,901,140 | -488,658 | -158,178 | -290,000 | -391,500 | -8,860,163 | 25,729,739 | 555,279 | 730,026 | 6,640,711 | 7,926,016 | 7,926,016 | 33,655,755 |
| Year 10 | | -630,687 | -6,901,140 | -488,658 | -158,178 | -290,000 | -391,500 | -8,860,163 | 16,869,577 | 599,701 | 270,671 | 7,171,968 | 8,042,340 | 8,042,340 | 24,911,917 |
| Year 11 | | -630,687 | -6,901,140 | 10,549,751 | 3,414,934 | -290,000 | -391,500 | 5,751,357 | 22,620,934 | 647,677 | | 7,745,725 | 22,358,088 | 8,393,403 | 31,014,337 |
| Year 12 | | -630,687 | 50,700,195 | -1,054,975 | -341,493 | -290,000 | -391,500 | 47,991,539 | 70,612,473 | 699,492 | | 8,365,384 | 59,765,070 | 9,064,875 | 79,677,348 |
| Year 13 | | -630,687 | -10,140,039 | -1,054,975 | -341,493 | -290,000 | -391,500 | -12,848,695 | 57,763,778 | 755,451 | | 9,034,614 | 9,790,065 | 9,790,065 | 67,553,843 |
| Year 14 | | -630,687 | -10,140,039 | -1,054,975 | -341,493 | -290,000 | -391,500 | -12,848,695 | 44,915,083 | 815,887 | | 9,757,383 | 10,573,270 | 10,573,270 | 55,488,354 |
| Year 15 | | -630,687 | -10,140,039 | -1,054,975 | -341,493 | -290,000 | -391,500 | -12,848,695 | 32,066,389 | 881,158 | | 10,537,974 | 11,419,132 | 11,419,132 | 43,485,521 |
| Year 16 | | 7,566,211 | -10,140,039 | -1,054,975 | -341,493 | -290,000 | -391,500 | -4,651,797 | 27,414,592 | 951,651 | | 11,381,012 | 19,898,873 | 12,332,663 | 39,747,255 |
| Year 17 | | -1,080,887 | -10,140,039 | -1,054,975 | -341,493 | -290,000 | -391,500 | -13,298,895 | 14,115,697 | 1,027,783 | | 12,291,493 | 13,319,276 | 13,319,276 | 27,434,973 |
| Year 18 | | -1,080,887 | 74,495,219 | -1,054,975 | -341,493 | -290,000 | -391,500 | 71,336,364 | 85,452,061 | 1,110,005 | | 13,274,812 | 88,880,037 | 14,384,818 | 99,836,879 |
| Year 19 | | -1,080,887 | -14,899,044 | -1,054,975 | -341,493 | -290,000 | -391,500 | -18,057,900 | 67,394,162 | 1,198,806 | | 14,336,797 | 15,535,603 | 15,535,603 | 82,929,765 |
| Year 20 | | -1,080,887 | -14,899,044 | -1,054,975 | -341,493 | -290,000 | -391,500 | -18,057,900 | 49,336,262 | 1,294,710 | | 15,483,741 | 16,778,451 | 16,778,451 | 66,114,713 |
| | | | | | | | | | | | | | 430,586,074 | 196,059,302 | |
| NPV | | | | | | | | | | | | | 162,488,774 | | |