NON-GRAVITY TAKE-UP TECHNOLOGY

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INTRODUCTION

Despite the title of this paper, there is no intent to discredit gravity take-up towers which have been in operation for decades and will remain so for years to come.

Modern belt conveyors require more complex take-up systems than the older, slower conveyors of years gone by in that the technology to effectively ramp and run conveyors has advanced considerably over the past 20 years.

An example is given of a conveyor that requires a large take-up capacity such as a longwall development conveyor or a gate conveyor. Typically this requires an effective take-up length of at least 300 m. Storage lengths of up to 720 m have been built.

The importance of the take-up system sensitivity as a whole is emphasized. It is thus necessary to consider ropes, sheaves, carriage rolling elements etc.

The aggressive nature of conveyor ramping plays an important part in the selection of the take-up technology. Fortunately, in modern conveyors, the designer has suitable ramping technology available for smooth conveyor starting. These technologies are more lenient on the take-up systems employed.

Furthermore, a case is presented addressing the safety issues pertaining to stored energy where this has proved lethal. It thus becomes necessary to advise personnel about the effective removal of stored energy from a conveyor prior to work being carried out on the conveyor. If the stored energy cannot be released, then the necessary precautions need to be taken to work in a safe manner, being aware of the presence of the stored energy.

Gravity take-up units (GTUs) are well understood and have been used for the tensioning of various strings or strands on belts for decades. GTUs, as we know them, make use of a pre-calculated mass designed for the requirement and then applied in a vertical or horizontal take-up tensioning device. To give an example outside of the conveying industry, note how the power feed lines are tensioned for electric locomotives on most railway systems worldwide. The advantage is that the GTU applies a constant tension and accommodates the linear differential in accordance with the coefficient of linear expansion measured in m/°C for the particular overhead feeder cable in use.
This paper discusses technologies other than gravity based technologies used in the tensioning of conveyor systems.

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A T2 AREA DESIGN REQUIREMENTS

Before discussing any of the methods employed to tension a conveyor, there are a few issues that require clarification. The importance of sensitivity to the take-up system as a whole needs to be emphasized. It is thus necessary to look at the aspects pertaining to the T2 area of the conveyor.

Definition of T2 area of the Conveyor:
The T2 area of a conveyor encompasses the region where the belt departs from the last drive pulley entering the take-up system to where the belt enters normal structure on the return side of the conveyor. The winch, GTU or other take-up methods positioned in this region form part of the T2 area of the conveyor.

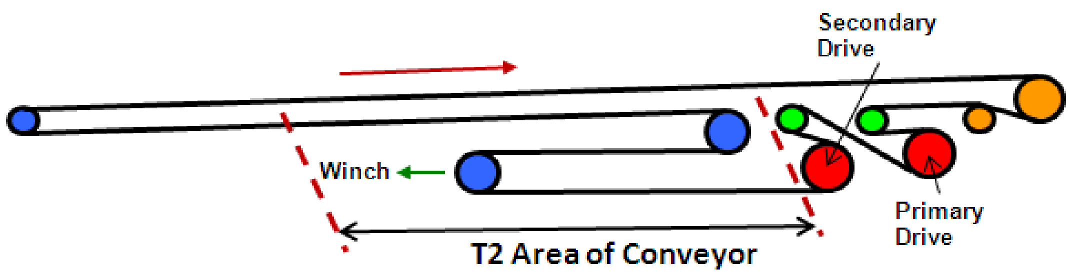


Figure 1. T2 area of conveyor

The carriage design, the rail or guidance system, LTU pulley, carriage wheels, steel wire ropes, sheaves, clamps, belt storage units, LT pulleys, applicable guards and nip guards, tensioning device, load cells with indication and feedback, mechanical and electrical limits etc. are all part and parcel of the T2 area.

It is imperative that the T2 area is correctly designed and ***properly maintained*** in order to offer effective tensioning to the conveyor. The reason for this requirement is that the take-up system needs to at all times be ***sensitive*** and capable of responding easily to the changing requirements of the conveyor during ramping, running, coasting and braking, as well as load variations if applicable.

A1 TAKE-UP CARRIAGE, PULLEYS AND ROLLING ELEMENTS

The design of the take-up carriage needs to be "over square", preferably by the ratio of 1,5:1. This effectively requires that the length of the carriage between the carriage wheels should be 1,5 times the width between the carriage wheels. This allows the carriage to track without undue side resistances in the carriage rails, thus preventing skewing of the carriage or unwanted resistances that would decrease the sensitivity of the take-up or have a negative effect on tracking.

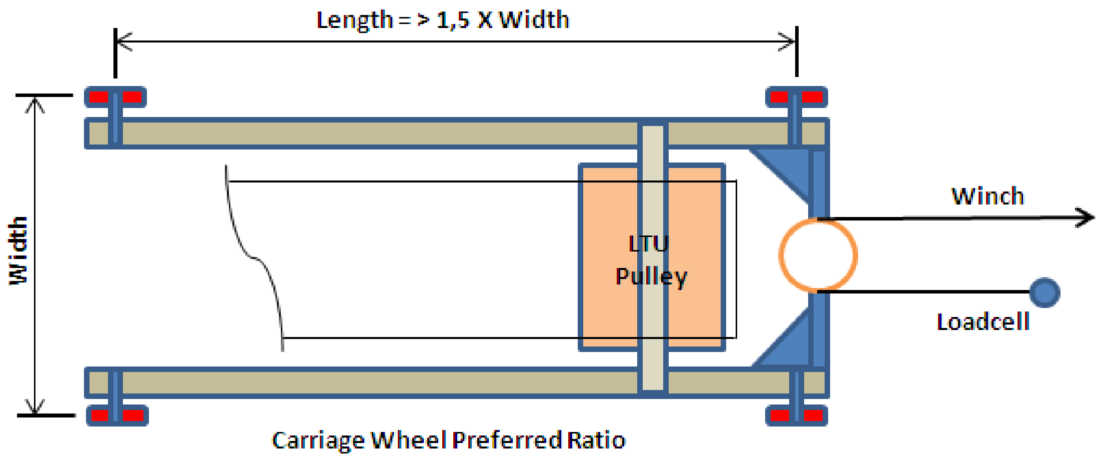


Figure 2. Carriage wheel preferred ratio

The rolling elements should incorporate roller bearings and no bushes of any sort. Bronze, brass, Glacier and industrial plastic bushes have an unacceptably high rolling resistance and for this reason they are not recommended. Greased roller bearings can be used provided that they are greased on a regular basis, alternatively sealed bearings should be fitted. It is not uncommon to fit two or three sealed bearings per carriage wheel dependant on the loading, based on the combined pulley and carriage mass. On belt storage carriages, there are normally three take-up pulleys fitted, requiring highly loaded rolling elements.

Carriage wheel design needs to be considered, but encapsulated carriage wheels are preferred. In areas where fines, dust and minor spillage is present in the LTU area, it is advisable to fit scraper blocks on either side of the carriage wheels to further reduce resistance to sensitivity.

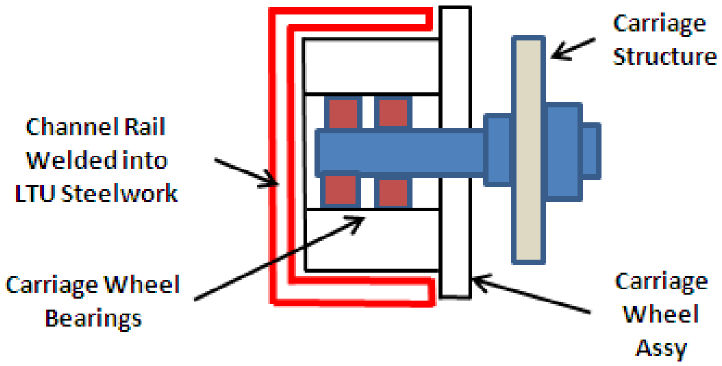


Figure 3a. Encapsulated carriage wheel (Preferred)

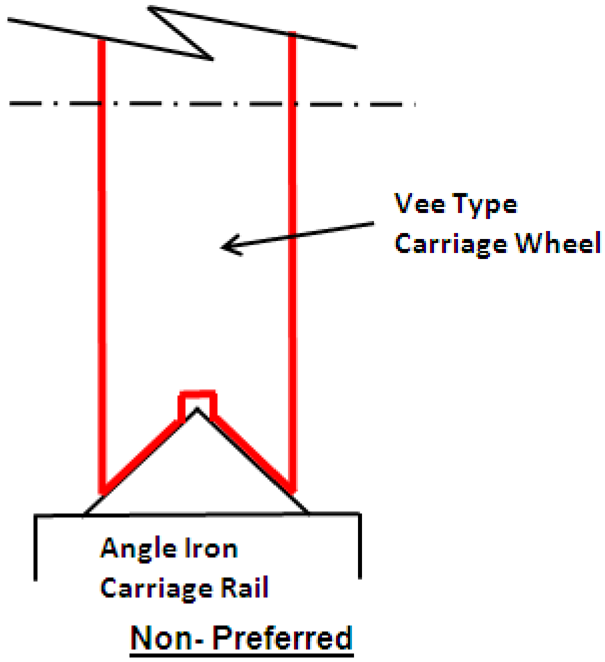


Figure 3b. Vee type carriage wheel (Non-preferred)

When carriage wheels of the Vee type are used, one end is located on the axle to prevent any "snaking" of the carriage due to rail misalignment, and the opposite end is free to move laterally on the carriage shaft. For this purpose bushes are normally used which add to the insensitivity of the carriage making it non-preferred. A second inverted angle is normally placed above the lower angle with a 3–5 mm gap to prevent carriage derailment.

A2 WINCH ROPES AND SHEAVES

The design of the winch rope is critical and important to the conveyor. Although it is recommended that 6 x 36 construction rope be used, if a more inflexible rope is used, then the system must be designed for this choice of rope. The rope is normally terminated at a load cell required to indicate belt tension within the system. This termination generally uses suitable Crosby clamps correctly placed according to the rope manufacturer's specifications.

Rope Termination

The rope end normally terminates onto a thimble attached to a load cell by means of a suitable shackle. The fold back must be in accordance with the required rope safety standards and the correct thimble and applicable number of Crosby clamps must be correctly fitted. BS 462 specifies the following number of Crosby clamps to be used on a termination:

Diameter of Rope	Not Less Than
Up to 19 mm	3
19 mm to 32 mm	4
32 mm to 38 mm	5

Table 1. Diameter of rope and number of Crosby clamps necessary

The Crosby clamps should be spaced at a distance of six rope diameters. If correctly fitted and spaced, the termination would be expected to hold up to between 85% and 90% of the rope's actual breaking strength.

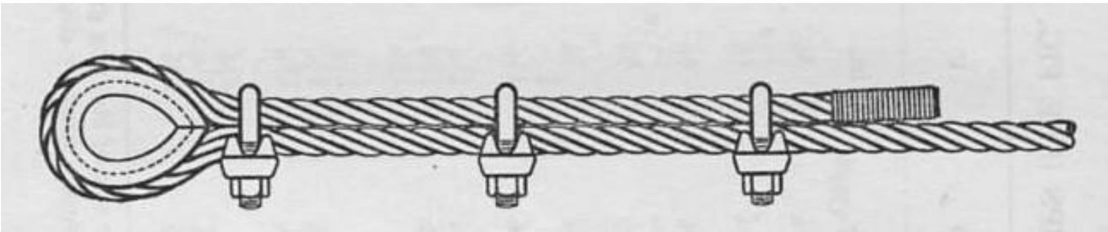


Figure 4a. Correct method of fitting Crosby clamps – BS 462

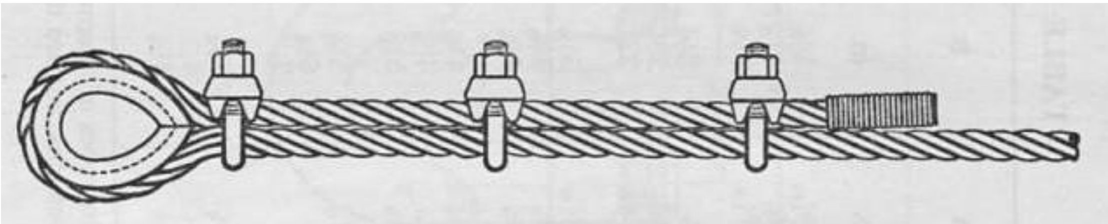


Figure 4b. Incorrect method of fitting Crosby clamps – BS 462

Rope Type and Construction

A 6 x 36 rope construction is recommended when used for the tensioning of the conveyor take-up systems due to its flexibility and reduced requirement on the sheave diameter.

Bending Friction

When a rope is bent around a sheave or pulley, its component parts attempt to re-align themselves in such a way as to equalise the stress throughout the cross-sectional area of the rope. The smaller the sheave diameter, the greater the bending stresses.

Distance between Sheaves

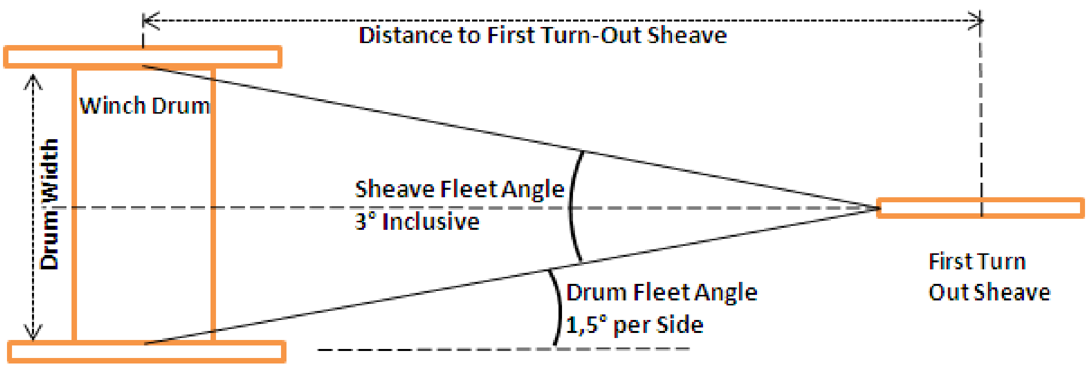
The distance between sheaves should allow the stresses set up as a result of bending around the sheave to relax prior to being bent again by another sheave. This distance is calculated in accordance with the specifications stated by a reputable rope manufacturer.

Sheave Bearings

Take-up systems need to be very sensitive to the take-up requirements of the conveyor, thus sheaves with bushed bearings of any description are not recommended. Only bearings with rolling elements are used, preferably sealed units. The static and dynamic load ratings of the bearings must be adequate for the operation of the conveyor based on the T2 tension requirements and must also be capable of withstanding abnormally high induced tensions due to an aborted start and a crash stop situation.

Fleet Angle

The fleet angle is formed between the rope at the first turn-out sheave and the winch drum. Thus the wider the winch drum, the greater the distance required to the first turn-out sheave to maintain the required fleet angle. This fleet angle is inclusive and not to exceed 3° or 1,5° per side taken from the centre of the drum. The alignment of the drum to the first turnout sheave must be at 90° or the fleet angle on each side not to exceed 1,5°



Winch Rope Fleet Angle

Drum Width	Dist to Sheave
200mm	4 Meters
300mm	6 Meters
400mm	8 Meters
600mm	12 Meters
900mm	18 Meters
1200mm	24 Meters

Figure 5. Winch rope fleet angle

Sheave Diameter and Profile

The rope speed for conveyor take-up winches which are generally classified as being "slow" i.e. < 1 meter per second. The diameters D are shown in Table 2. Due to this slow rope speed, a maximum of 25% reduction in the normal calculated diameter is allowable plus ½ rope diameter. This K factor is dependent on the rope construction and is derived as follows:

Construction	K Factor
Rope construction	6 x 19 28x Rope diameter
Rope construction	6 x 25 23x Rope diameter
Rope construction	6 x 36 19x Rope diameter

Table 2. Rope construction vs. K factor for sheave diameter

Example:
A 20 mm 6 x 36 steel wire rope is used on a conveyor take-up winch. Calculate the minimum sheave diameter D.
Solution:
From the above, the K factor for a 6 x 36 rope is 19. The rope diameter is specified as 20 mm. The sheave diameter D is thus 19 x 20 = 380 less 25% = 285 plus 10 mm = 295 mm.
The sheave dimensions should conform approximately to Figure 6 and Table 3.

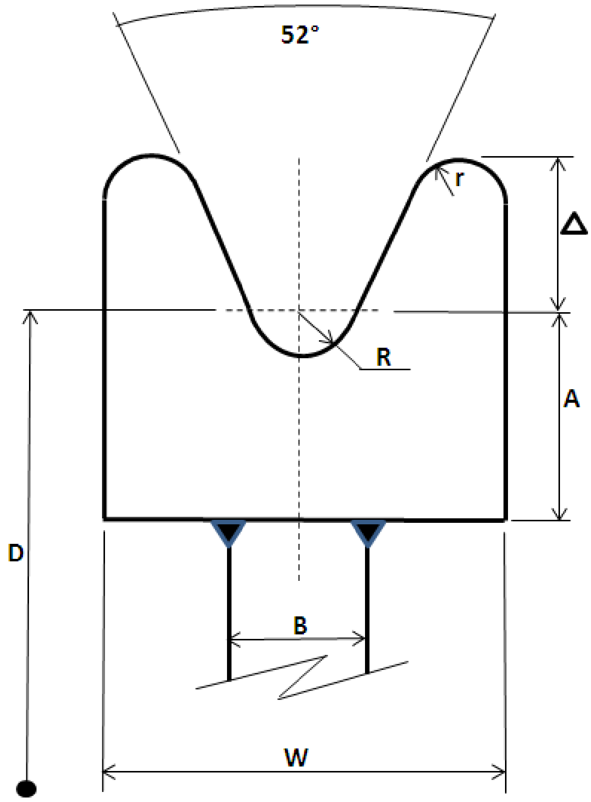


Figure 6. Sheave wheel dimensions

	Rim W	A	B	R	r	Min Sheave Diameter Rope Construction		
Rope Dia						6 x 19	6 x 25	6 x 36
10	25	15	10	5.25	2.5	214	174	148
12	30	18	12	6.3	3	252	206	182
16	40	24	16	8.4	4	336	274	238
20	50	30	20	10.5	5	420	348	294
24	60	36	24	12.6	6	516	410	358
32	80	48	32	16.8	8	642	546	484

Table 3. Rope and sheave diameters

A3 TENSION FEEDBACK METHODS

It needs to be stressed that in all cases where tensioning is applied to conveyors it is necessary to measure the belt tension. Note the following statement:

If you don't measure it, you cannot manage it.

By measuring the running tension in the belt the tension can be adjusted to suit the initial conveyor design requirement to satisfy the minimum tension to drive the belt and the T-Sag tension.

A3.1 Tension Transducers

Conveyor tension is measured reliably and accurately by a tension transducer (strain-gauge load cell) at the stationary end of the winch rope. However, every component of friction is to the detriment of measurement accuracy.

Two-wire tension transducers have precision internal electronics that eliminate all external interface electronics. Transducers are pre-calibrated to enable direct replacement without adjustment.

Figure 7. Loop powered two-wire 4-20 mA tension transducer

A3.2 Hydraulic Tension Indication

On smaller conveyors, a hydraulic load cell with a calibrated tension gauge is a good indication of belt tension.

Figure 8. Hydraulic tension indicator

A4 ACCELERATION EFFECTS ON CONVEYOR TENSIONING

Ramping or acceleration of a conveyor refers mainly to the time and the profile of the ramp. Ideally it is preferable that the ramp is linear. This implies that the rate of change of speed is proportional to the rate of change in time, giving a straight line acceleration, as shown in the centre straight line in Figure 9.

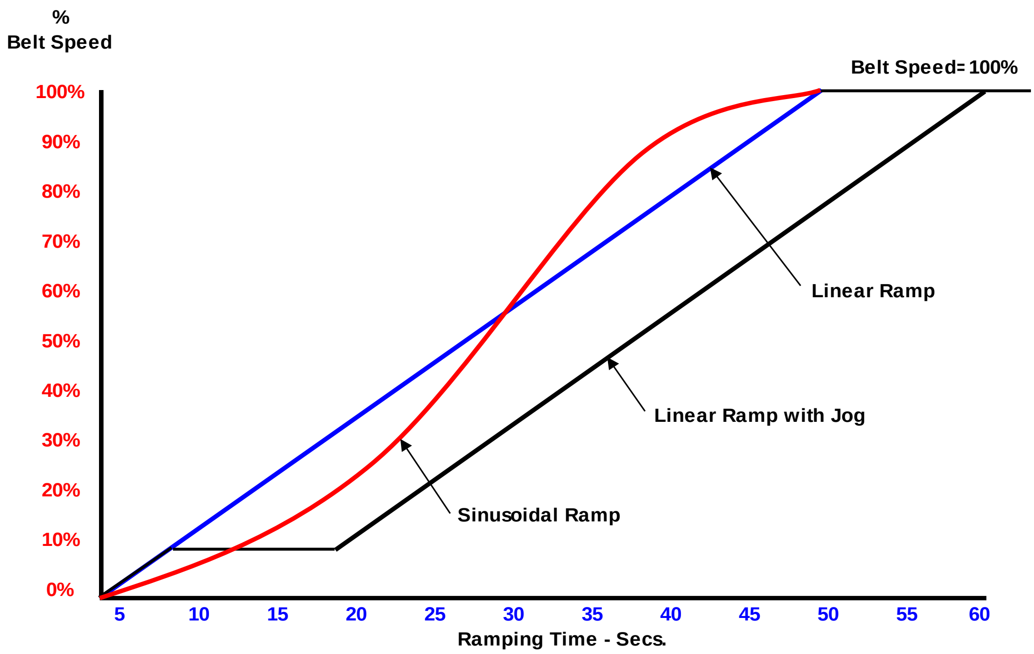


Figure 9. Ramping profiles

It is however, not always possible for all acceleration devices to comply with idealistic situations. It is thus preferable that the gradient created by the device does not exceed in whole or in part the requirements regarding an acceptably smooth and non-aggressive start. This implies that the ramp needs to be gradual rather than sudden at any point throughout the entire acceleration period.

A4.1 Drive Start Factor, DSF

The drive start factor is defined as the ratio of the power required to accelerate the conveyor vs. the power to run the conveyor. The DSF is thus dependant on the rate of acceleration of the conveyor. The longer the ramping time, the lower the DSF.

DSF can be typically as high as 200%, which may be acceptable for a small plant conveyor of, say 15 m in length with a low inertia. The higher the inertia and the higher the terminal velocity of a conveyor, the lower the DSF needs to be purely as a result of the high system mass that must be accelerated to full speed.

Ideally, the DSF in large, high inertia conveyors should to be limited to < 120%. At these values, the dynamic effects due to acceleration are drastically reduced and belting manufacturers are also less reluctant to making allowances to decrease the operating FoS without compromising the guarantee on the belting.

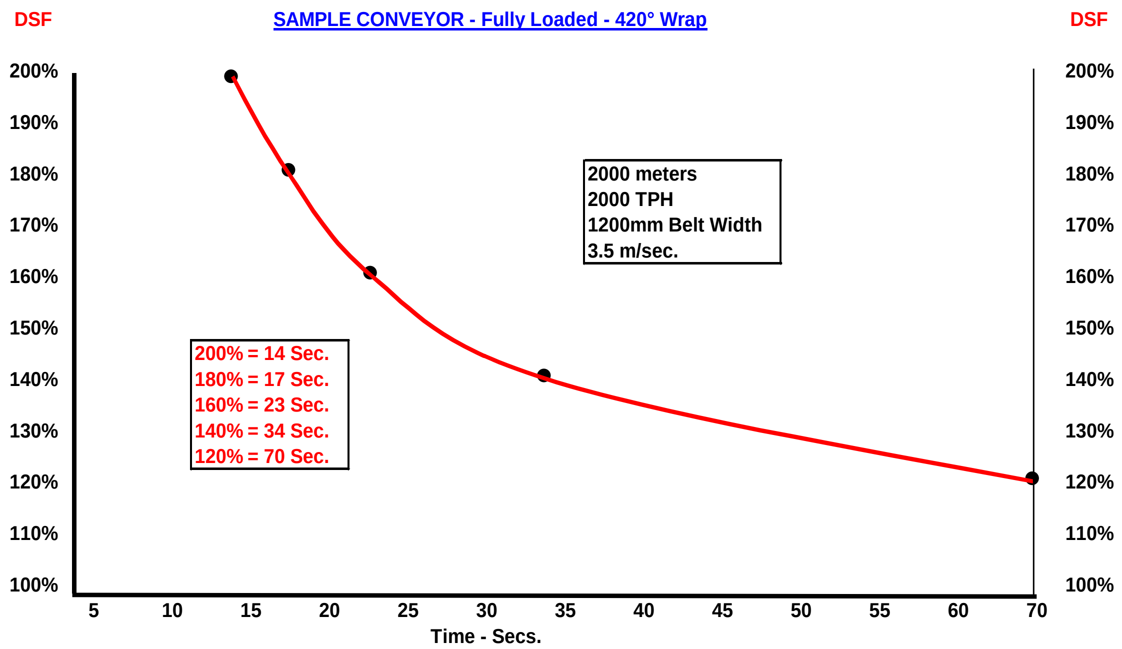


Figure 10. Sample conveyor, fully loaded 420° wrap

A4.2 Ramping Devices

Ramping devices refer to the hardware employed in transferring the power at an acceptable DSF from the source of power, the motor, to the speed reducer before applying it to the conveyor drive pulley or pulleys. There are currently many different such designs or devices available suitable for an array of conveying situations. These devices fall into one of the categories below.

A4.2.1 Uncontrolled Starting

The uncontrolled starting would include the following devices:

A4.2.1.1 – Direct On Line Starting (DOL)

Direct on line starting means no dampening devices used at all. This implies that the electric motor is coupled directly to the speed reducer, which in turn is coupled to the drive pulley. When the start signal is initiated, power is supplied directly to the motor. If the inertia in the conveyor is low, that is, the conveyor is small, short, lightly loaded etc., then this method of starting is acceptable. It is often used by small plant conveyors and should be limited to about 7,5 kW. Geared motor units are normally used.

A4.2.1.2 Fluid Coupling (Fixed Fill)

Constant filling hydrodynamic fluid couplings are usually installed in power transmissions between the electric motor and the speed reducer. Oil is used to transmit power from input to output with no mechanical contact.

These couplings reduce the load of the motor during acceleration thus allowing the motor to obtain full speed without seeing much load.

The speed ramp of a correctly sized and filled fluid coupling will usually follow a curve offering a given DSF, dependant on the coupling design in the fully loaded conveyor. An empty start subjects the conveyor drive to a much lower inertia level, which decreases the acceleration time, thus creating transient tensions within the system. Fluid couplings are therefore more suited to conveyors which operate under non-varying conditions.

Various delay-chamber volumes allow for faster or slower filling, permitting a softer start.

Traction couplings offer a fixed DSF with a given oil fill and a fixed load. If the coupling is overfilled, the start will be more severe than if the coupling were correctly filled. Should the oil level however, be under filled, then the coupling will slip and overheat. If the ambient conditions are inadequate to dissipate this excess build-up of heat, then the fusible plug will “blow” releasing the oil from the coupling and removing the fluid medium from the drive stop the transmission of torque.

The DSF of fixed fill couplings vary from about 180% at worst to about 135% at best for the “soft start” types. Fluid couplings generally slip between 2% and 3%. This slip is as a result of the inability to get 100% speed transfer between the inner wheel and outer wheel of the fluid coupling. These couplings are hydrodynamic drives and have no lock up facility. This slip is however, advantageous because when multiple drives are fitted, the slip takes place within the couplings allowing for good load sharing between the drives.

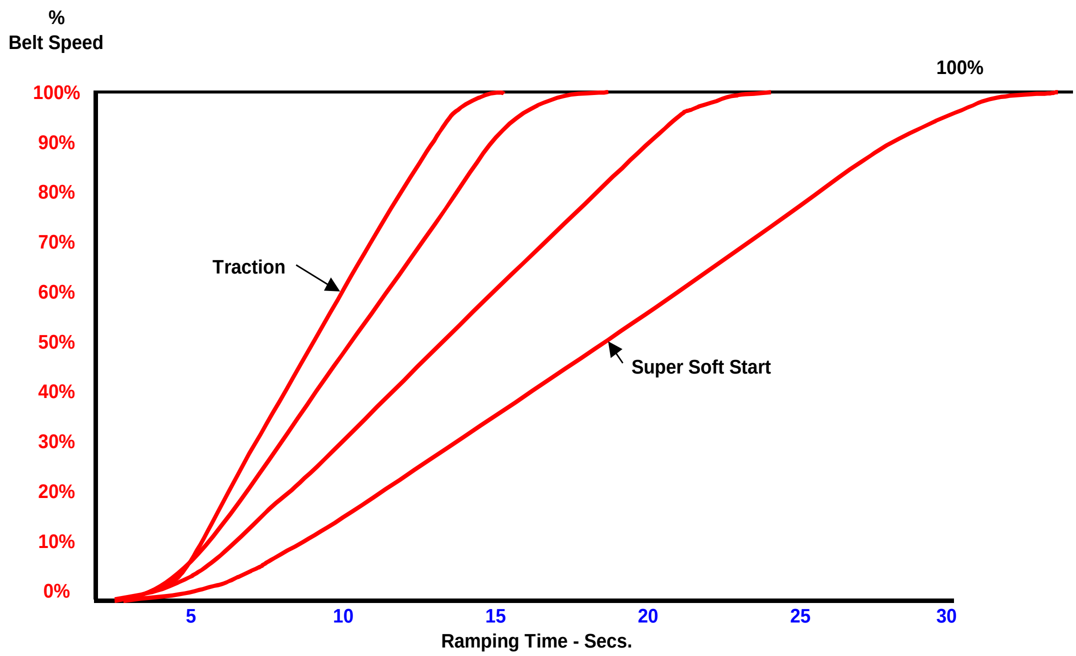


Figure 11. Drive-start factors for various fluid couplings

A4.2.1.3 Magnetic Drive Coupling (Fixed)

The principle of magnetic induction requires relative motion between the magnets and the conductors. This means that the output speed is always less than the input speed. The difference in speed is known as slip. Typically, when the coupling is operating at full rated motor speed, the slip is similarly between 1% and 3%.

The efficiency of the system is calculated by dividing the output (load) speed by the input (motor) speed. The DSF for these couplings is normally between 160% and 180%.

A4.2.2 Controlled Starting

This implies that external logic is programmed and applied to the drive to accommodate the ramping requirements and to monitor the execution thereof to the conveyor through the device. The controlled starting would therefore include the following devices:

A4.2.2.1 Scoop and Drain Couplings

Scoop couplings and drain couplings are primarily the same as a traction coupling with the exception that the oil level can be varied whilst the coupling is transmitting torque. This is done in order to achieve a longer ramp time for a given load, thereby decreasing the DSF of the device. The DSF can be low, but needs to be quantified by the coupling manufacturer. (Scoop and drain couplings function as other controlled start devices, but respond more slowly due to the time taken to increase or decrease the oil fill in order to increase or decrease the output torque). These devices are controlled by means of a PLC, and external oil cooling is required.

A4.2.2.2 Magnetic Drive Couplings, (Adjustable Air Gap)

When installed in a system, the coupling is controlled from a process signal. The control signal is provided to the coupling actuator. The drive will then modulate the speed of the load to satisfy the control needs. These drives are not normally used on conveyors, but are popular on HVAC applications.

A4.2.2.3 Viscous Friction Drives

Viscous friction drives operate on the basis of a series of fixed output steel plates and a series of intermediate sintered bronze plates in close proximity to one another. These plates are kept apart by Bellville washers maintaining a large enough gap such that virtually no torque can be transmitted when the oil is relatively warm. When the gap between the plates is reduced, torque is transmitted through viscous between the plates thus transferring power from the input side to the output side. Once the conveyor reaches its terminal velocity, the pressure is increased and the transmission stops driving on viscous and locks up on a clutch far more than capable of the highest torque.

Once locked up, there is no slipping and the drive is a “direct drive”. These couplings are all PLC controlled allowing for accurate acceleration to follow a ramping profile as programmed. Cooling and flushing oil is continually pumped through the coupling.

A4.2.2.4 Soft Starter

The soft starter is capable of ramping up a moderate load but lacks torque at zero speed. For this purpose it is not desirable if the load has a very high inertia. In order to raise the starting torque, the drive needs to be oversized.

A4.2.2.5 Variable Frequency Drive (VFD)

VFDs are, however, capable of producing 200% torque at zero rpm, thus allowing sufficient torque to move the load from standstill to overcome the breakaway friction requirements. For this reason the VFD drives are preferable for long, loaded conveyors and have gained popularity over the past ten years. Remaining within the Euro voltage of < 690 volts has proven to be most popular.

B TAKE-UP METHODS

Non-gravity take-up methods fall into three definitive categories, namely:

B1 FIXED TAKE-UP SYSTEMS – PRE-TENSIONING OF THE CONVEYOR

Screw take-up
Hand winch take-up
Electric winch take-up

B2 DYNAMIC TAKE-UP SYSTEMS OF THE CONSTANT *SPEED* TYPE

Electromechanical winch

B3 DYNAMIC TAKE-UP SYSTEMS OF THE CONSTANT *TENSION* TYPE

Gravity take-up or GTU (Not discussed in this paper)
Eddy current winch
Hydraulic winch using a constant torque motor
VFD winch
Hydraulic tensioner supplied by a constant pressure source.

All take-up systems, inclusive of GTUs, are sensitive to mechanical frictions, seizures etc. For this reason the control of conveyor tension take-up is deceptively difficult. In time, virtually every conveyor take-up system will fail, sooner or later, due to poor initial mechanical design and even more to poor or total lack of maintenance. Areas influenced by this are as follows:

a. Brake failure due to wear or contamination
b. Trolley wheel friction/seizure
c. Sheave wheel friction/collapse/seizure
d. Obstruction of trolley within structure or due to spillage
e. Damage to tension transducer or cable
f. Trolley at end of travel due to belt stretch
g. Loss of interfacing link between main control and tension controller
h. Increase in belt length causing overload/mismatch of winch
i. Increased throughput on belt
j. Change in the aggressiveness of the acceleration.

Identifying and diagnosing these problems is not an easy task because meaningful measurements cannot be readily obtained and suitably addressed.

B1 FIXED TAKE-UP SYSTEMS – PRE-TENSIONING OF THE CONVEYOR

These systems are generally used for short length conveyers. The length is determined by the belt class and type. The philosophy of fixed take-up systems is to allow for pre-tension in the belt such that sufficient tension is provided to meet all the requirements regarding ramping, running, coasting etc., plus an additional safety allowance. These systems are not sensitive at all to the changing tension requirements during ramping and are thus only used on short belts that can accommodate a pre-tensioning philosophy.

B1.1 Screw take-up

A screw take-up is normally employed on the tail pulley and applies a pre-tension to the belt which is of adequate magnitude to prevent slipping during ramping, correct tracking and to satisfy the T-Sag requirement. The tail pulley is tracked with the same set of tensioning screws. This take-up method has limitations relating to conveyor length and is generally used on very short conveyors. The tension can only be set when the conveyor is stationery.

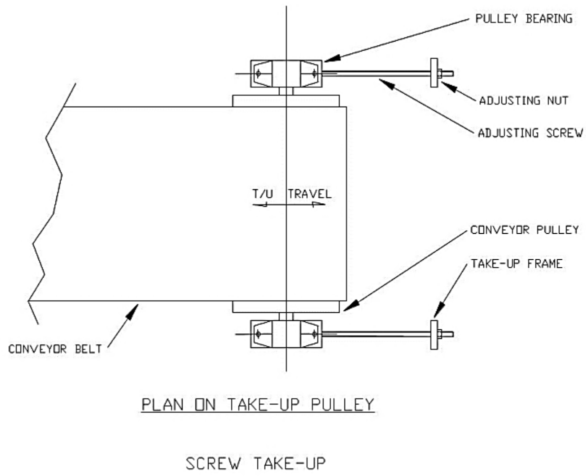


Figure 12. Screw take-up

B1.2 Hand winch take-up

Hand winches are used on small conveyors where a horizontal take-up carriage is used to tension the conveyor. This can be used in a loop take-up or a tail take-up. Pre-tensioning is conducted in the same manner as the screw take-up and satisfies the same conditions. A load cell or tension indicator can be fitted to the terminal rope end indicating the pre-loaded tension in the system. The pre-loaded tension must be calculated for the stationery belt and adjusted only when the belt is stationery.

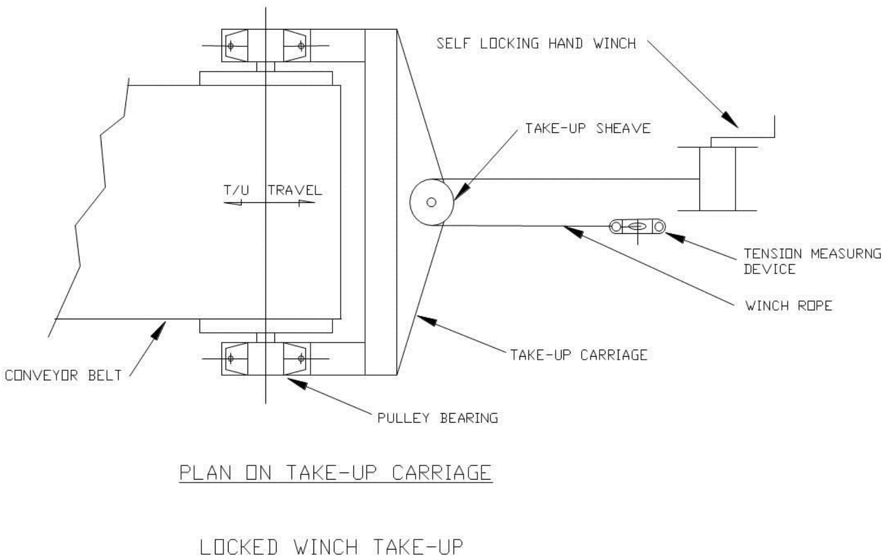


Figure 13. Locked hand winch take-up

B1.3 Electric winch take-up

The electric winch take-up incorporates a system whereby the hand winch is replaced by an electric winch. This winch is controlled by means of “inching” buttons allowing the tension to be set to suit the required pre-tension of the conveyor. It makes tensioning easier than using a hand winch, but the result is the same. Once again a tension measuring device is advised. Changes can only be made when the belt is stationery.

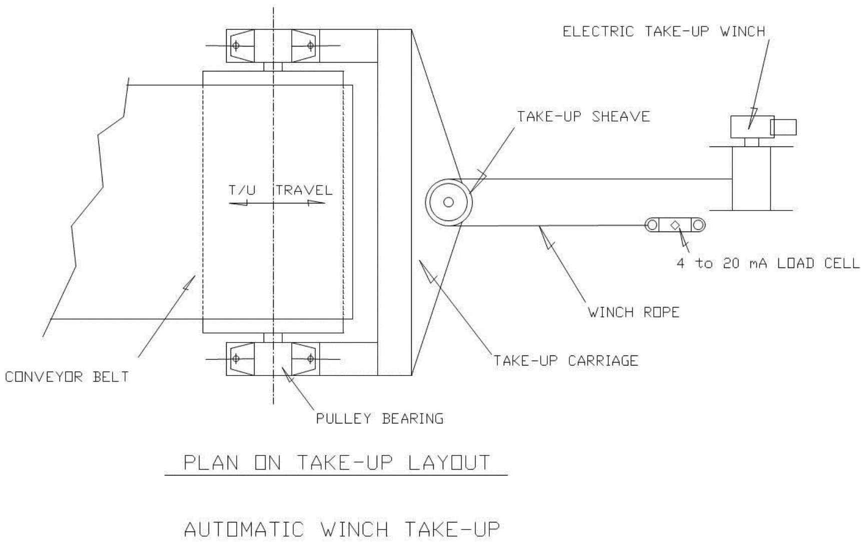


Figure 14. Electric winch take-up

B2 DYNAMIC TAKE-UP SYSTEMS OF THE CONSTANT SPEED TYPE

Dynamic take-up technology fundamentally means that as the conditions of the conveyor change as a result of ramping, running, loading, coasting or braking, the tension is adjusted to remain within the pre-set limits as programmed for the conveyor. These take-up devices normally apply the principles of operating at a constant line speed and a varying tension. The winch needs to be sized to exceed the maximum required take-up tension. This is necessary in order to have a higher starting tension which prevents belt slippage during the starting cycle in the event that the ramping of the conveyor is more aggressive than the take-up speed applied. This allows the elasticity of the belt to compensate for the slow winch speed.

B2.1 Electromechanical winch

The electromechanical winch is very popular and is generally found in tensioning applications on conveyors of whose length ranges from a few hundred metres to about 2 500 metres in length. The principle of operation is that the winch has a fixed ratio gearbox and is driven by a standard IEC 4-pole motor.

Fundamentally, the conveyor tension is altered by rotating the winch in one direction or the other depending on the feedback from the load indicator or load cell. The winch operates between the high limit and the low limit as determined by the conveyor conditions and communicated to the winch to adjust the tension between these pre-set limits. This implies that if the tension reaches the upper limit, the winch will start to release tension and then stop and apply the brake. In the event that the tension drops below the lower limit, then the winch will start up and haul in, thus adjusting the tension back to within the required limits. This tension adjustment philosophy applies to both the starting and running levels.

This process has been refined considerably with more modern electronics to improve and soften the control, but basically, to adjust the tension, the motor needs to be started in one direction or the other. There is an advantage from a maintenance point of view as the condition of the sheaves and wheel bearings can be assessed by comparing the tension results with the motor amperage readings. This ensures that the force applied by the winch reaches the belt.

Figure 15. Electromechanical winch

B3 DYNAMIC TAKE-UP SYSTEMS OF THE CONSTANT TENSION TYPE

Constant tension systems operate by applying a pre-determined tension generated and maintained electrically or hydraulically to the T2 zone of the belt. This take-up philosophy is best suited to, in particular, the longer conveyor systems as it responds to the requirements of the belt based on load, acceleration, aborted starts etc. There are various methods and designs available to meet requirements in generating these constant tensions.

B3.1 Eddy current winch

The eddy current winch is a reliable method of generating a constant output torque from an electric motor. This winch is also ideally suited to changing length conveyors that require a large capacity take-up system such as longwall gate conveyors.

These winches maintain a constant tension in the belt at the pre-set values by allowing the coupling to slip at between 0% and 160 %. This ensures that if the belt tension is less than the pre-set tension, the winch will haul the carriage in and if the tension in the belt is higher than the pre-set tension, then the winch will be hauled off against this pre-set tension. This allows the inductor to rotate in the opposite direction to the rotor but still retains the pre-set slip value. In the event of the tension being equal, then the rotor rotates at motor speed while the inductor remains static.

There is no mechanical bond between the rotor and the inductor. A given DC voltage is applied to the coil from the control system, which in turn builds up current in the coil. The control system measurers the current in the coil and then folds back the applied voltage maintaining the current level required that is directly proportional to the tension required.

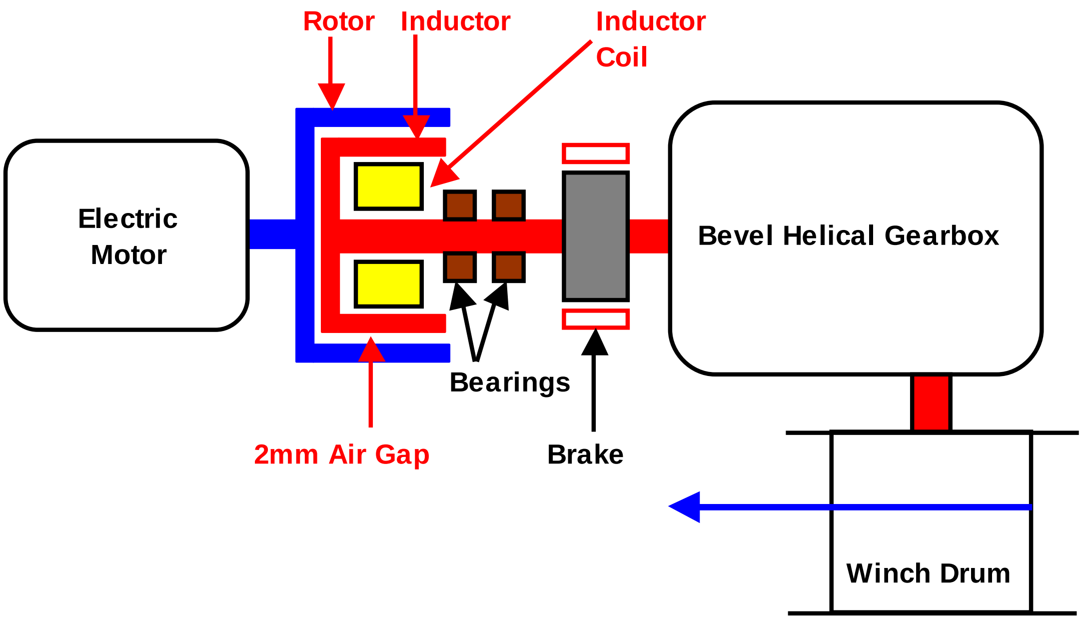


Figure 16. Eddy current winch schematic

Figure 17. Eddy current winch

B3.2 Hydraulic winch

Similarly, a constant output torque is generated by means of applying a constant pressure to a high torque–low speed hydraulic motor via a hydraulic circuit. This produces a constant tension to the conveyor take-up pulley. These winches are generally used in higher tension systems that require a fast take-up speed and are thus suited to large and long conveyors often operating with stretchy belting as found in high production collieries. These winches are built in various sizes and a 90 kW winch is not uncommon. These large winches operate with co-values of 1 m/sec at 75 kN tension. Reeling capacities of up to 720 metres are found in these take-up systems.

One advantage of the hydraulic winch is that it can be operated on a live system backed by a large bank of hydraulic accumulators to keep the system sufficiently "live" in the event of a power failure.

The brake is only a holding brake as the take-up can be hydraulically locked across the main winch motor. Hydraulic winches are controlled by means of the PLC used in the control of the conveyor or by means of a remote PLC.

Figure 18. Hydraulic winch

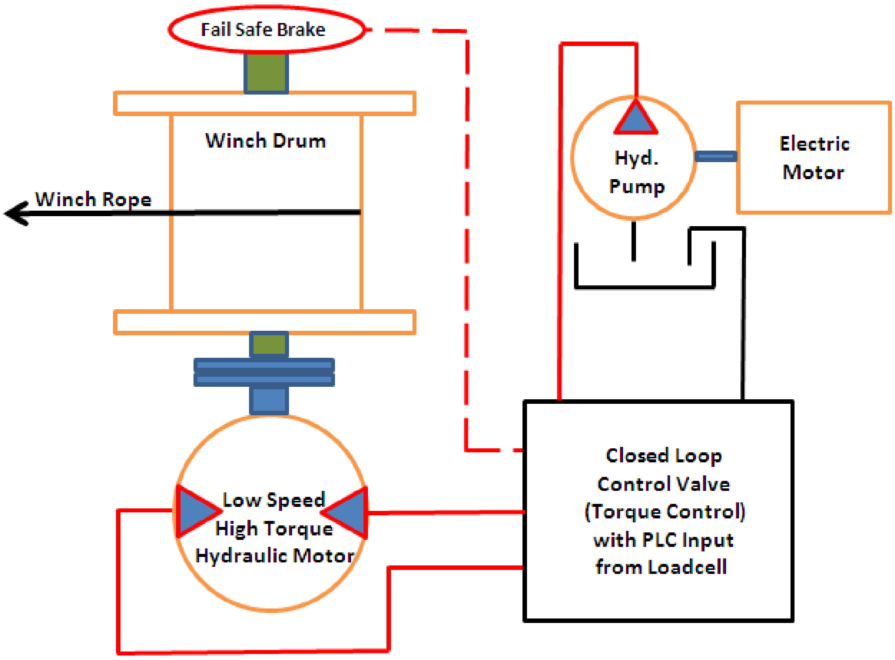


Figure 19. Hydraulic winch basic circuit

B3.3 VFD winch

The performance characteristics of the VFD winch follow the principles of constant tension. The VFD winch operates with the electric motor being in 100% stall for most of the conveying cycle.

VFD conveyor tensioning winches have been used to varying degrees of success both locally and internationally. In South Africa many of the mines use 1 000 volts as the normal supply voltage. Most VFD drives operate < 690 volts, which is known as the Euro voltage. Technically, however, there are no real limitations as to the capability to produce VFD systems that operate on voltages above 690 V. There is a commercial disadvantage to higher voltages when using VFD systems as the components are not produced in meaningful quantities resulting in the high cost of low volume components. In the South African market, this places a restriction on the use of this technology, not only for conveyor take-up systems, but for all systems operating above 690 V, as many of our larger operations are 1 000 V.

If VFD drives are used in conveyor take-up winches, then the following needs to be noted and applied:

- A four quadrant drive should be used with the grid dissipating the braking power
- In-line chokes to be fitted to reduce voltage spikes
- A separate cooling motor to be fitted to supply cooling for the main motor as a result of low speed or when the winch is in the holding state and the motor speed is zero
- Load cell feedback to be applied to the logic of the control system
- Optional encoder feedback to be fitted if required

- The motor to be sized on maximum torque required inclusive of all losses and not necessarily on the hauling or holding power
- Dependant on which VFD is used, the on-board logic in modern VFD systems should be sufficient to control the drive as a stand-alone unit. An external PLC may thus not be required
- An effective holding brake is required to hold the tension in the case of an emergency stop and a normal power off situation.

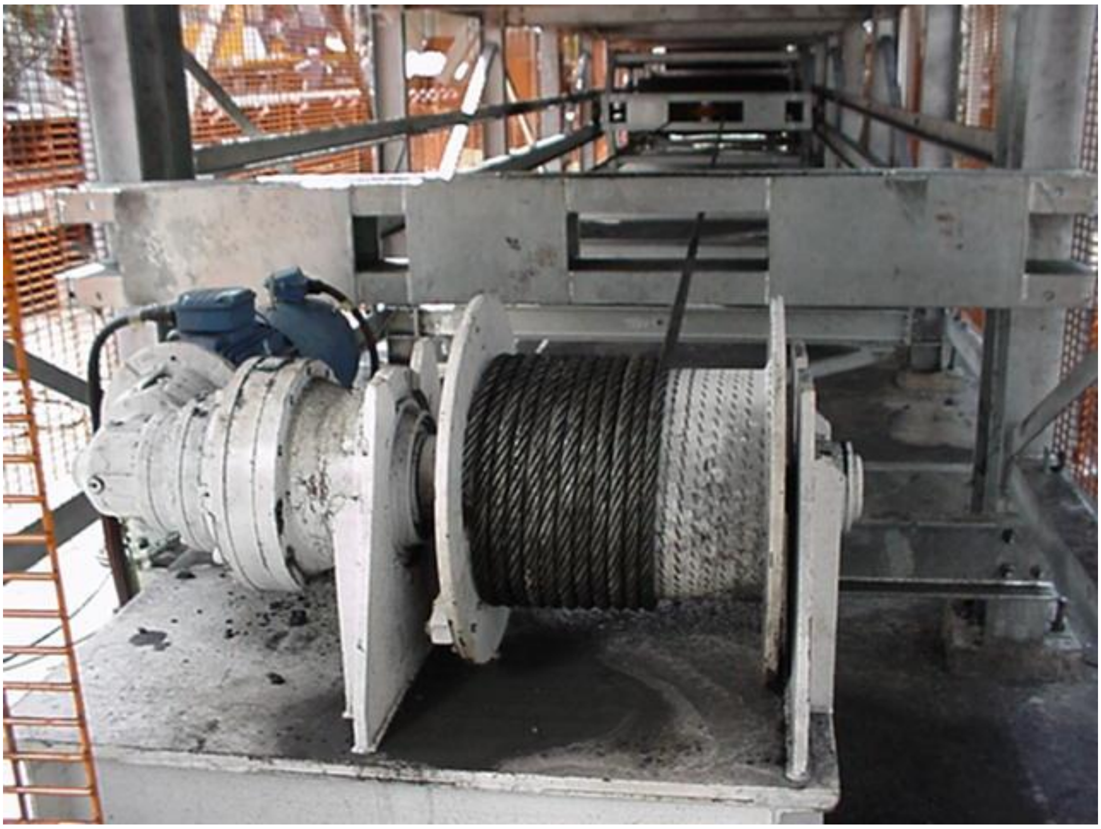


Figure 20. VFD winch with HS electric brake incorporated on motor shaft

B3.4 Hydra Power Conveyor Tensioner

This method of tensioning is seldom seen today, but was used in low seam belt storages in American designs incorporating some rapid advancing mining systems for the purpose of development

On normal conveyors in some deep level mines, a static water head generates a constant pressure. The cylinder is designed to suit the tension requirement of the conveyor and the static head pressure. In this case, the cylinder is manufactured from stainless steel to operate on the normal hydra power water supply.

Similarly these take-up systems are used with a hydraulic power pack generating a pressure which is stored in hydraulic accumulators for use by the take-up cylinder as and when required.

There are normally seven sheaves with six falls of active rope which allow adequate capacity to supply a long enough take-up length to suit the conveyor. The carriage moves 6 metres per metre of cylinder movement. When used on hydra power with a static head there is no energy cost. The system is friendly towards the removal of stored energy.

Figure 21. Hydra power tensioner

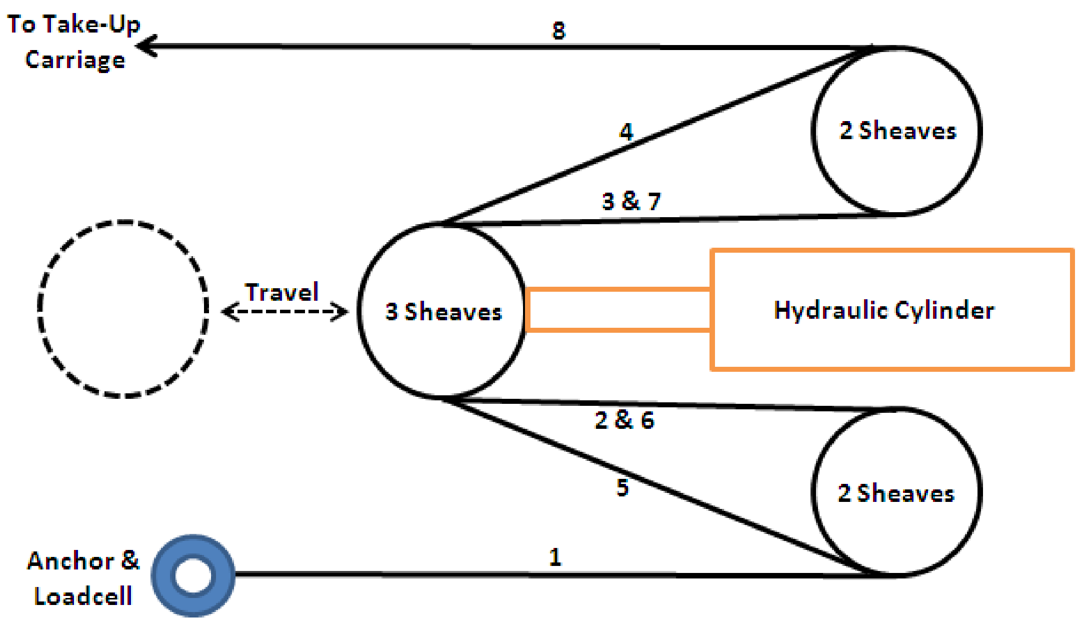


Figure 22. Hydra power tensioner – reeving schematic

C. SAFETY REQUIREMENTS

C1 STORED ENERGY

Stored energy is normally held by the take-up device and this is the point where the energy needs to be released when work is to be done on a conveyor. A risk assessment is required prior to any work being done.

- Belt conveyors retain stored energy when the power is turned off.

  Definition of stored energy

  Stored energy is the potential energy derived from the elasticity of the belt, that is stored in a belt strand within a conveyor system and if released, presents itself as an instantaneous danger to human life and equipment.

Stored energy is thus the **hazard** that you **cannot see** and **MUST** therefore be **UNDERSTOOD**.

It is a topic that cannot only be stated and **so requires permanent attention.**

- It is therefore vital to continually address, raise, discuss, train and educate all personnel as to the **HIGH POTENTIAL DANGER** encompassed in STORED ENERGY.
- A misunderstanding of this potential energy has proven to be **LETHAL** in our industry.
- Risk assessments must be completed by the required persons in accordance with the legal requirements and are then communicated to personnel for implementation.
- The question arises, as a result of accidents originating from stored energy, whether these assessments are correctly understood by ALL persons working on the conveyors.
- If accidents of a similar nature are recurring, then how should the industry address these issues in order to reduce these occurrences?

Example 1 - Maintenance Accident (Stored Energy)

- An artisan was setting up a nip guard on a conveyor. The necessary risk assessments were completed and the work as planned was carried out in a “safe” manner.
- A second team was replacing idlers on the same conveyor, also with the necessary risk assessments completed and the work as planned being carried out in a “safe” manner.
- The above mentioned two “safe” work tasks took place simultaneously on the same conveyor resulting in a fatality.

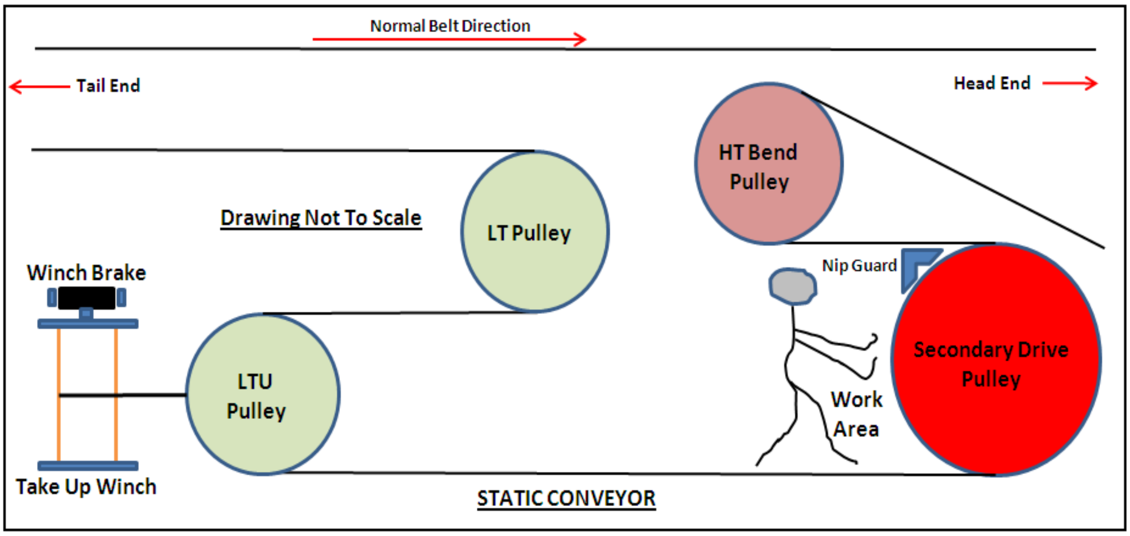


Figure 23. Maintenance is conducted on the nip guard between the belts

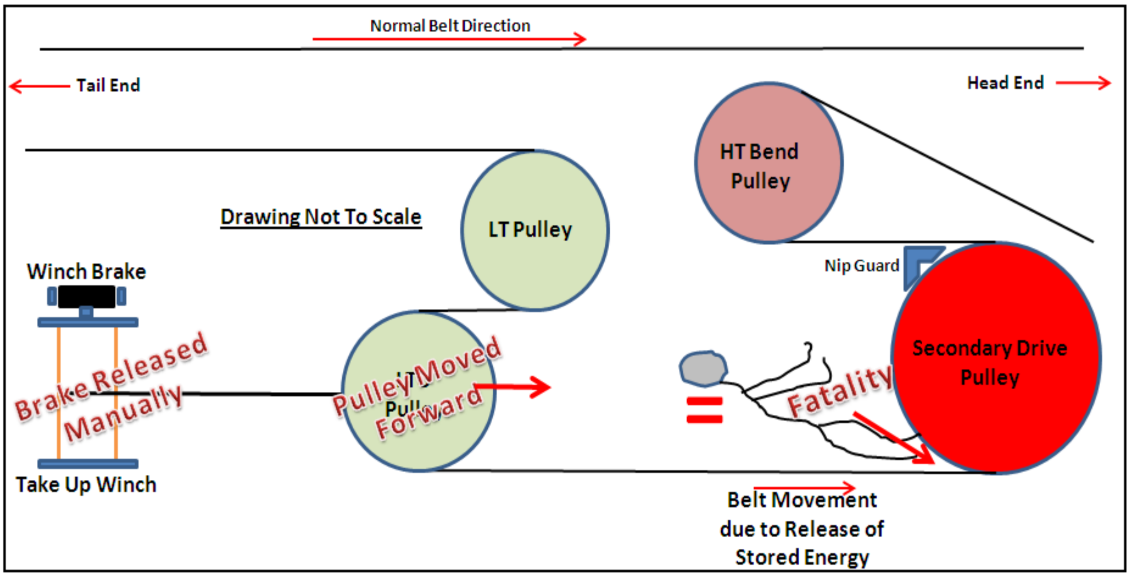


Figure 24. When the brake was released, the lower belt pulled the artisan into the pulley

Example 2 – Tail Pulley Accident (Stored and Trapped Energy)

- An incline conveyor tripped on electrical overload as a result of a large rock lodged between the tail pulley and the return strand.
- A worker commenced reducing the rock in size in order to clear the obstruction, not realising that there was a differential tension between the carry and return belt strands.
- Once the obstacle was sufficiently reduced, the differential tension normalised releasing the energy and pulled the worker through the tail pulley resulting in a fatality.

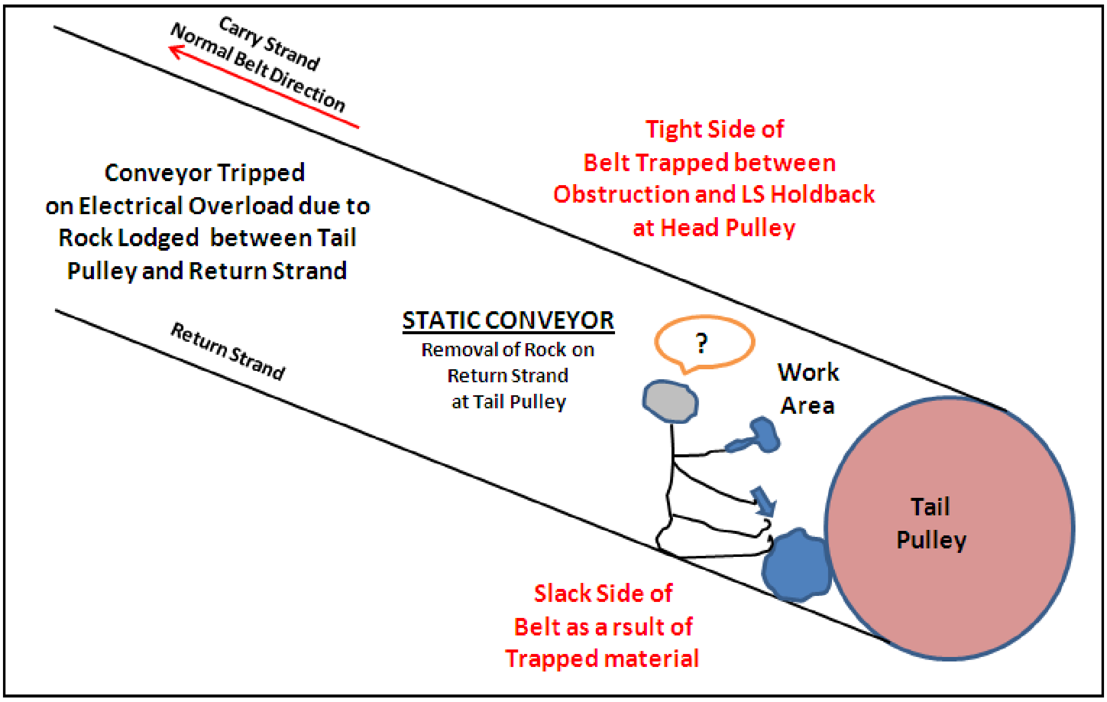


Figure 25. Worker reducing rock size to clear obstruction

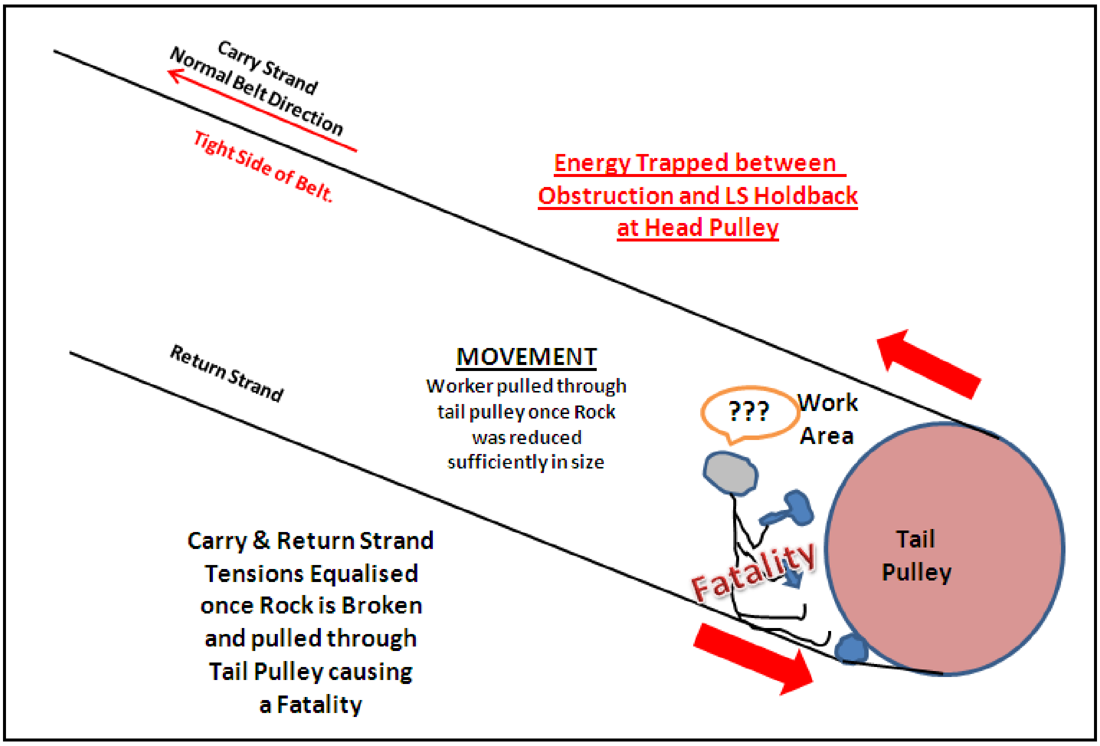


Figure 26. Obstruction reduced sufficiently to be pulled through by differential tension

Trapped Energy – Between Holdback and Rock in Tail Pulley

This accident refers to **trapped energy** held between the head pulley as a result of the holdback functioning correctly, and the obstruction preventing the tail pulley from rotating. The carry strand is thus excessively stressed.

This energy **must** be removed **before** the obstruction can be removed.

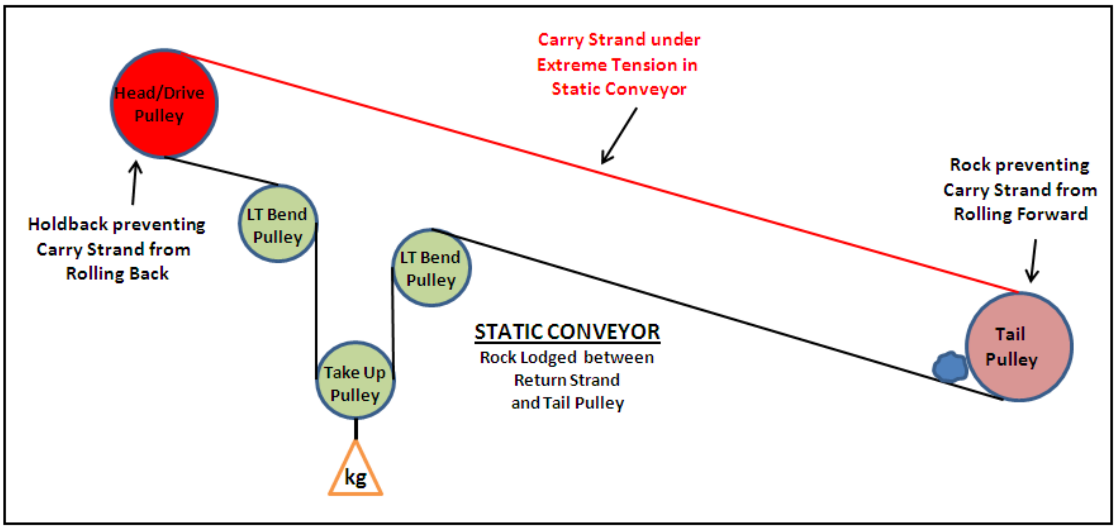


Figure 27. Energy trapped in carry strand due to tail pulley obstruction

CONCLUSIONS

- The design and maintenance of the carriage, sheaves etc. is critical to the sensitivity of the take-up system. This includes the selection of the rope construction to minimise bending frictions.
- The choice of the take-up method must be suitable and appropriate to the application.
- Maintaining an acceptable DSF throughout the ramp is critical to effective tensioning. An aggressive acceleration requires an aggressive take-up.
- The system must be designed to accommodate the transient tension induced into the system due to aggressive ramping and that of an aborted start.
- Current ramping technology available today, if applied correctly, is more forgiving towards the take-up system.
- All work must be conducted safely by removing all stored energy.
- Prevention of re-occurrence of similar accidents can only be achieved through following correct, approved procedures and secondly by training, re-training and training again.

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Alan Exton has been involved in the mining industry since 1969 where he commenced his training at West Rand Consolidated Mines Ltd as an apprenticed fitter and turner. During his apprenticeship he obtained a National Technical Diploma in Mechanical Design. After seven 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 of both coal and hard rock mining equipment for various companies until 1990, and then specialised in the field of belt conveyors.

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