Understanding T2 Tensioning Requirements and The Philosophies Pertaining thereto

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SYNOPSIS

Tensioning is considered to be critical in order to prevent conveyor downtime, yet in many cases it is not understood nor applied correctly by manufacturers, contractors and particularly end users. The theoretical tension requirements in a conveyor can be attributed to various ramping profiles, loading methods, belt type & class, the coefficient of drive friction, whilst the general maintenance of the entire T2 take up area also needs consideration. Stopping of conveyors is as important as ramping and the paper will discuss the effects of normal stopping vs. emergency stopping pertaining to take up response time. Transients need to be curbed in all situations in order to minimise damage to the belt, conveyor components, take up system etc. Belt types, various ramping profiles and tensioning methods are considered and discussed including the effect of the elastic modulus of the belt. All the T2 elements such as ropes, sheaves, take up carriages, winches, gravity systems, response times, shock loading, etc. will be discussed.

DEFINITIONS

Work Work is defined as the energy required to raise a mass of 1 kg to a height of 1 meter.

Power Power is the rate of doing work. Power is measured in kW. This must however not be confused with belt speed. For example, conveying 1000TPH at 2m/sec requires the same power to move the load, as it will at 4 m/sec.
The total power required to drive a conveyor consists of the following:
Power to drive the load
Power to drive the friction
Power to drive the mechanical resistances
Power to accelerate the conveyor

Tension Tension is required for various reasons within a conveyor namely:

In order to effectively impart power from the drive pulley into the conveyor belting during ramping & running without slipping.
In order to apply acceptable tension to satisfy the T-Sag requirements.
To accommodate the belt stretch during ramping.
To accommodate the permanent stretch of the belting.
To Maintain a Controlled Tension
Various tensions exist within the conveyor belting, namely:

T1=Maximum Tension - This is the highest tension within the conveyor and exists at the point where the belt enters the first drive pulley.

T2=Lowest Tension - This is the lowest tension in the conveyor and exists immediately after the last drive pulley.

TE=Effective Tension - The effective tension is the differential between T1 and T2, Te=(T1-T2)

TT=Tail Tension - This tension exists at the tail end of the conveyor.

T-Sag=Sag Tension - The T-Sag tension is tension that is required to limit sag between the idlers is limited to the design of the conveyor.

Drive Coefficient of Friction The drive coefficient of friction is a factor based on the material characteristics between the drive pulley and the belt. This value varies with conditions but is normally applied at 0.35 for a rubber-lagged pulley onto a conveyor belt. In wet conditions this value could drop to 0.25 and can go as high as 0.4. In extreme conditions ceramic lagging of the pulley can raise this value to 0.7, but is expensive and is not standard practice under normal conditions.

Artificial Friction Coefficient The artificial friction coefficient comprises the rolling resistance of the carrying idlers and the belt advancement resistance. Many factors influence the actual value, but normally equates to a value of 0.022 for a conveyor that is correctly installed and operating at the design tension and capacities.

Relationship between Power, Tension & Belt Speed The following relationships are applicable to belt conveyors:

Power = Tension X Velocity
Effective Tension, TE=T1-T2

Drive Start Factor (DSF) The drive start factor is the ratio of the Power required to accelerate the conveyor v. the power to run the conveyor. The DSF is dependant on the rate of acceleration of the conveyor with the longer the ramping time, the lower the DSF.

Coasting Time The coasting time is the time taken for the conveyor to coast from full speed to standstill.

Belt Modulus The modulus of elasticity is dependant on the structure of the belt. Steelcord belting has a high modulus as a result of the low stretch due to the high tensile steel cords. On the other hand Solid Woven belting has a low Modulus due to the stretch being relatively high.

Aborted Start An aborted start is as a result of a power loss to the conveyor during acceleration and the highest transient tension will occur at a point about 65% into the ramp.

Belt Types Applications & Categories

Belts used in the conveying industry when applied to bulk material handling fall into 3 primary categories used as follows:

Steelcord Belting Steelcord Belting is usually used in applications where high tensions are prevalent. These are generally found in long overland conveyors and incline conveyors. Steelcord belts are always vulcanised. The modulus of elasticity for Steelcord belting is high offering a belt with low stretch. The take up system therefore does not require a high take up response rate to accommodate the stretch induced by the drive.

Ply or Fabric Belting Usually used in plant conveyors. Ply belting can easily be joined by use of clip joints but can be vulcanised for permanent installations. Depending on the no of plies, this belting requires relatively large pulley diameters such that ply separation is minimised. Belt modulus is relatively low.

Solid Woven Belting It is current common practice to use PVC Solid Woven belting in underground fiery mining applications. Solid Woven belting can easily be joined by use of clip joints but can be finger spliced by using a hot vulcanising method. Solid woven belting is used with smaller pulley diameters than ply belting, but has a low modulus of elasticity and take up travel is therefore high.

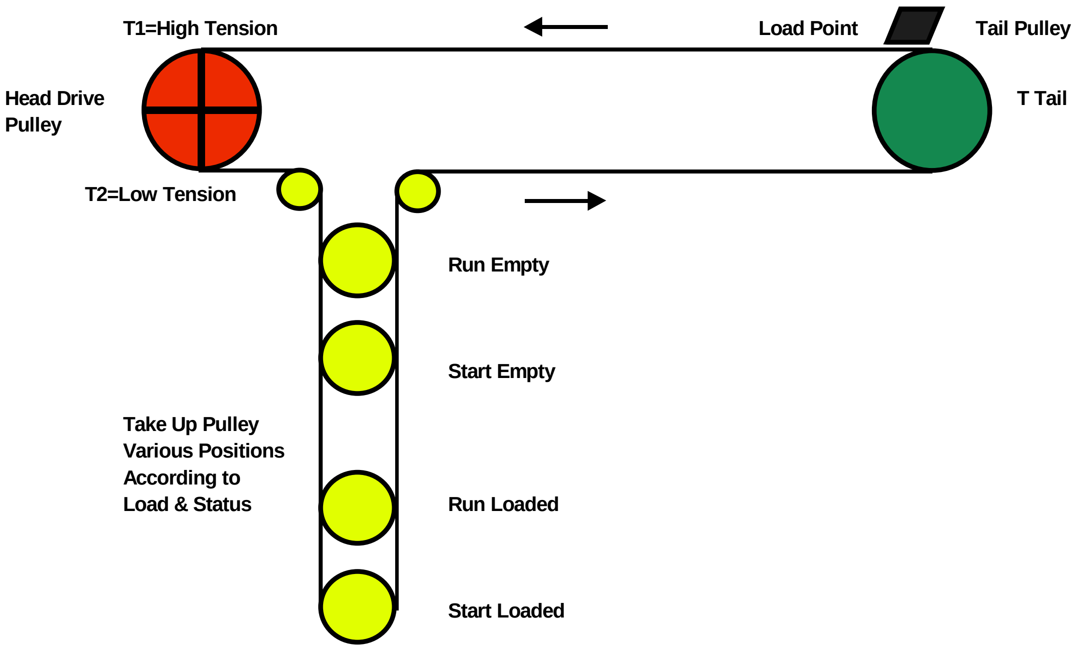
Belt Class This value relates to the minimum breaking strength of the belt carcass and is expressed in kN/m.

Allowable Operating Tension Belting manufacturers specify the operating tensions for the belt type. Generally Solid Woven belting & Ply belting are not to exceed 10% of the Belt Class Value whilst Steelcord belting is not to exceed 15% of the Belt Class Value in the fully loaded running condition. The ramping tensions are normally higher than the running tensions, but provided the ramp is not too aggressive, then the increased tension during ramping is not considered in the FoS. These recommendations may be varied by the belt manufacturers depending on the application.

Methods of Tensioning a Conveyor:

Various methods and devices are used in order to tension conveyors. Often inadequate equipment is selected on the basis that the person making the selection does not consider all the issues that will affect this important zone of the conveyor system. Take up systems fall into 3 categories as follows:

TAKE UP POSITIONS



Fixed Take Up Systems

These systems are generally used for short length conveyers. The length is to be 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 pertaining to ramping, running, coasting etc., plus an additional safety allowance. These systems are not insensitive and are thus only used on short belts that can accommodate this philosophy.

Screw Take Up - Adjustment by use of adjustable slider blocks.

Hand Winch Take Up - Adjustment by means of positioning a carriage with a hand winch.

Electric Winch Take Up - Adjustment by means of positioning a carriage with a manually operated electric winch.

Dynamic Take Up Systems – Constant Speed Machines:

These winches are generally termed “Electro-Mechanical” winches and are used for medium length conveyers. The length is once again determined by the belt class and type. The operation of these winches is to maintain tension within a pre-set band, which is sourced from a Loadcell. The Loadcell has a high and low limit setting and tension will be maintained between these limits. Whilst the tension falls within these pre-set values, the winch motor is not energised and the winch brake remains applied. Should the tension exceed the upper limit, the winch motor is started in reverse and simultaneously the brake is released. Once the lower tension value is reached, the winch will stop and the brake will be applied. The winch will pay out at a constant speed. Similarly the reverse hereof will be implemented should the tension reach the lower limit. The rate of response is fixed by the motor speed, gearbox ratio & the winch drum diameter.

Dynamic Take Up System – Constant Tension Machines

Constant tension systems operate by applying a pre-determined tension to the T2 zone of the belt. This take up philosophy is best suited to conveyor systems as it responds to the requirements of the belt based on load, acceleration, aborted starts etc. There are various methods devices that can be employed to generate this constant tension described as follows:

Gravity – This is possibly the simplest and oldest form of generating a constant tension and primarily consists of a vertical take up tower with a counterweight mass attached to the end of a rope. Through a series of sheaves the rope is fixed to the take up carriage. The force produced by the counterweight mass is in equilibrium with the required force pertaining to the conveyor.

Hydraulic Winch – Similarly a constant output torque is generated by means of a hydraulic circuit to apply a constant tension to the conveyor.

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 requires a large capacity take up system.

The Eddy Current Winch will maintain a constant tension in the belt at the pre set values by allowing the coupling to slip at between 0 and 160 percent. 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 will allow the inductor to rotate in the opposite direction to the rotor but still retaining 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 voltage is applied to the coil from the control card, which in turn builds up current in the coil. The control card measurers the current in the coil and then folds back the applied voltage maintaining the current level required that is proportional to the tension required.
VFD Winch – The performance characteristics of the VFD winch are similar to that of the Eddy Current Winch. The VFD winch operates with the electric motor being in 100% stall for most of the conveying cycle. Because the motor is in the stall condition, forced cooling is required which is done by means of fitting a separate cooling motor in order to cool the main motor. The VFD drive applies a constant output torque to the winch drum.

Tension Indication & Feedback: In order to access the tension within a conveyor, the T2 tension should be displayed at the drivehead of the conveyor and preferably at the Control Room. This is one of the most critical values required for effective conveyor set up and monitoring.
Loadcells are the most popular method used at present for display and monitoring purposes. If tension indication is required at the drivehead only, then a hydraulic Loadcell calibrated in kN is adequate and extremely reliable.

Take Up Design Considerations

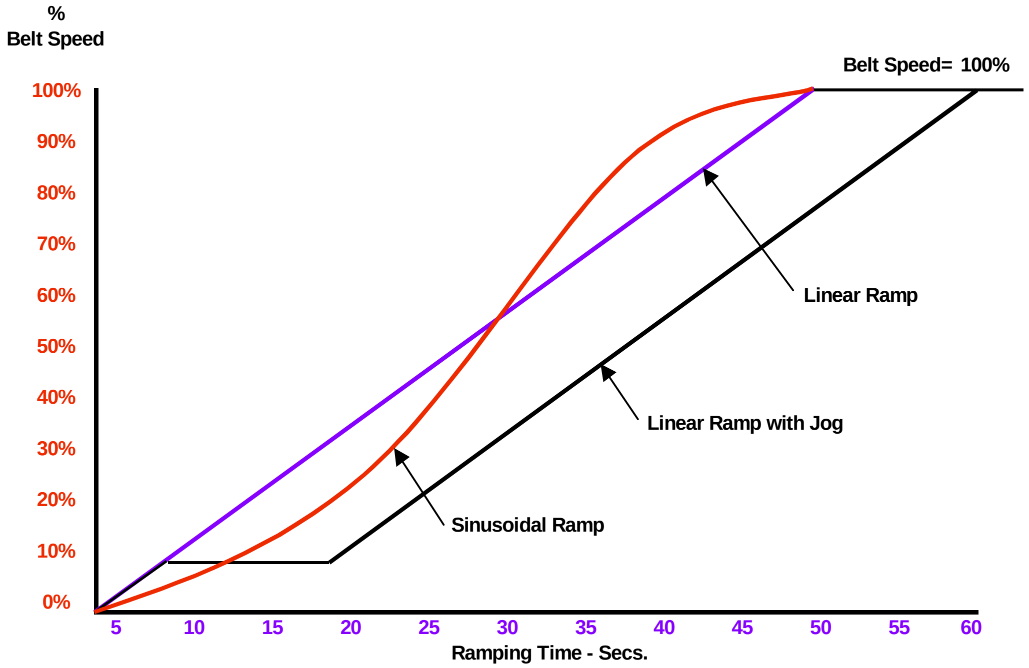
Take up Length Required – This is generally a function of the belt stretch. Belt stretch consists of the Elastic Stretch plus the Permanent Stretch of the belt. For example a class 1000 Solid Woven belt has an elastic stretch of about 1% and a permanent stretch of about 1%, giving a total stretch of 2%. If the conveyor is 2000 meters in length, then there will be approximately 4000 meters of belting within the conveyor. The take up length then needs to be 4000 X 2% = 80 meters. If a standard LTU is used, then the carriage travel needs to be at least 40 meters.

Carriage Design including Friction – It is important that the carriage is free to move within the take up steelwork. For this reason it is recommended that the carriage wheels and thrusters wheels are equipped with roller bearings and not brass bushes. Carriage restriction creates insensitivity within the take up system. The carriage should also be over square. This means that the length of the carriage should be 1.2 times the width.

Sheave Design – The sheave wheels are to be designed to suit the rope construction type and the diameter. Sheaves of insufficient diameter cause excessive bending to the rope reducing rope life and making the sheave less efficient. The sheaves must be fitted with roller bearings to reduce the rolling friction of the sheave. A sensitive take up system will always give good results.

Ramping of Conveyors

Ramping or acceleration of a conveyor refers mainly to the time and the profile of the ramp. Ideally we would prefer if the ramp were to be linear. This implies that the rate of change of speed is proportional to the rate of change in time, giving a straight-line acceleration.

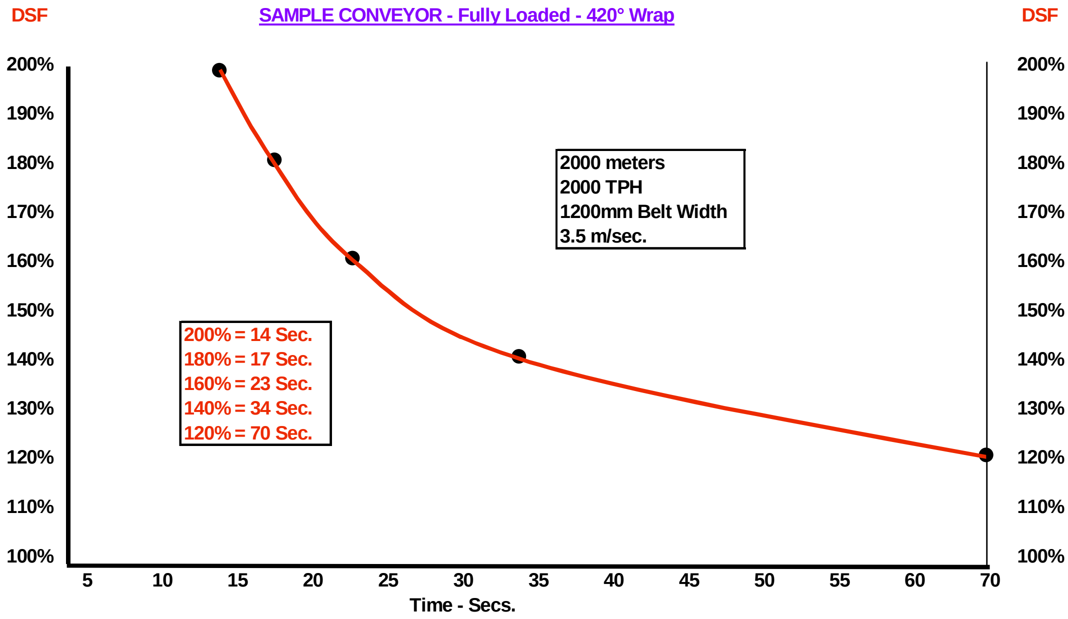


It is however not always possible for all acceleration devices to comply with idealistic situations. It is preferable that the gradient created by the device does not exceed in whole or in part the requirements pertaining to an acceptably smooth and non-aggressive start. This implies that the ramp needs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

Drive Start Factor

The drive start factor as defined earlier is the ratio of the Power required to accelerate the conveyor vs. the power to run the conveyor. The DSF is 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 of a conveyor, the lower the DSF needs to be purely as a result of the high system mass that needs to be accelerated to full speed.
The DSF in large high inertia conveyors needs to be limited to <120%. At these values the belting manufacturers are also less reluctant to making allowances to decrease the operating FoS without compromising the guarantee.



Ramping Devices

DOL Starting – (Direct on Line)
Fluid Couplings – Traction, Scoop & Drain
Controlled Start – CST, Boss, and VFD.

DOL Starting

Direct On Line starting, DOL, refers to 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, i.e. the conveyor is small, short, lightly loaded etc., then this method of starting is acceptable. This method is generally used small plant conveyors and should be limited to about 7,5 kW.

Fluid Couplings - General

Fluid Couplings – DSF=180% to 135%:

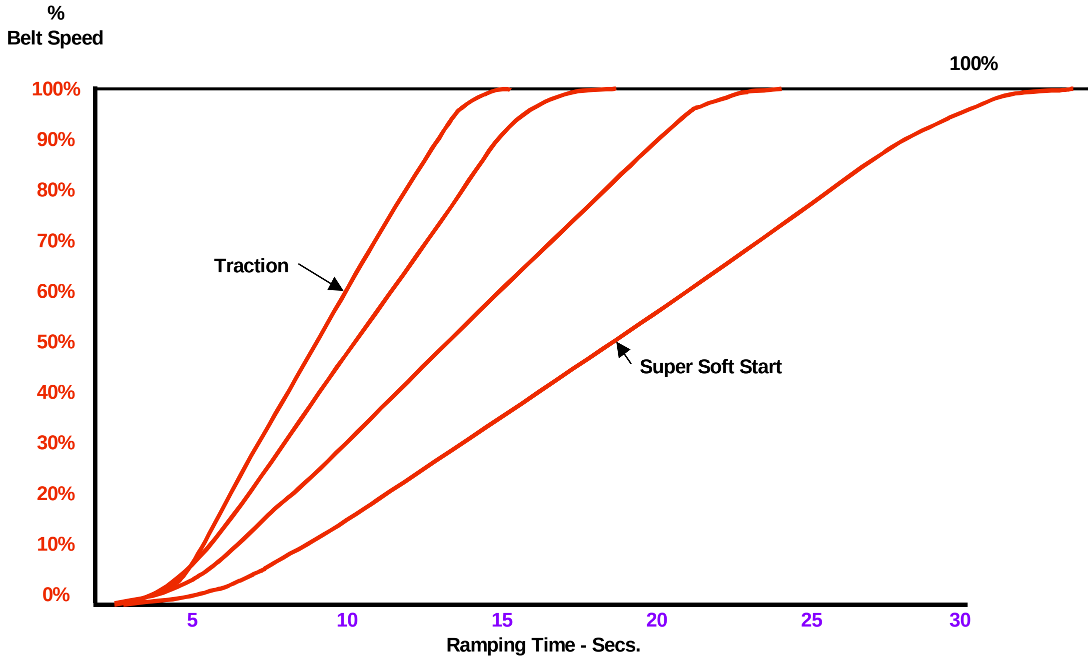
Constant filling traction couplings are usually installed in power transmissions between the electric motor and the speed reducer. Oil is used to transmit power from input to output with no mechanical contact.

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 generally follow a sinusoidal curve in the fully loaded conveyor. An empty start however subjects the conveyor drive with a much lower inertia level, which drastically decreases the acceleration time, thus creating transient tension within the system. Fluid couplings are more suited to conveyors, which operate under non-varying conditions.

Various delay chamber volumes allow for faster or slower filling thus allowing for a softer start.

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



The DSF of traction couplings vary from about 180% at worst to about 135% at best for the "Soft Start" types.

Scoop & 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 & Drain couplings tend to function towards that of a Controlled Start Device but responds in a lethargic manner due to the time taken to increase or decrease the oil fill in order to increase or decrease the output torque).

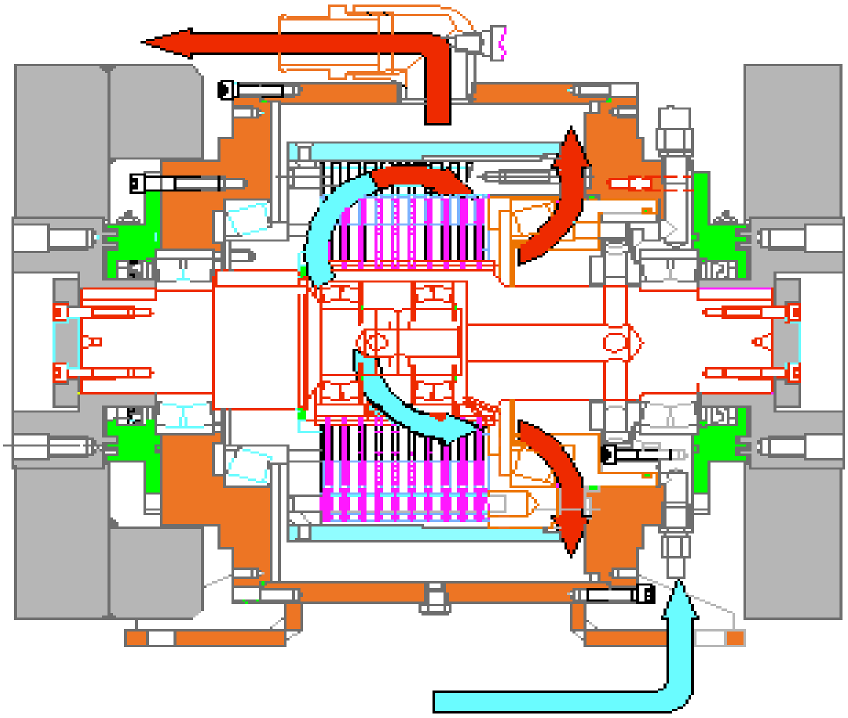
Controlled Start Devices

Various controlled start devices are available today, but for the purposes of this paper we will categorise them into two categories namely:

Viscous Friction Devices

There are two such devices namely the "BOSS" - "Belt Optimised Soft Start and Slave" and the CST – Controlled Start Transmission. The "BOSS" is manufactured in Australia by Nepean Conveyors and the CST is manufactured in the USA by Dodge.

"BOSS" Transmission.



Both these devices operate in a similar manner and consists of a viscous clutch that is modulated via a PLC in order to accelerate a conveyor in an acceptable manner or assist driving as required in the case of a tripper drive.

The primary difference is that the CST operates on the output end with larger driving and driven plates whilst the BOSS operates on the input side of the gearbox being a smaller more compact unit. VSD's & VFD's – (Variable Speed Drives and Variable Frequency Drives)

Both these drives are similar where the speed is primarily varied by means of changing the frequency.

VSD's: The VSD 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.

VFD's: VFD's are however capable of producing 200% torque at zero RPM, thus allowing sufficient torque to move the load from standstill in order to overcome the breakaway friction requirements. For this reason the VFD drives are preferable to long, loaded conveyors.

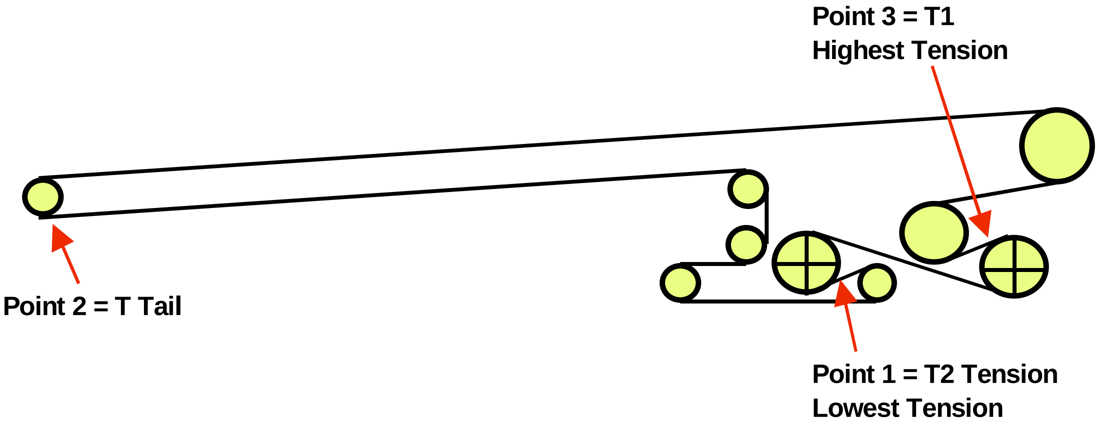
Sample Conveyor Data

Input Data

Belt Width (mm)	1200	Empty Friction Factor	0.02
Belt Speed (m/sec.)	3.5	Loaded Friction Factor	0.025
Belt Mass (kg/Lin. Mtr.)	20	Terminal Friction (Mtr.)	80
Belt Modulus (kN/Mtr.)	6000	Skirt Friction (kN)	0
Belt Sag (%)	1.5		
		Min Drive Wrap Angle (Deg.)	180 - 420
		Drive Friction Co-efficient	0.35
Trough Idler Mass (kg)	18.5	Drive Start Factor (%)	
Trough Idler Crs. (Mtr.)	1.5	Installed Motor Power (kW)	
Trough Angle (Deg.)	35		
Return Idler Mass (kg.)	22.5	Design Tonnage (TPH)	2000
Return Idler Crs. (Mtr.)	3	Horizontal Centers (Mtr.)	2000
Tot. Pulley Mass (kg)	10,000	Vertical Lift (Mtr.)	10

Profile Data

Section	Condition	Item #	Idlers	Horizontal	Vertical
1 to # 2	Empty	Load	Return	2000	-10
2 to # 3	Loaded	Disch	Carry	2000	10



The above specifications and profile points are applicable to the sample conveyor as discussed in the presentation.

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 applicable to the application.

Maintaining an acceptable DSF throughout the Ramp is critical to effective tensioning. An Aggressive Acceleration Requires an Aggressive Take Up Response.

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.

Authors CV

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

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

Relevant Affiliations

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