APPLICATION OF DRIVE TECHNOLOGY
PERTAINING TO CONVEYOR RAMPING

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INTRODUCTION

The reason for the correct selection of a suitable ramping technology is mainly as a result of the belting itself. The belting is manufactured to comply with international standards in accordance with the type and strength class of the belt. As a result of these belts being different in type and construction, the Modulus of Elasticity will also vary. The Modulus of Elasticity determines the stretch of the belt and this is why the ramping technology needs to be considered in a serious light, as if the belt is accelerated too fast, then the energy imparted into the belt carcass will contract creating huge dynamic tension waves within the system.

The modern conveyor is operating at considerably higher speeds and resultantly requires longer linear ramping profiles in order to prevent high-tension transients normally as a result of inappropriate ramping devices being selected.

Belts generally used within the bulk materials handling industry are as follows:

1. **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.

2. **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 number of plies, this belting requires relatively large pulley diameters such that ply separation is minimised. Belt modulus is relatively low.

3. **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 and resultant stretch is therefore high.

STARTING CHARACTERISTICS PERTAINING TO BELTS

The “Characteristics of Belting during Ramping” can be explained technically by means of mathematical calculations or in layman’s terms; the latter is hereby chosen in order to understand the principle of belt stretch and not necessarily the magnitude thereof. Simplistically put, conveyor belting has a given Elastic Modulus based on the “Class” or the “minimum breaking strength per meter width” of the belt carcass. The modulus is measured in kN/m width. The higher the modulus, the lower the stretch as in Steelcord belts and the lower the modulus, the higher the stretch as in Solid Woven Belts.
A belt therefore behaves in the same way as a catapult and will increasingly store energy whilst it is being stretched and will then release the energy suddenly when all the restraint is released. This stored energy will impart motion to the projectile and accelerate as it leaves the catapult.
Similarly during acceleration the belt will stretch and once the conveyor reaches full speed, the belt stretch will be released slowly to a value equivalent to the average running tension of the conveyor.
The problems occur when a relatively long conveyor with a low modulus is ramped at a high rate of acceleration. The sequences of events are as follows:

- The belt stretches as a result of the energy being imparted into the belt carcass by the drive pulley at which point a differential tension is created namely T1=Tight Side & T2 = slack side.

- In order to maintain friction between the drive pulley and the belt to impart energy at a rate that will satisfy the acceleration, a tensioning device needs to be placed within the T2 area of the belt.
- This device needs to offer sufficient tension to prevent slipping and such that the energy from the drive pulley can continuously imparted into the belt carcass. The take up also needs to be of sufficient speed to be capable of taking up the slack due to the acceleration of the conveyor.
- The rate of acceleration of the conveyor is calculated from the power required to accelerate divided by the power required to run. This ratio is known as the "Drive Start Factor" or the DSF. The higher the DSF, the more aggressive the acceleration, the faster the take up system needs to be sized. Unfortunately this high DSF also drastically increases the amount of stretch in the belt carcass that needs to be reduced to the normal running average tension.
- The longer the conveyor, the greater the belt stretch is in meters and the greater the amount of stored energy contained within the belt. If the power is lost 2/3 of the way through the acceleration, then the belt will be stretched to its maximum and this high value of energy will be instantly released trying to equalise the tensions within the entire belt. This sudden release of tension sets up dynamic waves within the belt applying extreme tensions within the steel structures, pulleys etc. equating to around 6 times the T2 tension. These high tensions are multiplied by the number of falls in the loop take up system.

An example of excessive stretch can be seen in the photograph below whereby a 20mm steel plate has been torn like a piece of paper due to the rapid contraction of a highly stretched belt. The belt in this instance was a Solid Woven class 1600 belt in 1650BW.

Structural Failure as a Result of Rapid Belt Contraction

Recommendations: In order to address the issues pertaining to belt stretch during acceleration, the following needs to be observed and applied:

- Avoid aggressive acceleration wherever possible although rapid acceleration will always be the cheaper capital option. Rapid acceleration will always generate transient tensions that will severely stress the conveyor belting; structures, pulleys and the loop take up system.
- If the conveyors are relatively long when used with "Stretchy Belt" such as Solid Woven or Fabric, then consider the dynamics and consequences that will result from aggressive acceleration.

- On short belts a DSF of 140% can be acceptable, but on long belts it is recommended that a DSF of 120% be applied in a controlled start. A DSF of <120% will effectively reduce the generation of Dynamics within the belt carcass such that ramping can be smooth and effective without unnecessary belt and structural damage.

CONVEYOR RAMPING REQUIREMENTS

Conveyors can be ramped or more simply put, started, using various methods. The starting methodology chosen needs to seriously consider the characteristics of the conveyor itself. If the conveyor is a short lightly loaded belt it would require simplistic technology for ramping and equally so if the conveyor is a long heavily loaded belt, it would require an equally sophisticated ramping technology to control the ramp from standstill to full belt speed. Failing to ramp a larger conveyor correctly, would lead to disastrous results and the conveyor ramp would be classed as being "Aggressive".

The prime mover in most conveyor applications is the electric motor although internal combustion engines are also used on smaller mobile applications in quarrying and building operations.

When the supply voltage is applied to the induction motor, it is by design of such a nature that it will accelerate to full speed in the shortest possible time span. This time span varies between types and manufacturers of motors and is also affected by motor size. Typically the no load starting time of a 300kW kW 4 pole 1000 Volt motor is 1,52 seconds and the full load starting time is 3,5 seconds. As can be seen the possibility to ramp a conveyor with a high inertia to full speed in this time would generate tremendous stresses within the system and cause high dynamic shock waves within the conveyor belt as a result of the elasticity of the belt. The effect would be reduced if a higher belt class were to be used as a result of the higher modulus of elasticity.

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

This effect of ramping a conveyor beyond its acceptable norms can be seen in the example below.

RAMPING DEVICES

These methods vary from simple starters to complex starting technologies being employed. The following methods of starting conveyors are used in modern conveyors, all operating with varying degrees of success dependant on the correct selection of the particular technology to suit the particular conveyor. The DSF or Drive Start Factor needs to be considered when selecting the suitable ramping technology for a conveyor.

DRIVE START FACTOR

The drive start factor is 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.

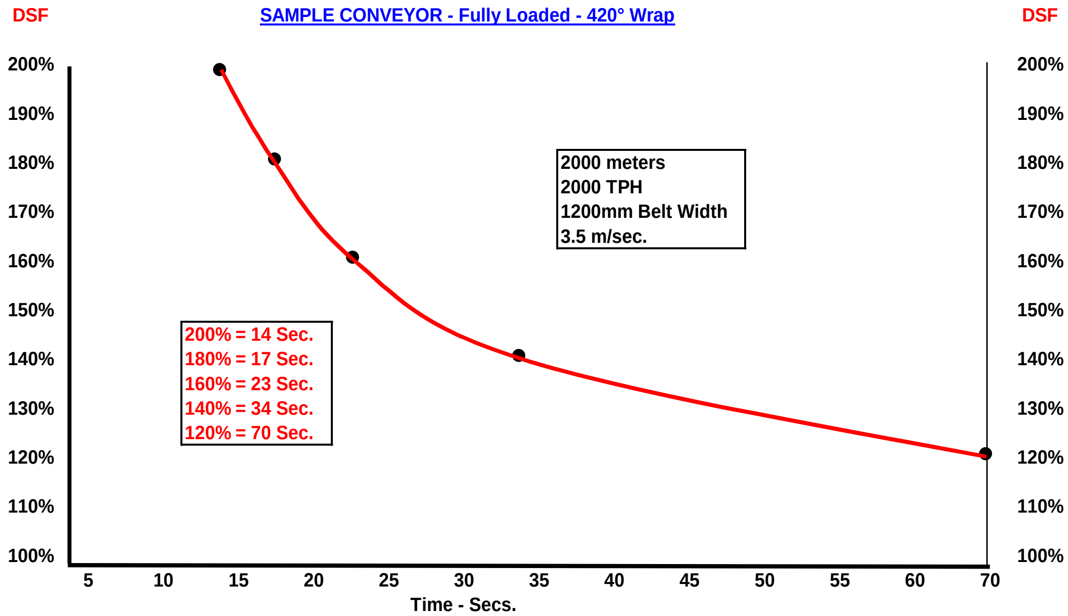
DSF can be typically as high as 200%, which may be acceptable for a small plant conveyor of, say 15 m in length with a low inertia. The higher the inertia of a conveyor, the lower the DSF needs to be purely as a result of the high system mass that needs to be accelerated to full speed.

The DSF can be calculated as follows:

DSF expressed in % = Power to Ramp / Power to Run X100

The DSF in large high inertia conveyors needs to be limited to <120%. At these values the effects on the belting are at an acceptable level such that the belt will not induce any dynamics into the belt carcass, thus not inducing high peak tensions into the mechanical components or structure.

The graph below indicates the ratio between the DSF and the time to accelerate the conveyor. The values quoted are for a 2000m 2000 TPH conveyor.



DSF for Sample Conveyor

In order to achieve an acceptable ramp for a conveyor, the conveyor itself needs to be firstly considered and then a suitable ramping technology needs to be selected in order to achieve an acceptable ramp to full belt speed without creating any unnecessary dynamics that can damage the belting of associated components.

There are many factors that will have a bearing on this selection and we need to consider the inertia within the system. The inertia is comprised from the following elements:

- Belt Length & Belt mass
- Modulus of Elasticity of the Belting
- Pulley Mass
- Idler Rotating Mass
- Idler Artificial Coefficient of Friction
- Carry & Return Idler Spacing
- Load of material on the conveyor that needs to be accelerated

A conveyor with a high inertia and a high terminal speed requires a high level of ramping technology that can provide a near linear ramp over a long ramping time with a sufficiently low DSF such that no dynamics are introduced into the belt.

The general ramping devices used in the Bulk Material Handling Industry can be categorised into two sections namely:

UNCONTROLLED RAMPING DEVICES

- DOL Starting
- Fluid Couplings with a Fixed Fill
- Magnetic Drive Couplings – Fixed Torque

CONTROLLED RAMPING DEVICES

- Fluid Couplings with a variable Fill

- Viscous Friction Transmissions
- Electronic Soft Starts
- VSD's
- Hydraulic Drives – High Torque
- Magnetic Drive Couplings – Variable Torque

UNCONTROLLED RAMPING DEVICES

DOL - Direct-On-Line Starting
(DSF=200%)

This method is possibly the simplest and most effective ramping method for small conveyors. It is difficult to quantify, but can be used up to 7,5kW. This method allows for no damping and does nothing to "soften" the start of the conveyor and resultantly does not address any belting stretch issues. Most conveyors in this size range will be fitted with a screw take up offering no "live" tensioning. The power is supplied to the drive motor by means of a Direct-On-Line starter or commonly known as a DOL starter.

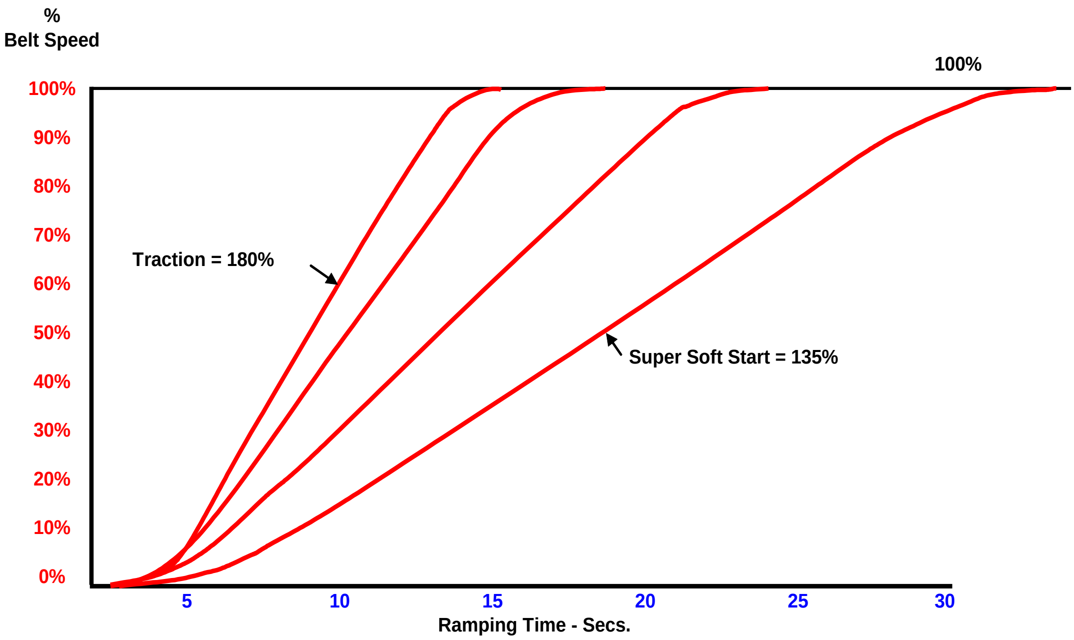
FLUID COUPLINGS – GENERAL – DSF 180% TO 135%

- Fluid Couplings are commonplace within the conveyor industry with limitations as to the power capacity and the coupling design.

Fluid couplings are hydrodynamic devices whereby power is transmitted from the driving half of the coupling to the driven half of the coupling through the application of hydrodynamic power transmission.

The classification of the fixed fluid couplings are however different by design and are typically as follows:

Traction Coupling – Constant Fill	180% DSF
Single Delay Chamber – Constant Fill	150% DSF
Double Delay Chamber – Constant Fill	135% -140% DSF (Super Soft Start)



Acceleration Profiles for Fixed Fill Fluid Couplings

FIXED FILL FLUID COUPLINGS
The constant fill coupling can only offer a fixed ramping profile under given conditions.

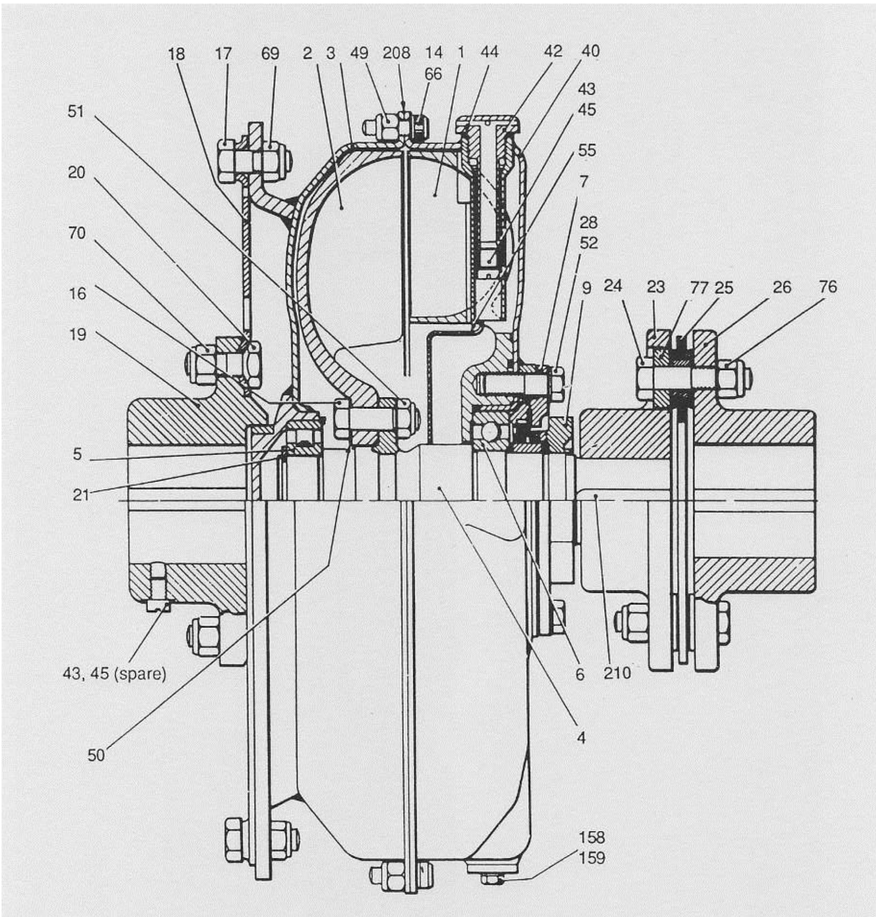
Constant filled fluid couplings are usually installed in power packs between the electric motor and the speed reducer. Oil is used to transmit power from input to output with no mechanical contact.

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 to a much lower level of inertia, which drastically decreases the acceleration time, thus creating transient tensions within the system. Fluid couplings are more suited to conveyors, which operate under non-varying conditions.

Various delay chamber volumes and configurations allow for faster or slower filling thus allowing for a more aggressive or less aggressive start.

Fluid couplings generally offer a fixed DSF with a given oil fill. If the coupling is overfilled the start will be more aggressive than if the coupling were correctly filled. Should the oil level however be under filled, 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 coupling, thus stopping the transmission of torque and resultantly stopping the conveyor. The DSF of constant filled fluid couplings varies from about 180% at worst to about 135% at best.



Typical Fixed Fill Fluid Coupling

Fluid couplings are composed of three basic elements: a driving hydraulic turbine or runner, a driven impeller that acts as a centrifugal pump, and a casing that encloses the two power components. Hydraulic fluid is pumped from the driven impeller to the driving runner, producing torque at the driven shaft. Since circulating hydraulic fluid produces the torque and speed, there is no mechanical connection between the driving and driven shafts. Power produced is based on the amount and density of the fluid circulated, and torque produced, in proportion to input speed. Since the pumping action within the fluid coupling is dependent on centrifugal forces the output speed is less than input speed. This is called slip and the difference is normally between 1% and 3%.

With fluid couplings, the ac motor starts virtually unloaded and, as the motor accelerates, torque smoothly increases from zero to conveyor breakaway torque. No compensation is provided for different conveyor loads; so unloaded starting can be considerably faster than loaded conditions. Changing the coupling fill controls the accelerating torque: Decreasing the amount of fluid reduces starting torque, but increases slip. The coupling fill must however always be sufficient to carry the maximum load without exceeding the coupling's self-heat dissipation.

With a simple fluid coupling, load balancing on a multiple drive conveyor is easily accomplished by observing the ac motor currents under full-load conditions. The difference can be corrected by removing fluid from the more loaded drive or adding fluid to the less loaded drive.

MAGNETIC DRIVE COUPLINGS – FIXED TORQUE

These couplings are relatively new to the Bulk Materials Handling Industry when used in conveyors for ramping purposes. The principle of operation is to transmit torque from one magnetic disc to another at a constant torque. This occurs as a result of the two discs being placed with a fixed gap between them. The torque can be increased or decreased by setting the discs relatively closer together or further apart.

The driving element will accelerate up to full speed as the motor starts transmitting torque to the driven element at a fixed torque value. The driven element then transmits torque to the drive pulley through the gearbox by slipping from a high value to a lower value until the conveyor gets up to full speed, at which point the slip will be minimal.

Should there not be sufficient torque transmitted, then the coupling will slip constantly and the conveyor will not reach full speed.

CONTROLLED RAMPING DEVICES

CONTROLLED START FLUID COUPLINGS (SCOOP & DRAIN TYPE)

The controlled fill couplings such as the scoop type coupling offers a controlled start ramping profile under varying conditions.

Scoop couplings and drain couplings primarily transmit torque in the same manner as a traction coupling with the exception that the oil level can be varied whilst the coupling is transmitting the required torque. This is done in order to achieve a longer ramp time for a given load, thereby decreasing the DSF of the conveyor. It also has the ability to slip at a higher than normal value, but the cooling capacity needs to be increased as the slip value is increased. This additional cooling is achieved by fitting an external heat exchanger. 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 slower due to the time taken to increase or decrease the oil fill in order to increase or decrease the output torque).

VISCOUS FRICTION DRIVES OR TRANSMISSIONS

The device is a multi plate modulated oil cooled transmission developed specifically to control output torque as required. This control is achieved by means of a PLC, which is programmed to follow a given ramping profile in order to take the conveyor to full speed whilst maintaining a low DSF thus not creating any dynamics within the belt.

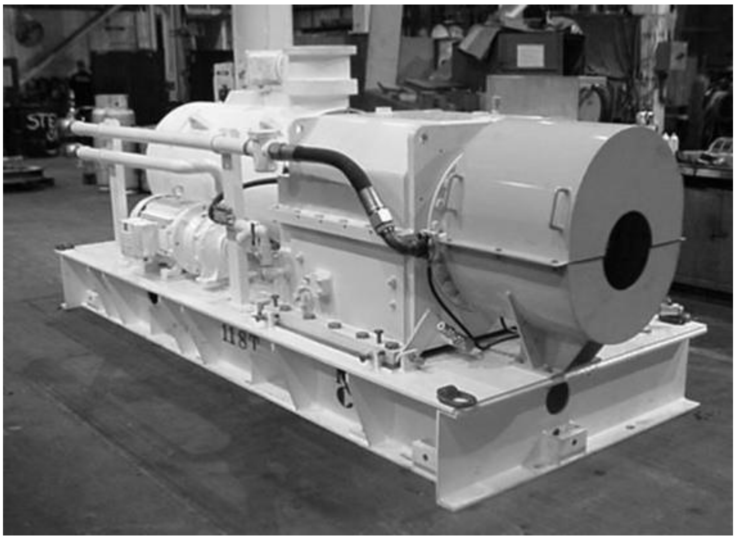
The transmission consists of a number of driving plates attached to the input shaft and the appropriate number of driven plates attached to the output shaft and is filled with oil that is continually being flushed, filtered and cooled. The required torque is transmitted by increasing the pressure applied to the springs separating the plates, thus reducing the gap between the driving and driven plates by means of the annular piston, which is in turn controlled by the PLC. The torque is applied in accordance with the code as programmed for the particular application.

Dependant on the design, the device is situated on the high-speed or low speed side of the drive module. Viscous Friction Transmissions operating on the high-speed side of the gearbox are generally smaller in size due to the lower torque requirement than those that are applied on the low speed side of the gearbox.

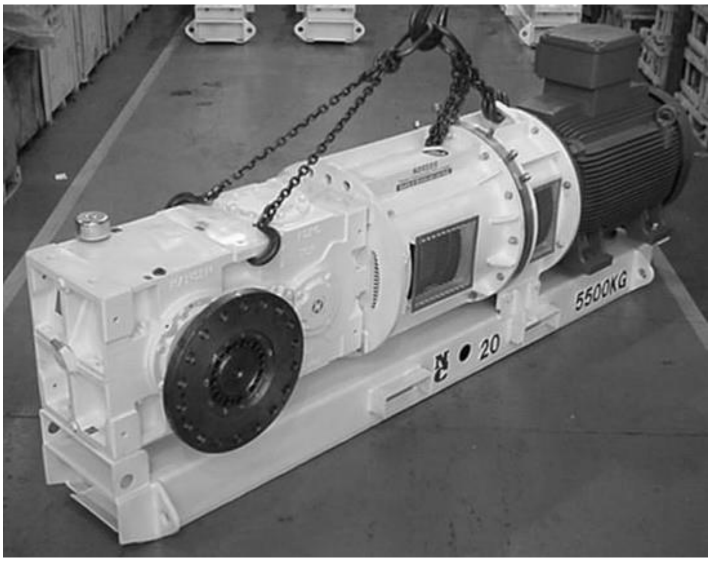
There are two manufacturers of these transmissions, namely:

- The CST manufactured in the USA – Speed modulation on the low speed side.
- The "BOSS" manufactured in Australia - Speed modulation on the high-speed side of the power pack.

The following photographs indicate the difference in the configuration of the two Viscous Friction Transmissions:



Dodge CST – In Line type Power Pack



Nepean Boss Torque Arm Type Power Pack

ELECTRONIC DRIVES

REDUCED-VOLTAGE STARTERS, (SOFT STARTER) — DIRECT DRIVE

As conveyor power requirements increase, controlling applied motor torque during acceleration becomes increasingly important. Since motor torque is a function of voltage, motor voltage can be controlled with reduced-voltage starters. Many of these starters control voltage with timers, so each voltage increment creates a step change in the applied motor torque. To eliminate the torque spikes that often occur with each step change, silicon controlled rectifiers (SCRs) are recommended, as they allow continuous control of motor voltage throughout starting.

A reduced voltage starter begins with a low voltage (to take up conveyor belt slack) followed by a timed linear ramp-up to full voltage and full belt speed. Keep in mind, though, this starting method doesn't produce constant acceleration of the conveyor belt. When acceleration is complete, SCRs are bypassed and full line voltage is supplied to the motor.

VARIABLE FREQUENCY DRIVES, (VSD'S) — DIRECT DRIVE

VFD's provide variable frequency and voltage to the induction motor at all times, resulting in excellent starting torques and acceleration rates for belt conveyor drives. These VFD drives, available from fractional to several thousand kW, are electronic controllers that rectify ac line power to dc and then (through an inverter) convert dc back to ac with frequency and voltage control. Due to the electronics' current limit, VFC drives will not run overloaded; for this reason, correct size selection is important.

VFD drives are mechanically simple, but electronically complex. On most installations, voltage controlled transformers and extensive surge protection is required, but the drives are reliable if properly installed and electrically protected.

When equipped with the proper electronics, VFD drives provide excellent speed and torque control when starting conveyor belts, and can be designed to provide load sharing for multiple drives. In general, the cost of a VFD drive is higher than other systems, particularly where high-voltage motors are specified or power requirements are above 200 kW. VFD controllers are frequently installed on lower-powered conveyor drives, retrofits where standard induction motors are used and higher-powered belt systems where sophisticated variable speed operation is required.

These VSD Drives 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.

HYDRAULIC DRIVES – HIGH TORQUE

High Torque Hydraulic drives are often used particularly in Belt Feeders where a very high pull out torque is required as a result of feeding material onto a normal conveyor when it is being drawn from the underside of a bunker, silo, hopper or bin. Greater use of Hydraulic Drives is however being seen when applied to conventional belt conveyors. These drives are normally of the radial type allowing for high torque at very low speeds. The control of these drives is also easily achieved to allow for a linear controlled ramp.

MAGNETIC DRIVE COUPLINGS – VARIABLE TORQUE

These couplings are very similar to the Fixed Torque type described earlier with the exception that the distance between the driving disc and the driven disc can be varied thus increasing or decreasing the torque being transmitted. The gap can be varied manually or can be automated by means of a PLC in order to allow a controlled ramp.

The following table describes the various drive types with their typical applications.

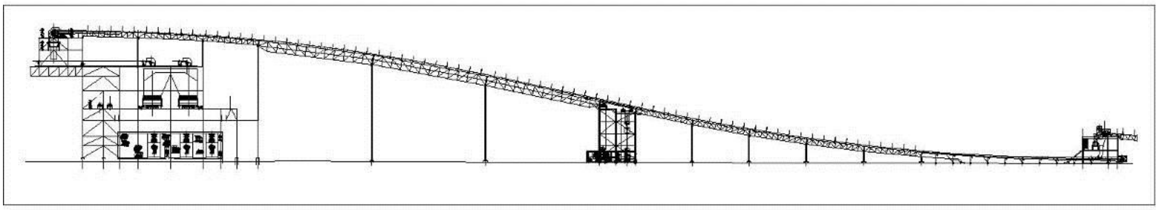
Item	Description				
	Uncontrolled Type	**DSF**	**Ramp Control**	**Application**	**Power Range**
1	Direct On Line	200%	Nil	Small Plant Conv.	< 7,5 kW
2	Fluid Coupling Traction	180%	Poor	Medium Plant Conv.	< 15 kW
3	Fluid Coupling Soft Start	150%	Poor	Medium Plant Conv.	< 37 kW
4	Fluid Coupling Super Soft Start	135-140%	Fair	Med ROM & Short Conv.	< 110 kW
	Controlled Type	**DSF**		**Application**	
1	Scoop Coupling	Variable	Fair to Good	Long Centre Dist. Conv.	200 - 400 kW
2	Fluid Coupling - TPKL	Variable	Fair to Good	Long Centre Dist. Conv.	400 - 800 kW
3	Boss Transmission	Variable	Good	Long Centre Dist. Conv.	250 - 400 kW
4	Dodge CST	Variable	Good	Long Centre Dist. Conv.	250 to 750 kW
5	Frequency Control	Variable	L Start Torque	Medium Plant Conv.	15 - 75 kW
6	Var. Volt/Var. Frequency (VSD)	Variable	Good	Long Centre Dist. Conv.	150 - 1000 kW

EXAMPLES AND COMMENTS APPLICABLE TO THE RAMPING OF CONVEYORS

Conveyor Data:

Material Conveyed:	Iron Ore
Design Tonnage:	1650tph
Conveyor Horizontal Length:	249m
Conveyor Vertical Lift:	26m
Belt Speed:	1.83m/s
Belt Width:	1050mm
Input Power:	250kW (Single Drive)
Counterweight Type:	Vertical Gravity

CONVEYOR LAYOUT



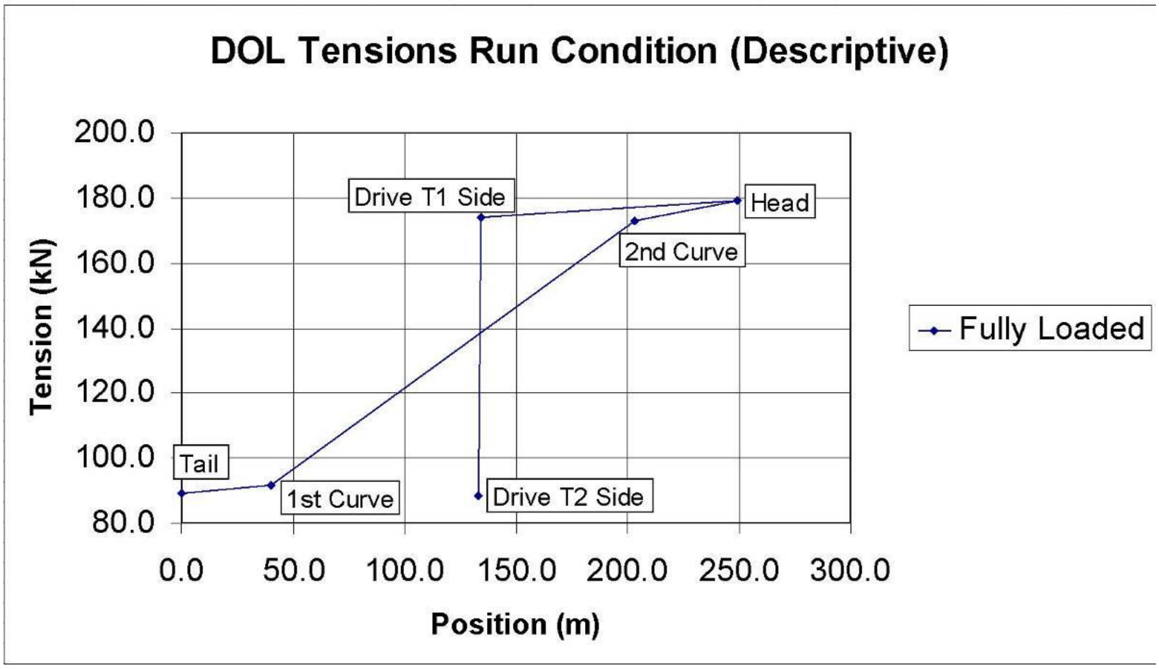
Depicted is a typical elevating conveyor featuring concave and convex curves, the drive is ground mounted and has a standard gravity take-up. The conveyor is fed at the tail end and discharges at the head end.

DESCRIBING THE TYPICAL GRAPH

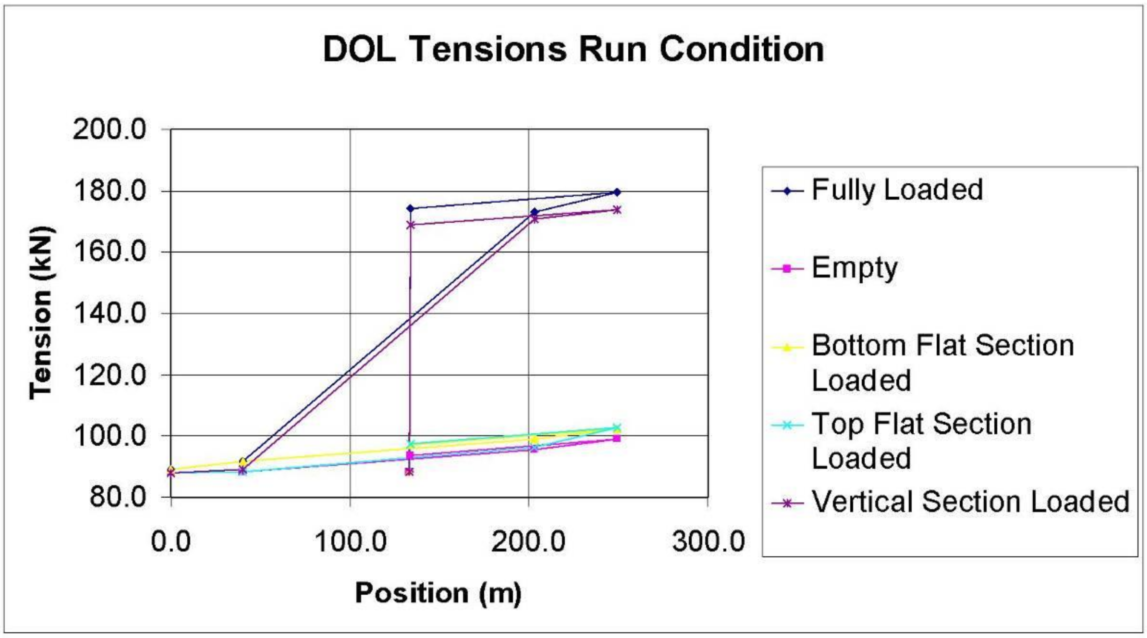
Firstly it is important to label the points on the graph that allow for easy reading and a better visualization of the graphically represented conveyor layout.

The graph takes it zero position from the "Tail" and maps out known points along its 249m path before retreating to the "Drive T1 Side" position.

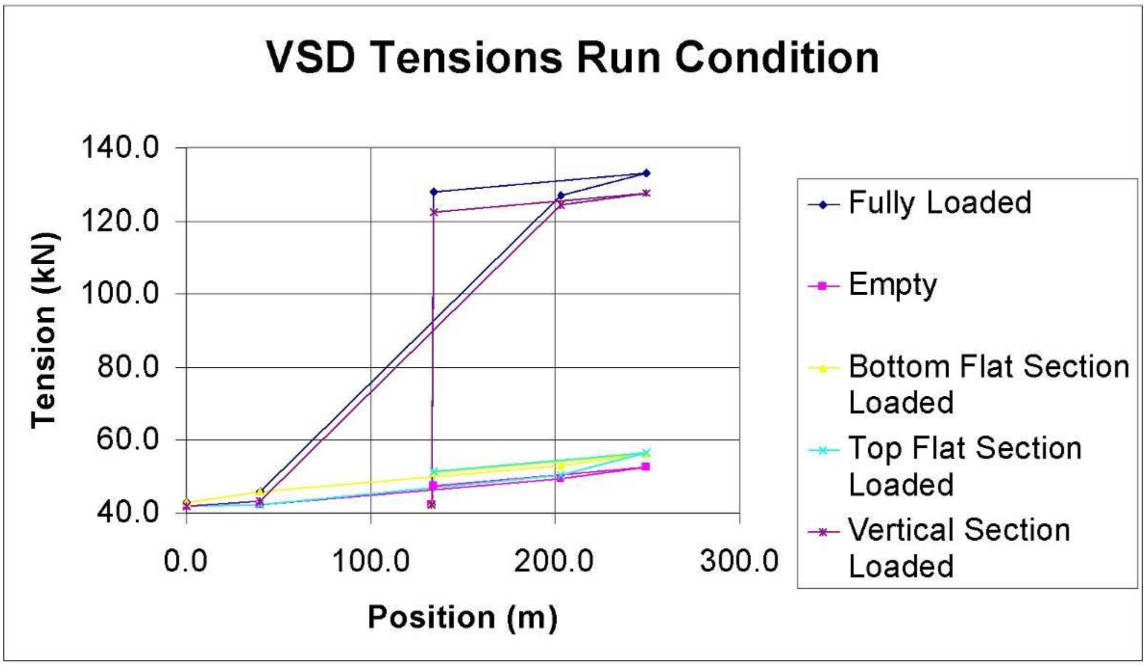
Moving from the "Tail" to the "Head" the first intersection is found at position 40m, the Concave Curve. There has been no vertical elevation in this section but due to the loading a steady increase in tension is calculated. The next section has both horizontal and vertical displacement and moves to position 203m. This point is described as the Convex Curve. There has been a significant increase in tension due to the conveyor lifting the applied load through 26m. The next point is the "Head" at position 249m, there has been a horizontal displacement but no vertical displacement from the last point but again a steady increase in tension is calculated. The graph then depicts the return belt along the conveyor route to the "Drive T1 Side" where it then drops to the tension of the "Drive T2 side". This sudden change in tension is the imparting of power at the drive pulley. The cycle will be completed after a linear path is followed from the "Drive T2 side" to the "Tail".



COMPARING THE "RUN" TENSIONS BETWEEN DSF EXTREMES
The following graphs illustrate the tension distribution along the belt for the conveyor using DOL drive.

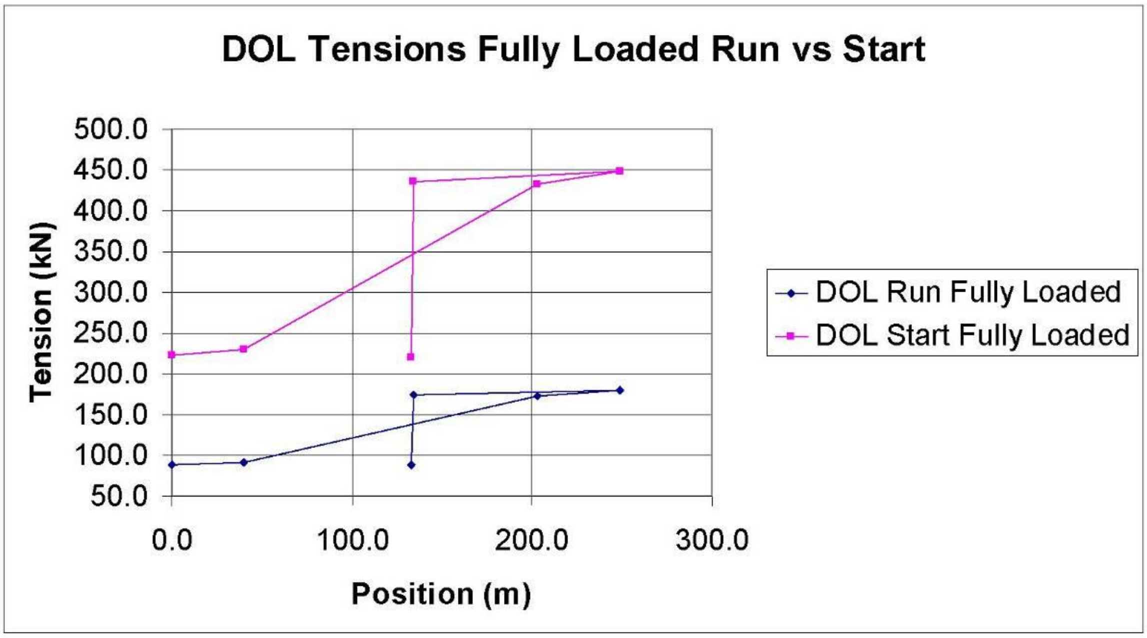


The following graphs illustrate the tension distribution along the belt for the conveyor using VSD drive.



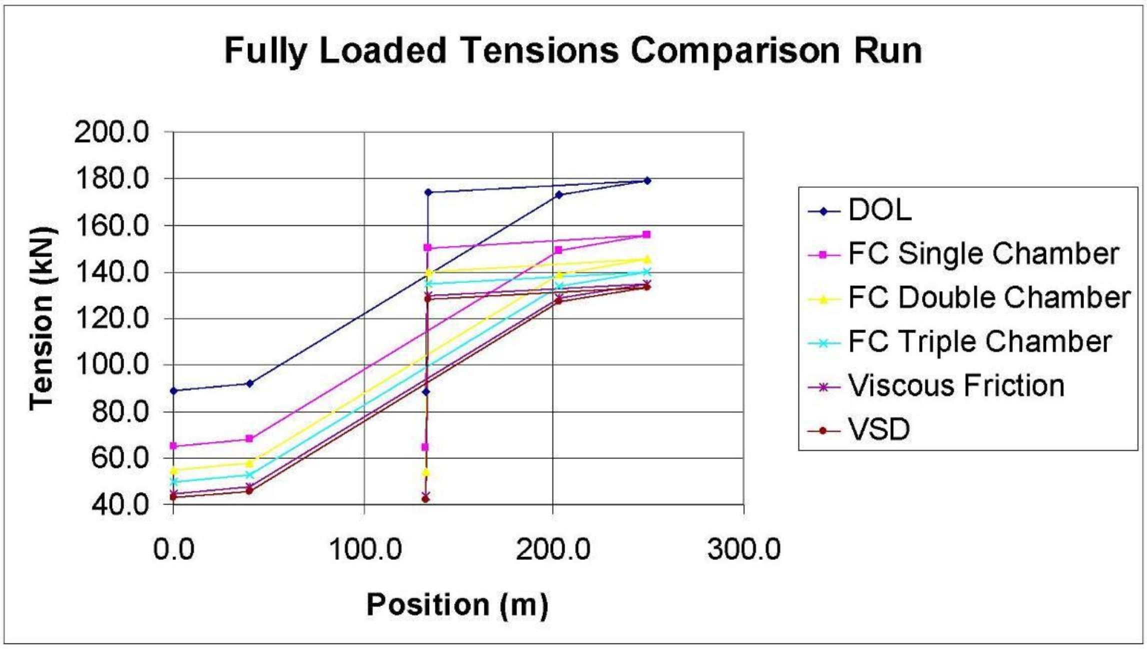
Both the graphs depict a similar pattern; the major difference however is the conveyor belt's inherent tensions. For the DOL graph we find a "Head" tension of 179.3kN and for the VSD graph the same point shows a 133.2kN. The difference is attributed to the required counterweight mass that is derived from the amount of T2 tension required so that no slip occurs at the drive during start-up.

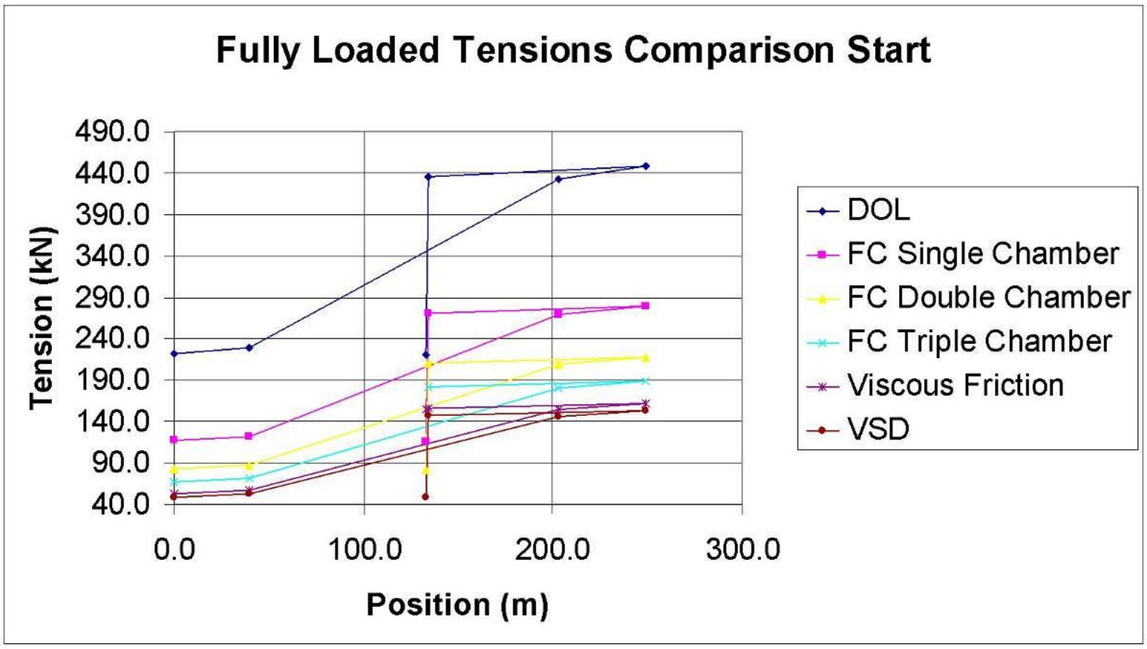
This can be illustrated by comparing the "Run" and "Start" graphs for both the "DOL" and "VSD" drives.



The difference that the DSF factors impose leads to the different required counterweight masses. For the "DOL" drive a counterweight mass of 17.31ton is required and for the "VSD" drive a counterweight mass of 8.26ton is required, a difference of 210%.

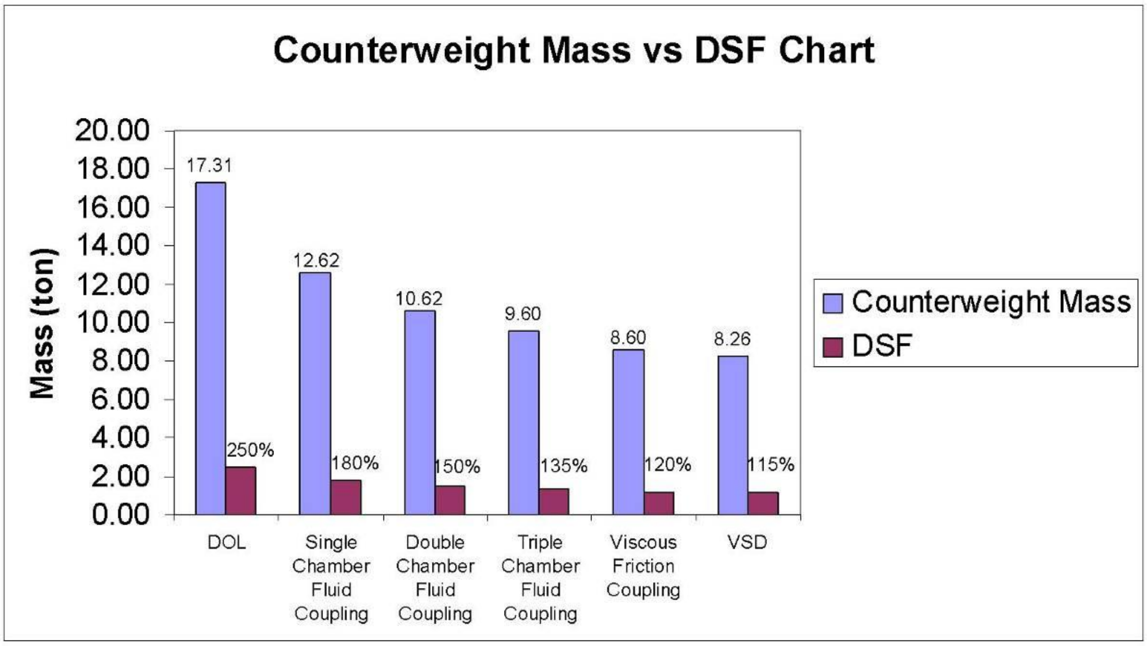
A similar graph can be plotted that depicts various tension curves for different DSF's. Below are two graphs that plot results for a fully loaded belt under "Run" conditions and the other for "Start" conditions.





THE COUNTERWEIGHT MASS

By applying different DSF's to the same conveyor the required counterweight mass shall change accordingly. The following chart records the changing counterweight mass in relation to the required DSF.



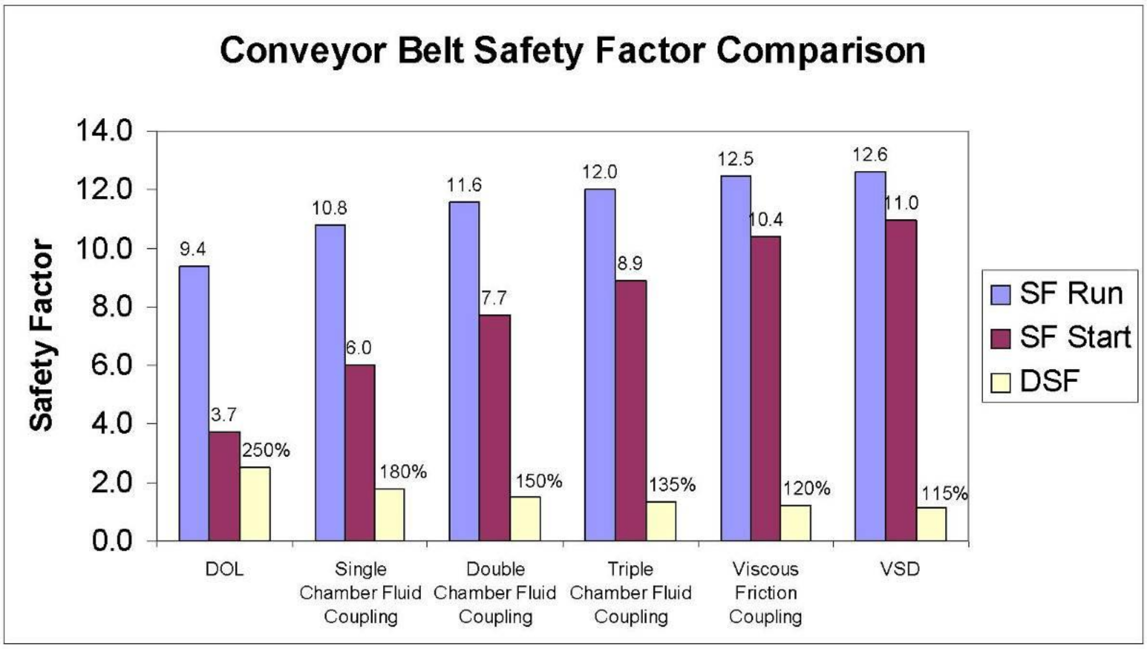
Although the counterweight mass had an increase of 210% using DSF's of 250% and 115% respectively the systems average tension would increased by 152% from 88.8kN to 134.9kN for the DSF factors.

CONVEYOR BELT CALCULATED SAFETY FACTOR

The increase of the systems tension by applying different DSF's negatively influences the Safety Factor for the conveyor belt. For a multi-ply conveyor belt the well-documented safety factor of 10 is to be adhered to.

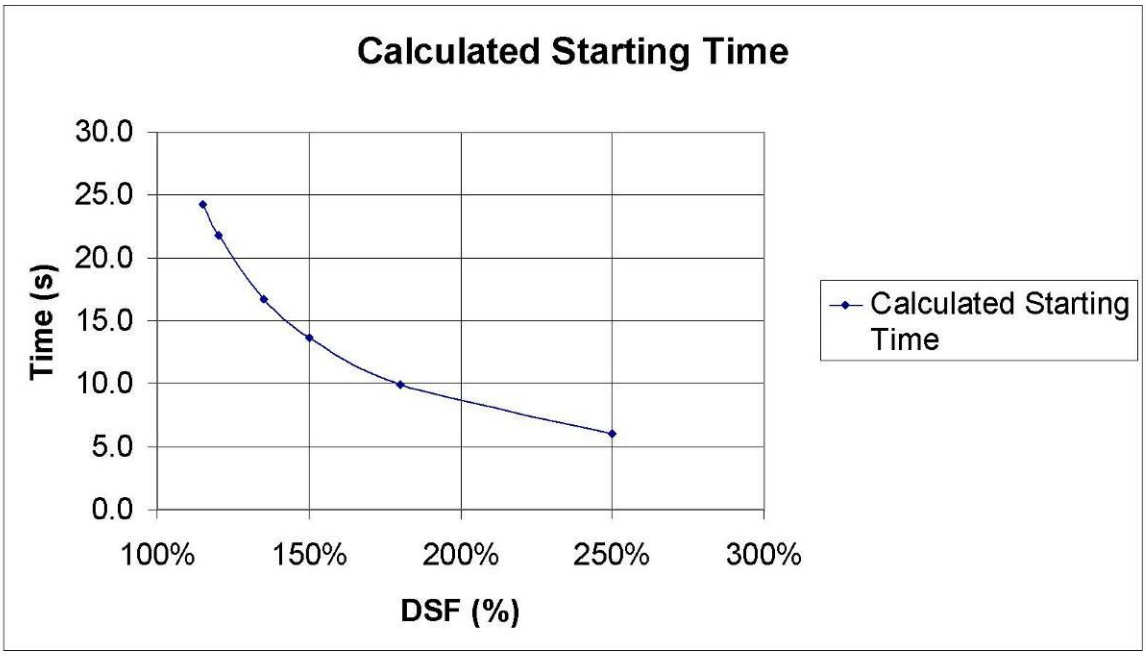
In the table below the "DOL" start causes the safety factor to drop below 10 thus requiring a more superior belt. The aggressiveness of the different drive technologies is also visible when the difference of the "Start" and "Run" safety factors are calculated.

In some cases a lighter conveyor belt with less tensile strength may be used because of the advantages gained from utilizing a better DSF.



CALCULATED STARTING TIMES

As previously seen this conveyor imitates the typical "Starting Time" vs "DSF" curve. A "DOL" start is calculated to start the conveyor in 6.0s and a "VSD" is able to start the same conveyor in 24.2s.



CONCLUSION

This study does not allow for the conclusive selection of a drive technology that is required. Other factors such as cost, redundancy and location play major roles. It is also left to the discretion of the designer to ascertain what acceptable DSF can be utilized. This particular conveyor shows probably acceptable values from 150%, other designers may feel that 135% and better are more acceptable.

AUTHORS' CURRICULUM VITAES

ALAN EXTON

The author of this paper has been involved in the mining industry since 1969 where he commenced his training West Rand Consolidated Mines Ltd as an apprenticed Fitter & Turner. During his Apprenticeship he obtained a National Technical Diploma in Mechanical Design. After 7 years employment in the mines, he joined the private sector in the Mining Division of Dowson & Dobson (Pty) Ltd. as a design engineer. He was involved in the design field of both coal & hard rock mining equipment for various companies until 1995.

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

Relevant Affiliations:

- Director of Companies
- Member of the South African Institution of Mechanical Engineers.
- Professional Member of South African Institute of Materials Handling.
- Past Chairman of the Conveyor Manufacturers Association of South Africa Ltd.
- Past Member of Beltcon 8, 9, 10, 11, 12 & 13 Committees.
- Member of Beltcon 14 Committee.

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