Management & Control of high elongating belt
In long centered conveyors.

Peter R. Gilbert
Nepean Conveyors International Pty. Ltd

INTRODUCTION

During my career in sales & design of conveyor systems, especially the most recent years, I have noticed the lack of grasp many decision-makers have of the basic dynamic characteristics of a conveyor and the implications of labelling it "just another conveyor".
I have been at this caper for twenty-six years and to date, have never found two exactly the same yet.
One of the most fundamental issues, more so with Solid Woven carcass belt when it is selected for a conveyor is its comparison to a large elastic band.
Many hear and read conveyor belt specifications but still not seem to grasp, in practical terms, the reality of how the conveyor will behave as a dynamic system and the then required conveyor system control process that is required to be put in place to manage the dynamics of the conveyor.
This paper is not a technical brief or a matrix of math resulting in a theoretical conclusion. I purely wish to share in layman's terms some pretty staggering examples of the results & realities of selecting a particularly "stretchy" belt for use in a longer centered conveyor system and few suggestions at the ways, means & methods of controlling it.

2. A REVIEW OF BELT TYPES AND THEIR TRADITIONAL APPLICATIONS…

The predominant thrust of my conveyor design business is directed towards the underground coal mining discipline which, by nature, is confined in available space and thus has historically required the smallest diameter pulleys.
The second most dominantly considered issue (but in reality, the first) in my customers conveyor selection is price when matched to belt life compared with how much is left in the Budget.
Both requirements lead my customers to solid woven belt.

To digress, and for the purpose of not leaving any stone unturned for the beginner, there are three mainstream conveyor belt carcass types available to the conveyor designer.

A. SOLID WOVEN BELT.

Solid Woven belt is constructed with one rather thick carcass of interwoven poly-cotton material with very high peaks & troughs in the weave and is predominantly the more economical of the major belt types of equal carcass strength.
There are several "carcass" thicknesses leading to a range of ultimate tensile strength's (UTS) from as low as 200 kN/M to 2000(kN/M).
After the carcass weaving process, a molten liquid PVC product is drawn into the carcass under a vacuum impregnating process evacuating all air inclusions to form a solid mass carcass that protects and seals the Poly-cotton carcass backbone of the belt.
During the PVC application process, a further 2+2 (meaning 2 additional millimetres on top and 2 millimetres on bottom) will be applied thus providing protection for wear & impact for the life of the belt from the product (carry side) and the carry idlers (belt underside). Any reasonable variable top and bottom cover may be selected dependant on the expected life & duty of the belt.
Further, smoother and more durable "Nitrile" covers have recently been introduced for longer life and more efficient cleaning however, at a price.

The interesting issue with respect to this publication and Solid Woven belt is the construction and materials poor resistance to stretch.
In technical terms, Solid Woven belts modulus figures drop as low as 4000 kN/M/W. The reality is the stuff compares very closely to chewing gum.

Copyright is vested with IMHC

Generally, solid woven belt will have 1.5% permanent and 1.5% working stretch. The reality is, sometime after commissioning and during the early life of a 3,500 metre conveyor, the loop will have to actively absorb in excess of sixty metres of belt during a loaded start and remove or absorb a further seventy metres while the belts getting its permanent stretch act together. (think about it, we'll revisit this issue later)

B. PLIED FABRIC BELT

The more common Plied Fabric conveyor belt is constructed from between one and five separate single layers or "plies" of variations of cotton or Poly-cotton fabric to generate the conveyor belts backbone and strength, each separated by a thin layer of the belts main rubber construction material.

As with its Solid Woven counterpart, Plied Fabric belt is provided with a further layer of rubber based product top and bottom (more commonly, more on top) to provide for a wear cover against product, carry and return idlers.

Plied belting is traditionally more expensive than Solid woven but in return, and as a generalisation, provides for a longer wear life and far superior hot vulcanized splice leading to a more reliable conveyor installation.

Fabric belts have a considerably higher modulus of elasticity, generally double that of Solid Woven due to several factors not the least being its fabric layers are virtually already pulled taught and have a much finer weave.

The nett result is Fabric belt provides for a much "stiffer" and considerably more predictable long centred conveyor belt system.

C. STEEL CORD BELT

As a comparison to the previous belt construction, Steel Cord belt is exactly that: A carcass constructed with a number (generally forty to fifty) 6mm to 10mm steel cables depending on the belts strength rating, laid in line and cast together and hot vulcanised into the parent rubber envelope.

Steel cord belt is typically specified for highly powered or extremely long centred conveyors that generate immense belt tensions or where resultant elongation or stretch must be kept to a minimum which Steel Cord belt provides admirably for.

Steel Cord belt has, as quite literally a result of its steel carcass, a modulus of elasticity in excess of ten fold that of Plied Fabric and twenty five fold that of Solid Woven which makes it extremely predictable and controllable as it provides for a very stiff and reliable platform in a dynamic sense.

Although this type of belt also has its pro's & con's of operational, economical & design characteristics & for the purpose of this paper, I want to draw the comparison between Steel Cord & Solid Woven where the latter is in excess of twenty five times more "stretchy" however, is also being drawn into longer and longer centred conveyors through the use of Tripper and Linear Booster Drive stations.

3. USE OF OLD TECHNOLOGY BELT WITH NEW TECHNOLOGY CONVEYORS.

We may all by now be familiar or aware of the introduction of Tripper or Linear booster drive stations over the last twenty years both in South Africa and overseas. For those that are not, it is a relatively new technology that allows the operator to extend the traditional length of his conveyor by three, four & five times (see Sketch #1) by inserting belt-tension sensing drivehead devices at the appropriate locations along the conveyor thus limiting high belt tensions to that prescribed by the belt manufacturer or conveyor designer.

Theory has it that the length of a "Tripper assisted" conveyor is bounded only by the capacity of the loop take-up and the continuance of the conveyor in a straight line (although the latter is continually being challenged).

There have been indeed, more commonly involved with the underground coal industry, some exceptional cases of multiple Tripper assisted conveyors, predominantly utilising low stretch Plied Fabric belt.

However, where economising is paramount, capital investment low and the traditional thinkers prefer to stay with the Solid Woven belt we are now delving into the newly generated field of utilising an old reliable (but very stretchy) friend combined with a relatively new Tripper technology that pins no theoretical restrictions on conveyor length.

Copyright is vested with IMHC

This proposition is delightful to the operator as he has saved significantly on additional loops take-ups, winches, transfer points, pulleys, winders not to speak of the heartache of starting (or non-starting) a sequence of multiple conveyors, all of which is a commendable progression of technology & economising.

We must however, never forget the belt strand is the same old Solid Woven with its elastic stretch & resultant contraction but is now in a four & five times longer strand.

There are essentially two phenomena that should be heavily considered when designing a long centred, highly powered (typically tripper assisted) conveyor involving a low modulus or high elongating belt type such as Solid Woven.

> ***1…***Its ability to stretch under acceleration & running.
> ***2…***The dramatically increased peak dynamic loads created as a result of the unusually long belt contraction when power is suddenly removed.
>
> I will address these individually…
> ***1…***Its ability to stretch under acceleration & running.

For the first part, the technology of maintaining a constant tension take-up and actively storing sixty metres of belt (as was mentioned earlier in a typical 3500 meter conveyor) is not hard or new. It totally precludes gravity take-up in a practical sense and even using a powerful winch, with a full speed of 0.5 m/s, the belt starting time must immediately be well in excess of 2 minutes.
Again, this is not unusual today, however, this immediately precludes to accelerate the conveyor the use of simple fixed torque devices such as fluid couplings that have traditionally been "paired up" with a standard type 1400 Solid Woven conveyor.
Simply ramping the long centred – low modulus conveyor to full speed using "S" curve or a linear speed ramp is sometimes still sub-standard from a first principles of engineering standpoint as 90% of the starting effort & control is put into the first 40% of the acceleration cycle. This then follows that an abnormal "S" curve should be provided to serve the changing needs throughout the ramp to full speed.
Ideally, the control philosophy of these types of conveyors should be "event driven".
Because the loading condition of the conveyor can be anywhere from empty through to fully loaded during each accelerating and decelerating cycle, the process to perform the simple function of starting the conveyor should be directed by the specific need at that time, therefore, the ideal of a pre-determined pre-programmed start time or torque ramp becomes obsolete.
To perform an event driven start-up of a complex conveyor with high elongation, several detection devices are required to provide information back to the conveyor control centre such as extremely high resolution belt and drive pulley tachometers, actual & real time belt tension load cells, motor current feed back along with any other temperature range monitoring of critical heat sinks or dissipating cooling devices.
An ideal acceleration control for such a conveyor should be broken into several stages (see enclosed Sketch #2) that each "state" is allowed to perform its function wholly, prior to allowing the next state to be entered into. Because the amount of belt stretch that can be developed in our 3500 meter conveyor will vary immensely dependant on load, time is not considered (except where regulations permit), where completing the task is.
Firstly, a torque ramp should be generated at the drive pulley in a gentle manner, gradually "torquing up" the drive pulley shafts ***prior*** to pulley movement. This condition can be prompted by gently but quickly applying 80% of the previously known motor current value just prior to the last motor stop.
Given that both motor current & pulley speed are being real time monitored, a "ramp to jog speed" function should be enabled only at a point where the drive pulley has just started to move.
Now here's the tricky bit…
A gentle & timeous acceleration to, say 10% full belt speed should follow and on reaching "jog" ***hold*** this speed until the ***entire*** conveyor belts carry & return strands are moving at the same speed.

Copyright is vested with IMHC

Notes…
A well designed long centred, high elongating belt system should provide for belt speed detection at drive pulley(s) at host and all tripper stations, belt speed into the drivehead(s), belt speed out of the loop take-up, winch cable speed with all data brought back to a common PLC trending package.
The "jog" function is performed primarily to fully elongate the partially or fully loaded carry strand of the conveyor and then the return strand prior to accelerating the belt to full speed.
Depending on the varying load situations, the jog time will vary significantly, thus, the requirement for multiple speed detection with good resolution.
Full elongation of the belt system prior to run-up to full speed is paramount to the successful ramp cycle as pre-mature acceleration at the host drivehead will result in a significantly magnified elastic contraction of the "unusually long centred" carry belt strand (and its load) which will almost certainly result in catastrophic failure at the loop-winch area of the conveyor.

Under comparison, once the various conveyor belt speed stations have stabilised at jog, the conveyor can now be accelerated over the desired "S" curve using a time base that is appropriate to the ***current*** load. A look-up table is appropriate in this case that aligns the magnitude of total drives current to an acceleration cycle that is matched to the conveyor belts modulus of elasticity thus ensuring that the belt is never over extended to the point of uncontrollable elastic contraction throughout the ramp to full speed.

It is notable that during a conveyors ramp cycle, vastly differing amounts of energy are required at differing stages of acceleration (see Sketch #3), for example, as previously mentioned, 90% of the effort is put into the first 40% of ramp.
Conversely, as the conveyor approaches full speed the effort required to "feather" the load to 100% is extremely slight.
Again, in order to ensure no overspeed is generated, a highly elastic belt should incorporate a "roll-off " routine that quite literally "rolls" the top of the ramp cycle into full speed by very gently feathering the applied power to the belt drive.

Sketch #2 highlights the several receding stages of gain throughout the latter portion of the ramp cycle that would be recommended to a long centred "stretchy" belt installation.

Once up to speed and (if any) minor elastic contractions have settled, the influences a highly elastic belt will have on a long centred conveyor will be minor, although, a few points should still be born in mind.
If the conveyor is an on-the-run extending or retracting type conveyor such as a Longwall maingate or Breaker line support panel belt, the speed at which the mobile tail end advances or retracts should never exceed 50% of the loop take-up or belt storages winching maximum speed as dynamic-elastic acceleration of the belt strand will influence the finally required loop absorption of the belt slack allowed into the belt system.
An interesting note at the Invincible Collierys Maingate conveyor, Lithgow NSW, a long centred 1400kN solid woven belt system, the detensioned tail portion of belt travelled as a "slug" down the full length of the 3000 meter conveyor whenever the tail end was retracted by 3 meters to arrive at the drive & belt storage system at one 10 second mad rush sending the winch to full speed and threatening drivehead slippage throughout.
The dynamic effect of load-up & unload of the long centred, highly elastic conveyor more or less cares for itself as the rate at which it can fully load from empty to fully loaded is relatively slow and thus provides the take-up system with plenty of time to perform its duty of dynamically hauling out & storing then releasing back into the belt system the working stretch of 1.5% from empty to loaded condition.
A further magnified consideration in a highly elastic belt system using tripper or linear booster assistance during running is the requirement for exceptional speed control and performance between driveheads in the common belt system, although, this subject is extensive & worthy of another paper drawing comparisons of drive devices & technologies available today.

2…The dramatically increased peak dynamic loads created as a result of the unusually long belt contraction when power is suddenly removed.
This subject is easy to provide for under powered & normal circumstance, but there again, one must design for the abnormal.

Copyright is vested with IMHC

Firstly, and again in layman's terms, we must understand what happens within the highly elastic belt system when power is suddenly removed from the drivehead.

If the belt was fully loaded just prior to power loss, the carry strand would have been fully elongated along its various portions of "linked" belt between host and tripper & tripper to tripper drives.

Sudden drive power loss releases the high belt tension at the drivehead to contract (with its load burden) ***backwards*** into the belt system under elastic contraction of the highly tensioned belt carcass thus bringing its drivehead to an appropriately decelerated stop.

To bring this into reality, an example loaded belt of the long centred, tripper assisted type at Wambo mining in the Hunter Valley NSW, typically stopped its host drivehead in four seconds from full speed of 3.8 m/s due in the main, to elastic contraction of the carry strand. This tripper assisted solid woven belt conveyor was further burdened by a 67 metre lift, which naturally causes the carry belt to stop quickly. The combined effect however generated massive resulting belt tensions through the loop developed from the return strands speed and weight of 3.8 m/s and sixty one tonnes.

The nett result given the belt is super-elastic ***and*** unusually long is piles of t-sag down at the tail end spilling hard earned product all over the place.

This type of conveyor profile characteristically requires a power-down function that is in reality a reverse-ramp to elevate high return belt strand tension problems and avoids the accompanying results.

This is not uncommon technology but introduces two complications:

- What should be done in case of power failure?
- Introduces by regulation two modes of stop being normal and emergency stop.

The first has traditionally been handled by additional bunkering & addition of inertia fly wheels although with the heavy introduction of VVVF technology into long centred conveyors, the concept of using the running down motor as a generator to provide power to simultaneously power down is now a reality.

The second, in just about all the installations I know underground is being resisted due to the expense of duplicating the entire stop system to differentiate from "emergency".

A further consideration when providing anti-runbacks to support a long centred-low modulus conveyor is the sheer multiplied elastic "pull-back" firstly of the belt, exaggerated by the load at the peak point of elastic stretch, just before breakaway at the start of a ramp cycle. If power is removed at this point (a pre-mature aborted start) the reaction against the drivehead is to be pulled wildly backward by stored energy that may have been piling up for fifteen to twenty seconds ***instantly.***

In this case, the use of high speed, low torque gearbox inti- runbacks should be avoided as they will not withstand the accelerated "snap on" given the collective backlash clearance of the downstream gear teeth. United Colliery attests to this condition (3400 m ctr's, 136 m lift 2000kW installed, type 1800 Solid Woven).

The preferred anti-runback in this case would be the high torque, low speed pulley shaft type and although expensive, provided they are sized three times their relative power module torque, they will perform admirably under the super-elastic conditions.

Incidentally, although the rule book says "where there's one runback device, a second should be provided in case of failure" the reference is per. Conveyor, not per drivehead in Australia ie: we may install one runback on the host drivehead and a second on one tripper, which sort of defeats the purpose!. Frankly, I would stay with three times the power, per drivehead, ***with*** a spare.

All the above points considered, I would like to slip into some case studies and real examples of what all of the above is eluding to…

PROBLEMS ENCOUNTERED & REAL EXAMPLES
CASE STUDIES

Copyright is vested with IMHC

INVINCIBLE COLLIERY, MAINGATE #1…1981

2700 MTRS LONG, 5MTRS LIFT, 700KW INSTALLED ONE DRIVEHEAD, 1400KN SOLID WOVEN BELT.

Although now a few years back, I distinctly remember my first overpowering demonstration of how ***not*** to do it.

My part, for the above installation was to design & manufacture what was amongst my first eight lap maingate belt storage systems, "Octopulley" I think we called it.

The current thinking at that time had little appreciation for belt stretch & contraction. The company at that time provided a dual drivehead three times bigger than the "normal" and fitted a pair of 350kW Loher motors along with single-sump, very ordinary but very big Traction fluid couplings that were probably designed for large pumps with an extremely tolerant DOL starter and covered by a very benevolent insurance company.

Our rationale was, just take what we've been doing for the last ten years and triple the size.

Empty commissioning went off successfully only with a few scares, my beloved Octopulley belt storage system fitted with what I now realise was a very ordinary, immensely underpowered electro-mechanical winch, getting an occasional violent thrashing due to minor but significant elastic belt contraction on start-up.

My superior on site (who I later deduced *should* have been a pastry cook) calmed me with the notion that once the conveyor were laden, the Traction couplings would "come into their own" and the ramp time & torque would ease significantly providing for a more gentle start.

I remember standing on top of the belt storage winch guard to obtain an optimum view of the first fully loaded conveyor start.

Production had commenced and with the belt running successfully, it had taken twenty minutes to fully load up prior to stopping in readiness.

All were there, the Mine Manager and his Engineering Dignitaries, my boss (the pastry cook), and above all, Angelo Butta, a major shareholder in the Invincible Colliery venture.

The command was given, the belt started & what happened during the next twenty seconds scared the pants off of everyone present, simultaneously setting a challenge for me in future years.

The first ten or twelve seconds saw the drivehead accelerating hard, but no belt was being pulled ***out*** of my belt storage, in fact, my very inept winch was pulling belt slowly ***into*** it.

All at once, at around fifteen seconds, a horrendous tug towards the tail on the return belt strand lifted me clean off my winch guard perch which as matters unfold, was to my very good luck.

I now understand that a dynamic belt retraction wave we deliberately induced travels at approximately eight hundred & fifty metres a second, as about six seconds later, an apparition travelling towards us from the direction of the tail was not unlike the mine had exploded from inbye, but was, in fact, a levitating belt whip lifting the coal product off the carry belt to be smashed into the mine roof & fall in a mess.

Being a little fitter than he, I remember almost running over the somewhat overweight Angelo Butta in seek of refuge in a cut-through.

The following mind splitting crash drew everyone's attention back to the beltline at just the appropriate moment, as if the onlookers needed to be made aware, I had designed the winch with a worm reduction gearbox, as the winch drum, cable, worm shaft & gear-but-nothing-else passed at lightning speed from right to left.

There were, I remember, a few other bangs & crashes, the least of which had dislodged the delivery pulley & frame, but the dust settled, an autopsy was held, a ramp that was too fast found the culprit, rapid reparations made, and the conveyor made ready to run with a new technology to the mine, a Thyristor Soft Start which was super-ordinary, but got us all out of trouble.

At that point, I almost made it a career challenge to get whatever had happened under control.

Copyright is vested with IMHC

SOUTH BULGA COLLIERY
MAINGATE CONVEYOR NO 1 …1994
3400 METERS LONG, 134 METRES LIFT, 3500TPH, 1500 SOLID WOVEN, 4 M/S, ONE HOST DRIVE 640KW AND TWO TRIPPER DRIVES, EACH 640KW, SUM TOTAL POWER 1920KW

Another decade & my own company provided the above drives & belt storage for South Bulga's maingate suite.

The lessons learned told us to provide for a 120 second start and be prepared for fifty plus metres of belt take-up on start, however, the conveyor was not provided with a centrally located trending system (a tool I would never attempt to complete the process without again), and the entire commissioning process was performed between one belt storage and three separate drivehead voice communication systems, and teams of two with stop-watches, three separate chart recorders & sheer faith.

In all fairness and following a considerable amount of frustration & stress, the conveyor was commissioned empty & loaded with the loaded start producing the following data:

Station	Belt movement detected	Speed at host
Host drivehead	0	0
Tripper One	16 seconds	13%
Tripper two	35 seconds	21%
Tail end	45 seconds	35%

For my part, standing at Tripper two (or the inner-most tripper) it was quite daunting not seeing the slightest movement of belt at my station, however listening to Host Drive team exhalting the ramping performance of the soft-start devices at the host drivehead thirty five seconds after host ramp start at which point it was approaching 30% speed.

There was clearly enough time to call each station and ask if we're all talking about the same conveyor!.

Unfortunately, the separate drivehead pen & paper chart recordings have been lost to the "seven year cleanout" however thanks to electronic QA 9002 system recording; the enclosed Sketch # 3 data was revived for this document which highlights the extensive winch take-up period.

Again, the purpose of this paper is to highlight the obvious requirement to manage the completely excessive (and sometimes not even thought about) masses of stretch a long centred low modulus conveyor will generate and how it must be managed.

UNITED COLLIERY…JULY 2002
MAINGATE CONVEYOR #1…418 PANEL
3400 METERS LONG, 136 METRES LIFT, 4.5 m/s, 1200 BELT WIDTH TYPE 1800KN SOLID WOVEN, 1000KW INSTALLED IN HOST DRIVE PLUS 1000KW INSTALLED IN ONE TRIPPER DRIVE, 2200 TPH.

In late 2001 my company secured a contract to provide a five-conveyor Longwall upgrade to United Collieries in the Hunter Valley.

The four trunk conveyors were upgraded with multiple 400kW "BOSS" transmissions to provide controlled trunk conveyor acceleration whereas my company selected VVVF technology for the maingate conveyor as specified above.

All previous experiences and data were funnelled into one project conveyor with respect to highly elongating long centered conveyors and a low modulus conveyor belt management philosophy designed into the project from conception.

The conveyor at full length will have a potential for sixty metres of belt stretch during belt start and was provided with a start state machine & philosophy not unlike that previously mentioned.

It follows that, in a worst case loaded scenario, the belt storage winch (rated at a maximum speed of 0.6 m/s could theoretically require in excess of twenty five seconds to fully elongate the conveyor prior to ramp and then some.

Twin VVVF drive packages of dual 500kW drive stages and matched electric motors was selected to provide the 2 megawatts required and twin sub-stations designed with closed loop

Copyright is vested with IMHC

refrigerated air cooling to provide for up to a thirty second fully loaded “jog” cycle followed by a 120 second ramp to full speed at 110% of installed power or 2,200kW.
A full CITEC trending package was installed to monitor all points of data required pertaining to belt speeds at several locations (host drive, belt storage & tripper drive), belt tension, motor current, VVVF drive temperature etc and brought back to one United PLC location to which, Nepean Conveyors (NSW) were linked on-line to for trending & monitoring purposes.
The results were recorded and transposed to a spreadsheet for the purpose of including with this paper and is shown Sketch # 4.
Although the grading is staggered, the chart highlights the winch speed (peaking at 0.6 m.p.sec.) and the fact that it was hauling in for well over sixty seconds.
The host drivehead displays a well-controlled “jog” period of around 50 seconds prior to ramping and a reasonably controlled rise in belt speed to “jog” at the tripper prior to ramp.
Once the whole conveyor had been elongated and was moving at, in this case around 20% speed, the ramp to full speed at the host and tripper drivehead stations almost emulate each-other.
Further points to note are the host and tripper motors effort (motor current), which notably halves once past the 40% mark of ramp to full speed and the significantly gentle “roll off” routine produced by the very well controlled VVVF drive stages as the acceleration cycle is “feathered” into full speed.

CONCLUSION …

As the dates of the subject conveyors suggest, we as an industry, have had plenty of time to sort out the problems I first witnessed back in 1981 at Invincible and there is no doubt, we have come to a point at which we can say “we have the long centred-highly elongating conveyor” pretty much under control.
The lengthy path of evolvement has been due to a number of reasons, opportunity & available technologies being the two greatest.
The capital opportunity to advance and improve on the last long centred low modulus conveyor comes about reasonably infrequently due to its almost “boutique” method of conveying & the peculiar circumstances its application fits.
There is no doubt that the advancement of mechanical, electrical & control technology has vastly improved during this period, to a point of almost serving the solution up on a plate, however I am rather proud to say our company of staff has had the technical ability ***and*** the opportunity to bring ***all*** the requirements together to provide the solution.

Copyright is vested with IMHC