ADDER SNAKE: LOW-ANGLE TO HIGH-ANGLE WITH NO TRANSFERS

Marcus J. dos Santos

Dos Santos International, LLC

INTRODUCTION

In his landmark Society for Mining, Metallurgy and Exploration (SME) 2000 writing, "Theory and Design of Sandwich Belt High Angle Conveyors According to The Expanded Conveyor Technology" J. A. Dos Santos generalised the belt conveyor technology to include all possible variations and augmentations including, particularly, multiple belts along a common carrying and/or return path as is the case most notably in the sandwich belt high angle conveyor technology and belt-on-belt type intermediate (booster) drives. Figure 1, excerpted from his writing, represented the proposition of the generalised "Expanded Conveyor Technology", abbreviated ExConTec.

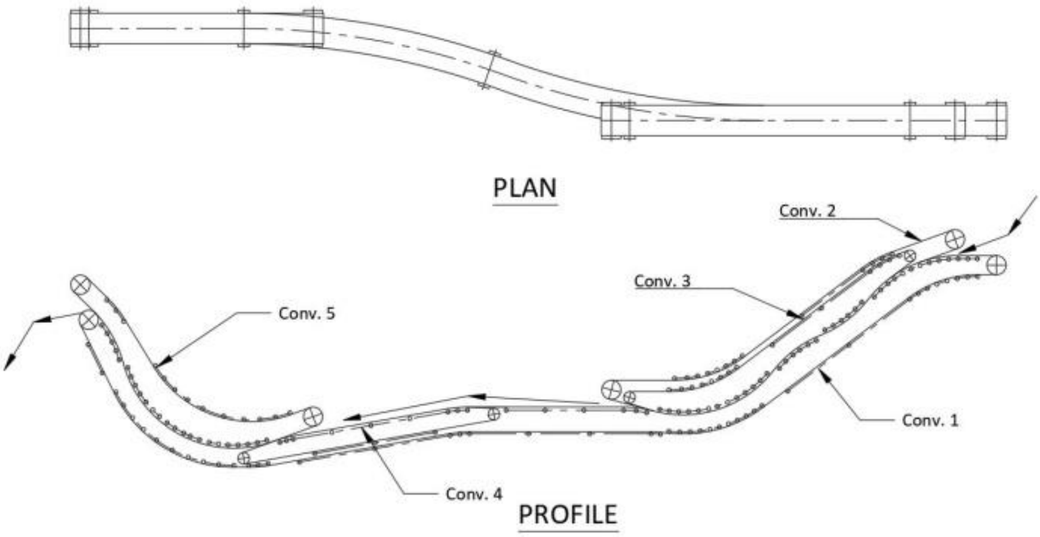

Figure 1: Y2K basis model for the Expanded Conveyor Technology (ExConTec)

This formed the basis for the generalization which was completed in theory and in math before 2000 and presented by J. A. Dos Santos at the Y2K SME Annual Meeting and in the writing which can be found in the SME library[2] . While Figure 1, with the supporting mathematical development solved the generalisation, it failed to identify the variation that would prove to have the greatest significance. As with most significant developments, necessity is the mother of invention. This is the case with the Adder Snake belt technology, the subject of this writing.

BACKGROUND

The concept of elevating bulk materials at a high angle using the sandwich belt concept was first introduced in 1951. That introduction did not produce any lasting success. Commercial success in sandwich conveying was achieved in the 1970s with the Loop Belt, a sandwich belt elevator of C-shaped profile developed by Stephens Adamson of Canada. The Loop Belt was and is the vital element of a conveyor based self-unloading ship system. Such self-unloading ships have had great success achieving unloading rates above 10 000 t/h with Loop Belts of width to 3 048mm (120”). Being strictly of C-profile, Loop Belts could not be adapted to the general high angle conveying path which is predominantly along a straight incline. It was the success of the Loop Belts that inspired the Dos Santos Sandwich Belts of the 1980s. These expanded the Loop Belt capabilities by producing endless elevating profiles that could take the most direct and/or conforming path between the loading and discharge points. Sandwich Belt high angle conveyor systems have seen great success through the years, with more than two hundred installations throughout the world.

The sandwich belt conveyor technology has been implemented in a variety of roles, including plants, mines, and marine applications. As these have typically been custom applications, the layout of the system was usually tailored to work with incoming and outgoing equipment, leaving the sandwich conveyor itself as an isolated solution to the requirement of a high-lift, short-footprint system, often fed by, or discharging onto, low angle conventional equipment. The primary advantage of the sandwich conveyor in these cases is therefore the ability to eliminate long, low-angle elevating conveyors with their heavy, expensive elevated structure.

In another writing[1], the value of the sandwich conveyor is compared to conventional conveying methods. A sandwich conveyor must use wider belts than a conventional conveyor carrying the same capacity at the same speed to maintain a proper belt edge seal. Accordingly, a conventional conveyor will be cheaper than a sandwich conveyor of the same carrying length. However, as the lift requirement increases, the high angle capability of the sandwich conveyor allows it to take a shorter path, which the conventional conveyor must use increasingly heavy elevated structure to reach the same end point. With this in mind, it is expected that at low lifts, the conventional conveyor would have the economic advantage and that the sandwich conveyor gains an advantage as the lift increases (see Figure 2).

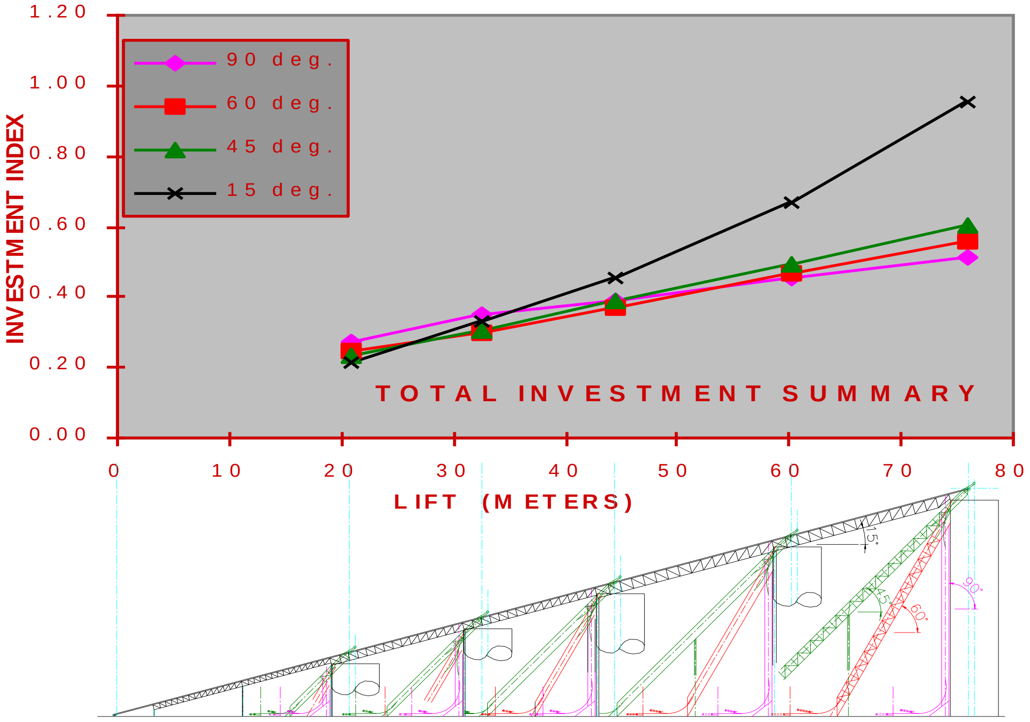

Fig 5: Investment Comparison (Engineering and Supply) of Elevating Options

Figure 2: Investment summary from *Cost/Value* article

The Cost/Value article calculates the crossover point at which a 15° conventional conveyor becomes more expensive than the small-footprint sandwich belt conveyor for the same capacity. A premise of this comparison is that the loading point of the sandwich conveyor can be much closer to the discharge point (horizontally) than that of the conventional conveyor, allowing for considerably less structure on a high lift sandwich conveyor. When the start point and end point are fixed, however, the economics change. There is still a crossover where it is advantageous to use the sandwich conveyor in conjunction with a conventional conveyor running along grade, rather than slowly elevating over the entire length. Historically, this combination of equipment would be the most economical solution for a high lift requirement which could run at grade until close to the end point.

Various applications through the years have required arrangements such as that described above, and the determination had to be made regarding the most economical of three choices: 1) A shallow-angle elevating conventional conveyor; 2) A sandwich conveyor combined with a conventional conveyor along grade; or 3) A sandwich conveyor with its wider bottom belt extended back to the start point. A very high lift would eliminate the first choice, as the elevated structure would quickly become exceedingly expensive. The choice then became whether to extend the wider sandwich belt or to employ a transfer between a conventional conveyor along grade and a high angle elevating conveyor.

The options above offered sufficient flexibility for a number of applications through the years. However, in August 2014, a unique requirement demanded development of a better solution. In a raw sugar and grain application, the abrupt upturn of underground collecting conveyors that reclaimed from multiple inline feeding points from the above dome storage silos was considered (See Figure 3 and Figure 4). Eight such conveyors came together to feed onto three outgoing conveyors, five from one side and three from the other. These outgoing conveyors took the collected material to ship loading. Because of the tight space between the domes and the outgoing conveyors, without an abrupt upturn the outgoing conveyors had to be underground, in a concrete vault. This was at significant expense and vulnerability to water as the water table was near the surface. Further, the material flow had to be routed to any one of the three outgoing conveyors, requiring a shuttling head in the initial subsurface arrangement developed by a third-party consulting firm.

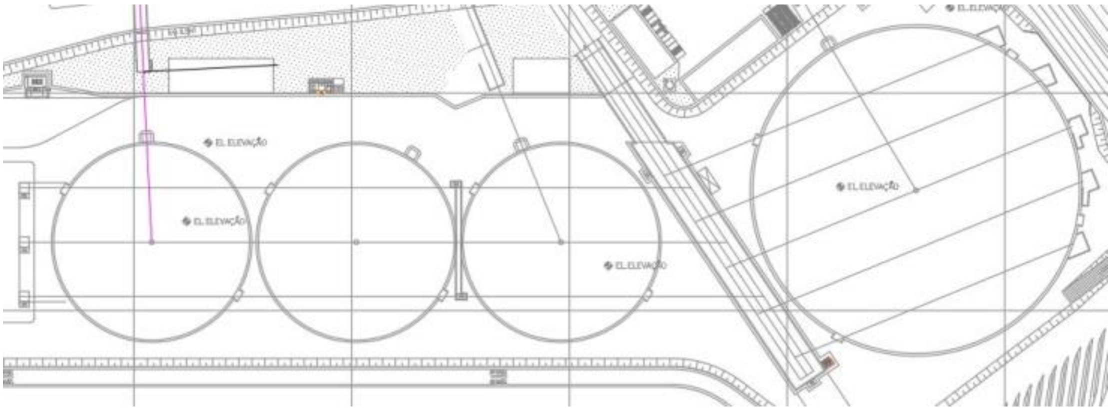

Figure 3: Plan view of dome unloading conveyors

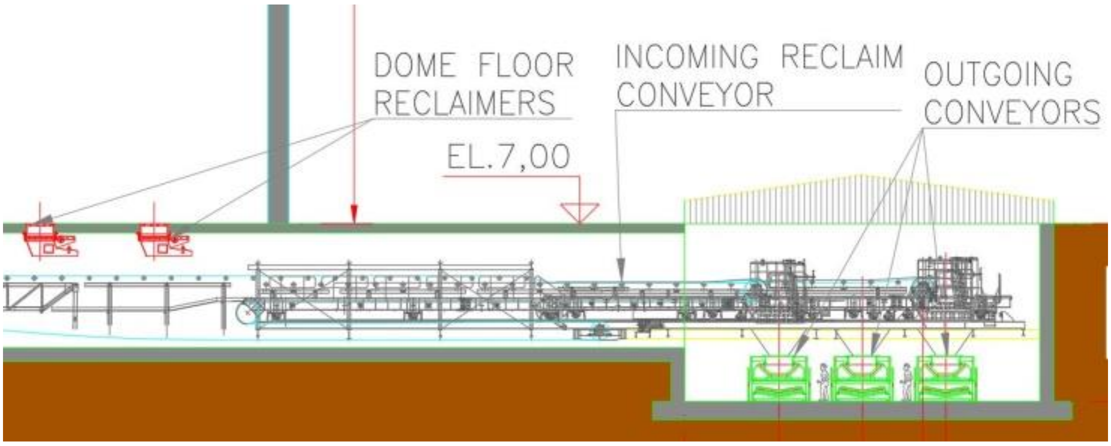

Figure 4: Subsurface solution for outgoing conveyors loaded by dome storage reclaimer

The historical solutions for this problem were the first instinct, but these came at a cost. The sandwich belt high angle conveyor technology with its tight convex curves could be used to accomplish the needed abrupt upturn, bringing the discharge points to above the three surface conveyors. However, this would require extending the (wide) bottom belt tail to act as the collecting conveyor. Subject to the reduced cross-sectional filling of the sandwich belt, the extended collecting bottom belt would have to be wider along its entire length (around 320m), driving up the cost of the conveyor and the tunnels beneath the domes. Alternately, the narrow conventional collecting belt could discharge onto the Sandwich Conveyor shortly before the upturn. However, there was very limited space available to accommodate a transfer between the two conveyors, and the end user did not like the idea of this underground transfer with its maintenance implications.

During a brainstorming session, the idea occurred to the writer to combine the economics of the narrower conventional conveyor and the advantage of the abrupt upturns of the sandwich belt, while eliminating the transfer. Limiting the high angle conveying to a short upturn and discharge, each conventional collecting conveyor could continue directly into the sandwich, be carried through the upturn, and the material could then be discharged well above ground.

The resulting arrangement not only allowed the subsurface conveyors to be elevated to grade, but also provided ample space for a trifurcated chute to distribute the collected material to the appropriate surface conveyor, eliminating the complication and added expense of a shuttling head end. (See Figure 5)

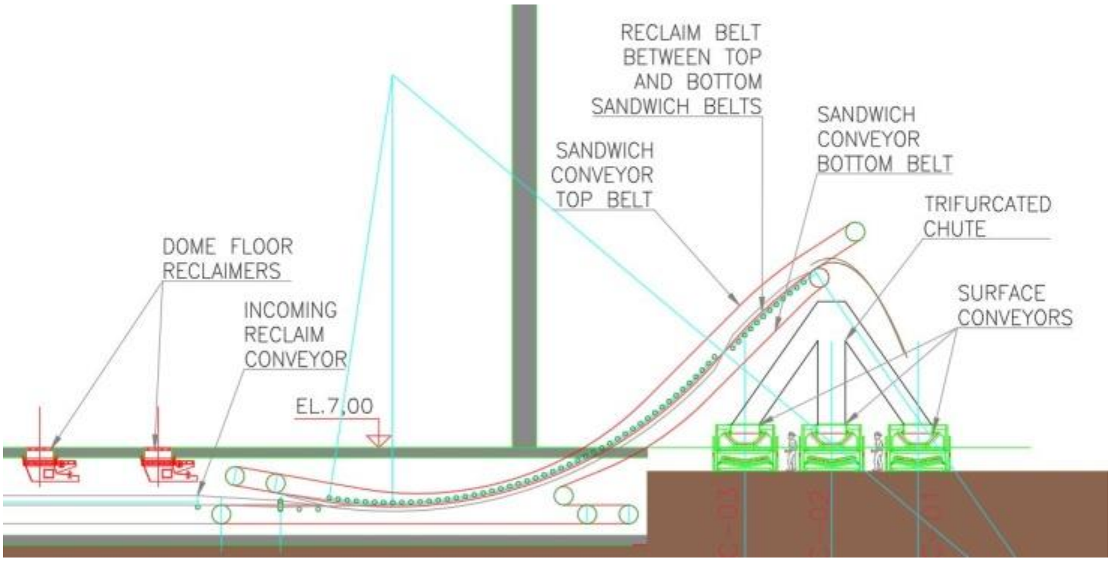

Figure 5: Surface solution for outgoing conveyors employing Adder Snake technology

As a result of this development, the Expanded Conveyor Technology basis is now updated to include the Adder Snake technology as shown in Figure 6. Though the difference in the image is subtle, the implications are quite extensive. By simply adding the possibility of varying belt widths running along the same path, the Adder Snake technology and all its advantages can be further explored.

Once conceived, the broad implications came to light in rapid succession. The remainder of this writing will present some of the possible variations and the positive possible implications. As in the Y2K Figure 1, the 2017 Figure 6 does not likely present all possibilities as such are infinite.

A patent for the Adder Snake design was applied for in December of 2015 and awarded 14 November 2017.

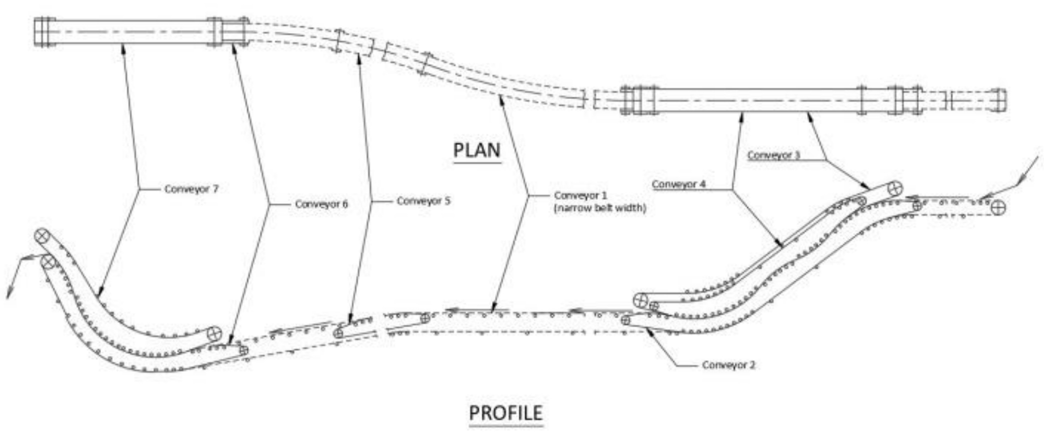

Figure 6: 2017 Basis Model for the Expanded Conveyor Technology

DEVELOPMENT, APPLICATIONS

The conception of the Adder Snake system was spurred by a specific application. The tunnel gathering arrangement which was subsequently developed is certainly a very good application of the Adder design. However, the use of this technology extends to a variety of other applications, many of which are likely yet unrealised.

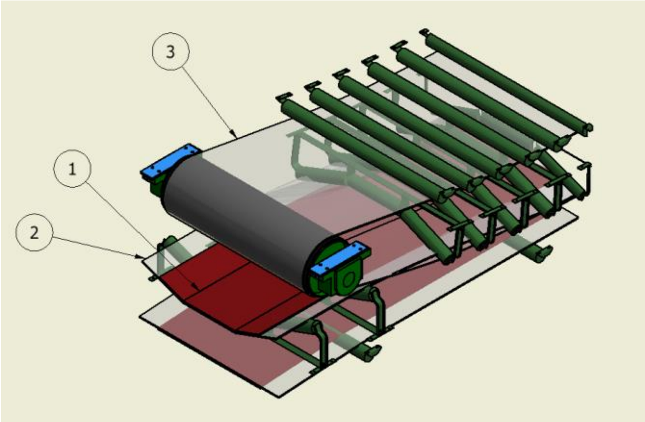

Figure 7: Adder Snake generalized sandwich entrance – conventional belt in red; Sandwich belts semi-transparent

The primary advantage of the Adder Snake in the tunnel gathering project was that it eliminated a potentially messy transfer, while not penalizing the overall conveying path with a wider belt than necessary.

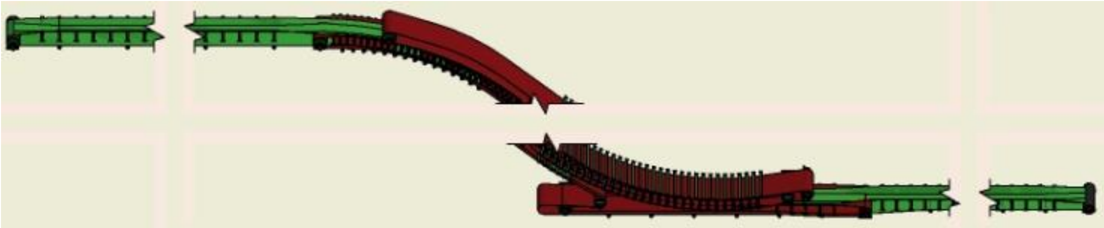

Figure 8: Adder Snake generalized layout – conventional belt in green; Sandwich belts in red

In further developing the concept for use and for patent protection, a wide variety of applications were considered. Two of these are discussed further below.

OVERLAND SYSTEMS

The 2017 Expanded Conveyor Technology model (Figure 6) hints at the application of the Adder Snake concept in complex overland systems. Indeed, there are many applications in which a long conventional conveyor encounters significant steep terrain in its path, both elevating and lowering, in order to negotiate a relatively modest net lift. In other cases, a conveyor or its path is modified to avoid an abrupt elevation change. This may be accomplished by cut-and-fill, additional superstructure, adding transfers and conveyor flights, or by introducing complexities to the conveyor that would not otherwise be needed.

A sandwich conveyor can be arranged to receive material from one flight of overland conveyor and deliver it to a receiving flight at a higher or lower elevation, but this will require two additional transfers, along with all the terminal equipment that accompanies a complete conveyor system. The Adder Snake technology can better handle such a scenario by swallowing the conventional overland belt into a sandwich conveyor that exists only at the steep grade. The overland conveyor can therefore negotiate a previously unachievable path, with no disruption.

As an added benefit, the sandwich conveyor that envelops the conventional belt can double in function as a belt-on-belt type booster drive for the overland conveyor. The sandwich conveyor drives can be sized and controlled to handle the local elevating requirements and further drive the belt as desired to control the tension of the overland belt, allowing for a reduction in the belt strength, and therefore, in the cost of the overall system.

MARINE TERMINALS, DOCKS AND SHIPLOADING

Dock length (structure) is very expensive in any marine terminal. As larger ships become more commonplace, shiploaders must increase their height. In turn, this requires the conveyors that feed these shiploaders to elevate material higher. A simple geometric calculation, based on the low incline angle alone, indicates that for every meter of additional lift, the standard tripper design used at many docks will require more than three and a half meters of length. This does not include the substantial additional length of the conventional empty belt uplift curve from tangency at the dock belt structure to tangency at the tripper incline.

Sandwich belt systems have already been employed at ship-loading applications to mitigate this problem, though these were executed before the Adder Snake design was conceived. A historical method was therefore used, discharging from a dock conveyor at grade onto the sandwich conveyor tail via a short tripper and transfer station. While successful, such installations could have benefitted from the Adder Snake arrangement.

Dos Santos International has been offering the Adder Snake for a variety of ship-loading applications. Figure 9 and Figure 10 show views of one such offering, in which a 20 metre lift is required to reach the outgoing shiploader.

In the overall view (Figure 9), a phantom profile is included for the conventional arrangement that would be required to accomplish the same lift as the Adder Snake. The Adder design in this function consumes just under 40m of horizontal space from the uplift of the belt to the head end. By contrast, the conventional solution extends nearly 135m back from the head end. It is worth noting that, because the elevated material is wood chips in a tropical environment this conventional arrangement is given the benefit of conveying at an incline up to 20°. Many designers will not allow conveying angles beyond 15-18°, which would further amplify the benefit of the Adder Snake.

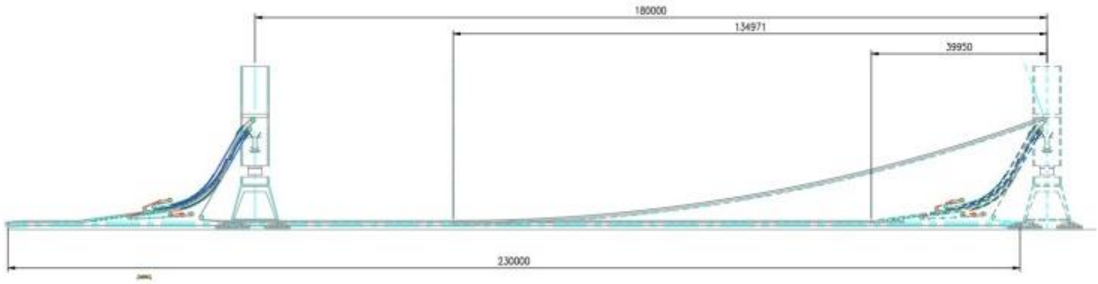

Figure 9: Comparative view of Adder Snake and conventional dock conveyor design

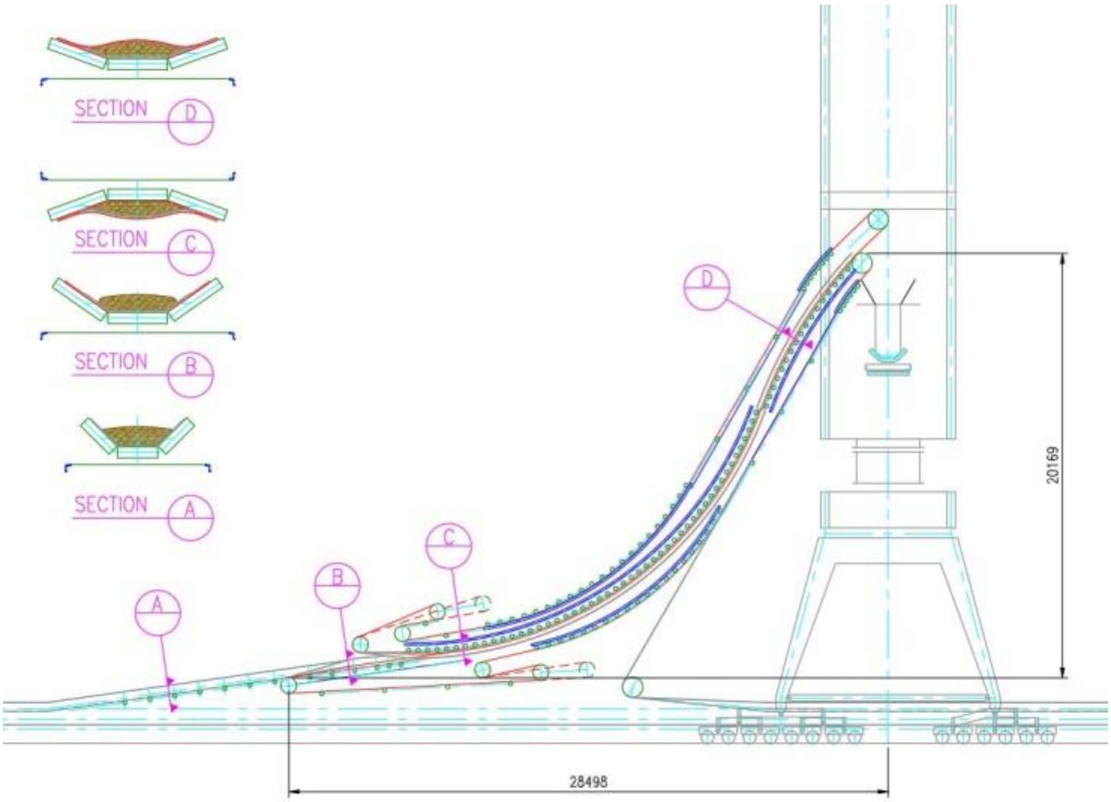

Figure 10: Sample Adder Snake application with cross-sections

BELT MODULUS, TENSION CONSIDERATIONS

A key feature of the Adder Snake design lies in the elastic modulus constraints that are so important in sandwich conveying. To maintain the tight curves that keep the sandwich conveyor compact, a low elastic modulus nylon-nylon carcass belt is typically used. While this belt was once a standard offering, it has become more difficult to obtain as polyester-nylon belts have become dominant in the industry. Accordingly, the price can sometimes be higher than the corresponding conventional belt.

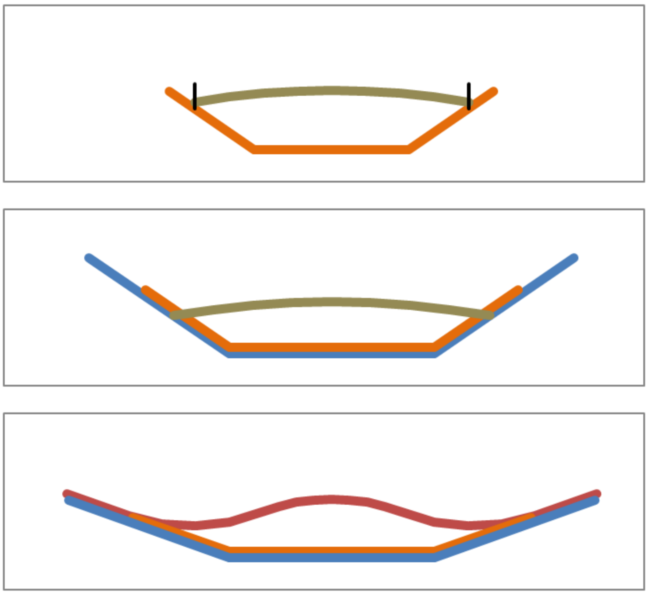

Figure 11: Adder Snake belt cross-sections: from top to bottom – Conventional belt only in loading and approach area; conventional belt (with effective long centre roll) after combining with sandwich bottom belt; Sandwich profile with conventional belt between top and bottom belts

The beauty of the Adder arrangement in this case is that the narrower conventional belt, typically of polyester-nylon construction, will take an advantageous shape through the tight sandwich curves. Whereas the wider sandwich belt will take the typical troughing profile with the belt centre at approximately one third of the belt width, the conventional belt will effectively have a long centre roll arrangement, bringing down its neutral axis considerably. This allows the higher modulus conventional belt to travel comfortably through the tight sandwich curves.

As the required angle of the sandwich conveyor increases, the advantage of the Adder Snake is amplified. This is a result of the de-rating of the allowed sandwich cross-sectional filling with increased incline angle.

A detailed analysis of belt width combinations was executed to determine the optimal choice considering a few variables. The analysis was executed as follows:

1. Material density was set at 1 t/cu-m, troughing angle in the sandwich was set to 20 degrees and troughing angle on the conventional (Adder) belt was set to 35 degrees.
2. Conveying rate was incremented from 200 t/h to 4000 t/h in 200 t/h increments.
3. Conveying angle was incremented from 60 degrees to 90 degrees in 10 degree increments.
4. The conventional (Adder) belt width was set at each capacity scenario to be loaded at approximately 80 per cent to 85 per cent of the CEMA load when

running at a conservative belt speed (1-3 m/s for smaller capacities, 3-5 m/s for larger capacities)

5. The sandwich belt width was then chosen to achieve 90 per cent to 95 per cent of the DSI sandwich conveyor loading criteria. For reference, 100 per cent DSI sandwich loading at 50 degrees is equivalent to around 70 per cent of CEMA load on the same conventional belt width. At 90 degrees, it is about 42 per cent of CEMA.
6. The conventional belt in each case was assumed to be of polyester-nylon construction, while the sandwich belts were of nylon-nylon construction.
7. The initial curve radius of the sandwich conveyor was set to a value that would ensure the edge of neither belt was overstressed, and the tension was set to keep the centre of either belt from buckling.

The graph below offers a visual summary of the corresponding belt widths that were determined as a result of this analysis.

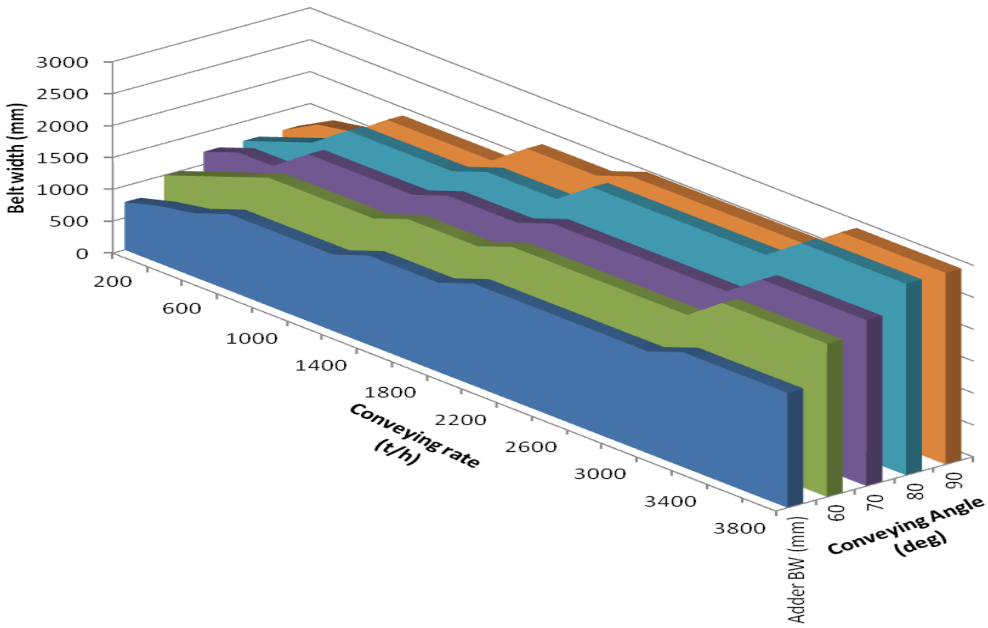

Figure 12: Chart showing belt widths of conventional (Adder) and corresponding sandwich belts at varying conveying rate and angle.

The first area, nearest to the conveying rate axis, shows the belt width of the conventional belt for a given conveying rate. Each of the following areas, labeled 60, 70, 80 and 90 indicate the belt width of the corresponding sandwich belts at that conveying rate that will envelop the conventional Adder belt. As is required by the DSI criteria, the steeper conveying angle requires a wider sandwich belt to match the conventional conveyor belt.

The difference between the conventional and sandwich belt widths for proper compatibility range from 450 mm at the lower capacities and angles up to 1200 mm at the high end.

A more interesting point that is not shown in this chart is that at the lower conveying rates, the size of the entrance curve to the sandwich conveyor is dictated by the conventional belt, rather than the sandwich belt. This makes sense when considering the shape that the conventional belt takes in the sandwich in the various cases. At the lower angles, the difference between the conventional belt width and the sandwich belt width is smaller. As a result, the neutral axis of the conventional belt is not greatly reduced. However, at steeper angles, the sandwich belts are quite a bit wider than the conventional belt, which results in an effective long center roll for the conventional belt, bring its neutral axis down considerably. At around 70 degrees, the sandwich belts begin to dictate the curve entrance radius.

The following images offer a more visual explanation of this phenomenon. The images in each column progress through the conveying angle increments from 60 degrees to 90 degrees. The first column shows the 1200 t/h conveying rate, and the second column shows the 2400 t/h conveying rate. The orange belt line is the Adder, or conventional belt. From the images, it is clear that at the lower conveying angle, the conventional belt has a narrower effective center roll length. As a result, its neutral axis is higher, and its ability to wrap around a curve is reduced. At the higher angles though, the conventional belt is quite narrow compared to the sandwich belt, so even with its high modulus of elasticity, it is no longer the determining factor in wrapping around a tight sandwich curve.

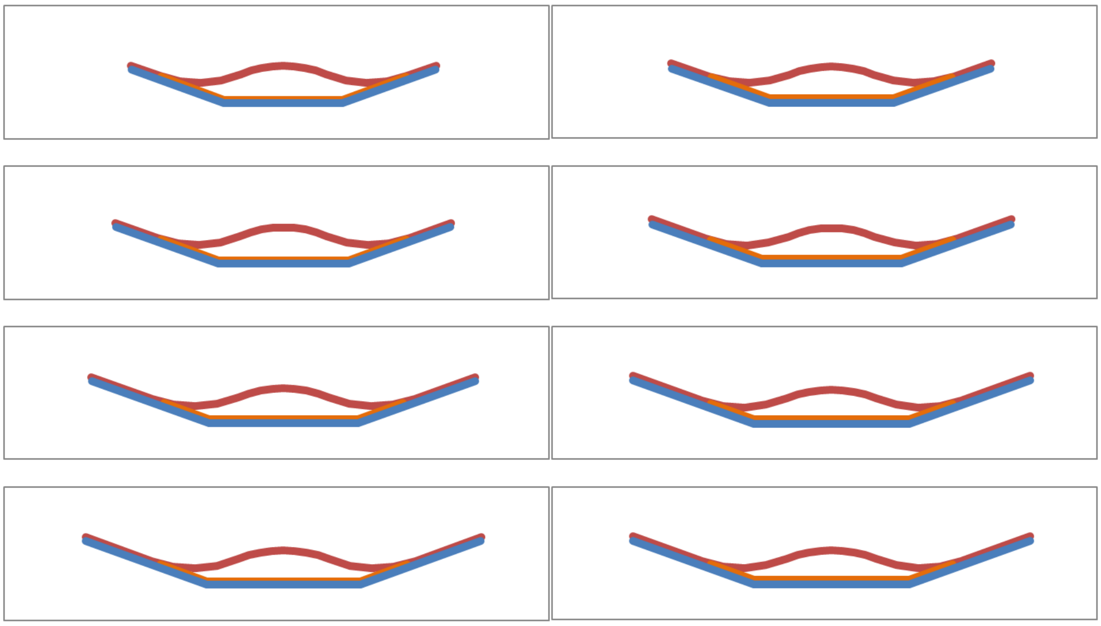

Figure 13: Adder Snake cross-sections at increasing angles. Left column of images is 1200 t/h capacity, right column is 2400 t/h capacity. Rows start at top at 60 degrees and progress to bottom at 90 degrees. Orange (Adder) belt's center length increases, which in turn decreases neutral axis depth.

OTHER APPLICATIONS

Very good applications of the Adder Snake will be at ports and terminals in ship-loading applications, particularly as shiploaders must increase their reach as they are elevated to accommodate larger vessels. Historically, sandwich conveyors in this capacity have been arranged as a separate piece of equipment, each receiving material from a dock conveyor mounted along the surface with a traveling tripper.

By employing the Adder Snake design, the low cost conventional conveyor can remain in place. The sandwich conveyor portion will be integrated into the traveling tripper. The only modification necessary is to splice in additional belt to achieve the new, increased lift.

In mining, the primary application of the Adder design will be in overland systems. Any scenario in which the conveyor path must take a large and abrupt upturn or downturn will benefit from employing an Adder Snake rather than the alternatives of rerouting the conveyor, disturbing the environment to excavate a low angle path, or using extensive elevated structure.

The reduction of the conventional belt tension in this case is available as a byproduct of the primary Adder Snake function. Depending on the requirement, boosting (or braking) of the belt may prove advantageous. This benefit is available to use either way.

ADDER SNAKE CASE STUDY

Dos Santos International is currently executing an Adder Snake design for a shiploading application in Holland. The benefit of the design in this application is different from those advantages noted thus far.

In this application, as is typical, the new shiploader is perpendicular to the existing dock conveyor, and its elevation is such that a high angle path is necessary to reach the height required within the horizontal space available. The sandwich conveyor was therefore integrated into the design.

The initial design concept used a conventional conveyor stinger boom from the tripper to the tail of the high angle conveyor. This had the disadvantage of the transfer and extra equipment so the client readily embraced the idea of running the tail of the high angle conveyor back to receive the material directly from the dock conveyor tripper. Attempted implementation of this new arrangement immediately revealed that sufficient tripper height did not exist to allow the tail of the sandwich belt high angle conveyor.

The space around the existing dock conveyor is very restricted in height, and the tripper onto the high angle conveyor tail accordingly does not allow enough space for the transfer (See Figure 14). The limitation is so severe that the minimum pulley diameter required for the standard Sandwich Conveyor belt consumes too much of the space. Therefore, the Adder design was employed, using a light, thin main belt that can be wrapped around a somewhat smaller tail pulley. This belt, which is also 400 mm narrower, will carry the material through the loading point and will travel just under 7 meters before being enveloped into the 1600 mm wide sandwich belts.

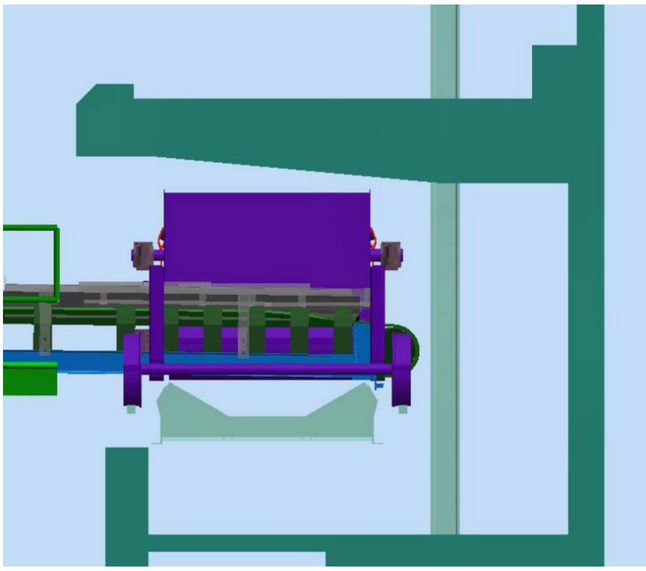

Figure 14: Limited space in case study tail section

CLOSING

Though the Adder Snake concept, using belts of varying width, was conceived only a few years ago, it has a very solid basis in the sandwich belt technology that is approaching 70 years of existence, and the expanded conveyor technology that is nearly 40 years old. This writing likely does not cover all important points and capabilities of the technology. Such will continue to be discovered as the system is applied to the various projects that may benefit from it.

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ABOUT THE AUTHOR

MARC DOS SANTOS

Marc dos Santos has been exposed to the sandwich belt high angle conveyor his entire life, as he is the son of Joseph A. Dos Santos, the inventor of the technology. Marc has been Joe’s business partner at Dos Santos International since 2004 and shares his passion and continuous desire for development. Marc has continued to further the development of the technology throughout his career, including complete design, engineering and execution of many DSI sandwich belt installations, studies spanning the materials handling realm, and advancement of the DSI in-house conveyor analysis software, ExConTec. Marc graduated from MIT in 2002 with a Bachelor’s Degree in Aerospace Engineering, but has shifted focus from the skies to apply his engineering education on the ground and underground in the conveyor world. Marc and his wife Julie live in the Atlanta area with their two children.

Marc dos Santos

531 Roselane St NW, Ste 810, Marietta, GA 30066, USA, +1 404 518 0620, marc@dossantosintl.com.

