Screw Conveyor / Bucket Elevator Section

CEMA Std. #350 - Chapter 7 revision

Inclined Screw Conveyors

DRAFT - 10/01/2017

Screw conveyors arranged to convey bulk materials up an incline are often utilized due to minimum necessary equipment and space utilization. Many alternate conveyance arrangements require multiple conveyors to first move material horizontally, and then vertically respectively.

While inclined screw conveyors offer many benefits, some considerations must be taken for proper application and operation.

As the angle of incline increases there may be a significant loss in efficiency, often dependent on the type of material conveyed. Several direct consequences arise from this loss in efficiency:

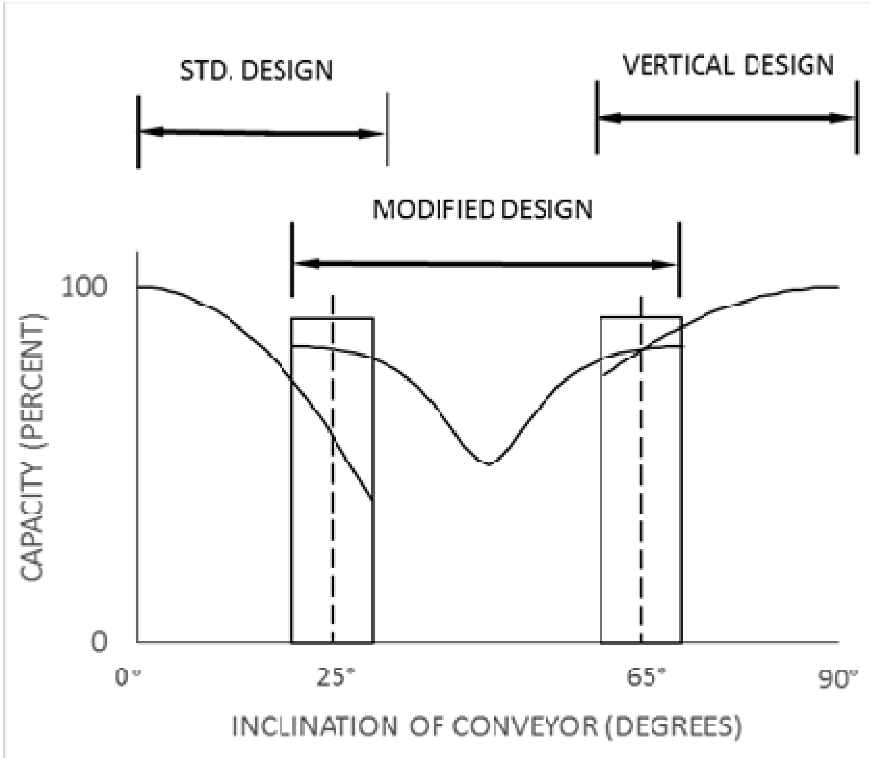
1.) As the incline increases the overall expected capacity may be drastically reduced.
2.) The required horsepower of the unit increases.

Various reasons cause these effects. As the angle of incline increases, there is a reduction of the effective angle of the flight as it pushes against the material. See Figure X.X. At certain angles of incline and screw pitch values, a portion of the helical flight is virtually on the horizontal plane; this reduces the forward action of the flight, resulting in loss of efficiency, in addition to material turbulence and trembling.

The losses in effective capacity due to improper flight/angle/pitch combination may ultimately result in a larger than expected cross-section of material within the screw conveyor. This increased cross section is especially important when considering an obstruction such as an intermediate hanger bearing. The turbulence and tumbling of material will also likely result in the need for increased horsepower (power that is not really useful in the conveyance of the material).

Inclined screw conveyor efficiency may also be detrimentally affected by the geometry of a standard U-trough. A U-trough design contains void space over the rotating screw, resulting in material fallback during operation. This furthermore exasperates increased cross-sectional loading and material turbulence, resulting in further loss of efficiency.

Figure X.X exhibits a theoretical conveyor capacity of a screw conveyor at various angles of incline for standard designs, modified designs, and for vertical designs. The capacity curve shows that even conveyors modified for incline service experience minimum theoretical capacity between angles of 25° and 65°. The angle of minimum capacity in this range is not specified; it greatly depends on material characteristics, flight pitch, speed, housing geometry, etc.



As shown in figure X.X, there are several modified design considerations that may increase the overall efficiency of inclined screw conveyors:

1.) Omit utilization of “standard” screw components (IE full pitch screws, U-Troughs, standard speed etc.) in applications >25°, preferably over 15°.
2.) Usage of close clearance between trough and screw:
    a. CEMA std. clearance of ½” between flight outside-diameter may allow for material to fall back between this gap. Reducing this gap can prevent material from falling through this open space. Note that it is important to consider deflection value of screw if reducing clearance, to avoid possible rubbing on trough.
    b. This gap can be reduced in one of several ways:
        i. Adding a liner material between the trough and screw O.D.
        ii. Increasing the flight diameter to close the gap.
3.) Increase the speed over normally calculated horizontal screw conveyor of same size.
    a. When performing a standard horizontal screw calculation, consider adding rpm to the final calculated value to overcome the loss in efficiency from the incline.
    b. The increase in speed of screw rotation imparts a greater forward material velocity, which may aid in in pushing material past an intermediate hanger bearing. Despite the increase in agitation and turbulence of the material, the net result may be an increase in capacity.
    c. Performance gain from a speed increase may greatly depend on material characteristics. Note that some materials may aerate and/or fluidize at increased speeds, resulting in a

net loss of capacity. Please refer to the material characteristics chart for further information.

4.) Usage of short pitch (IE 2/3 or ½ pitch) if the material handled permits.
    a. See figure X.X. *(image showing pitch angle versus incline to be inserted)* The helical flight modified in this manner places the carrying face of the flight closer to a vertical position relative to the incline. This results in less material fallback, and a more effective angle of the flight as it pushes against the material.
    b. Reducing the pitch of the screw will create the added benefit additional flights, creating more "walls" to help reduce material fallback.
    c. Reducing the pitch of the screw in a horizontal conveyor reduces the overall capacity, as each volumetric flight pocket is smaller. This must also be considered in an inclined variant, typically requiring an increase in speed to overcome this.
    d. Attention to the material type must be paid when reducing pitch. Specifically on smaller diameter screws, one must ensure that the lump size of the material isn't too large for a reduced pitch.
    e. *(image showing pitch angle versus incline to be inserted)*
5.) Omitting of hangers to reduce obstructions in flow.
    a. Elimination of a hanger bearing is usually achieved by increasing the length of a standard screw.
        i. Larger than standard screws must consider increased deflection, possibly resulting in the need for a larger pipe size. Take careful note when increasing pipe size to ensure the reduction in cross-sectional carrying area allows for the desired material capacity.
        ii. Note that hanger obstruction is one of the most common problem areas for inclined screw conveyors. Elimination of a hanger when possible not only removes a possible failure mode, but potentially decreases maintenance of a wear area in the coveyor.
        iii. In some applications at appropriate rpm, screws may be close-coupled and clocked for an extended length, and ride on a liner. Contact your conveyor manufacturer before pursuing this option.
        iv. *(Possibly add image showing reduction in capacity due to increased pipe size)*
6.) Use of tubular trough style versus U-trough to reduce void area at top portion of flight O.D.
    a. On specifically aggressive inclines or high speeds, material may fall backwards over the O.D. of the flight at the void area of a U-trough. Closing off this area with a tubular style trough reduces the gap between the flight O.D. and trough, assisting in the reduction of material fallback.
    b. *(Possibly add image showing tubular trough versus U-trough)*

It is worth noting that the theoretical capacity and horsepower of an inclined screw conveyor may be greatly dependent on material characteristics, and often cannot be accurately predicted. Materials that can accumulate on pipe/screw surfaces, aerate, and fluidize pose challenges and can greatly affect the expected performance of an inclined conveyor. As such, it is important to consult a screw conveyor manufacturer with detailed application data to allow for proper design of a product that will meet the end-users needs.

Horsepower of inclined screw conveyors – This section can remain the same in reference to the calculations. Modify final paragraph discussing drive arrangement:

When considering the drive arrangement of an inclined screw conveyor, it is important to recognize that material will typically fall due to gravity to the bottom portion of the inclined unit. Noting this, one should use a robust high quality seal for the proper material application. For the same reasons, the drive on an inclined screw conveyor should always be mounted at the top end of the incline when possible; mounting of the drive unit on the bottom end may result in material infiltration into the drive unit. If a drive unit must be mounted on the lower end, usage of a bulkhead style end plate or roller chain drive may allow separation of drive components from the conveyed material. Additionally, one should always consult the conveyor/reducer manufacturer for proper oil levels when mounting on an incline.

Vertical Screw Conveyors

A vertical screw conveyor is used to convey materials upward in a vertical path. Vertical screw conveyors are sometimes referred to as “lifts” or “elevators”, but such names are ambiguous. Vertical screws have the advantage being compact, and can often fit into much a much smaller footprint that equipment such as a bucket elevator. There can be additional benefits with the usage of vertical screws:

- Relatively low cost compared to other systems of elevating material
- No special maintenance required from staff already familiar with screw conveyor systems
- Screws and housings are often standard screw conveyor components
- Can be manufactured to contain dusty materials

Vertical screw conveyors can handle many of the bulk materials shown in the material table Chapter 2, column V. Generally this includes all materials listed with the exception of those containing large lumps, is extremely dense, or is excessively abrasive:

1.) Lump Size – Material with large variance in particle size, or excessively large lumps tend not to properly convey in a vertical screw. In general, free-flowing material that does not degrade will work suitably in a vertical screw. Friable material along with extremely fine powders that aerate will often have issue working properly in a vertical screw.
2.) Extremely Dense Material – Very dense material that has little to no compressive capability may not convey properly due to the fully loaded condition and speed at which a vertical screw operates.
3.) Abrasive Materials – Due to the high speeds and full contact of the material to the screw, abrasive materials may rapidly degrade components, along with prematurely wearing seals and drive components.

A vertical screw is constructed in fairly similar fashion to a horizontal screw, with a few notable exceptions. A typical unit consists of rotating conveyor screw in a tubular housing with a variant inlet type, along with a discharge at the upper end. The drive is preferably located at the top of the screw (for similar reasons discussed in the inclined screw section), but may be mounted on the bottom if necessary. The top bearing for the screw shaft must be able to handle both radial and thrust loading. Note that in the case of a top-mounted drive, the screws opposite end shaft may either be external with a seal and bearing, or mounted on a dead-shaft to fully enclose the end of the screw. Several types of intake arrangements are possible:

1.) Gravity Inlet Hopper *(insert updated 3D rendering for all inlet styles)* – The gravity inlet hopper is typically arranged as shown in figure X.X. It funnels material by gravity to the lower end of the vertical screw. While the hopper can be fed manually by dumping sacks or other containers, they are often fed from another device uniformly. Successful use of this inlet type is greatly dependent on the material type; it is recommended to contact a screw conveyor manufacturer should this style be necessary.
2.) Straight Intake – This inlet type is generally interfaces a feeder screw conveyor to the vertical screw at 90°. The horizontal screw is used to force feed the material into the vertical. A hanger bearing is generally used at the end of the horizontal conveyor, at the intake of the vertical. This type of intake is most frequently used with free flowing material that won't prematurely wear, and doesn't easily degrade from being force fed. Note that the drive on the horizontal feed screw can only be mounted on the inlet end for this intake arrangement. For a straight intake, the hand of the screw for most efficient operation is as follows:
    a. A vertical elevator with a straight inlet will have all the same hand of screws for infeed, vertical, and take-away screws, right or left (Right-Right-Right or Left-Left-Left).
3.) Offset Intake – This type of intake connects to the vertical casing at a 90° angle, however is offset from the center of the vertical as shown in figure X.X. The advantage of the offset intake is that the shaft of the horizontal feed screw extends past the vertical casing, eliminating the need for a hanger bearing. This allows the external bearing on the horizontal screw to carry the thrust load as well as the radial load of the screw. The horizontal screw may also be driven from either the inlet or discharge end in this arrangement. In the case of an offset intake, it is important that the correct combination of vertical to horizontal screw hands are chosen for the most efficient operation:
    a. Right-Left-Left – A vertical screw elevator that is offset to left of the intake will have a left hand screw and should be fed by a feeder with a right hand screw. The take-away conveyor should be a left hand screw (Right-Left-Left).
    b. Left-Right-Right – A vertical screw elevator that is offset to the right will have right hand screw and will be fed by a feeder with a left hand screw. The take away conveyor will also have a right hand screw (Left-Right-Right).

The method by which a vertical screw conveyor is fed is extremely important, as some materials behave differently than others. Take for example very light materials: A gravity fed hopper inlet would not function well, as the high rotating speed of the vertical screw would act as a fan, and blow material back away from the intake. This can be addressed by leaning the vertical screw to a slight incline, and allowing for the hopper intake to remain on top of the vertical screw. In general, a uniformly force-fed horizontal conveyor is generally the superior feed method for efficient operation.

Note that vertical screw conveyors do not perform well in batch-type operations. The unit functions somewhat like a pump, in that it must be “primed” or filled until material begins to discharge. Material will also not fully discharge from a vertical screw; some material remains in the system upon stopping the infeed. As such, degradable organic materials such as food products are not recommended for use in vertical screw conveyors, as contamination may occur over time. This can however be counteracted by a complete wash-down of the internal components post operation.

Vertical Screw Speeds

This section is good

Capacities of Vertical Screw Conveyors

This section is good

Vertical Screw Conveyor Housings and Casings

This section is good

Discharge Arrangement

Discharge of material in a vertical screw is achieved through an opening similar to that of a horizontal conveyor. The discharge spout may be connected to an elbow or other type of discharge to move material into a subsequent conveyor or process.

To ensure positive discharge of material, vertical screws are often affixed with “kicker paddles”, other flat paddle-type or reverse flights to foster complete discharge of the material. Even so, there are times when it is advisable to provide a safety overflow. This is usually an opening diametrically opposite and above the discharge spout, arranged to spill the material if the discharge spout becomes clogged and unable to handle the normal material flow.

Hanger or Stabilizer Bearings

Intermediate hanger or stabilizer bearings usually are necessary in vertical screw conveyors when extended heights of lift are required, to eliminate excessive screw deflection and “whip.” These hanger or stabilizer bearings are positioned between the sections of the screw and are supported between the housing flanges. The particular kind of hanger or stabilizer bearing to use is determined by the characteristics of the material being handled.

Some materials travel upward in a mass and would experience obstruction by an intermediate stabilizer or hanger bearing. One such material is cottonseed. With it, hanger bearings are not used. Certain other materials tend to center the screw within the housing, thus eliminating the need for stabilizer bearings. Some lighter duty materials can also allow for wear-shoe made out of a material such as UHMW; this is simply a flight that extends slightly past the O.D. of the screw to assist in centering and eliminating “whip.”

Horsepower look good; no need to modify. Does group want to add more detail on specific vertical screw drive arrangements? Need feedback at this point.