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Tubular Pipe Conveyor Design Using a Standard Fabric Belt

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Summary

The installation and operation of tubular pipe conveyors is increasing where environmental conditions and complex profiles justify their application. However, this type of equipment is usually of a proprietary design and there can arise on occasions, for varied reasons, some difficulty in obtaining spare parts, in particular, replacement belt at competitive costs.

This paper discusses the application of retro-fitting a typical standard fabric belt used for trough type conveyors from alternative belt manufacturers in lieu of a special belt from the original supplier. The problems are usually associated with the fact that the belt manufacturer is not able to give recommendations and warranties to select and supply the belt or advise of changes that occur in the running conditions.

This paper discusses the impact that a standard fabric belt could have on power requirements and other factors, such as, troughing to form the circular shape, tracking to avoid twisting in a curved section of the conveyor and increased maintenance and operating costs. Also, the paper discusses only the type of tubular conveyor in which the belt is formed into a circular cross-section by a six roll hexagonal shape idler sets.

1. Introduction

In general, a design check on a tubular pipe conveyor to operate with a standard fabric belt is undertaken by applying similar methods used for conventional trough type conveyor belts. One area of major concern is the troughability of the belt in the six roll idler configuration; other areas of concern are:

- additional stresses due to the traverse stiffness
- increased power consumption
- crushing of the tubular shape in the curves
- inducing increased stress in the belt plies
- transition distances at the head and tail pulleys
- sealing of the belt by the available overlap.

This paper uses the CEMA [4] approach to calculate power consumption and belt tensions using the modifications suggested by Maton [12] and an approach to tubular belt design suggested in Maton [14] and additional allowances for an increase in power consumption due to belt flexure and travelling through curves suggested by further observation.

In general, a tubular pipe conveyor would be selected for one or more of the following advantages:

- small radius curvature for horizontal and vertical curves
- enclosed material reduces dusting losses
- product security
- smaller cross-sectional envelope
- economical layout by reducing transfer points.

2. Tube Conveyor Parameters

2.1 Belting

There is a wide range of standard fabric belting available. The major difference from a tubular proprietary belt would be in the weft strength for flexibility to trough and sufficient strength to hold the tube shape both to support the load and resist belt fatigue. It is the weft materials and construction that will be the major difference between a standard fabric belt and a special belt for tubular pipe conveyors.

It is assumed that for a tubular conveyor the tension plies are usually loaded evenly across the belt and therefore there will be sealing problems at the overlap because the tension will cause the belt to press more against the idler rolls on the opposite side away from the overlap. The result may be that the sealing will not be as efficient as the original belt and also that the belt could be stiffer and therefore less flexible and hence require larger minimum curve radii.

The maximum length is based on experience but with current fabrics available and depending on tube diameter, number of curves and material conveyed, a maximum length of up to 0.5 km should be achievable. Longer belts are feasible but usually require steelcord belts with special cord arrangements to assist belt sealing at the overlap. The application of steelcord belts for tubular pipe conveyors is not considered in this paper.

2.2 Capacity

The loading profile is usually limited to 75% of the cross sectional area of the tube and belt speed is limited to an idler rotation of 750 rpm maximum. For a typical idler diameter of 90 mm this gives a maximum belt speed of 3.5 m/s.

Overfilling must be prevented at all costs because of the obvious damage that can be caused to the idler sets and difficulty in forming the overlap seal. Also, for similar reasons vulcanised splicing is recommended. Sufficient belt length should be allowed to accommodate permanent belt stretch and splice maintenance.

For dusty materials the limiting belt speed would be the same as a conventional trough conveyor since at the loading and discharge points the belt operates during loading and discharge similarly as for a

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conventional conveyor. The maximum lump size is usually limited to 33% of the tube diameter.

2.3 Power

Power consumption is based on methods similar to trough belting with additional allowance for belt flexing for forming and maintaining the tube shape and increased resistance at curves.

The main resistances are:

- rotational resistance of the idler rolls, bearings and seals.
- drag resistance due to tilting and slewing of the idlers
- belt/roller interface pressure particularly in curves
- belt and material flexing.

In this paper modifications have been made to the CEMA methodology but equally valid would be similar modifications to the DIN standard 22101 and ISO 5048. A more reliable basis would be to obtain feed back from experience and field tests.

2.4 Curves

For vertical and horizontal curves the minimum radius recommended is 300 to 600 times the tube diameter i.e., for a 300 mm tube this gives 90 to 180 m depending on the included angle of the curve. Reduced radii will tend to increase power consumption and require stronger traverse reinforcement to resist idler reaction loads.

In general any deformation of the circular shape must be avoided because of damage and ply separation and relative overfilling because of the reduced cross sectional area. However, it is suggested that this phenomena be investigated because if properly controlled much higher incline angles could be achieved.

For horizontal curves there is also the tendency of the belt to twist. The amount of twisting depends on the actual tension the centroid of resultant tension and the radius of curvature. Idler spacing is determined by idler loading and bearings and seals similar to trough belt idlers

2.5 Sealing

Obtaining an optimal seal is much more difficult with a standard fabric belt. The normal termination of reinforcement at the edge of the belt is usually relatively too stiff to form an efficient seal, particularly between idler sets and when the centroid of belt tension is not near the seal side.

The factor adversely affecting the seal is the tension force centroid not being at the belt edges but towards the opposite side of the circular shape and therefore there is a tendency for the belt to lift open at the overlap.

This effect is aggravated by cross winds and with driving rain may negate the primary advantage of preventing moisture getting into the product. It may be an advantage, but, much more expensive, to cover the conveyor if maintaining a dry product is mandatory such as with cement or quicklime.

There is also an increased safety hazard with this type of tubular belt because the idler nip point does not have an escape side as with a conventional belt conveyor and therefore, there is an additional reason to consider covering the conveyor.

Although not strictly a standard belt, the belt could be specified without reinforcing in the overlap areas at the edge of the belt or with fewer plies being taken the full width of the belt to allow more flexibility to properly make an effective seal.

The idlers can effectively force the belt to close but allowance has to be made for increased power consumption if the additional idlers are used to close belt seal between the major idler sets.

2.6 Tracking

The tubular pipe conveyor must be correctly tracked to ensure the belt is central over the head, tail, bend and drive pulleys and also to correct the twisting phenomena when travelling through horizontal curves.

As for trough belts it is the lower three idler rolls which are most effective for tracking since they are usually carrying the higher loads. However, similarly for sealing the belt, tracking is assisted if the centroid of belt tension is on the sealing side.

For steelcord belts the cords could be concentrated at the edges or have two cords of sufficient strength (one each side) to transmit the tension. However, steelcord belt applications are not the subject of this paper.

2.7 Maximum Incline Angle

It is recommended that the conventions for limiting the incline angle be similar to those for conventional trough conveyor belts, i.e., material surcharge angle, the degree of vibration from idlers and surroundings and whether or not the material is sensitive to the aeration phenomenon.

However, the inherent closed circular shape and the maximum filling ratio limit may allow steeper incline angles to be achieved but, because of the concerns with overfilling more research is required to be undertaken to determine the absolute maximum incline angle which can be safely operated with respect to belt fill ratio and the shape of the tubular area.

3. Calculation Example

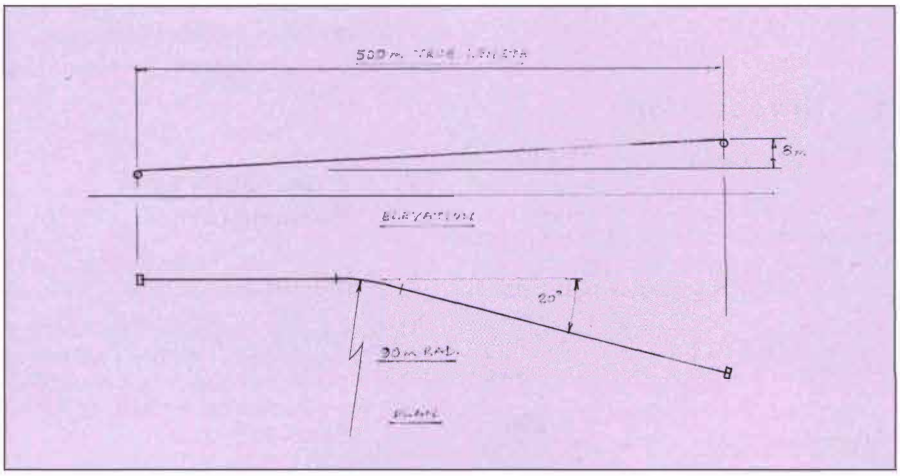
By way of an example, consider the belt profile shown in Fig. 1. The design of a belt conveyor is an iterative process requiring that an estimate is initially made to preselect conveyor components particularly the belt and idler size and spacing. The components are reselected until a satisfactory design is achieved.

3.1 Conveyor Criteria

The parameters for this conveyor are:

- Capacity 300 t/h of coal at 1 t/m^3
- Surcharge angle 5 to 20 degrees
- Lump size 100 mm maximum
- Belt speed 1.5 m/s
- Belt specification 1,100 mm width – 2 PN 450, 4 x 3 mm covers

Fig. 1: Typical belt profile



- Ambient temperature minus 5 °C
- Idler Configuration
  - Six roll hexagonal
  - Troughing angle 60°
  - Roll diameter 89 mm
  - Total drag/set 24 N
  - Spacing 1.8 m carry and return

3.2 Conveyor Tube Diameter

Assuming a loading factor of 75% of tubular cross sectional area a 300 mm diameter tube requires a belt speed of 1.5 m/s, while a 250 mm diameter requires 2.3 m/s and 200 mm diameter requires 3.5 m/s. For this example the 300 mm diameter is selected but it would be usual to undertake an economic feasibility study to include, at least, the 250 mm diameter case. To form a 300 mm tube with a 150 mm overlap a minimum belt width of 1,100 mm is required.

3.3 Belt and Idler Selection

The actual troughing angle for a six roll tubular conveyor is 60 degrees. Recommendations are not available from belt manufacturers for the troughing of standard fabric belt greater than 45 degrees However, an elliptical shape could be considered where the trough angles are 45 degrees and the closing angles are 90 degrees. Again, however, this is a special modification outside the scope of this paper.

However, in this case example experience suggests that a 2 ply belt will trough reasonably satisfactorily and have sufficient strength to support the load. As a first iterative case a 2 PN 450 belt with 4 x 3 covers is selected and the idler sets are 90 mm diameter at a spacing of 1.8 m for both the carry and return sides.

The belt selection is dependent on practical experience particularly with selecting the appropriate factors of safety. In this case the range is shown in Table 1.

On the available information from belt manufacturers of typical standard fabric belting it is recommended that a conservative factor of safety is used for design, this also assumes that the warp fabric is similar to the weft fabric properties. At this stage of knowledge no recommendations can be made regarding the belt life particularly opening at the reinforcement and cover interface. The splitting of the plies from the cover allows water to migrate between the plies and further accelerate the deterioration of the belt.

3.4 Power and Belt Tension

The calculated power using the methodology of Maton [12] modified for tubular conveyors is estimated at 82 kW and a 90 kW drive is selected with a traction type fluid coupling limiting the start up torque to 150% MFLT. The calculated maximum tension is 67.6 kN and at the horizontal curve I.P. it is 53.8 kN.

Belt Spec.	Running	Starting
2 PN 500	16.3	12.1
450	14.6	10.8
400	13.0	9.7
350	11.4	8.5
300	9.8	7.3

Table 1: Selection of safety factors for belts

3.5 Curves

Calculating the minimum permissible belt radii using conventional belt methods needs more research particularly for maintaining the circular shape. Some conveyors have been observed where the shape in the curve tends to be elliptical which will reduce the life of the belt. However, it should be noted that this phenomena can also reduce the cross-sectional area of the tube temporarily causing a fill ratio of 100% thus allowing a possible increase in incline angle.

At this stage of information, observation and research it is recommended that a safety factor of not less than 3.0 should be applied for determining all belt curvature radii to prevent overstressing on the outer side and lack of tension on the inner side. Obviously further research is required to allow more economic recommendations on minimum belt curvature.

3.6 Transitions

Transition lengths for head and tail ends may be determined by using conventional trough belt theory since both for the discharge at the head end and the loading at the tail end the belt is opened out and acts the same as a trough conveyor.

The most important consideration at the transition is to ensure that the seal is at the 12 o'clock position before entering the transition length to open out to form a conventional trough belt for discharge. This also applies to the reverse at the tail end for loading.

4. Concluding Remarks

This paper has shown that it is feasible to install a typically standard fabric belt on an existing tubular pipe conveyor. There will be some adverse operational conditions arising, such as reduced belt life and increased power consumption.

However, in situations where a stop gap replacement belt is required, a locally supplied belt has some cost advantages over an imported special belt. Better published data is required from belt manufacturers to ensure that a more satisfactory application can be made.

The major data required is troughability for trough angles greater than 45 degrees, weft fabric specification for forming and operating in the circular shape and ply reinforcement to prevent ply separation (belt fatigue).

Sealing requirements will usually require more power consumption to force the belt into shape and hold the seal between idler sets. Intermediate closing rolls may be required in special cases. However, using a standard fabric belt will usually require a compromise on the effectiveness of the belt sealing.

The arguments presented in this paper suggest that when using a typical standard fabric belt an elliptical shape may be better than the conventional circular shape. Further research is required in this area.

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