bulk solids handling Journal

Technical Article

Residuals Removal at Maritza E 1 – Design, Installation and Commissioning of a Tube Belt Conveyor

Edited by on 20. Apr. 2020
Published in bulk solids handling, Vol. 34 (2014) No. 1

With the reconstruction of the power station Maritza East 1, the residual materials disposal system has also been reorganized. This project was contracted to Takraf in 2006. The heart of the residual material transportation system is a 4.5 km tube conveyor that follows the course of an old railway line and was realized in cooperation with ContiTech.

Lignite from the Maritza basin has always played a key role in Bulgaria’s energy supply balance. The three major power stations Maritza East 1, 2, and 3 deliver around 40% of the overall energy production of Bulgaria. Since 2006, the new owner AES has been replacing one of these three power stations – Maritza East 1 – with a new build comprising two blocks with a power output of 300 MW each.

Fig. 1: Old (left) and new (right) part of the Maritza East-1 power plant. (Pictures: Contitech, Takraf)

1. Residue Disposal at ‘Maritza East 1’

The process of generating electricity from lignite produces significant amounts of residual products, which need to be either disposed of or put to other continued use. Pulverized fuel ash and gypsum can be reused in the construction materials industry, while bottom ash is usually dumped in landfill sites. Due to the lack of any subsequent infrastructure on the side of the construction materials industry, owner AES decided to permanently deposit all of the arising residual products at the dumping ground of a former open-cast mine situated around 9 km away from the power station.

In the old power station, the ash was put into interim storage in a sluicing dump before subsequently being transported by rail to the site of the dumping ground. As part of the plans for redeveloping the power station, the issue of residual product disposal was also examined and re-evaluated. In the process, the existing practice involving railway transportation was eliminated in advance from further considerations, as was the possibility of transporting the materials via truck, as this would have involved driving through a village and almost half of the route would have been on public roads.

As a conventional conveyor belt transport system was found to be non-viable on account of the complexity of the route along the former railway line, the decision was taken at a relatively early stage to use a tube conveyor. Three possible variants were considered for the long-distance transportation from the power station to the landfill site:

- A 4.5 km long tube conveyor combined with a truck loading station at the end of the conveyor line and transportation via truck for the final 4 km, with an option for upgrading the second part at a later date and adding a second tube conveyor with a length of 4.3 km. This variant requires the lowest initial investment. It is slightly more flexible than the other two variants. Since a fleet of 24-t trucks needs to be available anyway for the second part of the transport chain, this means that a back-up is already in place that allows at least some of the waste products to be disposed of from the power station by truck if the conveyor fails.
- Single 8.8 km tube conveyor with intermediate storage facility at the end of the conveyor line. In terms of technology, this variant is the most reliable. The material is transported in a single stage right up to the landfill site area, where it is dumped on two transfer heaps. From here, the material is distributed with wheel loaders or trucks to the final landfill destination and

dumped. However, there is no back-up in the event of failure of the conveyor system, as only a small number of trucks is kept available for use on the landfill site.

- One conveyor line with an overall length of 8.8 km, comprising two tube conveyors measuring 4.5 km and 4.3 km in length, respectively, with an intermediate storage facility at the end of the second section of the conveyor. Transportation from the unloading point of the second tube conveyor to the dumping site is performed similarly to the setup for variant 2 with a small fleet of trucks or wheel loaders. As mentioned before, in the event of the conveyor system failing, there is no possibility for performing the complete transportation of residual products with the aid of trucks.

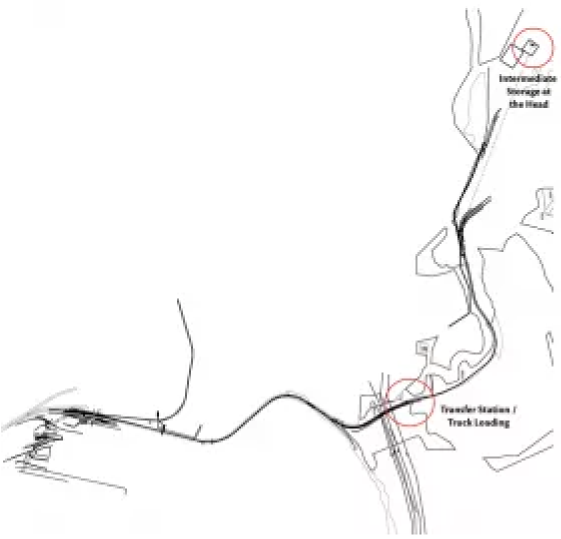

Fig. 2: Possible layouts for the Tube Conveyor System: The red circle in the middle of the route shows an uploading point at 4.5 km-tube conveyor for combination with truck transport (variant 1) or a transfer point of the 8.8 km-tube conveyor comprising 2 sub-conveyor-sections (variant 3).

On the basis of the available financial framework, the power station operator opted for the first variant, which does not involve truck-based transportation on public roads here. This solution represents the best compromise for the customer in terms of the funds available for investment, environmental requirements and the operational safety and reliability of the plant. The option for extending the conveyor line to 8.8 km at a later date has also been incorporated in the plans (Fig. 2).

After a tendering process that took around a year and enabled AES to arrive at a final decision, the order for the design, construction, supply, assembly, and commissioning of the entire residual product disposal system was awarded to

Takraf in August 2007.

According to the specification, the mixture of materials being conveyed is made up of 48% pulverized fuel ash, 45% gypsum and 7% bottom ash, whereby both the moisture content and density of the materials can vary. In addition to a mixture of the three materials, it must also be possible for each material to be conveyed individually. This made it very difficult to predict how the material would behave during transport. In addition, previous experience showed that, depending on the mode of operation of the power station and silo installations, the actual demands placed on the system during day-to-day operation can differ greatly from the specifications defined beforehand, so it was important that the transportation system should be able to cope with any such deviations.

Fig. 3: TC-3A routing: horizontal curve (left) and one 3D-curve section (right).

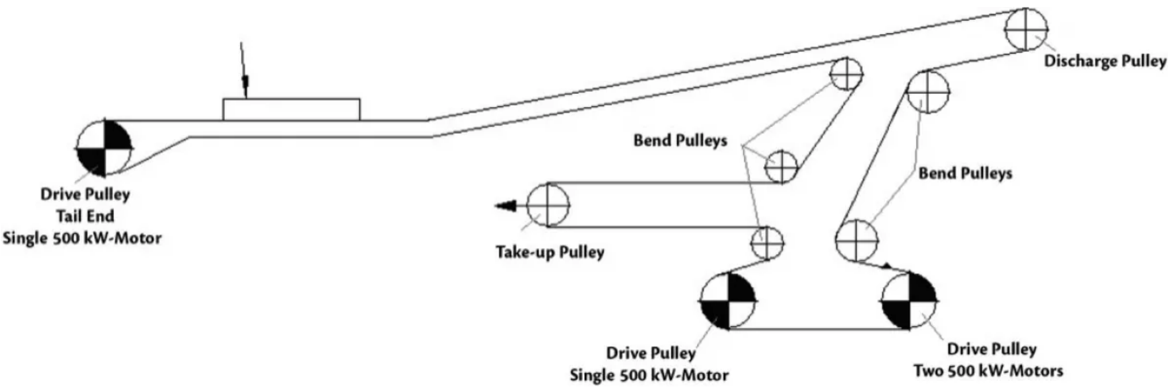

Fig. 4: Drive and take-up configuration of conveyor TC-3A.

2. Tube Conveyor Design

The TC-3A-overland tube conveyor system connects the power plant to the truck loading station.

Conveyor running resistance is determined following the DIN 22101 standard applicable for troughed belt conveyors. Auxiliary, grade and special resistances apply nearly unchanged for the dimensioning of the tube conveyor, but additional resistance components are likewise included in the determination of the main resistance.

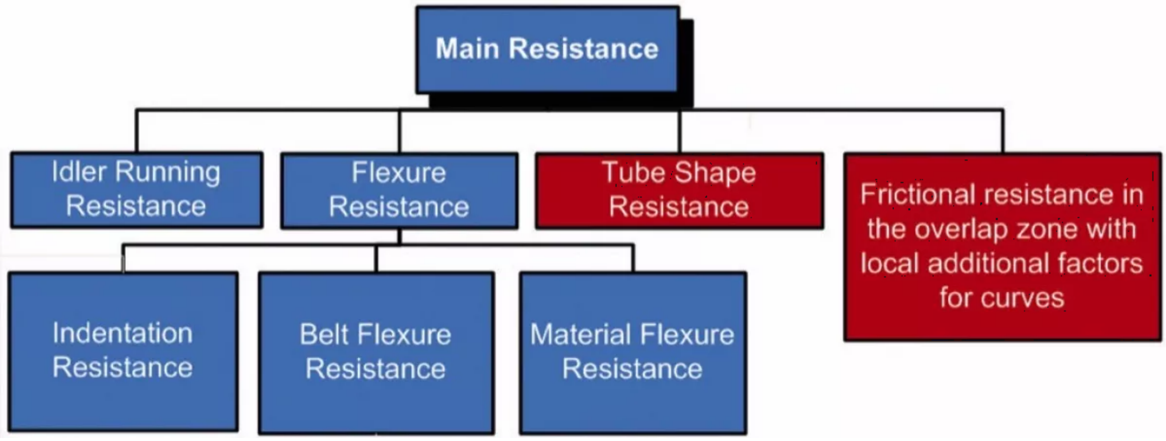

Fig. 5: Main resistance of the tube conveyor.

The form forces of the tube is determined primarily by the tube diameter and the transverse stiffness of the tube conveyor belt.

Friction resistance in the belt overlap zone results from the permanent opening and closing of the tube cross-section when passing through the idler stations. The tube belt opens by reason of its transverse stiffness, when not supported from the circularly arranged idlers. The circular cross-section is then re-established at the idler stations. This effect leads to a main resistance component not present in the troughed belt, since the overlapping belt edges cause friction resistance when the conveyor cross-section is opened and closed.

General technical details of TC-3A

Material	Ash and Gypsum
Centre Distance	C-C = 4535 m
Elevation	I = 24.5 m
Design mass flow	$I_m \approx 1400$ t/h
Max. belt speed	v_{max} = 4.8 m/s;
Max. fill ratio	$\eta_F \approx 0.72$
Steel cord tube conveyor belt	HS-Rollgurt 1500 S-K2 7T:6S Conti Extra, width 1500 mm, nominal breaking strength kN=1500 N/mm
Operating temperatures for the belt	-35°C ≤ T ≤ 60°C

General technical details of TC-3A

Outer (idler) diameter in top strand	$D_T \approx Ø$ 430 mm
Outer (idler) diameter in bottom strand	$D_B \approx Ø$ 400 mm
Idler spacing in straight	p_S = 2.0 m
Idlers spacing in curves	p_C = 1.5 m
AC-Motors	Head TL2: 2 x 500 kW + 1 x 500 kW Tail TT1: 1 x 500 kW
Curves	8 „tight“ horizontal und 7 vertical curves (min. Curve Radius Rmin = 350 m)
Take-up	at head TL2
Belt rip protection	Sensor loops embedded (vulcanized) in the belt top cover every 200 m and two ContiProtect rip detection units with two pairs of transmitters and receivers at head and tail

Additional change on the outer diameter of the conveyor cross-section occur if the tube belt conveyor follows a curved route. Expansion of this kind leads to a reduction in the conveyor cross-section and thus to increased friction resistance in the belt overlap zone.

Thus this additional main resistance component occurring on the tube conveyor is determined by the following parameters:

- tube diameter
- belt tension
- idler spacing
- curve radius
- transverse stiffness of the conveyor belt
- friction value between the overlapping belt edges.

The current research on conveyor running resistance in the case of tube conveyors does not yet allow for a determination of the two aforementioned main resistance components using the individual resistance method.

The standard procedure remains in place. Adapted to account for the main influential variables, namely

- belt design,
- line layout (curve layout) and
- ambient temperatures,

a fictitious friction coefficient is defined that can be used to determine the main resistance.

Belt properties determine main resistance to a much greater extent in the case of tube conveyors than in the case of troughed belts.

Various belt manufacturers supply tube belts with different belt designs and thus strongly deviating properties, particularly in terms of transverse stiffness.

It is recommended that the conveyor calculation be coordinated with the potential belt supplier before the contract is awarded. This allows for consideration of the specific features of the conveyor belt used.

The conveyor was designed in consultation with ContiTech based on a fictitious friction coefficient of DIN-f = 0.043 for the loaded conveyor in a stationary state.

Analog to the computation for the troughed belt conveyor, the belt tension values for all operating conditions, namely:

- all routes loaded at maximum running resistance
- all routes loaded at minimum running resistance
- only routes graded upward loaded
- only routes graded downward loaded
- idling

are to be determined in equilibrium, at start-up and during braking. Initial tension is determined for tube conveyors in a manner similar to that of the troughed belt. The goal is to ensure traction between the drive pulley and the belt in all operating states and to rule out unallowable belt sag and buckling.

3. Design of the Tube Belt

Takraf ordered an approximately 9.1 km long tube belt from ContiTech Conveyor Belt Group for the new Maritza tube conveyor system in Bulgaria. ContiTech also helped during the planning, installation and commissioning of the system. They have supplied more than 120 tube belts worldwide since 1987 and enjoy a high level of trust and confidence both from OEMs and from many plant operators.

In comparison to a conventional troughed overland conveyor belt, which can be operated at maximum conveyor speeds of v_F = 8.0…8.5 m/s, the maximum conveyor speed of a tube conveyor system is limited to around v_F = 6.5 m/s. Furthermore, the conveyor cross-section of a troughed conveyor belt of equal width is around 3 times larger. However, a tube conveyor belt offers decisive advantages over a troughed conveyor belt, and in some cases these advantages make the use of a tube conveyor belt actually indispensable. A summary of the advantages and disadvantages of a tube conveyor system is outlined in Table 1.

Advantages: Tube vs. Trough Conveyor	**Disadvantages: Tube vs. Trough Conveyor**
Tight horizontal & vertical 3D-curve radii easily conforms to terrain	Higher energy consumption
Steep conveyance angles up to 35° possible	Higher operation and maintenance costs
No need for transfer points	Higher manufacturing and installation costs
Material conveyed is shielded from outside environment	Lower capacity
Minimal space required thanks to compact design	Special knowledge is required for design, installation, commissioning & operation
Minimal spillage of material along conveyor structure	

During the selection and design of a tube conveyor and the tube belt itself, many factors need to be taken into account, such as the radii of curved sections, the significantly increased running resistance caused by the high form forces and additional friction forces in the belt overlaps, the shape of the overlap zone, and so on. This is why a new tube conveyor and the tube belt are often jointly designed by a OEM and a conveyor belt manufacturer. The new Maritza tube conveyor uses a high speed tube belt “HS-Rollgurt 1500 S-K2 7T:6S Conti Extra” with a width of 1500 mm and a nominal breaking strength of k_N = 1500 N/mm. Figs. 6 to 8 present the special features and requirements associated with a tube belt.

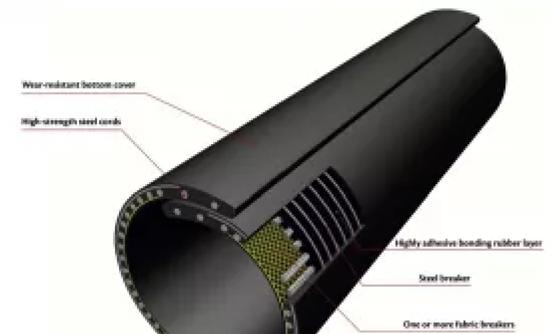

Fig. 6: Design of the steel cord tube belt.

The highest friction forces in the conveyor system occur during the initial hours (days) when the tube belt is first taken into operation (i.e. empty) (exception: conditions when the belt is first pulled in). The design of a tube belt should always be based on a “normal operating state” (i.e. after the running-in period), while the choice of suitable drives should always take into account both possible operating states (i.e. during commissioning and after the running-in period).

If a tube belt is designed, selection of the optimal transverse stiffness and overlap design is essential. Fig. 7 shows a different behaviour of a tube belt between idler panels: good (left) and unsuccessful designs of the tube belt (middle and right). Fig. 8 shows a different behaviour of a tube belt under tension in a horizontal curve: sufficient (left) and non-sufficient (right) transverse stiffness.

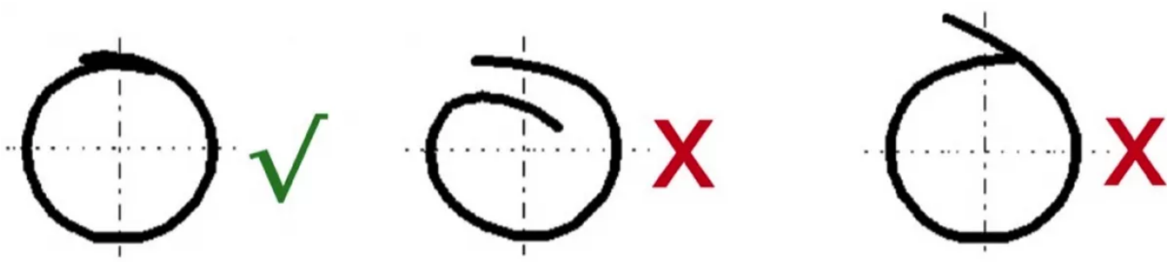

Fig. 7: Good (left) and unsuccessful designs of the tube belt (middle and right).

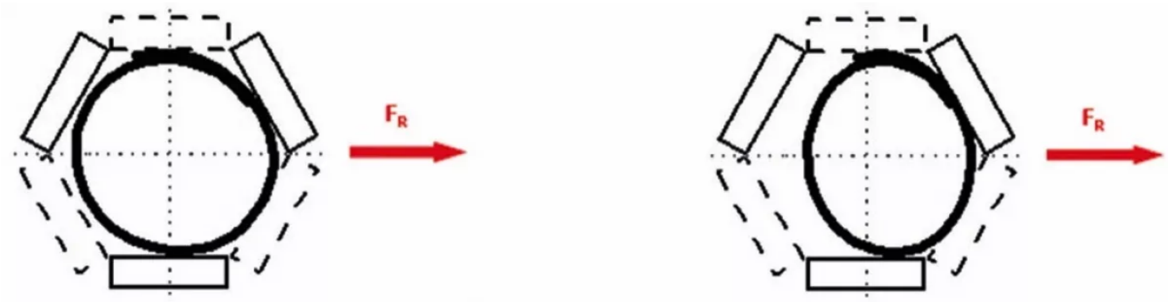

Fig. 8: Sufficient (left) and non-sufficient (right) transverse stiffness.

Once the tube belt design has been decided upon, the forming forces and overlapping zone are tested with the aid of a test sample (Fig. 9). Various operating factors such as the ambient temperature, temperature of the material, and the minimum radius for curved sections need to be taken into account here. Optimized transverse stiffness should maintain the tubular shape in curves to provide sufficient tube cross sectional area for the material and not cause very high running resistances resulting in high power demand.

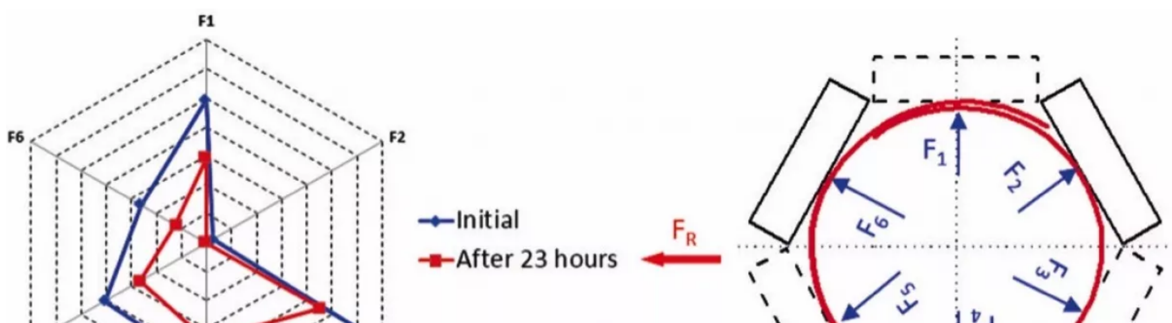

Fig. 9: Testing the optimum tube belt design in the lab: Measuring of form forces $F_1 \ldots F_6$ and their distribution for the min. curve radius by applying a radial force F_R.

4. Pulling in the Belt

The process for pulling in a tube belt needs to be coordinated between the OEM, belt manufacturer, service company and end-user. The pulling in procedure should be perfectly matched to the system.

The following factors need to be taken into account:

- The forces required to pull in the belt should be calculated in advance and monitored during the pulling-in process.
- Appropriate tools, machinery and auxiliary equipment matched to the demands of the system must be made available on-time (dozers, cable winches, crane, fork-lift truck, special pulling-in devices, connecting tools, splice shed, powered belt reeler, etc.).
- The optimum timing for pulling in the belt needs to be coordinated with the customer (special measures may be required if it is particularly cold).

Before start to pull in, a preliminary installation meeting between all participants should be held on site. The following strategies are possible for pulling in the belt:

- The entire tube belt can be pre-spliced next to the system (e.g. at the tail end or at the head end) and then drawn into the system.
- Each section in turn can be drawn in or counter the conveying direction from one particular position or from multiple positions in the system in the top strand and/or bottom strand.
- During the pulling-in of the belt, it is possible to use drive(s), dozer(s), cable winch(es) or a take-up device (either alone or in combination).

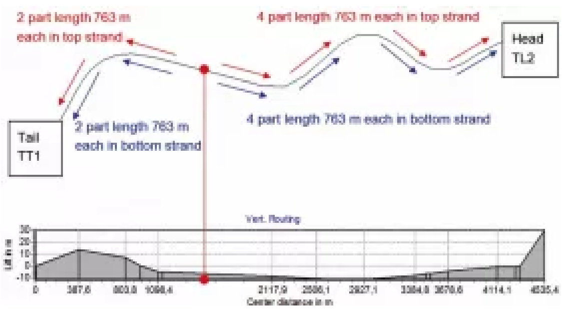

Fig. 10: Final pulling-in strategy for the Maritza tube belt.

Fig. 10 shows the final strategy chosen for pulling in the belt.

The standard procedure for replacement of a tube belt involves the use of drives in order to reduce the very high pulling forces at the cable winch (dozer) or on the powered belt reeler. In this case the belt is pre-spliced and laid down next to the installation in order to reduce downtime. Drives are often not possible to use in a new installation. Here, the belt is pulled in sections that are connected one after the other. This also reduces the very high pulling force. The choice of the correct location in the system from which the belt can be pulled in is of paramount importance. Ideally, the system should have no curved sections and no elevations at this point. Figs. 11 and 12 show the special equipment used to pull in the belt.

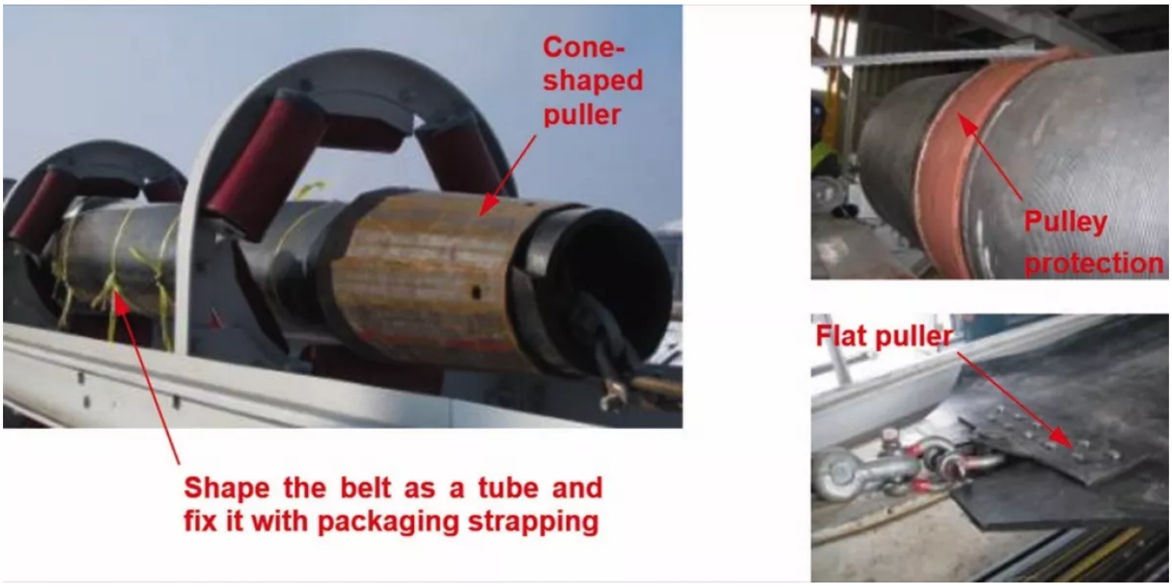

Fig. 11: Special pulling-in equipment.

The cone-shaped belt puller (clamp) allows the belt to be pulled in smoothly through the hexagonal idler stations in the system. The rolled-up tube belt is fixed form-locked in the pulling-in clamp between two steel cones. Here, the eye bolt of the inner cone must be able to rotate freely around its axis so that rotations on a pull rope that is not free of twisting can be compensated for.

Fig. 12: Special pulling-in equipment: “Pulling-in table” with finger idlers for rolling up the flat pipe belt in the top strand (left) and bottom strand

(right) of the conveyor system.

In order to reduce the form forces of the tube conveyor at the start, packaging strapping (yellow) was wrapped around the first 5 m of the belt (0.5 m each). If necessary, further binding straps can be attached to the tube belt. In the area of the pulleys and/or the flat-to-troughed and troughed-to-flat transition zones, a conventional, flat puller (clamp) is used. Here, the pulley of the system must be protected against a tensioned pull rope with special pulley protection attachments. The pulling-in table with adjustable idlers seats and finger idlers has a very special design.

The process of pulling in the belt was performed in “creep mode” with a speed of vP = 4…5 m/min using a pulling dozer, a stationary dozer and a cable idler pulley system. A special beam with cable idler pulleys was used to pull in the belt at high elevations of the system. At the head of the system, the belt was pulled in with the aid of the already installed take-up. At the same time, a sliding additive was continuously fed in at the pulling-in table in the overlapping zone of the tube belt in order to reduce friction forces between the rubber belt edges of the overlap.

Fig. 13 shows the pulling in process at ground level and at an elevated point in the system.

Fig. 13: Belt pulling-in process on the ground (left) and at a high elevation of the system (right).

During the process of pulling in the belt, the camber angle of the idlers was adjusted to ensure that the belt overlaps remained in the desired twelve o’clock position for the top strand and in the six o’clock position for the bottom strand. As a rule, there were around 16 idler seats on which the idlers need to be realigned. If the position of the overlap changed, it was necessary to turn back the tube belt. The low ambient temperatures resulted in high belt tensions and also caused additional difficulties due to snow and ice on the idlers and belt.

Special attention was paid to the technology used for splicing of the different sections. By using a special splice design, it is ensured that the same tube belt characteristics (such as optimal transverse stiffness, belt overlap, etc.) found in undisturbed sections of the belt are also provided at splices. All splicing work was supervised by an experienced ContiTech-supervisor on site.

5. Commissioning

Fig. 14: Position of the belt overlap.

Commissioning of the Maritza tube conveyor took place in the spring of 2010. Similar to the process of pulling in the belt, the tube belt was carefully monitored at the critical points during commissioning (particularly in curved sections and the flat-to-troughed and troughed-to-flat transition zones). The commissioning process for a tube belt system is normally accompanied by very high running resistances, which are caused by high form forces during the run-in period of the tube belt and by high friction forces in the overlapping area. As a result, an increased power demand needs to be taken into account when designing the drive power of the conveyor system.

In order to reduce the high friction forces in the belt overlap, a sliding additive (e.g. talcum powder) was added in the belt overlapping zone. Corrective measures were immediately put in place if the tube belt displayed any twisting (Fig. 14).

6. Power Consumption

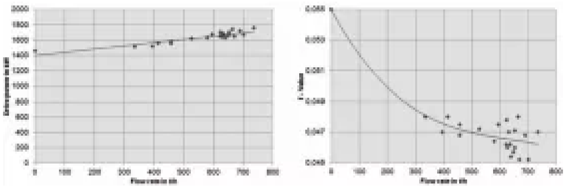

Fig. 15: Drive power and the fictitious friction coefficient DIN-f as a function of the flow rate.

Following an approximately 6-month test operation – a time span resulting from the start-up cycle of the power plant – measurements were taken to determine the power consumption of the TC-3A.

At peak throughputs of 1000 t/h, the power plant was able to provide a maximum average loading of the entire conveyor length of approx. 700 t/h. Fig. 15 (left) shows the individual measurements as measuring points to which a trend line was

added.
Of particular note here is that there is no significant difference between idle power and the driving power of the loaded belt. If the fictitious friction coefficient ƒ is calculated back from the individual measurements, the following image results in Fig. 15 (right).

Idling gives rise to a fictitious friction coefficient that significantly exceeds the value for the loaded belt. This is caused by the aforementioned additional components of main resistance. These are largely independent of the loading state and determined primarily by the belt properties.

The design of the tube conveyor must take this effect into account. Particularly for small throughputs and/or conveyor goods with small bulk densities, the idle behavior of the conveyor belt largely determines the power requirement.

The conveyor belt was designed, as described above, with a fictitious friction coefficient of ƒ = 0.043. When the trend line shown above is extended to the finally estimated throughput of 1400 t/h, a fictitious friction coefficient of around 0.044 results. This is affirmation of the installed driving power of 2000 kW.