# "New Dimensions of Curved Conveyor Belt Systems"

Presented at
BELTCON 7
International Materials Handling Conference, IMHC,
October 1993
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## 1. Introduction

Since the foundation of BERNHARD BEUMER MASCHINENFABRIK in 1935 the belt conveying technology has been forming an essential part of the company's scope of supply.

The basis for the initial activities in the field of belt conveying technology was a patent for the sealing of the idler bearing.

Afterwards the manufacturing programme had been extended consequently according to the customers' requests.

Today the range of products includes the fields of conveying, loading, palletizing, packaging and distributing systems.

The main market for the "conveying technology" was and still is the cement and building material industry.

In the Sixties BEUMER made the basic work in the field of troughed belt conveyors with horizontal curves. The theoretical considerations and calculations found their practical realization in the establishment of the first curved belt system for Holderbank in Switzerland, which was put into service in 1970 as transport connection to the cement factory Wildegg.

The customer's requests regarding conveying technology lead to studies of new system and transport conceptions with alternative designs. The demand for more narrow curve radii, larger inclination angles and a higher total economy of the conveying systems were essential project parameters.

Based on the individual parameters new curved belt conveyor systems were realized by application of the belt sack conveyor, the tube belt conveyor and the troughed belt conveyor. These three conveying systems can be characterized and differentiated by the distinctive features as conveying method (open/closed), minimal curve radius, maximum volume flow rate, design of the conveying belt and the type of belt control.

Hereinafter examples of realized systems, which have been put into service recently, will illustrate the practical use of curved belt conveyor systems.

## 2. Belt sack conveyor

The difference of the belt sack conveyor compared with the classical flat belt conveyors is made clear by the cross-section illustration.

The functions of the conveying load assumption on the one hand and the belt control and tension transmission on the other hand are arranged separately and three-dimensionally.

Two profiles vulcanized to the load-carrying belting have the function of belt guidance. On the conveying distance they are kept closed by support and guide rollers. The tension transmission is made by means of a steel cable traction device integrated in the profiles. A flexible belt sack without textile or traction device inlays takes up the conveying load and surrounds it from all sides on the entire conveying route.

The characteristic vertical arrangement of the profiles vulcanized to the load-carrying belting with steel cable traction device and of the belt sack which is arranged underneath vertically as well is the basic precondition for the realization of the minimum possible curve radius of only 0.4 m.

The belt strands conveying back and forth can be arranged either vertically one above the other nearby, or they can be arranged horizontally side by side.

The minimum curve radius, the flexible arrangement of the conveying strands and the possibility of intermediate feeding and discharge predistine this conveying system in particular for the internal transport.

The installation of the belt sack conveyor at the Alsen-Breitenburg works in Lägerdorf is a typical example for this.

Chemical gypsum resulting from the flue gas desulfurization of power stations is applied as aggregate for the cement production. The chemical gypsum has got critical conveying load characteristics. The material flows problematically with changing humidity and tends to bake on.

Dependent on the process 50 t of chemical gypsum per hour must be supplied to the process in one-shift-operation. On the basis of a newly installed feeding station with storage bunker the alignment had to be integrated into an existing building complex. These demands could only be met by a belt sack conveyor.

Besides a nearly straight-lined ascending part the route included two 90° curves within the building complex in front of the discharge point.

The drive power rating is distributed among two drive wheels which were realized on the one hand combined with a gravity tensioning device in a corner of the installation in the feeding area and on the other hand as intermediate drive in the first 90° curve.

Due to the low conveying capacity and the favourable small total resistance to motion the drive power rating with 7.5 kW each can be characterized as extremely low.

The material discharge behind the second 90° curve was designed as a so-called vertical discharge. The design of the discharge point with a vertically opened belt guarantees an optimum emptying of the belt sack, even of adhering conveying material as chemical gypsum in this case.

After the vertical discharge the returning strand is closed again keeping the remaining adherents from dirtying the conveying section. Therefore, you do not need any belt cleaners or any similar cleaning devices.

On principle we can state that - corresponding to the type of belt sack conveyor - we can realize volume flow rates of up to 400 m3/h with a conveying speed of 3 m/s.

Besides the volume flow rate to be achieved the maximum granulation of the conveying load is decisive for the necessary belt width.

The belt width graduations are the sizes of 650, 800, 1000, 1200 and 1400 mm. According to the type of installation the minimum curve radius varies between 0.4 and 1 m.

The described system for the transport of chemical gypsum was commissioned in December 1990 and from that date on it has been in operation without any problems. Due to the positive experience the customer gained from the belt sack conveyor he decided at the beginning of 1993 to have the same system conception built by BEUMER for the transport of so-called bleaching earth.

## 3. Tube belt conveyor

The tube belt conveyor is - just as the belt sack conveyor - a closed conveying system. However, there are differences in the cases of application and in the construction.

Compared with the belt sack conveyor the tube belt conveyor can transport considerably higher volume flow rates. On the other hand, however, larger curve radii are required. For example, with a tube diameter of 800 mm and a filling degree of 75 % a tube belt conveyor achieves a volume flow rate of approx. 4000 m3/h, which is ten times more than the volume flow rate achieved by a belt sack conveyor as described before.

The construction elements used for the belt guidance of the flat belt in the normal condition and of the belt rolled-in on the conveying section as tube cross-section are identical to those of the conventional troughed belt conveyor.

This includes, amoung others, the idlers as well as the tension and drive stations in their principal constructional design.

The specific conditions of operation of a tube belt conveyor, however, call for a basically new conception of the belt structure. This influences the various traction device materials and their arrangement in the conveying belt itself. They have to be located in such a way that a trouble-free closing of the belt, a constant distribution of the traction forces and a controlled rotation of the tube cross-section is guaranteed.

The possibilities of operation are shown by the example of the tube belt conveyor which was commissioned in 1992 for the company Wülfrather Zement, Soetenich plant.

The task was to connect the newly built limestone quarry to the Soetenich plant. The limestone produced there is fed to the crushing station shown in the picture on the right side of the top by dump trucks.

The connection of this crusher station to the storage bunker in the plant was very difficult as a deep valley including a public road, a river and a railway line had to be negotiated.

The difference in height between the crusher station with the feeding point and the storage bunker with the discharge point was 5 m only. The bottom of the valley, however, was about 50 m underneath the feeding station. The use of a tube belt conveyor made a very good course of the route possible which nearly met the profile of the terrain and which reduzed the number of bridge constructions to a minimum.

A conventional conveying equipment with a troughed conveyor belt would have required higher and longer and therefore much more expensive bridge constructions.

Furthermore, in case of a troughed conveyor belt the maximum inclination angle would have been limited to 16°. By using the tube belt conveyor, an inclination of 25° could be realized which corresponded to the course of the terrain.

Beginning from the material feeding point, the tube belt conveyor goes horizontally through a short tunnel. Leaving the tunnel the conveyor descends by 50 m to the lowest point of the course.

On this section the maximum inclination is 25°. Then the conveyor inclines in some steps to the storage silo in the plant itself. Six vertical and three horizontal curves with radii of 150 m in total are overcome by the tube belt conveyor.

For the required mass flow of 350 t/h a tube belt diameter of 250 mm and a nominal conveying speed of 2.5 m/s were chosen.

Starting and stopping are effected by programme-control with the speed of the tube belt conveyor being flexibly adapted to the material flow being fed.

The determination of the installation conception was made in cooperation with Clouth who were responsible as belt producing company for the design, manufacture and splicing of the belt.

A textile belt quality type R-EP 800/2 was used. The installed drive power rating of 110 kW is fed to the installation as single drive unit at the head drum.

Measurements of the operating conditions of the installation helped to obtain new basic values for the design of new tube belt conveying installations.

Tests in practical operation showed lower resistances to motion compared with the theoretical calculations. The main reason is that the tube belt cross-section is more rigid in reality as it was thought when calculating the resistance to motion at the idler stations.

The entire system showed safe working and operating conditions even under extremely unfavourable loading constellations which were produced for test purposes.

Since the successfull commissioning the installation works trouble-free and secures the supply of raw material of the Soetenich plant.

The advantages of the tube belt conveying technology can be summed up as follows:

- protection of the conveying material against the environment

- protection of the environment by dirty-free and dust-free transport

- no loss of material on the conveying path

- small space required

- flexible alignment

- minimizing of the investment cost even in unfavourable terrains

- high specific conveying capacity

- absolutely operational reliability.

## 4. Troughed belt conveyor

The oldest and best known type of belt conveyor with horizontal curves is the troughed belt conveyor. It is used to bypass long distances even with a difficult terrain topology. A number of individual and straight belt conveyors with the related discharge and feeding points can be replaced by only one curved conveyor with small curve radii of a minimum of approx. 750 m.

The capital expenditure required for the installation of such a system is much less than that for a tube belt conveyor. The frame construction of the troughed belt conveyor can be simpler, and there is a maximum of three idlers necessary per idler station instead of six for the tube belt conveyor. Furthermore, at least one usual standard conveying belt can be used.

The balance of forces between the belt tensile force directed to the inner curve and the belt guiding forces directed to the outer curve is of much importance for the working safety of a troughed belt conveyor with horizontal curves.

As compared with a straight belt conveyor, in the horizontal curve the belt is subjected to an additional radial force component (transverse force) which results from the tensile force in the belt and shifts the belt into an asymmetrical position in relation to the centres of the idler sets. In consequence of this asymmetrical position there occur guiding forces which counteract the radial force component. These guiding forces can be increased by giving the supporting frame or the idler sets a superelevation (cant) as well as by additionally tilting the idlers.

Of great importance for the operationally reliable design of a complex belt conveying equipment with horizontal curves is - besides the knowledge of the calculation basis - the information of the empirical calculation values which can only be found in practical operation.

On the basis of the know-how gained from a considerable number of installations, BEUMER was able for the first time to commission a 4.2 km long belt conveyor with horizontal curves with the simultaneous transport in the upper and lower conveyor.

The conveyor supplied for Halla Cement in South Korea links the harbour of Okke to the cement plant located in the interior of the country at a distance of 4.2 km. The cement started its operation with two new production lines with a capacity of each 5500 tons of clinker per day. A harbour terminal, included a handling and a dispatch plant and a grinding plant for cement clinker, was built as part of this expansion project.

The relocation of the cement grinding plant in the harbour areas was necessary as there was not enough space left in the cement plant.

The new conveyor belt system might be called the "umbilical cord" between the cement plant and the harbour. It replaces the discontinuous transport by truck which could no longer come up to the new capacity demands to an acceptable degree.

A considerably high degree of efficiency could be achieved in this installation due to the fact that it is used for the transport of clinker to the harbour as well as for the transport of material required in the plant simultaneously.

850 tons of clinker per hour are transported from the plant to the harbour and at the same time 575 tons of coal or alternatively 250 tons of aggregates are transported in the lower conveyor from the harbour to the plant where this material is required for cement production.

Due to the topology of the terrain it was necessary to follow the natural course of a river in a relatively narrow valley. This river becomes a raging torrent during the rains so that a considerable part of the conveying route had to be laid on concrete columns. It was also necessary to negotiate a railway line, a mountain ridge, industrial plants, a main road and a residential area.

Because of this, 73 % of the route length is made up of six horiontal curves, most of which are overlaid by vertical curves. The longest curve measures 763 m and the longest straight section 694 m.

The radii of the horizontal curves are between 1200 m at the minimum for curve no. 4 and 2000 m at the maxium for curve no. 1.

The steel cable reinforced belt of a width of 1000 mm and a nominal strength of 1250 N per mm belt width tranports the bulk material with a conveying speed of 2.62 m/s.

The picture shows the route course near the head station in the area of curve no. 1. The upper conveyor is loaded with clinker which can have temperatures of up to 100°C in normal operation. This required the use of a temperature resistant belt.

After commissioning the belt conveyor was completely covered over to protect the material from the elements and to protect the area from noise and dust.

At the cement plant's end the belt conveyor system is designed both as a drive station and as a loading and delivery station for the material conveyed. At this point the clinker is loaded onto the belt and the coal and aggregates are discharged.

The station at the harbour has a similar configuration, but belt tensioning equipment is also provided which is designed for the balance of the belt lengths between summer and winter as well as for the controlled starting and stopping of the installation.

To ensure optimum reliability for the operation of this installation a completely new drive conception was developed. Two drive drums were installed both at the cement works end and the harbour end. The capacity of the six drive units installed is divided in a relation 2 : 1 per drive station.

All six drives are torque-controlled. When the belt is restarted they are started again and stopped by a torque-controlled system governed by the static inertia torque ultimately required by the belt conveyor system.

The build-up and decay of torque at any given time follows a given mathematical function. The installed electrical drive power ratings required are 6 x 132 kW. The drive motors are asynchronous motors controlled by frequency converters super-controlled by a Simadyn-D system.

These newly developed starting and stopping procedures restrict the tension generated in the belt to a defined level. This ensures that for any possible state of loading of the belt the conveying system can be started and stopped reliably while at the same time keeping the local tension of the belt to a minimum.

This also includes the measurement of the belt tension with load cells and the adjustment of the setpoint value for the belt tension taking the operating situation into account.

Monitoring and controlling of the setpoint value for the belt tension at the tension winch is made automatically.

This newly developed starting and stopping procedures restrict the tension generated in the belt to a defined level. This could be proved in practice after a period of two years of operation.

The advantages of curved belt conveyor systems of bulk transport over long distances were demonstrated again at Okke. A conveyor belt system of this type is highly suitable for large continous flows of material, needs a small cross-section for the route, with low location costs, is environmentally friendly and has no dustry transfer points. Modern control technology ensures a high degree of operational reliability.

## 5. Summary

Curved belt conveyor systems are available in various types of construction for different cases of application. Basically, they are marked according to their cross-section as open or closed conveying systems.

The most essential constructional characteristics and technical parameters for the belt sack conveyor, the tube belt conveyor and the troughed belt conveyor are described by means of examples of installations in the cement industry.

The individual examples illustrate the limits of application areas and show specific construction characteristics. This especially refers to the curve radii to be achieved in connection with the maximum possible mass flows.

The belt sack conveyor is to be recommended as a conveyor for lower capacities and volume flow rates of up to 400 m3/h, especially for the internal area of the plant with smaller curve radii.

The tube belt conveyor combines in an ideal manner smaller curve radii with high conveying capacities at the same time. Proven construction elements are used from the troughed belt conveyor technology for the belt guide. The tube belt conveyor has special technological characteristics regarding the conveying material.

The troughed belt conveyor with horizontal curves is predestined for the bypassing of long distances with high mass flow rates to be realized at the same time. A special efficiency is achieved by the simultaneous transport in the upper and lower conveyor. A new torque-controlled drive and control conception is used and guarantees defined tensile forces in the belt in all operational conditions.

The examples given underline the high state of today's conveying technology.