

PIPE CONVEYORS, A MATURE TECHNOLOGY

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1. INTRODUCTION

Japanese Pipe Conveyors (JPC) became available around the same time of the first Beltcon conferences around four decades ago [1].

South Africa was a significant player on the early days, but the popularity of the technology has declined in the local market in the last few years, with almost no new installations.

Meanwhile, elsewhere Pipe Conveyors are no longer an emerging technology for low tonnage and short distances, but a valid alternative to conventional conveyors, reaching capacities, tensions and lengths comparable to other belt conveying alternatives.

We will present the state of the art in Pipe Conveyors through application examples and testing developments in the recent years.

2. HISTORY

We can trace the Pipe Conveyor design to the original patent from 1965 [2] while the actual industrial development took place in the late 1970's by a consortium of Japanese companies, led by Bridgestone, which started commercialising pipe conveyors under the trade name of "Japanese Pipe Conveyor" or "JPC.

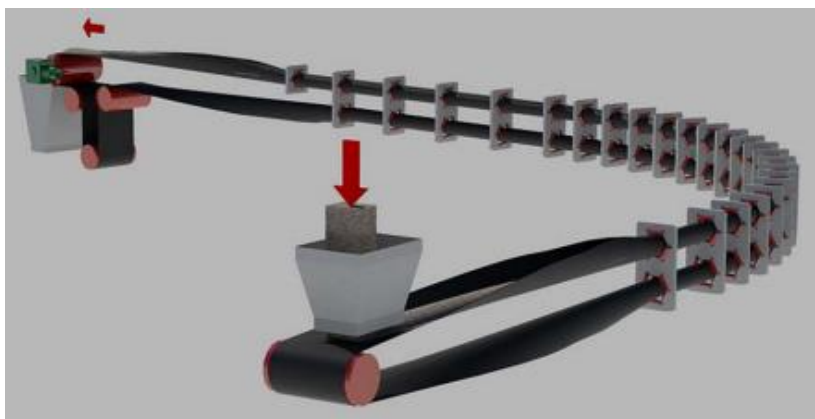


Figure 1. Pipe Conveyor Schematics

Source: Beumer Group

The first few hundred pipe conveyor systems were installed in Asia, mostly in process plants, with lengths of a few hundred meters, capacities well under 1000 tph and pipe diameters mostly 150- and 200-mm. Pipe Conveyors were marketed by the Japan Pipe Conveyor consortium and their licensees according to patents.

During the 1980's and 90's several pipe conveyors were installed in Southern Africa mostly in coal and diamond applications. South African EPC and consulting companies participated in projects around the world, that included the largest diameter pipe conveyor with 700 mm in Brazil at the beginning of last decade, but their activity has dwindled down significantly in our days.

With the arrival of this century, the patents subsided, and the systems became longer, with larger diameters and capacities, with current benchmarks being about 15 km long, 700 mm diameter and 5,500 tph capacity. They are a well established alternative to conventional systems in the cement industry and thermal coal industry. In mining they are the preferred solution for minerals concentrates handling. In India they have become the preferred technology for coal, iron ore and other materials overland transport due to their fully enclosed nature in environmentally sensitive areas.



Figure 2. 5,500 tph Pipe Conveyor for Iron Ore

Source: Beumer Group

3. BELT CONSTRUCTION

Pipe conveyor belting requires a proper transversal stiffness that guarantees pipe formation and alignment (no undue rotation) as well the transversal cross section area required for the adequate transport of material, while it opens and closes properly at the head and tail ends.

Due to the overlap (around 60 degrees) the centre of gravity of the folded belt is above the geometric centre formed by the idler rolls, creating a tendency of the belt to rotate under its own weight. The friction against the idler rolls prevents this from happening but it requires the belt to press against the rolls as shown in Figure 11.

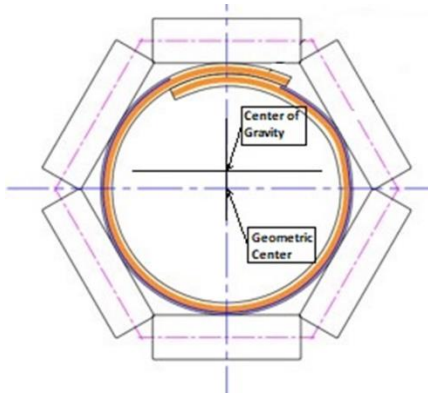


Figure 3. Pipe Conveyor Section

As observed in numerous installations with horizontal curves over the years, the overlap section which is not only heavier but normally has a higher longitudinal stiffness (larger transversal section) tends to follow the shorter path and rotate to the inside of the curve. The bending forces in the curve also tend to reduce the pipe diameter due the additional tensions caused by the belt strain. The belt needs to have the necessary transversal rigidity to maintain the pipe/tube shape particularly in tight curves and maintain a good seal in the overlap zone while it is between idler panels.

Standard conveyor belting does not have the necessary characteristics for use in a pipe/tube conveyor except under dire emergencies [3]. Using a “normal” belt might result in failure to keep the tubular shape, as it can be seen in Figure 4, where such a belt was installed as an emergency measure on a 400 mm dia. pipe conveyor, handling coal in a power station. The conveyor could not work and had to stand until the proper belt arrived at site.



Figure 4. “Normal” belt recently installed in a Pipe Conveyor

However, if the belt has too high a transverse rigidity, then the power consumption will increase dramatically mainly as result of the rubber indentation in the idler rolls, and in some extreme cases losing the pipe shape in between idler panels. One such case is a “pipe” belt supplied by an unexperienced supplier for another Pipe Conveyor,

350 mm dia. at the same site of the past example, also handling steam coal. Due to the excessive stiffness, the belt opened between panels and the power consumption of the empty belt was higher than the expected full load consumption during commissioning.



Figure 5. “Pipe” belt recently installed opening between panels due to excessive stiffness.

The longitudinal flexibility is required to allow the tight curves that pipe/tube conveyors are best known for, without overstressing the belt, and although there is a strong need for just the right amount of transverse rigidity in the belt, the belt edges in the overlap zone must still be flexible to seal adequately, as appreciated in field observations. This is accomplished in many ways. One is by having the belt constructed so that the edges have little reinforcement in the overlap zone, and the middle portion of the belt having a higher-than-normal transverse rigidity. In the smaller pipe/tube diameters this is done by increasing the skim rubber thickness between the plies in the middle portion of the belt and leaving the belt edges of normal construction for the flexibility, as shown in figure 6:

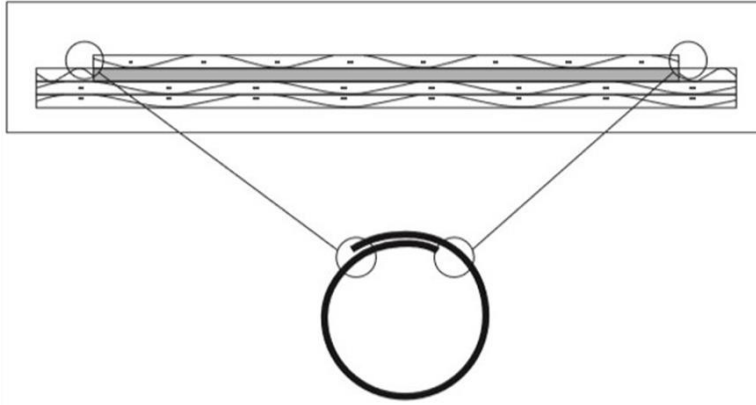


Figure 6. Textile belt with increased transverse moment of inertia in central section

Source: CEMA Handbook [2]

In Steel cord belts it becomes even more relevant to increase the transversal (weft) stiffness as the cords are oriented only in the longitudinal direction (warp). The following figure 7 represents a cross section of a steel cord belt, showing the different rubber layers, the steel cords a top fabric breaker and a bottom steel breaker.

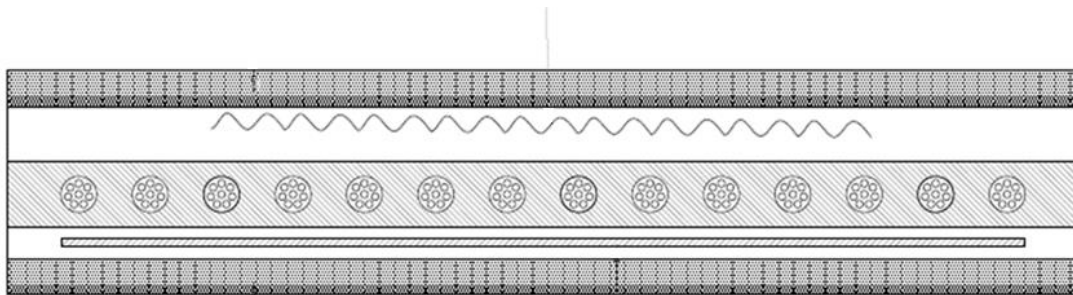


Figure 7. Steelcord belt with fabric (top) and steel (bottom) breaker reinforcement

Source: Oriental Rubber Industries Pty. Ltd.

Several tests, most non-standard, give indications of this transversal stiffness. One test that is “borrowed” from conventional conveyors is the transverse stiffness (Troughability) test according with ISO 703:2007 [4], which is simple to perform as it measures the deflection of a full width sample under its own weight, as shown in Figure 8:



Figure 8. Troughability Test

Source: Oriental Rubber Industries Pty. Ltd.

The test gives an initial indication of whether a belt construction is suitable for a pipe conveyor application, but it is not an accurate predictor of performance.

A more accurate way of measuring the belt cross stiffness is the 3-point bend test, performed in a universal test machine, as seen in figure 9:



Figure 9. 3 Point Bend Test

Source: Oriental Rubber Industries Pty. Ltd.

Sometimes this data is used to build a FEA model of the belt as done by well-known consultants in the field, in this case, the test is performed at the centre of the belt and in the edges, to consider the reduced stiffness normally used in this part of the belt. It is also normal to let the sample stand for 24 hours, to measure the relaxation over time, which is associated by some with the relaxation observed in the belt after repeated closing and opening cycles.

A more representative test is done measuring the outward force as the belt forms a pipe, with the so called 6-point test, which is shown in Figure 10:



Figure 10. 6 Point Bend Test

Source: Oriental Rubber Industries Pty. Ltd.

Load cells measure the force in each of the supporting points that mimic the idler rolls. It is customary to measure the forces with the overlap in the 6 different positions, obtaining later an average value that is called “Pipe Formation Force”.

Again, some manufacturers and consultants use the value measured after 24 hours as an indication of the reduction of the pipe formation forces in time.

It is a well reported phenomena that initial power consumption with a new belt is high in pipe conveyors due to the high stiffness of the belt. After a few hundred loading cycles this force diminishes as the belt relaxes and absorbed power drops accordingly. Over time the belt relaxes further up to a point where pipe formation is no longer satisfactory and operational problems are experienced.

A commonly used criterion to evaluate the remaining relaxation life of the belt is to measure the diameter of the pipe formed in the straight sections, where a reduction of 15% of the initial diameter is deemed as the acceptable limit before the belt needs replacement. Alternatively, it can be stated that at least 4 rolls need to be in contact with the belt to avoid its rotation when empty.

Each belt relaxes and changes shape in accordance with its construction, in some the diameter reduces while the overlap keeps sealing the pipe. In other cases, the inner part of the overlap collapses first and the seal is lost, while the top part remains in contact with idlers.

A way to measure the actual belt relaxation in time is to use a custom-made rig to roll in and out the belt sample, simulating the actual bending in operation. The belt is removed at certain intervals to be taken to the 6-point measuring machine, measuring the reduction in pipe formation force against time as shown in Figure 11. After the initial relaxation, the outward force keeps on decreasing steadily with the number of cycles, sometimes reaching a point where this reduction increases. The belt tends to collapse rapidly, but normally there is a point where the outward force is not enough

to maintain the pipe shape and the alignment. This causes operational problems, and the belt must be replaced. In Figure 11 we can see the variation of the force for two samples on a Mineral Concentrate Carrying Pipe Conveyor, where the blue line represents the pipe formation force of the “original” belt and the orange line the same measurement for the “replacement” belt.

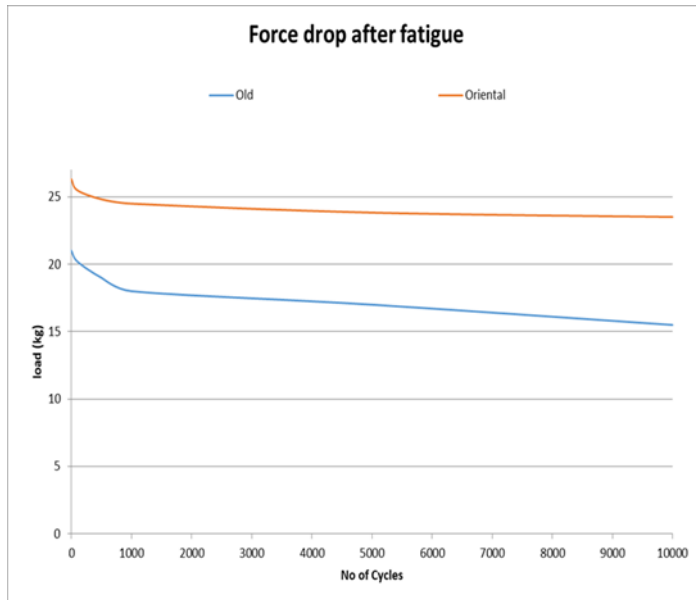


Figure 11. Relaxation of Belt with Operating Cycles

Source: Oriental Rubber Industries Pty. Ltd.

It can be appreciated that the original belt has a much lower pipe formation force, and it relaxes (loses stiffness) rapidly with the opening and closing cycles, which lead to the conclusion that failure could be expected shortly. Based on the test results, a replacement belt with higher stiffness and slower relaxation over time was ordered. Unfortunately, before the new belt could arrive the belt failed to open at the head pulley during loaded operation as shown in Figure 12, and a major incident was caused.

The new belt has been operating successfully for the last 2 years, without signs of loss of stiffness.



Figure 12. Belt folded over the head pulley of a pipe conveyor

In actual operation, the belt tension influences how the pipe forms, due mainly to the Poisson effect. The bending on the curves also influences the way the belt forms the pipe. A way to try simulating this phenomenon is to use a pipe testing rig, where a significant section can be installed. Rolls simulate the actual idler rolls and can be located to form a curve as the belt is tensioned. Pipe formation forces can also be measured in one or more locations. This type of rig was pioneered in South Africa by the turn of the century.

This is as close to a simulation that can be practically done, and it is very useful to assess the belt behaviour. The downside being that a full production prototype must be built and installed in the rig, which is not a minor operation on large diameter pipes. This kind of test remains a “quality assurance” exercise before mass production and is not practical as a development tool for a new belt. Figure 13 shows the largest of such rigs in existence, with capacity for a 12 m sample and 700 mm diameter pipe belt.



Figure 13. Pipe Conveyor Belting Test Rig

Source: Oriental Rubber Industries Pty. Ltd.

If pipe conveyors are going to grow in tensions and capacity, understanding how the construction of the belt determines the mechanical properties on site becomes imperative to shorten the learning curve and avoid mistakes that could be potentially disastrous in large installations.

4. MAINTENANCE TROLLEYS

Another South African innovation on pipe conveyors was the implementation of self-propelled maintenance trolleys on elevated structures. The first such trolley was used together with a conventional belt in a triangular frame in Richards Bay, during the early 90's. Similar designs, conserving the use of a diesel generator and hydraulic drives were used in other locations, like the Coal Pipe Conveyor in Colombia shown in Figure 14.



Figure 14. Pipe Conveyor with Triangular Frame and Maintenance Trolley

Source: ZING e.i.r.l.

In our days it has become more common to use electric drives and VFD's for the trolleys and rectangular frames are usually preferred. The weight reduction of the triangular frame is outweighed by higher transport cost when fabrication does not take place near site. Figure 15 shows one such trolley in operation in India, where the tendency is to use fairly large trolleys over long distances. The system shown in the picture has several flights with a total length of 18 km, all in elevated structures maintained with a trolley and it is one of many such systems operating in India today.



Figure 15. Pipe Conveyor with Rectangular Frame and Maintenance Trolley

Source: ZING e.i.r.l.

When handling low density materials such as grains and coal, the weight of a supporting elevated structure is greatly influenced by the weight of the maintenance trolley. Using a compact design, gasoline generator and batteries together with electric drives can result in a more cost-effective solution. Figure 16 shows a trolley supplied for a Pipe Conveyor in Argentina being tested at the factory.



Figure 16. Pipe Conveyor with Rectangular Frame and Compact Maintenance Trolley

Source: ZING e.i.r.l.

An added advantage of the battery operation with electric drives is the low noise generated, which allows the maintenance crews to listen to belt and idlers during inspection. Noise is one of the early signs of idler failure. Other monitoring systems, such as thermal- and image-based can be added to the trolley allowing for remote monitoring of the Pipe Conveyor.

5. U-SHAPE CONVEYORS

A quite recent development of a Pipe Conveyor variation is the U-Shape Conveyor as supplied by the Beumer Group (Figure 17).

One of the main limitations of the pipe conveyors is the inability to handle oversize material, especially if such material is close to or larger than the pipe diameter. When handling alternative fuels as done today in many cement plants, it is quite difficult to have an effective control on oversized material. U-Shape Conveyors were developed for this application as an alternative that allows 50% larger lumps while keeping most the flexibility of the pipe conveyor.



Figure 17. U-Shape Conveyor in European Cement Plant, typical section

Source: Beumer Group

6. FUTURE OUTLOOK AND CONCLUSIONS

Pipe conveyors can make continuous handling viable in cases where conventional conveyors are not able to compete with mobile equipment (trucks). The pressing need to reduce the Greenhouse Effect Gases, already acknowledged by most mining houses strategic plans, gives a new urgency to the replacement of trucks with conveyors.

Even when compared with hydrogen propelled trucks, the amount of energy required to move the material will always be lower in a conveying system as the equipment moving mass is much lower, reducing the energy requirement per ton of mineral transported and make the target of zero emissions more attainable.

In Chile and Peru, where almost half of the copper of the world is produced, the mines move large amounts of mineral and even larger amounts of overburden, often in high altitude or mountainous terrain. Both quantities increase continuously as copper grades decrease and open pit mines get deeper. Pipe conveyors can be used where conventional belts falter, taking advantage of their ability to follow higher inclinations and routings with tight vertical and horizontal curves. But to be able to fulfil the requirements they will have to handle larger capacities and tensions than ever before as current references achieve 5,500 tph in iron ore and ST 3,500 belt rating. Capacities required go up to 16,000 tph and ratings up to ST 10,000 if we consider the projects being developed today.

U-Shape Conveyors can handle large volumes and lumps while keeping most of the flexibility of the Pipe Conveyors and are also a good candidate for future conveying solutions.

On the other hand, the growing need for saving water as well as continuous accidents involving tailing dams are increasing the practice of replacing such dams with dewatered tailings dumps. These tailings, usually coming out of a filter plant, with

high humidity, high cohesiveness and stickiness are not easy to handle. Here, pipe conveyors with its potential to reduce the number of transfers as well as the elimination of spillage along the routing are most of the time the best conveying solution.

We expect South Africa to recover part its lost leading role in the developing of these future applications.

REFERENCES

- 1 Buchanan, C., "The Pipe Conveyor", BELTCON 3, Johannesburg, South Africa, September 1985,
- 2 US3338383, Pipe Conveyor, Kunio Hashimoto, 1965
- 3 Belt Conveyors for Bulk Materials, Conveyor Equipment Manufacturers Association (CEMA), Seventh Edition, 2016
- 4 ISO 703:2007 Conveyor belts — Transverse flexibility (troughability) — Test method



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