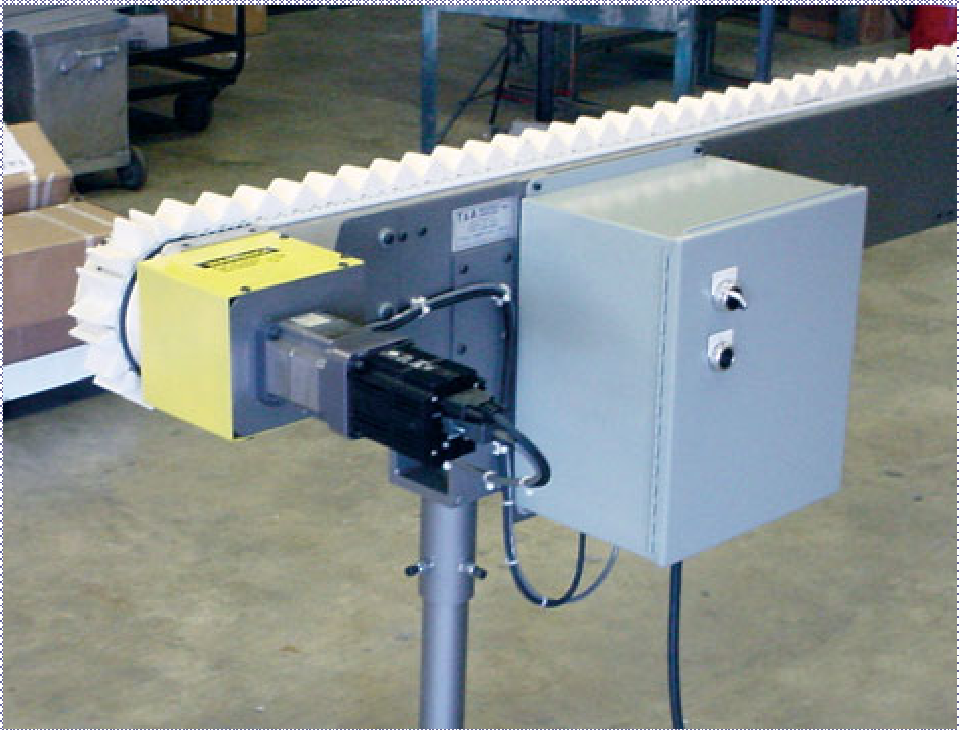
Textile Reinforced Conveyor Belt



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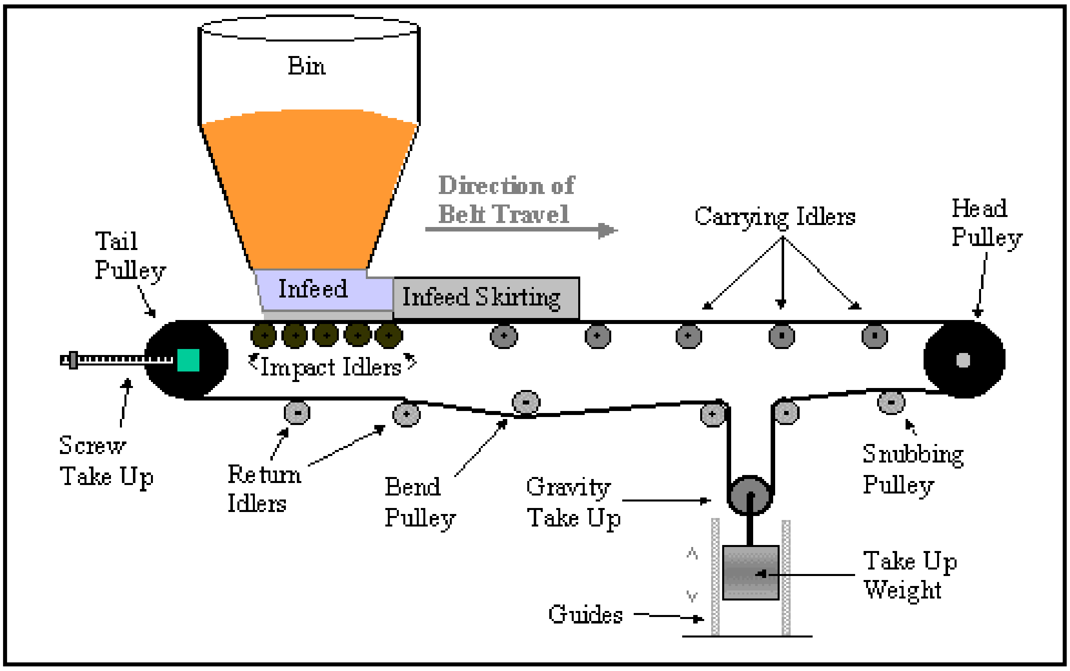
Abstract

This paper contains an overall review of conveyor belt. It tells how conveyor belt developed, textile materials and structures used for manufacturing of conveyor belt and advantages of fabric conveyor belt over steel conveyor belt. Amongst the different fibres, the paper mainly highlights on Kevlar fibre which have excellent tensile and chemical resistant property. It also tells about the techniques and different type splicing of conveyor which is most important thing in conveyor making and a good splicing is very much needed to get better performance of a conveyor belt. It also highlights the different aspect of conveyor failure and how they can be minimized.

Keywords: Kevlar, Corded fabric, Reinforcement, Coating

Introduction

Conveyor belts are flexible composite plates that when interconnected it forms an endless entity and can efficiently transfer bulk materials or parcels form one place to another. Conveyor belt systems are composed of endless belt, pulleys, idlers, electrical motors, counter weight, rigid structure and other accessories. Below diagram shows a typical conveyor belt system. [1]



Typical conveyor belt system

Conveyor belts have to meet rather different requirements, depending on the particular application. The basic properties required include:

- High strength and flexibility
- Low extension in service
- Resistance to abrasion
- Impact and tearing resistance
- Resistance to moisture, oils and chemicals

- Fire-resistant
- Temperature resistant

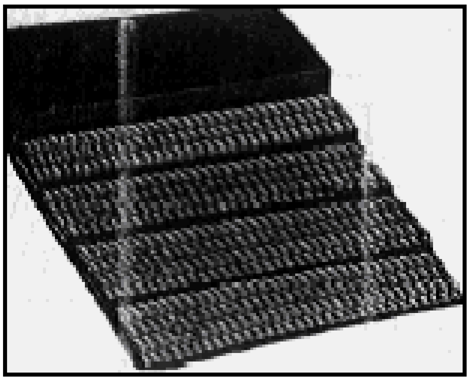
In addition to the above properties, conveyor belt material should also exhibit-

- Harmless as regards hygiene
- Good adhesion of the constituent plies and good adhesion to the driving drums
- Minimal tendency to electrostatic charging and last but not least,
- Should be reasonably priced.

The importance of these individual factors may considerably vary in different products.

The two main components in conveyors belts are the rubber and the reinforcing member that carries the load. The rubber has two primary functions; first to act as a binding element and second to protect the tension member. The performance level of conveyor belt, of course, posed on reinforcement materials as regards both fibre properties and fabric construction.

The traditional reinforcement materials are woven textile fabric and steel cord. The selection is determined by the working tension in the system. In general, the cutoff point is around 2100 N/mm. Following diagrams show the conveyor belts produced from textile material and steel cords as reinforcing material.



Textile reinforcement in conveyor belt

Steel cord reinforcement in conveyor belt

History of Conveyor Belts [2]:

The continuous handling of bulk materials by conveyors is based on the use of endless belts which do not only carry the material but also absorb the tensile forces. The belts run on idlers and are driven by pulleys, which they circumnavigate.

This conveyor system was first introduced at the turn of the century. At the time, its design was governed mainly by the requirements of the mining industry. Over the years, the belt materials and their properties have undergone considerable changes. The need for increased tensile properties, abrasion resistance and higher economy has encouraged belt users to join with belting manufacturers as well as plane engineers to develop tougher and more economical conveyor belting.

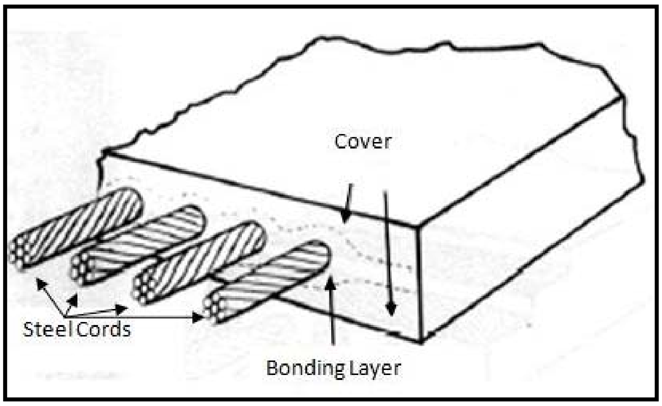
The mining industry proved to be a trendsetter once again. Particularly, in the field of underground mining where stringent requirements gave rise to a high standard of belting. Also the new ignite surface mines were responsible for bringing about major improvements in the design of heavy-duty conveyor belts. These changes were subsequently adopted by other industries.

The belt reinforcement was originally in the form of cotton plies. These were later replaced by plies such as rayon, polyester, polyamide and especially steel cords, which were to carry the tension loads of the belt. Steel cords not only proved to have outstanding flexibility, but also able to carry the highest belt tensions.

The belt plies were originally embedded in natural rubber. In the course of time , the rubber compounds were considerably improved to meet the stringent safety requirements for underground use, and inflammable natural rubber was supersede by non-inflammable or self- extinguishing rubber , or even plastics such as PVC . Extremely wear-resistant belts were developed for use in surface mining.

Steel Cord Belts [2]:

Steel cord belts consist in principle of parallel steel cords which are embedded lengthwise in rubber. The steel cords act as reinforcement, while the rubber protects them and forms a surface for conveying the material. The steel cords are purpose-made and extremely flexible. They are specially coated to make them corrosion-resistant.



The rubber is of a high quality synthetic type such as SBR (styrene butadiene rubber) which has excellent wear resistance. The belt incorporates a special layer of rubber around the steel cords designed to bond to the coated surfaces and wires and to fill in the spaces between them. The bond is extremely important. To facilitate transport, belts are manufactured in sections which are spliced together by overlapping the steel cords, and by vulcanizing new cover rubber both above and below the overlapping area with the aid of special mobile vulcanizing presses. This splice has the same tensile strength and service life as the belt as a whole. This is particularly important for the belt performance, as a weak splice could result in costly downtime, and may even be a safety hazard, especially in the case of steep conveyor systems. This conveyor belt design has proved to be a reliable and economical means of handling high capacities. The surface of the individual wire is galvanized to avoid rapid body corrosion when the protective rubber coating is damaged [3].

Textile Reinforced Conveyor Belt

The performance level of the conveyor belt mainly depends upon the type of textile material, i.e. fibre used and textile material construction. The product construction includes that of the basic threads used in the warp and weft, including the twist level, as well as that of the woven fabric, including the interlacing technique used.

1. Fibres for Conveyor Belt

The individual types of reinforcement materials have different shares of the market. In general, cotton fabrics are taken into consideration in certain application areas only when strength of up to some 100 N/mm is adequate. In applications requiring a higher strength level, viscose rayon fibres are used but, of course, these suffer from strength loss in a wet environment.

Number of plies in yarn used for conveyor belt cannot be increased at will. Usually 3 to 6 plies are considered convenient. In fact, an increased number of plies mean a higher, production cost and a poorer utilization of fabric strength, i.e., the ratio of the sum of the strengths of all plies to the strength of the conveyor belt body. In conveyor belts designed for heavy-duty application, nylon, polyester, glass and Kevlar, PTFE and PEEK fibres are used [4, 5].

Although rarely, but Jute and leaf fibre are also used as conveyor cords. They have very good adhesion with rubber. [6]

There are limitations to optimal utilization of each of the materials mentioned, and also different technical problems determine the forms of application of these materials. One way to obtain optimal properties of such a fabric is to combine two different fibres and thus utilize the most convenient properties of the two. Currently used are the viscose rayon/ nylon and the nylon/cotton combinations, but by far the most popular is the combination polyester/nylon (with the polyester fibres in the warp).

With these blend fabrics, no adhesions problems are encountered as with the case with the all-polyester woven fabrics. The other advantage includes the following [3]:

1. High strength and hence the possibility of construction transport conveyors of great lengths;
2. Excellent resistance to moisture, as a result, neither separation of individual plies nor a strength loss can occur.
3. High impact resistance;
4. High resistance to dynamic stresses enabling driving drums of smaller diameter to be used;
5. Complete resistance to extension in service makes it possible to use very long transport conveyors;
6. High resistance to chemicals enables conveyor belt filters to be used m the chemical industry;
7. Outstanding resistance to elevated temperatures.

Amongst the other textile fibre Kevlar is the best fibre for the reinforcement of conveyor belts. Kevlar has very good physical and chemical properties. Some typical physical properties of some high performance fibres are shown below [7]:

Material	Density g/cm^3	Tensile Strength (MPa)	Modulus MPa	Breaking Extension %
Kevlar 29	1.44	3,620	83,000	4.4
Kevlar 49	1.44	3,620	124,000	2.9
High strength Graphite	1.75	3,100	221,000	1.25
“E”- glass	2.55	2,410	69,000	6.5
Stainless steel	7.83	1,720	200,000	2.0

The table below shows the chemical resistance of Kevlar fibre [7].

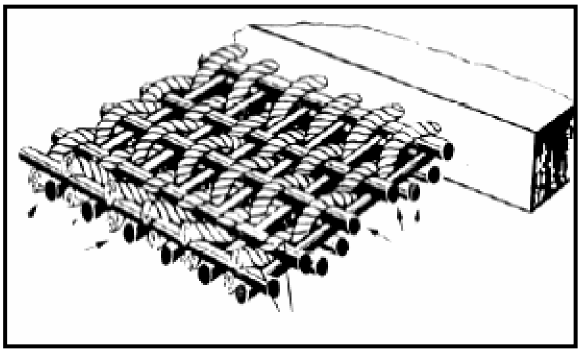
Environment (100 hour exposure at 21ºC)	Tensile Strength Loss (%)
Formic Acid (90%)	10
Hydrochloric Acid (37%)	90
Nitric Acid (70%)	82
Nitric Acid (1%)	10-20
Sulphuric Acid (70%)	100
Sulphuric Acid (10%)	10-20
Oxalic Acid (10%)	40 -80
Brake Fluid (for 312 hours)	2
Grease	0
Ozone	0
Boiling Water	0
Trichloroethyelen	0
Superheated steam at 156oC for 80 hours	0

These physical and chemical properties of Kevlar fibres allow using it as the reinforcement material for conveyor belts. By using this it is possible to design light and linger conveyor belts. This design feature is a major advantage in applications that require a high modulus, light weight belt as a replacement to steel cords, thus providing for the use of narrow, fast belts of high strength which can be employed efficiently over long distances. The use of these type of belt led to lower manufacturing and installation costs, reduced energy consumption, no sparking and non-flammability giving improved safety, better corrosion, better impact resistance and longer life. The advantages of Kevlar over steel reinforcement are shown below [8]:

Advantage	Benefit
No corrosion	Less repairs, less production stops, reduced replacement
Five times lower weight to strength ratio	Easier handling, reduced energy at equal consumption
Reduced belt thickness	Lower weight, fewer splices
Extreme non- flammability	Low heat conductivity, no sparking
Better fatigue resistance	Longer belt life

2. Fabric Construction for Conveyor Belt

There are four basic types of construction for reinforcing high strength belts- cord fabrics, straight warp fabrics, solid woven fabric and cabled cords [7].



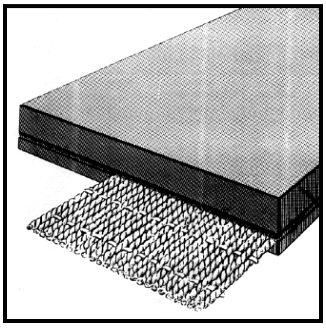
Textile reinforcement in conveyor belt

2.1 Cord Fabrics:

Filaments of Kevlar yarns have only 1.5 denier linear density. The cord constructions use Kevlar yarns as the strength member laid in warp direction, usually with a light weft of nylon or polyester to hold the cords together.

2.2 Straight Warp Fabric:

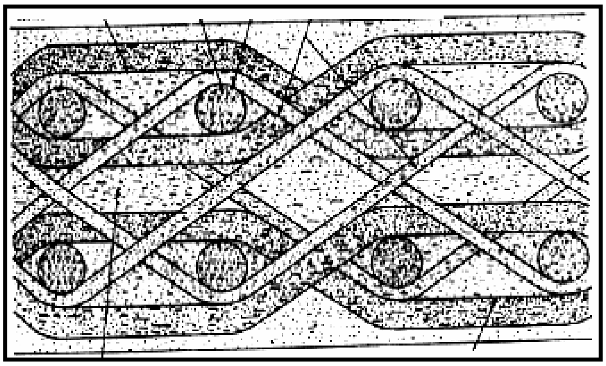
In the preferred straight-warp construction, the Kevlar warp cords are locked in place by a series of binder warps (of nylon) and weft yarns. This ensures that the straight-warp weave has minimum crimp and, hence, obtains 90% of the strength of the fibres in warp direction. Using straight-warp weaves; it is possible to achieve breaking strength of up to 150 kN/m. Using a "stacked" or double warp construction the elongation goes maximum 5%. This construction offers the cost-saving benefits of a single ply plain woven fabric and, also, provides high transverse impact and penetrational resistance, thus eliminating the need for breakers.



Straight Warp Fabric Conveyor

2.3 Solid Woven Construction:

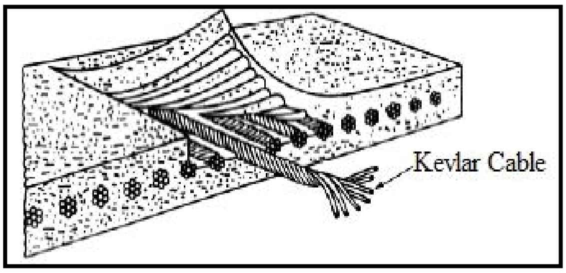
Kevlar fibres have disadvantage of being brittle, and they can be damaged by lateral pressure and friction. This demerit of Kevlar fibre can be overcome by solid woven construction. The solid woven construction causes the Kevlar warp to go through crimp, resulting in a higher elongation break. Because of the heavier construction, belt breaking strengths of up to 4000 kN/m are achievable. These constructions have high impact and tear resistance. Belt joining is achieved with metal fasteners or with standard finger splices. This type of construction is limited to medium or high tension belts.



Solid Woven Construction

2.4 Cabled Cord Construction

The cable cord construction is used in ultra-high tension belting ranging up to 5400 kN/m breaking strength. Adhesion to rubber is built into the cable of Kevlar, which allows direct replacement of steel cables within the steel belt manufacturing process. Another advantage with this construction could be gained with splices designed similar to those used with steel cable cord belts. Unfortunately, this type of belt construction has some of the disadvantages of the steel cable reinforced belts, such as being expensive to manufacture and having poor tear resistance along the belt and between the cable reinforcement.



Coating of Conveyor Belt [7]:

Problem associated with the use of Kevlar in conveyor belt is to obtain a good bond between the fibres and the rubber matrix through interface that will transfer the belt loads from the matrix to the fibres. To avoid this problem special dip systems have been developed for the aramid fibres, consisting of an aqueous solution of an epoxy for a pre-dip which is dried and baked on to the fibres. This is followed by a topcoat combination of resorcinol formaldehyde-latex (containing vinyl pyridine), which gives a high level of adhesion of the fibres to the rubber. Carbon black is dispersed in the RFL to increase the modulus of the dip film to a level intermediate between that of the fibre and the rubber stock. A typical aramid pre-dip (sub coat) comprises water soluble epoxide(2%), water (97.9%) and wetting agent (0.1%), with a mixture pH value of 11.5 (NaOH). The subcaot, which requires high temperature treatment to achieve optimum adhesion, is heat set to 245 ^{0}C, and the topcoat (RFL) is heat set to 220 ^{0}C. Instauration in the cord adhesive rubber is essential for maximum adhesion to the rubber compounds of the matrix; otherwise adhesion to the rubber is substantially reduced.

Problems Associated with Textile Reinforced Conveyor Belt

Challenges faced by the fabric conveyor belt are [1]:-

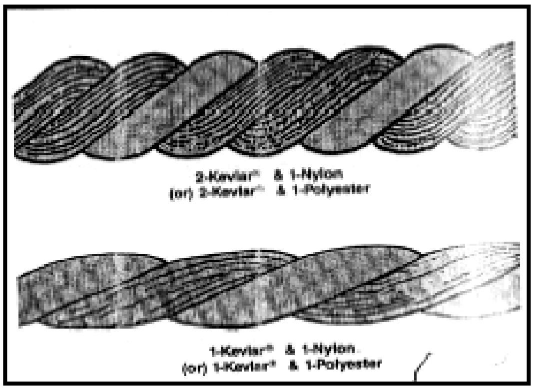
- Conveyor Belt Width
- Conveyor Speed
- Strength
- Versatility

There are two solutions to the challenge, and the first one is partially effective due to property trade-off.

Firstly, by increasing the number of plies in the belt. The tensile strength will increase but at the same time the resulting fabric composite will be stiffer in both the traverse and longitudinal axes. The belt will likely to have inadequate troughabilty translating into belt tracking problems, spillage and edge damage when the belt runs into the structure. Also, the increased number of plies will intensify the bending stresses and the inner ply shear forces when the belt and the splices go around the pulley. Larger stresses require larger pulleys.

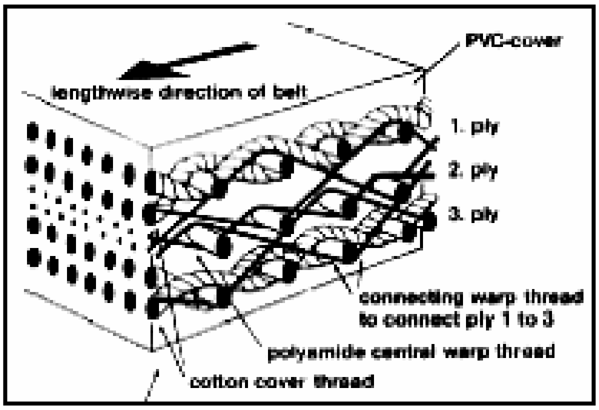
The second approach is to develop a new textile-reinforcing member that will carry far more load width of belt. When built into a carcass, the resulting product will trough on the idlers, will bend easier on the extra benefit of vulcanized or mechanical splicing.

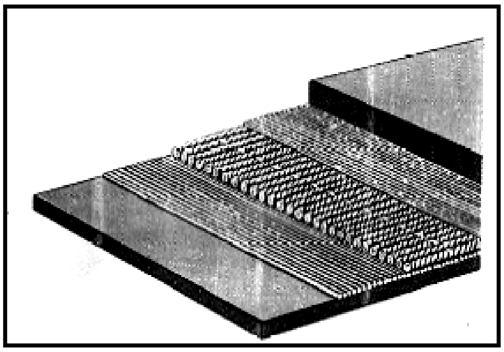
For better performance hybrid cords are also used. Hybrid cords with Kevlar and nylon are preferred for best fatigue resistance and compatibility of adhesive dips. Kevlar and polyester hybrid cords have higher initial modulus and lower growth than corresponding nylon and may be useful for application where dimensional stability is critical. Hybrid cords has very good fatigue resistance .It demonstrated elsewhere which shown by the below graph [8].



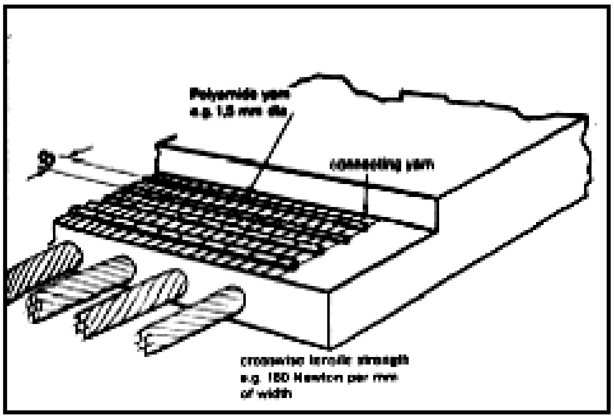
Some special designs are now used for manufacturing of conveyor which prevents failure and improve the performance of conveyor belts.

Fabric performance can be improved by cross wise reinforcement [2, 9]. Cross wise reinforcement increase the impact resistance of the fabric. It also increases the longitudinal tearing or initial tearing resistance of the conveyor belt. The following figures show PVC coated conveyor belt with multilayer fabric.





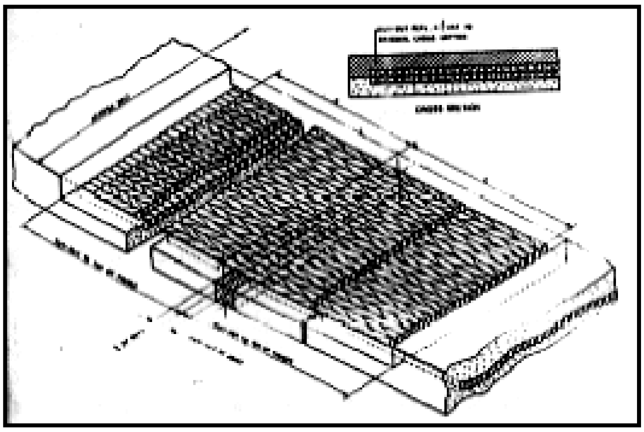
Conveyors are also produced by combining steel and cords which give better performance [2].



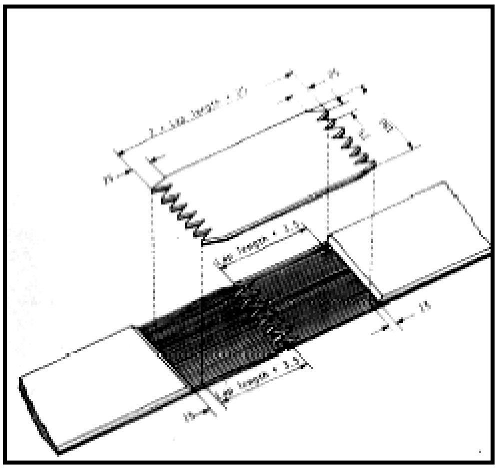
Splicing of Conveyor Belts

The splicing is very important in conveyor belt because it is the weakest point of conveyor belt. Most of the failure takes place in the splicing zone. Normally V-butt splice is used for splicing [7]. But the problem with this type of splice is failure under dynamic conditions, with cracking beginning at the top surface of the belt and then propagating along the fingers. The overall efficiency of this kind of splice is about 0.32 times that of the belt.

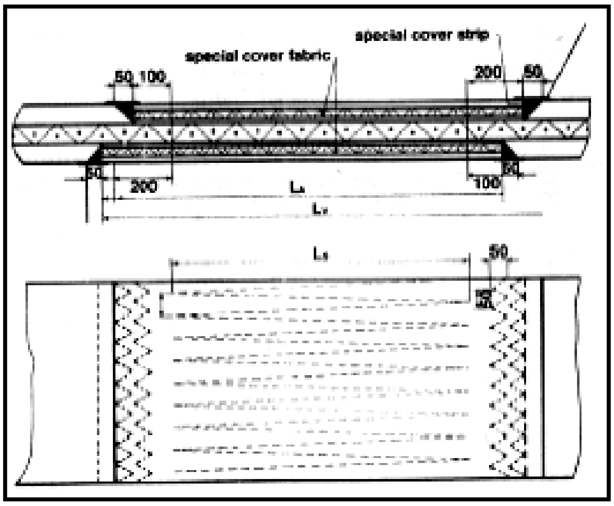
To improve splice strength, a new design concept is proposed, known as single lap joint splice, as shown in the diagram. It can be seen form figure that the rubber cover beneath the splice is retained to support the fabric attached. The splice geometry then resolves into a lap joint, with a full width layer of identical fabric weave forming a sheet of lap material placed on the top side of the butt joint. A small gap in the rubber beneath the fabric butt shown in figure 19 is filled with raw rubber strip, and a raw rubber sheet is laid on top of the splice to fill in the 3 mm space left above the lap joint. The whole lap joint area is then vulcanized to form the original shape of the belt cross section.



Some more improved splicing design is also available in practice which optimizes the strength; minimize the thickness of the joint adhesive and length of the lap. These are Double lap joint Splice (DLJS), Finger Splice System, etc [10].



Double Lap Joint Splice



Finger Splice System

Conveyor Failure [11]

By their very nature, conveyor belts have a finite life. While it is difficult to define this life, the modes of failure are known. These failures could be classified as 'gradual failure' or 'sudden failure'. Gradual failures mean that the development of a defect takes place slowly; implying that a certain defect or failure development time is involved.

Some factors which govern life of splice are -

- Environmental conditions - moisture, humidity, dust, handling (cleanliness) and temperature of the splice area
- Materials - age, shelf life, size of tie gum strips for the splice stage (step), type of solvents, compatibility of covers to bonder material, new to old belt splicing issues
- Mechanical - splice step design, cord spacing for the particular chosen step and cord diameter, splice length, length of butt gaps on the splice, matching belts from different manufacturers, splice curing time, layup quality, splice straightness
- Electromechanical - vulcanizer calibration, temperature sensor monitors, platten temperature distribution, pressure control, temperature control.

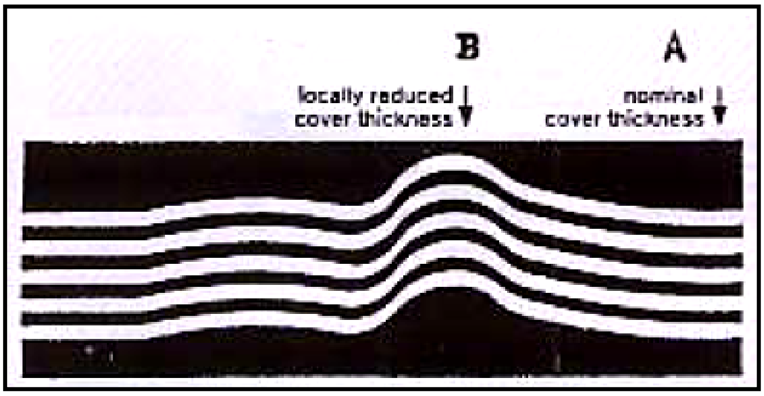
By understanding the three primary mechanisms of failure, one should be able to identify the factors that maximize belt life. The three primary failure mechanisms for conveyor belts are: *Yield*, *Wear*, and *Fatigue*.

Fatigue is the growth of microscopic cracks in a material caused by repeated loading and unloading. Fatigue failures are often confused with the belt becoming brittle.

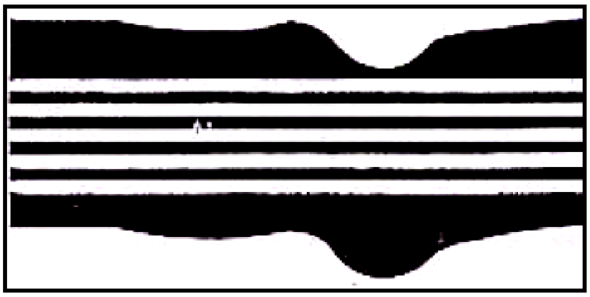
Most failures are caused by *yield*, which occurs when a belt is permanently deformed (bent). These failures are usually due to accidents or misuse.

Wear occurs as the joints hinge, or the belt rubs against other components. This results in a slight loss of material and weakening of the effected zone.

Various causes are responsible for failure of conveyer belt. Some of them discuss below. Cross waves in the carcass of the belt can occur in a part or along the full width of the belt. This causes a reduction in the thickness of the cover rubber at a number of places or grain formation at the top surface of the cover rubber. This occurs when plies are insufficiently stretched during preparation and vulcanization or may be due to high and uneven working pressure [11]. This results considerably reduction of life of conveyor belt.



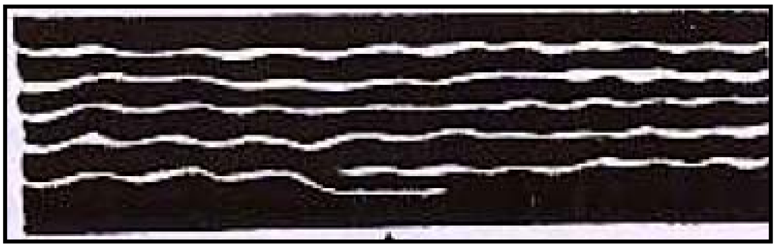
Cross waves of the carcass of a fabric belt



Buckling of the surface of a fabric belt with cross waves of the carcass when stretched

Like cross waves, longitudinal waves are also formed in conveyor. This type of defect occurs irrespective of the type of carcass and width of the belt or at different stretches of the belt, and reduces the thickness of the cover rubber locally. It reduces 40-50% life span and utilization of its capacity and a fall in efficiency.

Sometime plies are overlapped; as a result proper rubber covering not takes place, so it reduces the life of conveyor belt.



Effect on cover rubber due to overlapping plies

Belt width is very crucial for its performance. Actually capacity of belt depends upon belt width. So depending upon the load proper belt width choice is important, otherwise belt may be fail.

During use, conveyor belts are subjected to different abrasion [12]. As a result cover materials are subjected to abrasion and high stress. So covers may rub and ultimately life of conveyor belt is reduced.

The weakest point of conveyor belt is the splice joint. The strength of splice joint is less than half of the conveyor belt.

So proper splice, design is pre-requisite, which increase the life of conveyor belts.

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