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Rubber Textile Composites. Application of Fabrics in Conveyor Belts.

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Introduction

Whereas textiles have been produced in the same way for many thousands of years, it was only some 500 years ago when rubber was introduced in Europe and really only in the last two hundred years that textiles/rubber composites have been used. Since then, however, there has been very great development design and use of these materials. Within last years, there has been a great move away from natural materials (natural rubber and cotton) to synthetic products, both as regards the fibres and the polymers used, resulting in a very wide diversity of engineered composites, to meet many and varied performance requirements. Nevertheless actual knowledge about fabrics parameters influence for final product properties is limited. Fabric and belt designers in their work base generally on experience.

Conveyor belt. History of one of oldest rubber textile composite.

Conveyor belts are used throughout industry for transporting materials from one place to another. Their applications are very varied, from carrying small items over a metre or two, as at supermarket checkouts, to carrying bulk materials for many kilometres, as in many quarrying and mining installations. The earliest reference to the use of conveyor belting was by Oliver Evans in his 'Millers Guide', published in Philadelphia in 1795 [1]. Here the conveyor

was described as a 'broad endless strap of thin pliant leather or canvas revolving over two pulleys in a case or trough'. With the rapid development of many textile/rubber products in the middle of the nineteenth century the first application of a multi-ply textile/rubber conveyor belt seems to have been by S.T. Parmalee, who took out a patent in 1858. Slightly later, in 1863, O.C. Dodge was granted a US patent for a belt conveyor for handling grain [2]. The earliest recorded application for a textile/rubber plied belt in the UK was by P. B. Graham Westmacott and G.F. Lyster, engineers for the Mersey Docks and Harbour Board, at the Birkenhead and Waterloo docks [3]. They had experimented with a 12 inch (30cm) wide belt and showed that it was capable of carrying grain with less power than a conventional screw conveyor.

During several years conveyor belting technology developed significantly. Natural rubber was replaced by synthetic, man-made fibres replaced cotton and afterwards used rayon. Introduction of polyester and nylon yarns was possible only because improvement of chemical bonding system, base on RFL (resorcinol, formaldehyde, latex) impregnation. At the moment development in textile reinforcement concern mainly fabric structure which determine final belt parameters. Official knowledge in this area is very limited and rather concentrated at fabrics and belts producers. There was no revolution in technology since bonding system improvement and man-made fibres application. It is interesting that R&D is very poor in this area, especially when conveyor belt market is doing well.

Nevertheless, belt weaknesses are clear and limit such conveying system application in many places.

At the moment in Europe there are two main conveyor belt fabrics suppliers, Mep-Olbo and Kordarna (actually in insolvency, January 2010 took over by JET Investment). In India SRF ltd. is a monopolist on the local Indian market and expand in western markets investing in new plants, exmp. Industex from South Africa. Similar situation is in China, Shandong Heylon Polytex is a leader in domestic market and a very strong player in Europe. There are several smaller conveyor belt fabrics producers in the world, but their position is rather weak.

Belt Design [4]

The overall design of a belt is determined by driving unit requirements and the requirements imposed by the nature and volume of material to be carried. Belts in general are produced as a multiply (Figure 1.), single ply (Figure 2.) and solid woven (Figure 3.). In all three types fabrics parameters are different. In realising an adequate design, there are a number of parameters which have to be considered and satisfied:

- adequate tensile strength and modulus to transmit the power and to carry the material,
- low elongation at working tension to give minimum take-up requirement,
- good load support and sufficient width to carry the type and volume of load,
- flexibility, both directions, to flex round the pulleys, and transversely, for satisfactory troughing,
- dimensional stability to run straight and not to grow too much in service (low permanent elongation),
- good adhesion between all components to avoid delamination,
- good tear resistance to withstand damage,
- ability to be joined (mechanically or chemically) and be close in loop.

Multiply belt

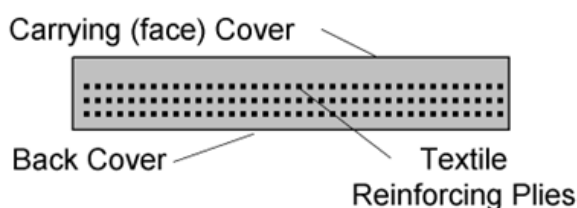


Figure 1. Multiply belt—schematic model [4]

It is most popular belt construction. It has 2-6 plies and can have breaking strength up to 3500kN/m. Such belts are spliced (in loop) mechanically or chemically (cold glue or hot vulcanizing).

Single ply belt

Not so popular like multiply belt construction, but more flexible, what is important for special applications. Breaking strength can be up to 1000kN/m.

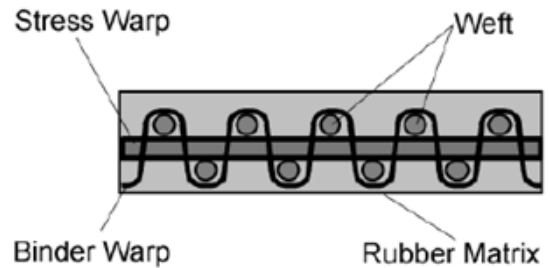


Figure 2. Single ply Belt—schematic model [4]

Solid woven belt

Construction commonly use in underground belt, especially as a impregnated by PVC for flame resistance applications. This belts are spliced mechanically. Figure 3 present schematic model of this belt.

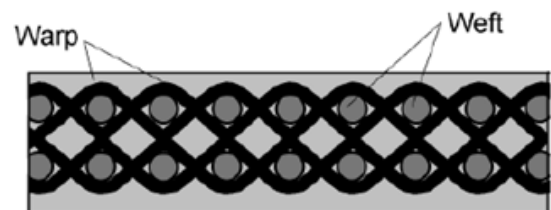


Figure 3. Solid woven Belt—schematic model [4]

Actually used material

On the beginning cotton was the most popular material used for conveyor belts production. Cotton gives very good mechanical adhesion and good high temperature protection (no melting). Afterwards cotton was replaced by rayon. Actually mainly polyester, polyamide and aramides are used in this type of composite. Hereafter brief summary about advantages and disadvantages of this polymers.

Polyamide (Nylon)

Compared with the cellulosic, the nylons are of much higher strength and also give much higher

values of elongation at break. This latter property imparts to nylon fabrics a greatly improved impact resistance, higher work to rupture and much better tear resistance. It is largely on account of these properties that nylon has been adopted as the principal weft yarn for conveyor belting fabrics. Additionally, the lower modulus of nylon also contributes to very good trothing characteristics in the finished belt. One characteristic of nylon, not possessed by the cellulose, is thermal shrinkage. Being a thermoplastic material, when heated nylon tends to shrink. On account of this, when processing nylon fabrics, either some restraint must be employed to control or limit this shrinkage or adjustment must be made in the design to allow for the subsequent changes in dimensions during processing. By choosing suitable conditions of processing, it is possible to modify the shrinkage characteristics to suit more precisely the final parameters to be satisfied. Generally speaking, however, if nylon is allowed to shrink, the elongation at break will increase and modulus will fall, depending on the degree of shrinkage. Nylon is almost entirely used as continuous filament, but there is a small application for spun staple nylon, as with rayon, primarily for bulk and adhesion requirements.

Polyester

In principle, polyester combines the strength and elongation characteristics of the nylons with the modulus characteristics of the rayons. This combination of properties suits many applications, but there are two main areas where problems exist. The first concerns adhesion: being relatively inert chemically, it is somewhat more difficult to obtain adequate levels of adhesion with polyester than with rayon or nylon. However, methods of treatment have been developed to overcome this. The second area relates to thermal shrinkage. Processes exist to modify the shrinkage characteristics of polyester and there are also various grades of fibres with differing shrinkage/modulus relationships, achieved by modification of the basic polymer.

Aramid

The properties of aramid are more akin to those of the inorganic materials than to the other textile fibres. The tensile strength, even assessed by the engineering method as strength per unit cross-section, is of the same order as those of steel and glass, so that when quoted as tenacity (where the advantage of low specific gravity is taken into account), the strength

is exceptional. The modulus is also very high, but this is coupled with a very low value for elongation at break, which introduces some difficulties in certain applications. The major disadvantage of this low elongation occurs when aramid is used in several layers. When flat, each layer of textile is able to contribute its own share of strength, but on bending, the low elongation of the outermost layer prevents it from accommodating to the curve, which places the other layers in compression. This directly reduces the contribution of the inner plies to the total strength but also, and more seriously, the performance of aramid in compression (especially its dynamic fatigue resistance) is not good. Under such conditions, premature failure of the inner plies is likely to occur. However, many applications have been developed which enable the excellent properties of aramid to be realised and much effort is being devoted to ways of overcoming the problems associated with this low elongation, so that other areas of use can be found for the unique combination of properties possessed by aramid.

Fabrics weaves [5]

Majority of conveyor belts are made as a multiply construction. Therefore typical fabrics are commonly use. Hereafter short characteristic of basics fabrics constructions.

The simplest weave is the plain weave. In this construction, each thread, both warp and weft, passes alternately above and below the threads in the other direction and out of phase with the adjacent yarns on either side, running in the same direction. A diagram of a plain-weave fabric is given in Figure 4a. The plain weave is the basic woven fabric structure and is very widely used. It forms the basis for the development of the more complicated interlacing patterns used in weaving. Most ply belting fabrics are plain weave as are most fabrics for coating applications. The plain weave construction, using very low twist yarns, enables a very smooth and flat surface to be produced, the yarns flattening out at the intersections and spreading to give minimum gaps or interstices between adjacent yarns, thereby giving a very full cover fabric.

As the strength requirements for the fabrics increase, it becomes increasingly difficult to insert the necessary number of yarns into the space available, notwithstanding the use of folded yarns, so it becomes necessary to modify the interlacing to obtain the yarn density required. The easiest way to modify the plain weave is to run two threads together. This is illustrated in Figure 4b, where two threads run together in the warp to give a construction referred

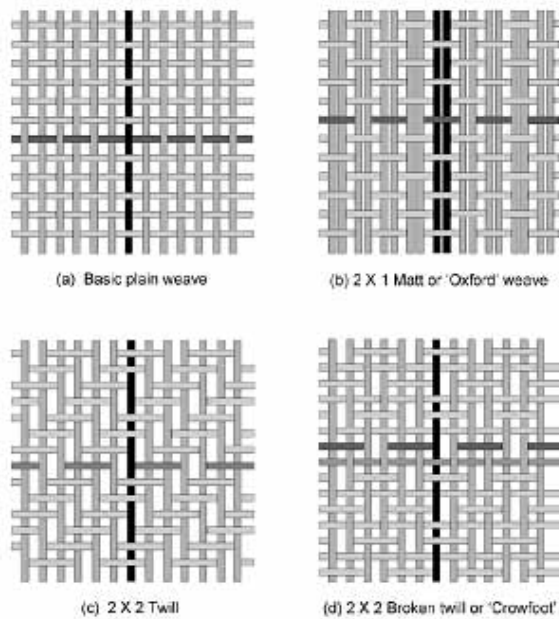


Figure 4. Basic weaves in conveyor belt fabrics [5]

to as a 2 x 1 matt or, more colloquially, as an Oxford weave. Similarly, the weft density can be increased by running two threads together as well – this would give a 2 x 2 matt. This principle can be continued, running three or four threads together in matt weaves. Another advantage gained from the matt weave constructions, is that by running more than one thread together, the tear strength of the fabric is improved. This arises from the fact that under the tearing action, the multiple threads bunch closely together, thereby requiring a higher applied force to propagate the tear. This effect is also used in lighter fabrics, and give a ‘rip-stop’ construction. This very simple modification to the basic weave gives a most significant improvement to the tear resistance of the final fabric compared with the basic plain weave version.

Another simple derivative of the matt weave is the twill. In this case, warp and weft threads still pass alternately over two and under two, but instead of each pair of threads running together, each is displaced one thread from the adjacent thread, thus giving a pronounced diagonal appearance to the fabric. This is illustrated in Figure 4c, for a 2 x 2 twill. It can be seen that the weave pattern repeats every four threads in both warp and weft. With both the matt and twill weaves, the longer ‘float’ of the yarns—that is the increased length from one intersection to the next—gives an improvement in tear strength, but at the same time, the total number of warp/weft intersections is reduced. In many applications this is not necessarily a disadvantage, but where mechanical fastening is required, the number of intersections has a very significant effect on the ease with which an object piercing

the fabric, such as a fastener, can comb threads out of the woven structure, giving lower fastener retention strength. This can be improved in the twill by breaking the regularity of the pattern, as illustrated in Figure 4d, giving a 2 x 2 broken twill or ‘Crowfoot’ weave. Here, the interlacing pattern of the third and fourth ends of the basic twill design are reversed. In this case, the increased float is maintained for all warp ends and for alternate picks, but every other pick now runs one up, one down, thereby increasing the number of intersections and giving the higher comb-out resistance and improved fastener retention.

Another basic weave construction, used for more specialised applications, is the leno weave. In this construction, the warp ends are arranged in pairs, and apart from interlacing with the weft, they also cross over each other, but one of the pair always crosses over the top of the weft and the other under the weft. This construction is illustrated in Figure 5, the major advantage of this weave is that the structure is very stable, with both warp and weft threads held firmly, allowing much more open fabrics to be produced. As mentioned above, a pair (or two pairs) of leno ends is used with rapier weaving machines to hold the weft tails firmly, to give a secure edge to the woven fabric. Generally, in leno weave fabrics, the warp yarns are half the size of the weft or heavier, so that, with the doubling of the warp yarns in the construction, the fabrics have effectively the same size yarns in both directions, giving very square properties. These fabrics possess good tear strength, and are often used as ‘breakers’, that is as an additional layer of fabric reinforcement, close to the surface of the final composite, to impart improved tear and cut resistance to the final product. One other specialised application, in which a very heavy weft yarn is held by much lighter warp threads, is as a breaker in steel cord belting, where the heavy weft yarns act as a rip-stop, to prevent the belt split-

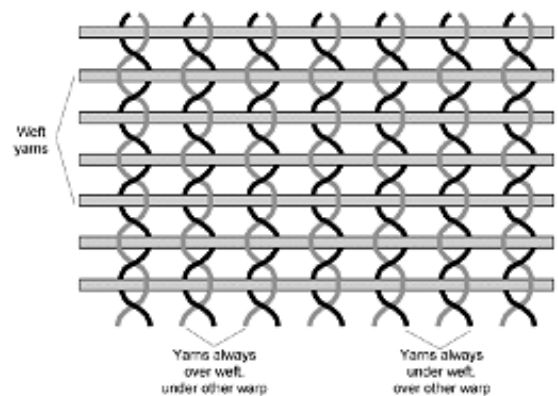


Figure 5. Leno weave model

ting longitudinally if it is punctured between the steel cords.

For very high strength fabrics, particularly those used for single- or two-ply reinforcement of belting, alternative designs are required. There is a limit to the number of threads that can be woven into a given fabric design. Generally as the warp strength requirement increases, so also does the weft strength, thus greatly increasing the total bulk of yarn that must be woven into a given area. There are basically two routes whereby the yarn density, that is the total number of yarns, both warp and weft, that can be incorporated in a unit area of the fabric, can be increased – these are the ‘straight’ or ‘stress’ warp fabrics and the ‘solid-woven’ fabrics. Considering the stress warp fabrics first, the main strength threads in the warp and weft lie in different planes and do not interlace with one another, thus allowing much greater density to be obtained, as it is the interweaving of these threads that limits the number that can be woven together. Effectively, the weft is divided into two layers, one above and one below the straight warp ends, and much finer ‘binder’ warp ends, lying between the stress warp ends, interlace with the two layers of weft, so giving the fabric its integrity. In this type of construction, with only fine binder ends passing between the stress ends and interlacing with the weft, it is possible to use much heavier yarns in both the stress warp and in the weft than would be possible if it were necessary for these to interlace one with the other. The simplest of these stress warp fabrics is the plain rib fabric—a cross-sectional diagram, in the warp direction, of this weave is shown in Figure 2. It can readily be seen that the heavy stress warp lies straight through the centre of the fabric, with the weft disposed in two layers, above and below this, and with the finer binder warp holding these two

otherwise separate parts of the fabric together. There are many variations of this basic structure possible by altering the ratio of stress to binder ends. In the simplest form, there is one binder end to every stress end, but it is possible to reduce the number of binders, although this is likely to reduce the fastener retention strength of the final fabric.

Summary

Article present basic information about conveyor belts design and fabrics used in this type of composite. Such technical fabrics application is very interesting, but there is limited research and development in this area. At present, engineers during conveyor designing use theoretical basic parameters, moreover, external institutes research only final composite parameters. Such situation causes big problems in product service life. Further articles will present significance of fabrics parameters in this application. Furthermore, adhesion mechanism will be explained.

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