SPLICING OF ARAMID REINFORCED CONVEYOR BELTING

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In the 1980's aramid reinforced conveyor belting became very popular and many thousands of metres were installed on a large number of conveyors. At the time, corrosion of the cords in steel cord reinforced conveyor belting and susceptibility to rip were issues that users were keen to eliminate. An aramid reinforced belt addressed both issues very well and since tenacity of aramid yarn is many times greater than steel there was an added attraction of a relatively light weight belt. In hind sight it is true to say that aramid reinforcement in conveyor belting was introduced too early in the development cycle. The design of the carcass to address known compression fatigue issues, difficulty to bond aramid to any other material and high cost of production were factors that led to a decline in the interest for aramid reinforced conveyor belts.

Thirty years on, these issues appear to have been resolved as a consequence of increased production capacity, huge advances in bond technology and new carcass weave designs. Add to this the demand for higher energy efficiency and aramid reinforced conveyor belting may well be the 'Next Generation' conveyor belt suggested by Lodewijks. This paper documents some research work carried out to establish viability of aramid as a conveyor belt reinforcement material. It is important to say from the outset that aramid reinforced conveyor belts have been available for many decades and there are currently many manufacturers' who can (and have) supply aramid reinforced conveyor belts.

The very high tenacity of aramid compared with traditional conveyor belt reinforcement materials, as shown in table 1, make it of significant interest as an alternative to steel. Therefore, it is to be expected that aramid reinforced belts would always be compared to steel reinforced belts. While woven steel carcass constructions are used in conveyor belts they are very limited and generally steel is used in a cord construction carcass. Thus, much of the research documented in this paper compares aramid reinforced conveyor belting to steel cord reinforced conveyor belting. A cord construction has relatively large gaps between the cords and no weft. This construction coupled with the high cut resistance of steel cords make steel cord reinforced conveyor belts prone to longitudinal ripping. Aramid is traditionally only supplied in yarn form comprising multiple filaments plied together. The yarns are twisted together to form a cord. It could be possible to use the cord in a conventional cord construction conveyor belt but for practical reasons this is not done but rather the cord is the base building block of a fabric.

Material	Tensile Strength (MPa)	Tenacity (mN/tex)	Elastic Modulus (MPa)	SG
Aramid	3600	2500	112000	1.44
Cotton	500	325	1600	1.54
Polyester	1000	700	7500	1.40
Nylon	850	750	4500	1.14
Steel	3925	500	170000	7.85

Table 1 – Properties of common belt reinforcement materials

The weakness of aramid yarn is that compression fatigue resistance is relatively low. If the aramid yarn is subjected to compression it is likely to fatigue and lose strength in a relatively short period. Therefore, for an aramid based fabric to perform well as conveyor belt reinforcement, it should eliminate compression of the fibre.

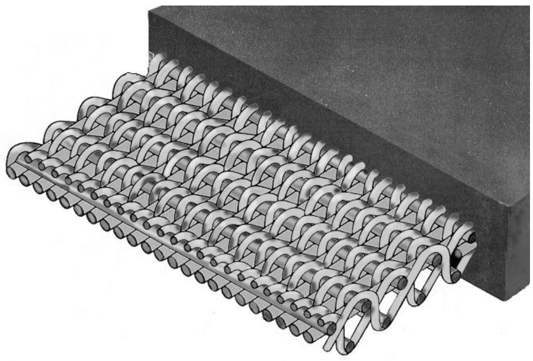

Figure 1 – Straight Warp Carcass

The modern aramid belt has a straight warp construction. By placing all the aramid yarns in a common plane of the conveyor belt reinforcement they will (during service) always be in a state of tension. For this reason it is also considered necessary to always limit aramid reinforcement to a single ply in the carcass. As can be seen in figure 1 all tension carry members lie in a single plane and have no crimp. In this respect the straight warp construction is similar to a cord construction. But the straight warp construction has weft members laid above and below the warp plane that are attached to the warp by means of highly crimped binder yarns. The weave pattern creates deep valleys between weft yarns which introduces a mechanical bonding mechanism in addition to the chemical bond between rubber skim layer and the RFL coating of the fabric.

A further advance in technology is a rubber receptive coating of the aramid fibre filaments in the production process. Conveyor belts have been manufactured with single ply straight warp carcass constructions utilising aramid warp and nylon weft and binder yarns in strengths of up to 3500 kN/m. Adhesion of conventional conveyor belt rubber covers (type E, M, N, X) is 2 to 3 times greater than minimum requirements of any conveyor belt standard.

Finger splice technology has improved to the extent that this method of joining belts is widely used in all types of rubber conveyor belting and is no longer exclusively used for PVC / Polyurethane belts.

Similar to the approach for steel cord reinforced belting the splice design has a fundamental assumption that the finger will break at the same force that is required to draw the finger out of the belt. Also it is assumed that the force acting on the finger diminishes along its length due to the fact that the cross sectional area reduces.

The standard dimension for the base of fingers is 50 mm, so chosen because all standard belt widths are divisible by 50. The length of the finger is determined by carrying out tests to determine the force to extract the finger. This is dependent on the properties of the material in which the fingers are embedded, the thickness of the material between the fingers and the bond of the splice material to the fingers. During assembly of the splice, the fingers, which are all cut to the same size, are drawn apart to introduce a gap that will be filled with the splice material. The practical limit to the gap that can be achieved is 2 mm. Referring to Figure 2, the amount by which the fingers should be separated, x, to achieve any gap g is

$$x = \frac{\frac{b_w}{2}+g}{\tan\varphi} - L_f$$

Where b_w = base width of finger
φ = slope angle of finger
L_f = finger length

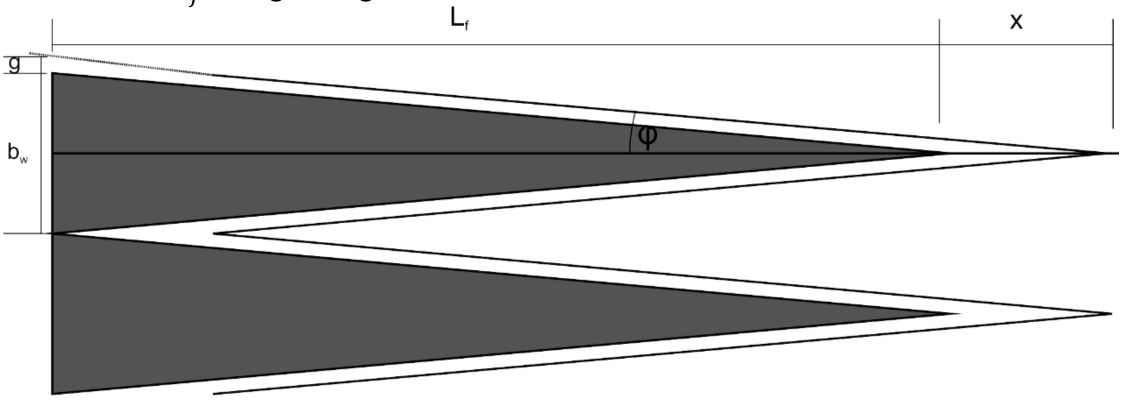

Figure 2. Finger dimensions

To establish the separation force needed to pull the fingers out of the splice a sample join is made with 100 mm long fingers having a base width of 50 mm. A single finger is cut from the sample join and the force to pull one finger from between the two half fingers is measured in a tensile test machine. The data obtained from a series of tests is used to determine the correct finger length for various width fingers when splicing with the tested splice materials.

The strength expected from a finger is derived by the product of the belt class and the finger base width. Hence, if the belt tested is a class T_b, the finger length of the sample is L_{fs} and the pull out force obtained is τ_g, then the length of a finger L_f having a base width of b_w is

$$L_f = \frac{T_b \cdot b_w \cdot L_{fs}}{\tau_g}$$

The fingers should be wrapped in an open weave fabric (the splice fabric shown in Figure 8) to help prevent them being separated when subjected to high radial forces at pulleys that have build-up or entrapped material. The strength of this fabric does not play any part in the design of the splice. An open weave fabric design is required to eliminate the possibility of adhesion failure that would detrimentally affect the ability of the fabric to prevent fingers 'popping' out. It is also important that the splice fabric extends beyond the finger ends by an amount that would not detract from the role of preventing finger 'pop-out'.

This paper is about the work that was done in proving firstly that the belt construction is reliable and secondly that the theory of the finger splice is valid for aramid reinforced rubber conveyor belting. For construction reliability it is also necessary to show that bond of rubber to the single ply straight warp carcass is high and remains high in typical operating conditions.

Research was carried out to determine if there was data on testing aramid belt splices. It was found that many companies had carried out their own research but that the information supplied about splicing was too commercial to be considered reliable. Case histories of belts in service all reported no issues with the belt or splice for many years. Yet with all other types of belt there are always belt and splice performance issues, related in the main to level of maintenance.

The conclusion drawn was that published information discounted maintenance issues and that for this reason it was not reliable. Research and independent test institutes approached had not tested any aramid reinforced belting.

On the basis that aramid belting is targeted to replace steel cord reinforced belting the first goal was achieving dynamic splice efficiency similar to that achieved with steel cord reinforced belts. Under the standard Hannover method for splice testing, spliced steel cord reinforced belts achieve results of 50%.

Therefore, a splice strength of 50% as measured at Hannover University was the initial goal. However the first trial splices that were made showed that, in spite of the fact that fingers did not draw out of the splice the joins failed well below 50% of the belt strength. Although the modulus of aramid is very high it is not as high as that of steel. The lower modulus has a multiplying effect on any inaccuracies in building the splice so it was felt that splice performance should be compared to performance of splices in other textile reinforced belts.

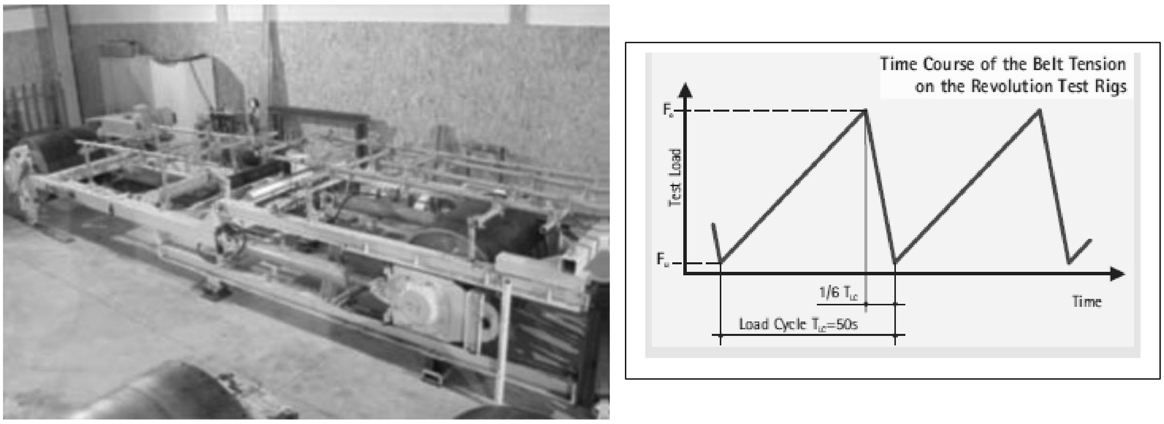

Fig 3 Dynamic Fatigue Test Rig – Hannover University

After searching test records for textile reinforced belts joined by finger splices it was found that dynamic tests of high strength solid woven finger splices returned an efficiency of just over 30% on the dynamic fatigue splice test rig at Hannover University.

The spliced endless belt is installed on the test rig (fig 3) and while rotating is subjected to a cyclic load that increases from 10% of the fatigue load to 100% of the fatigue load in a 50 second cycle. The fatigue load is a percentage of the whole belt break strength. The belt must be subjected to 10000 cycles without failure. To date three splices have successfully achieved a 30% dynamic fatigue strength on the Hannover University unit.

In an alternative fatigue test in which the belt passes around 4 pulleys to impose reverse bending also the spliced belts were subjected to increasing force starting at

Figure 4 Test rig for dynamic flex testing

12.5% of breaking strength and increasing by 5% every 125000 cycles until the belt failed. Belts all failed at the splice during the load cycle of 27 to 32% of whole belt breaking load. Thereafter the tensile strength of the belt was measured. A reduction of less than 5% in strength indicated that the belt construction can be subjected to high tension in reverse bending applications without any detrimental effects.

CONCLUSION

The results achieved on the belts tested have shown that past issues associated with aramid reinforced conveyor belting have all been resolved. Adhesion of rubber to the straight warp aramid carcass is at least double the highest 'standard' adhesion value. This ensures that splices having high dynamic efficiency are possible. Splices tested on dynamic testing equipment not only confirmed that dynamic fatigue strength in excess of 30% is possible but also that fatigue strength of the carcass is not compromised. The belt does not loose strength after many thousands of cycles under high tension. The real advantage of high rip resistance due to inclusion of weft members in the carcass and the substantial reduction in belt mass in comparison to a similar strength steel cord reinforced construction mean that the aramid belt is indeed the 'new generation' energy efficient product.

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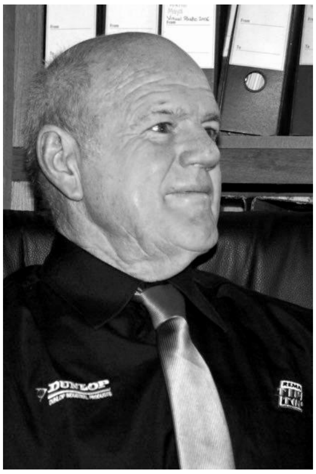
ABOUT THE AUTHOR

DAVE PITCHER

Dave has been involved in belt conveyor systems since 1974. He is experienced in many different aspects having stated off as an assistant to the applications engineer and moving into conveyor belt product development. For three years Dave worked in production and marketing of rubber products related to conveyor systems, skirt seals, pulley lagging, belt cleaning systems. A further four years was spent in the design, erection and commissioning of new belt conveyor systems.



He served on standards committees for standardisation of conveyor belting since 1976 when the first SABS conveyor belt standard was on the drawing board.

Dave wrote the first computer program for complete design and component selection of belt conveyor systems. He presented papers at the International Materials Handling Conference and currently serves on the organising and technical committees. He is a guest lecturer to engineering students on conveyor belt selection and operation of belt conveyors at university and design institutes.

Dave is currently the Technical Product Manager at Dunlop Industrial Products and serves on the Board of Directors of the Conveyor Manufacturers Association (CMA). He is a member of the Conveyor Belting and Handbook work groups of the CMA.

Dave obtained a Diploma in Datametrics from UNISA in 1979 with distinction.

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