WOVEN STEEL CORD FABRICS IN SPECIAL CONVEYOR BELT APPLICATIONS

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INTRODUCTION

Woven steel cord fabrics offer the right solution for many specific applications. The performance of such a steel carcass has been proven in steel mills, stone quarries and mining of minerals. This performance can be achieved by using specially developed steel cords in both the longitudinal and transverse directions of the conveyor belt.

Steel cords used in the longitudinal warp direction have been developed for excellent performance in elongation behaviour and impact resistance.

Steel cords used in the transverse weft direction have been developed in order to give adequate cutting resistance, while allowing troughability due to the very flexible steel cord. On the other hand, even very stiff steel cord has been developed for use in the transverse or weft direction, in order to achieve a very rigid conveyor belt.

Steel cord conveyor belts consist of a rubberized core which is built up from a set of steel cords embedded in adhesion rubber. This so-called carcass is surrounded by a top and bottom cover of rubber. The thickness of the rubber covers is determined by the dynamic loading.

Even though the main functionality for steel cord in the conveyor belt is strength, both the steel cords and rubber compounds are important in relation to the final application. In the same way that different rubber compounds can be applied for specific applications, different steel cords can be used to design a specific tailor-made solution for different applications.

CONVEYOR BELT CORD

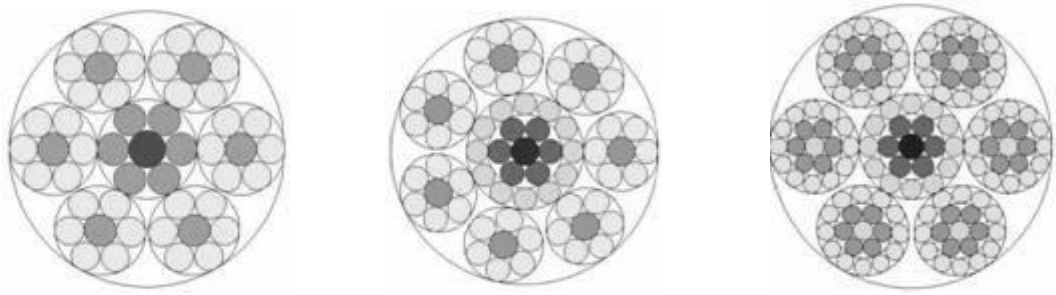
The conveyor belt has to perform over a long lifetime. In the technological evolution of steel cord reinforced conveyor belts, hot dip galvanised cords have emerged as the standard coating. This is so, because in a corrosive environment the zinc will always be attacked prior to the iron in the steel and in this way, zinc protects the steel.

Corrosion will only start when damage has been done to the rubber and moisture can enter into the carcass of the belt. Where the rubber penetration into the cords is good, the corrosion will remain localised.

A thick zinc coating is not a necessary requirement for a conveyor belt cord. A thick zinc coating leads to more zinc dust formation and hence an inferior adhesion.

Brass-coated belt cord can also be used. This has particular advantages for specific applications. The conveyor belt producers have always been very reluctant to use brass-coated cords for reasons of corrosion protection. However, when there is a good rubber penetration, there is no reason why a brass-plated cord reinforced belt should not perform equally well.

Traditionally, a conveyor belt cord is built up according one of the following construction types.
All of the types have open constructions in order to allow good rubber penetration (Fig.1).



7x7 7x19 19+7x7

Fig. 1: common Conveyor Belt Cord Constructions

The ratio of the core strand diameter to peripheral strand diameter D1/D2 should be greater than 1,05 in order to facilitate rubber penetration. (Fig. 2)

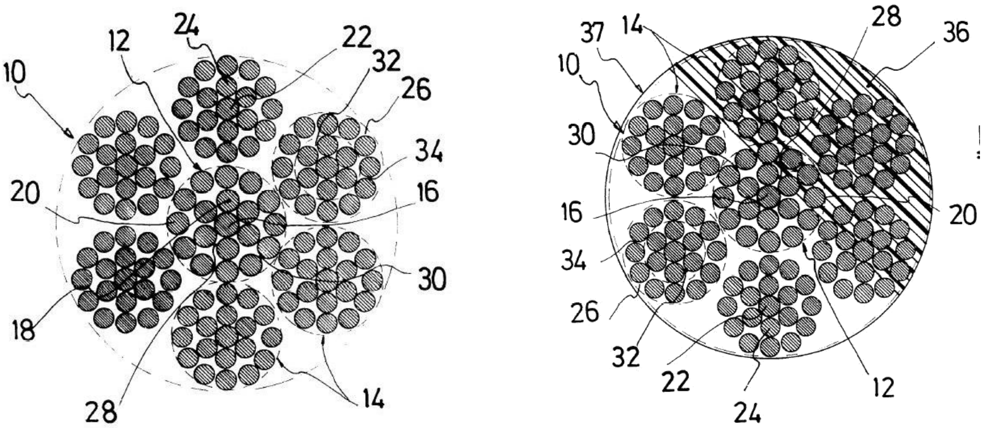


Fig. 2: Open Cord Construction

The strength of a conveyor belt is in direct relation to the strength of the cords used. There is a growing demand for stronger and stronger conveyor belts. Therefore stronger and stronger steel cords have been developed.

On the other hand, the filament diameters used are in direct relation to the fatigue level that a steel cord can resist. Therefore one filament is replaced by different smaller filaments in the core of the steel cord. This results in new constructions realizing a higher breaking load with still acceptable flexibility.

Another main development in achieving those higher strengths is the continuous increase of tensile strength of the wires used. The tensile strength of the wire in the final cord is always lower than the initial tensile strength due to the bending of the wire and the point contacts of the wire in the cord.

In practice this implies simply that cords with lower linear density can be developed – due to the lowered filament diameters - while still offering the same breaking load. This will again result in a relatively better fatigue resistance, lower weight of the finalized belt and hence a lower power consumption on a conveyor belt installation.

Given a diameter of 0,20 mm, the tensile strength for NT (normal tensile) will range from 2850 N/mm^2) up to 3350 N/mm^2 for a HT (high tensile) filament. There is still some way to go, because in other industries, already ST (super tensile 3600 N/mm2) and even UT (ultra tensile 4000 N/mm2 is successfully being implemented.

Samples of steel cord up to a cord diameter of 16 mm are available today. These cords allow designers to realize belt strengths up to ST 10000 and greater.

Typical strengths and cords are as follows:

Strength	Construction	Diameter (mm)	Breaking Load (kN)
ST 1000	7x7	3,60	14
ST 4500	7x19	9,30	77
ST 7800	7x19	13,20	128
ST 10000	39+8x19	16,00	210

Table 1

WOVEN STEEL CORD FABRICS

When applying steel cord in woven fabrics, it is of utmost importance to keep the full strength of the cord. A special weave structure allows the full strength to be retained, because both the longitudinal warp cords and the transverse weft cords remain straight (Fig. 3)

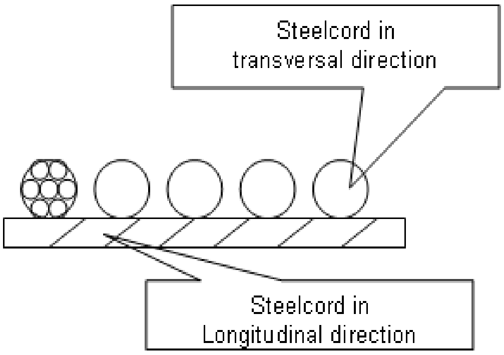


Fig. 3: Longitudinal and Transverse Steel Cords remain straight

The longitudinal and transverse cords are held together by means of a textile binder. When focusing on the longitudinal cords, the typical conveyor belt cords can be used besides other 'specially developed' cords.

LONGITUDINAL CORDS

Conveyor belt cords are, as mentioned, open cords in order to achieve good rubber penetration. When the cord is made more open, well beyond the openness needed to obtain full rubber penetration, a dramatic change in the behavior of the cord occurs. This will be noticeable before and after rubberizing. The open cord and the extremely open cord show a different elongation behavior. The difference occurs at very low forces. Increasing the force by a small amount will result in a much higher increase of elongation for the extremely open cords compared to the elongation of the normally open cords. This is called structural elongation (Fig. 4).

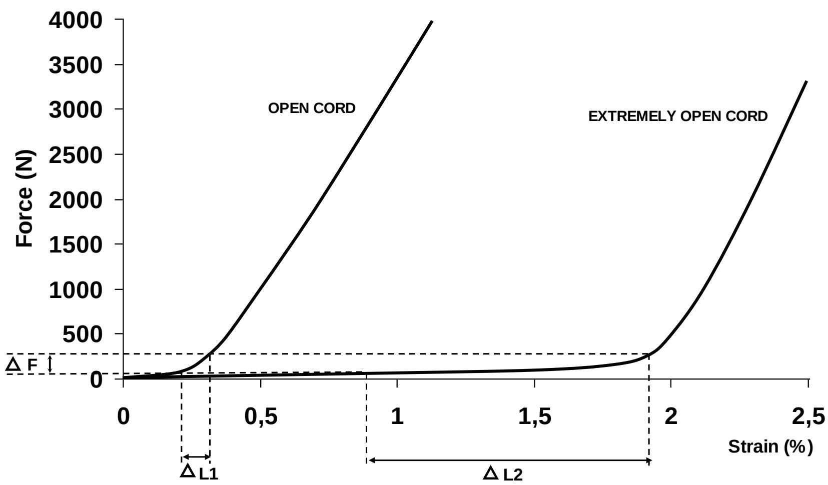


Fig. 4: Structural Elongation of Longitudinal Cords: Open Cord & Extremely open cord

When rubberized, this behavior will not completely disappear. In fact, the cord is fully filled with rubber, not only between the filaments, but also between the strands. This will allow the cord to act like a spring.

When compression is applied on the cord, it is capable of resisting the compression and after removing the force, it will return to its original length (Fig 5).

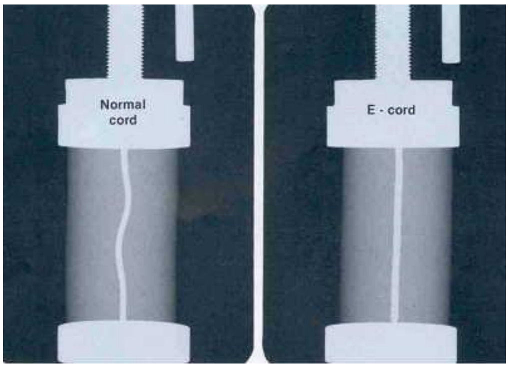


Fig. 5: X-ray of in Rubber Embedded Steel Cord

The elongation of a typical embedded conveyor belt steel cord is around 0,1 % at 10 % of its nominal breaking load. For the very open cords, the elongation will increase to 0,5 % of its nominal breaking load.

Material : SW 1600 RE
Specimen length : 320 mm
Specimen thickness : 15 mm
Specimen width : 44 mm

Load cell : 20 kN
Extensometer (path) : 200 mm
Pre-load : 100 N

Number of cycles : 50
Cycle speed : 50 mm/min
Lower reversal point (2 %) : 1408 N
Upper reversal point (10 %) : 7040 N
Upper reversal point (20 %): 14080 N

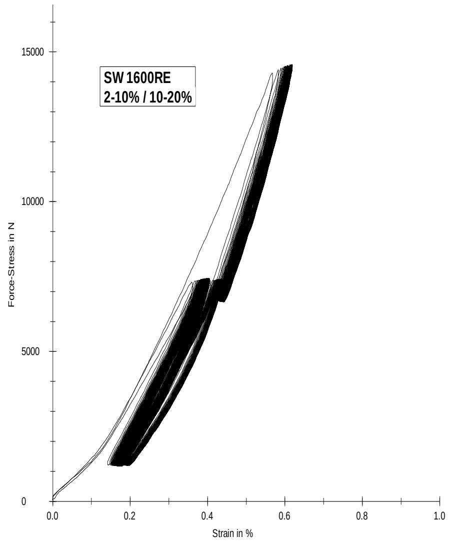
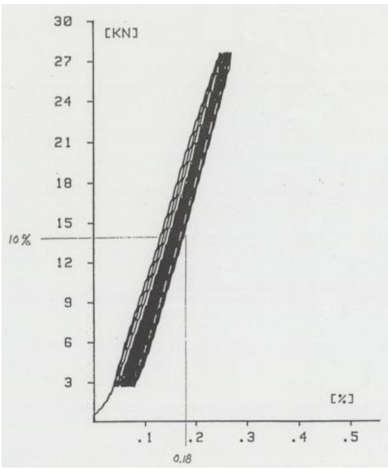


Fig. 6: Cyclical Load of Steel Cord with Structural Elongation



Material : IW R 2750
Specimen length : 320 mm
Specimen width : 54 mm

Pre-load : 750 N

Number of cycles : 50
Cycle speed : 50 mm/min
Lower reversal point (2 %) : 2970 N
Upper reversal point (10 %) : 14840 N
Upper reversal point (20 %): 29700 N

Fig. 7: Cyclical Load of Steel Cord without Structural Elongation

These so-called elongation cords, E cords for short, have a favorable elongation behavior that gives the belt better energy absorbing capability. Excellent rubber penetration is still guaranteed due to the very open construction. It has a high flexibility in the longitudinal direction. There will be less tension difference of the central cords compared to the edge cords in the transition area, thus allowing shorter transition distances from carrying idler to terminal pulleys. Finally, the adapted compression behavior will avoid bucking of the belt centre in the transition areas.

In general: the E-cords show important advantages where standard steel cords with lower elongation behavior do not meet all requirements. One of these important advantages is the resistance of E-cords to impact.

The impact resistance is measured by the “weight drop method”. This consists of dropping a weight, with a cone shaped striking surface, from a given height onto the belt section that is tensioned at 10% of its strength range (Fig. 8).

The belt is supported by two rollers, 100 mm diameter at 300 mm spacing. The applied impact energy is calculated by the falling height and the weight of the steel body.

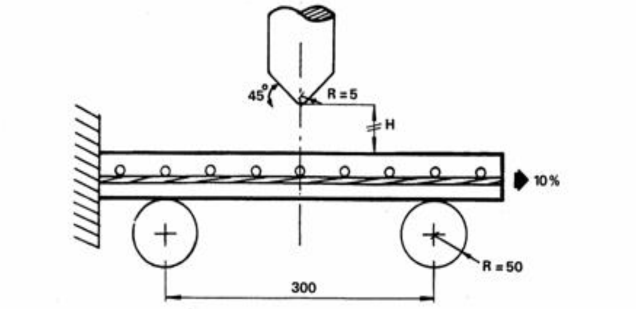


Fig. 8: Weight drop method

Impact resistance – Fall energy J (Nm)			
		E warp	E weft
Belt range	ST 500	370	225
	ST 630	440	300
	ST 800	600	460
	ST 1000	1100	750
	ST 1250	1400	1075
	ST 1600	2280	1350

Table 2: Impact Resistance

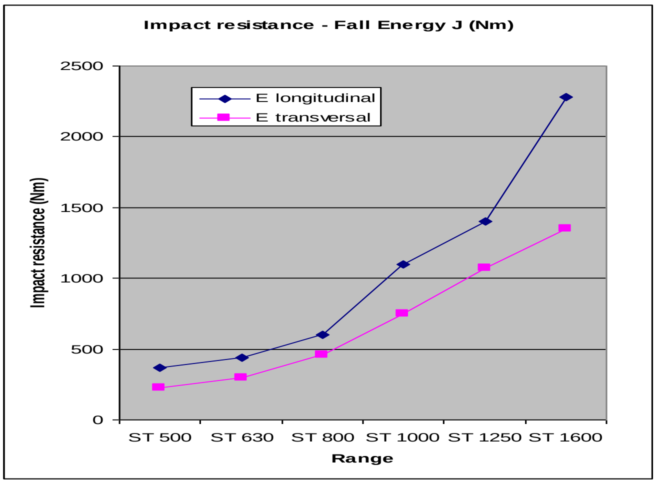


Fig. 9: Impact resistance

The energy absorbing level is directly linked to the cord diameter and its construction (Fig. 9). By using an E-cord and a higher density of longitudinal cords the total impact resistance can be increased.

Additional protection of the longitudinal cords can be given by adding transverse reinforcement.

TRANSVERSE CORDS

The transverse reinforcement of conveyor belts can consist of high elongation cords or rigid cords.

A rigid cord will be used to reinforce the belt and to stiffen it. Depending on the application, a more rigid or a less rigid cord can be used. These different stiffnesses can be obtained by changing the filament diameters used and by changing the lay length of the cord. A cord with more twists will be more flexible than a cord with fewer twists per unit length. A high elongation cord must be used for transverse reinforcement when the transverse flexibility of the finalised belt is to be preserved. Depending on the belt strength, even troughing over 45 degrees is still allowed.

Besides the breaking load, elongation is one of the main development criteria for steel cords in conveyor belts. For steel cords used in the longitudinal direction, the elongation at 10 % of breaking load is important. For steel cords used in the transverse direction, the elongation at breaking load is important. Here, one can see that while an E cord has the greatest elongation at 10 % of its breaking load, the high elongation cord has the greatest elongation at breaking load.

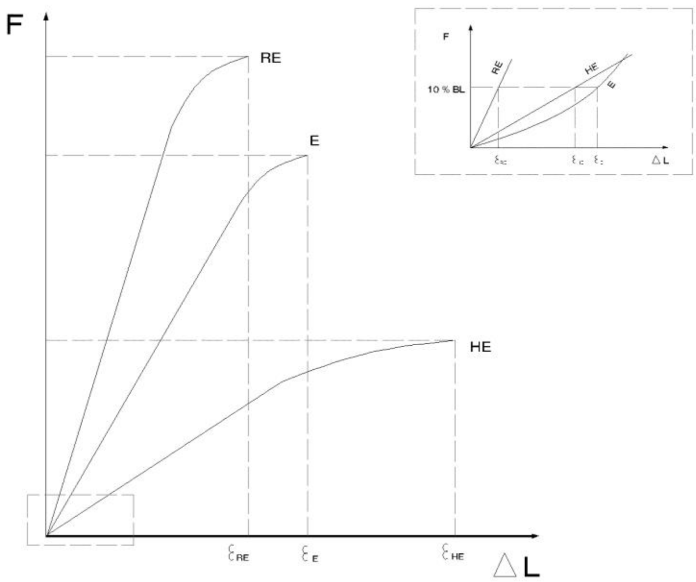


Fig. 10: Elongation Diagram of HE-cord

Regular cord (RE): ±1,5 % - E cord: ± 5 % - high elongation cord (HE): ± 7.5 %
(all values for bare cords) (see fig. 10).

Flexible weft cord for cutting resistance

Another main reason for introducing a transverse cord into a conveyor belt is to create a cutting resistance. Longitudinal cuts are a serious threat for conveyor belts.

The figure below shows a belt failure (Fig. 11).

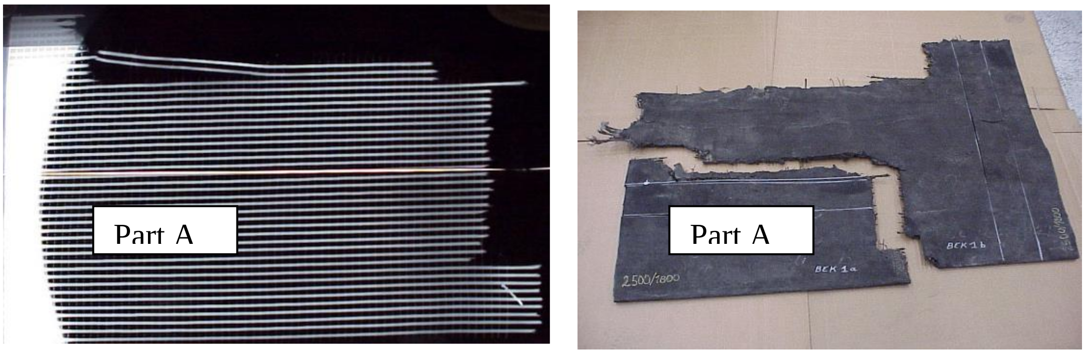


Fig. 11: Belt failure

Initially there was an impact of a heavy or sharp object that penetrated through the belt. When the object got stuck in the installation, it started to create the longitudinal cut. Due to the transverse reinforcement, the forces were deviated towards the outside of the belt; consequently the belt failure was reduced to a relatively short length.

The cutting resistance can be quantified by cutting a belt sample with a shaped cutter. The cutting resistance is the average required force in kN to cut the sample over a length of about 200 mm. The forces during the cutting operation are recorded.

High elongation cords, HE cords for short, used in transverse direction, will impart a high cutting resistance to the belt. By using different strengths of cords, or by increasing the number of cords per meter, a gradually increasing cutting resistance can be realized (Fig. 12).

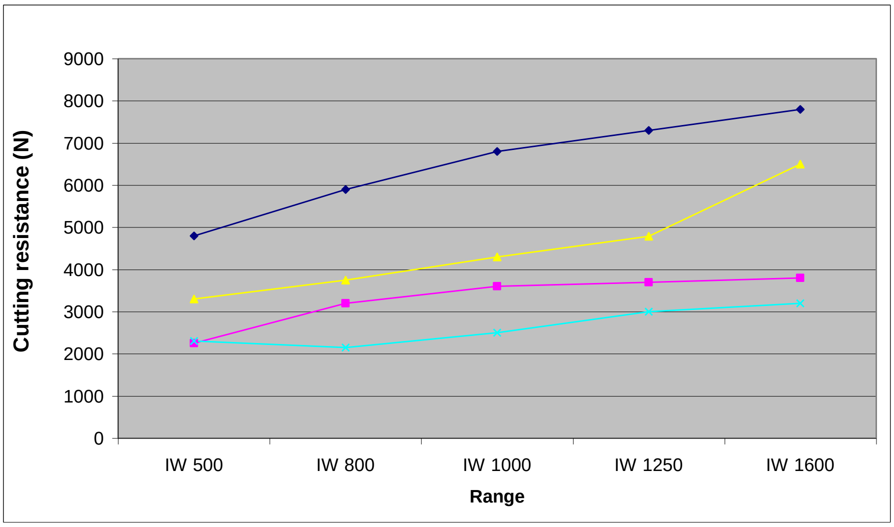


Fig. 12: Cutting resistance

RIGID WEFT CORD FOR SPECIAL APPLICATIONS

Example 1: Long haul cable belt systems

Besides the traditional conveyor belt systems, different conveying systems are still operational. Conveying over very long distances can be realised by the so-called 'cable belt' system. The belt can negotiate very difficult topography and is mainly build up by two ropes on both sides of a transverse reinforced "belt". A steel cord is used for transverse reinforcement. The stiffness determines the deflection of the belt in order to realise the best loading capacity of the belt.

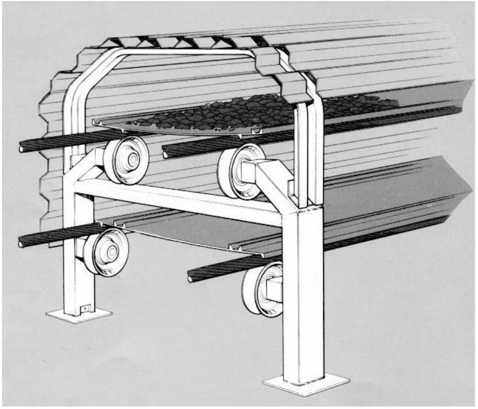


Fig. 13: Cable belt system

Example 2: Elevator belt
For elevator belts, specific fabrics can be developed by using adapted steel cords in both longitudinal and transverse directions.

In the longitudinal direction, a steel cord with an elongation of 0,3% at 10% of its breaking load is used. In the transverse direction, a very stiff steel cord is used.

SUMMARY

For long haul applications, a regular cord, RE-cords for short, is used in the longitudinal direction. Normally there is no need for a transverse reinforcement. The elongation of a rubberized cord is about 0,1 % at 10 % of its breaking load. These belts are used mainly in lignite mining, hard coal mining and the mining of minerals.

For industrial applications, an open cord, E-cords for short, is used in the longitudinal direction. Normally there is also a transverse reinforcement. Both longitudinal and transverse steel cord reinforcement guarantees an impact and cutting resistance. The elongation of a rubberized cord is about 0,5 % at 10 % of its breaking load. These belts are typically used in steel works, stone quarries, coke factories, sintering plants and slag handling. The belts are excellent in special cases where heat resistance of the carcass is required as the steel carcass helps to dissipate the heat.

For elevator applications, following the new developments by the elevator manufacturers and increasing heights of elevator belts, a specially developed open cord with an elongation of about 0,3 % at 10 % of its breaking load can be used combined with a rigid transverse cord.

Woven fabric allows the combination of advantages in both the longitudinal and transverse directions by the selection of a steel cord suitable for both directions.

AUTHOR'S CV

Ing Lode Puype graduated as a Mechanical Engineer in 1988. For at least ten years, he was active in product development. After joining Bekaert, steel cord producer, he focused on new steel cord developments for conveyor belt reinforcement. He covered both, conveyor belt cords and woven steel cord fabrics. Today, as product market manager for conveyor belt reinforcement, he is responsible for development and implementation of advanced steel cord products in the conveyor belt market, operating from Belgium but dealing with production platforms in Belgium and Slovakia.