

ARAMID IN OPERATING CONVEYOR BELTS EXTENDED LIFETIME, ENERGY SAVINGS AND ENVIRONMENTAL EFFECTS

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ABSTRACT

In recent years, aramid fabric as a reinforcement in conveyor belts has gradually found its position among traditional textile and steel cord reinforcement materials. Due to its unique properties, such as corrosion and heat resistance, aramid has been used on over 400 belts for more than three decades, in applications such as phosphate mines and steel production plants.

This paper provides some background to aramid reinforcement in conveyor belts and gives an overview and analysis of various installations. Advantages of the already installed belts include extended lifetime and energy savings. These advantages in turn have significant financial implications, with low cost of ownership and short payback periods, in addition to the positive environmental effects of lower carbon dioxide and particulate matter emissions as a consequence of reduced energy usage.

Several recent cases of belts running in hard rock mining and wood log operations in South America are described. Using similar belt covers, they show a lifetime increase of up to four times compared to traditional textile reinforced belts, and some of these belts have by no means reached the end of their life.

The paper also describes the experience of the Baodian Coal Mine, part of the Chinese Yanzhou Coal Mine Company (YCMC). In a pilot installation, Baodian used aramid in a 666 metre-long belt, with a 6° incline. Based on ease of operation and reported energy savings of 8%, YCMC group concluded that an aramid reinforced conveyor belt is a technically and economically viable alternative to steel reinforced belts. Positive results in this first pilot site led to the installation of a second aramid belt on a 3.4 km newly built system, installed in combination with optimised idlers. A 43% reduction in current absorbed by the system has been observed compared to a similar steel cord reinforced belt system. It is estimated that approximately 15% of energy savings can be attributed to the use of an aramid belt. The environmental benefits, in terms of reduced emissions of carbon dioxide and particulate matter, have been determined using a certified customer benefit model¹.

INTRODUCTION

The properties of aramid will only be briefly described here, since these have already been covered previously at Beltcon by Arts and Lodewijks^{2,3}. For the sake of completeness, however, the relevant details are summarised.

Poly-paraphenylene terephthalamide, also known as 'aramid from aromatic amide' is a very strong and lightweight synthetic fibre. It has a high modulus, is thermally

stable, and is highly resistant to impact and chemicals. It is used in conveyor belts in two different ways:

1. As aramid reinforcement fabric in the carcass
2. As a chemically treated aramid-based additive to the bottom cover compound in order to reduce rolling resistance.

For the carcass, the so called straight warp fabric construction is most commonly applied. A schematic view of the fabric embedded in rubber is shown in Figure 1.

It consists of aramid cords in the warp direction, polyamide 6.6 in the weft direction, held together by a polyamide binder yarn in the warp. Similar to the commonly used textile fabric (EP), the aramid fabric is treated with a resorcinol-formaldehyde-latex (RFL) dip formulation to obtain sufficient adhesion between the fabric and skim compound. For this reason, the nature of the cover compound to be applied is identical to current solutions.

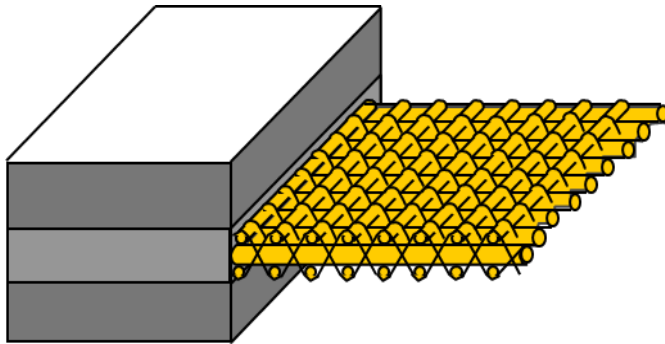
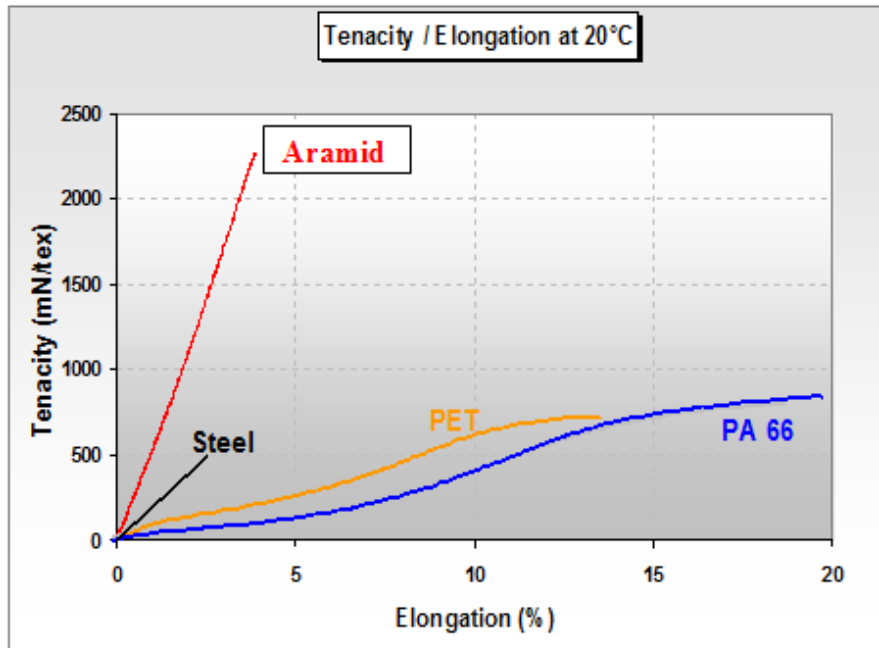


Figure 1. Schematic representation of a straight warp aramid DPP fabric construction.

A key advantage of using an aramid-based fabric instead of a steel cord carcass is its lightness, as shown in Figure 2. Aramid fibres have a density of just 1.44 g/cm^3 and are five times stronger than steel on a weight-to-weight basis.

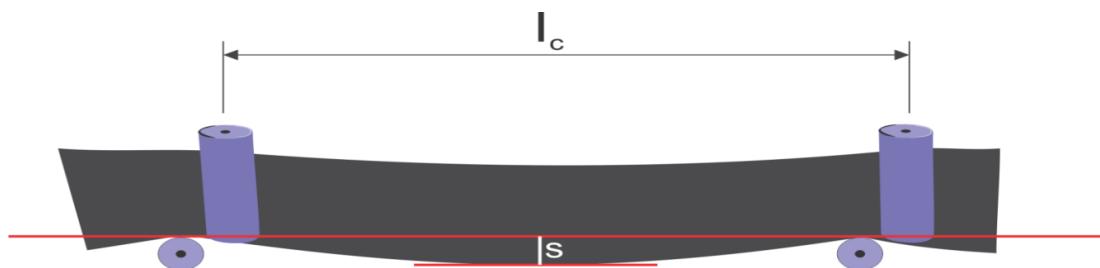


		Polyester	Polyamid 6.6	Steel	Aramid
Density	g/cm ³	1.12	1.14	7.85	1.44
Tenacity	mN/tex	820	780	330	1940
Elongation at break	%	13	20	2	3.5

Figure 2. Tenacity and elongation characteristics of reinforcement materials

Other parameters, such as belt sag and transition length, are similar to those defined for steel cord reinforced belts. Due to the low elongation characteristics of aramid, if the substitution concerns an EP textile belt, the transition length of the conveyor system may need to be checked and adjusted.

Belt sag is the distance between the line joining two adjacent centre idler rollers and the bottom of the belt and is a function of belt mass. It is normally expressed as a percentage (Figure 3). Sag is controlled by the amount of tension in the belt. The force applied by the take-up system must be great enough to keep sag down to an acceptable limit.



$$Sag = \frac{s}{I_c} \times 100$$

Figure 3. Belt sag definition.
Dunlop Industrial Products PTY⁴

Like steel cord construction, idler junction failure with an aramid reinforced belt is unlikely to occur if belt sag is limited to a maximum of 3%.

Aramid reinforced conveyor belts offer a number of advantages over steel and textile fabric belts. These are summarised below:

Aramid fabric vs steel cord (ST 630 – 3150 N/mm)

Less weight at same strength	—	Reduced energy consumption Reduced CO ₂ emissions
Higher flexibility	—	Smaller pulleys
No corrosion	—	Easier maintenance, higher durability
Thinner belt design	—	Better flexibility, fewer splices
Breaker functionality	—	Impact and slitting resistance

Aramid fabric vs Textile fabric (EP 630 – 3150 N/mm)

High ply strength	—	Single- vs multi-ply fabric concept
Thinner belt design	—	Bending resistance, impact
Low dynamic belt growth	—	Take-up length

Because of the aramid belt's greater flexibility compared to steel cord reinforced belts, pulley diameters can be significantly smaller. Optionally, the pulley diameters could be in the range of 20-25% smaller compared to steel cord belts^{4, 5}. Since a single-ply aramid fabric construction should always be applied, compression of the aramid cords, and consequently a drop in tensile strength, is negligible. In Figure 4, recommended pulley diameters from a manufacturer are listed⁵. These are in line with those reported by others⁴.

Pulley diameters

For the selection of the correct pulley diameter, the strength utilization has to be considered.

The recommended diameters also depend on the pulley group.

- Group A Drive, discharge or other pulleys, where belt tension is relatively high
- Group B Return, bend, takeup, or other pulleys, where belt tension is relatively low
- Group C Snub, deflection or other pulleys, where belt wrap angle is $\leq 45^\circ$

Utilization Belt type	Recommended minimum pulley diameter				
	Group A		Group B		Group C
	>60% mm	<60% mm	>60% mm	<60% mm	- mm
D, DP 500	315	250	250	200	200
D, DP 630	315	250	250	200	200
D, DP 800	315	250	250	200	200
D, DP 1000	500	400	400	315	315
D, DP 1250	500	400	400	315	315
D, DP 1400	630	500	500	400	400
D, DP 1600	630	500	500	400	400
D, DP 1850	800	630	630	500	500
D, DP 2000	1000	800	800	630	630
D, DP 2500	1000	800	800	630	630

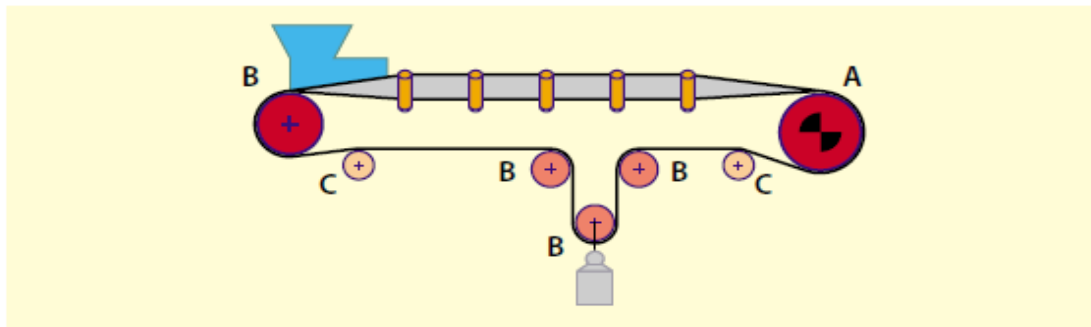


Figure 4. Recommended pulley diameters.

Metso Minerals

OVERVIEW OF SELECTED ARAMID BELTS IN OPERATION

As far as is known, the first aramid reinforced belts were installed in 1978. Since then, several hundreds of aramid reinforced belts have been installed around the world, covering a wide range of applications. Figure 5 provides an overview of selected aramid reinforced conveyor belts, some of which are discussed in detail in this paper.

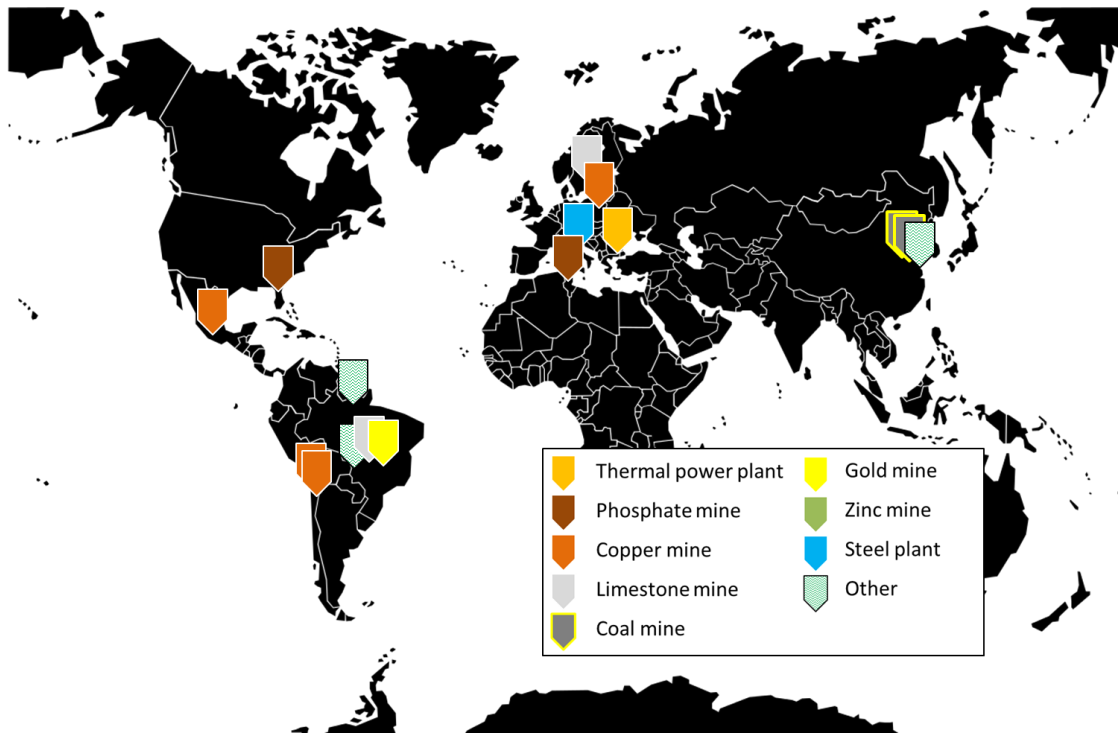


Figure 5. Overview of selected aramid reinforced conveyor belts.

CASE STUDIES: LIFETIME

The high, single-ply strength of aramid fabrics enables belt manufacturers to produce a more flexible belt compared to a multi-ply EP belt. This feature has been utilised to test the aramid belt's lifetime in primary crushers and stackers. The results of several pilot belts are described in this paper.

Table 1 is an overview of selected installations in South America, where aramid belts were chosen to extend the lifetime of textile reinforced belts, which needed continuous repairs and had short lifetimes. The aramid belts were manufactured and installed by a Brazilian belt manufacturer⁶.

End-customer	Anglogold Ashanti	Anglo-American	Votorantim
Mine	-	Mantoverde	-
Country	Brazil – Goiás State	Chile – Copiapó region	Brazil – Federal District
Application	Primary Crusher	Stacker	Primary Crusher
Ore/material	Gold	Copper	Limestone
Belt manufacturer	Correias Mercurio	Correias Mercurio	Correias Mercurio
Belt specification (According to O&M conveyor belt project)	EP1250/4 12x5 48" Din X	EP900/3 48" 6x3 Din W	Extrabelt PL440 12x5 48"
Customer complaint	Short lifetime due to cuts, Short MTBF particularly due to rubber upper cover repair	Short lifetime due to high abrasion of the ore conveyed	Short lifetime due to huge impact conditions and constant rip accidents
Original belt's average lifetime	6 months	4 months	4 months
Recommended aramid belt	EAS DPP1600 12x5 48" Din X	XEAS DPP1000 6x3 42" DIN W	EAS DPP1600 12X5 48"
Belt length (m)	128	286	165
Date of aramid belt installation	10-10-2014	5-6-2015	4-10-2015
Date of aramid belt replacement	still in operation	30-1-2016	still in operation
Aramid belt average life time	25 months and still in operation	6 months	12 months (expected)
Results			
Lifetime increase	400% Aramid belt still in operation with no change scheduled	50% longer lifetime	400% Aramid belt still in operation with no change scheduled
Energy consumption	8% less energy consumption (with 12° inclination)	Not measured	Not measured
Other	No cuts during the life of the belt	No preventive and corrective maintenance needed during the period tested	
	Far fewer rubber upper cover repairs		
	Much longer MTBF and shorter MTTR		

MTBF: Mean Time Between Failure (the predicted elapsed time between inherent failures of a system during operation); MTTR: Mean time To Repair (average time required to repair a failed component or device.)

Table 1. Overview of selected aramid reinforced belts.

Of these, the AngloGold Ashanti case is described in more detail. This is an AngloGold Ashanti gold mine in the Goiás State of Brazil. AngloGold Ashanti Limited is a global gold producer with 21 operations on four continents and 62 000 employees.

The mine asked for an impact-resistant crusher belt to transport minerals up to 500 mm. Multi-ply EP solutions need constant repair and have very short lifetimes (~6 months). The crusher operation, using the original EP four-ply belt, had experienced regular unscheduled stops almost on a weekly basis, generating high monthly costs.

The pilot belt offered was an aramid reinforced belt DPP1600, with equal thicknesses and compound grade for bottom and top covers. Figure 6 shows the belt in operation.



Figure 6. Aramid reinforced belt at AngloGold Ashanti, Brazil.

Following the introduction of the aramid belt, incidents of cutting or tearing were reduced to almost zero. Inspection of the top cover after the first year, in a 24-hours-per-day operating regime, showed that it was visibly intact, with no repairs having been required during this entire period. This exceptional result could only be explained by the flexibility of the aramid belt. According to the belt manufacturer⁶, the multi-ply EP is a rather rigid belt. Thanks to the greater flexibility of the thinner single-ply aramid belt, the energy of a large lump impact can be absorbed more easily on a flexible surface than on a rigid surface. The fairly loose construction of the straight warp fabric also contributes to better impact resistance compared to plain weave fabric constructions⁷. In addition to its superb impact performance, the aramid belt showed a reduction in energy consumption of approximately 8%, with a 12° inclination in the belt.

CASE STUDIES: ENERGY SAVINGS AND ENVIRONMENTAL IMPACT

The reduced energy consumption stemming from the use of aramid fabrics instead of steel cords has been described extensively in the past³. The gain is a result of the lighter weight of the carcass, a uniform load distribution from flat fabric as opposed

to steel cords, and the use of a thinner bottom cover compound. The effect of the weight can be quantified by using the equations set forth in DIN 22101.

Where

v is belt speed

η is the drive efficiency

F is the Total Motional Resistance

f is the friction coefficient

m'_G is the belt mass,

m'_L is the mass of the load

$$P = \frac{F \cdot v}{\eta}$$

Required power:

$$F = C \cdot L \cdot f \cdot g \cdot [m'_R + (2m'_G + m'_L)\cos(\theta)] + H \cdot g \cdot m'_L$$

The belt mass, m'_G , is proportional to F and thus affects the required power. With an inclination of the belt, the angle of inclination $\cos\theta$ and the factor $(H \cdot g \cdot m'_L)$ will start to influence the total motional resistance and the influence of the belt weight will decrease.

This paper describes two conveyor belts with an aramid carcass recently installed in an underground coal mine in mainland China.

The Baodian Mine of the Yanzhou Coal Mine Corporation (YCMC), which in turn is part of Yankuang Group, is the fourth-largest state-owned coal mine in China. It is engaged in underground mining, coal preparation and sales, as well as coal transportation services by rail. Its products are mainly low-sulphur coal, which is suitable for large scale power plants and for use in pulverized coal injection. The belt manufacturer is part of the YCMC group⁸. The results, which were presented at a CRIA conference in China in 2016⁹, are listed in Table 2.

The first (short) belt was installed on an existing line, replacing an ST 1600 belt. Cover thicknesses of the reference steel belt were 6+6 mm, weighing 38.6 kg/m. A weight reduction of 44% was achieved. This led to a reduction of the Total Motional Resistance component $(2m'_G + m'_L)$ of 19%. By reducing the bottom cover thickness from 6 mm to 5 mm, the friction coefficient, f , in the Total Motional Resistance should have been positively influenced³. However, due to the 6° incline, the second part of the equation, where belt mass is not taken into account, $H \cdot g \cdot m'_L$ becomes a major factor in the Total Motional Resistance and thereby in the total power consumption, P .

Both situations, the ST1600 vs DPP1600, were monitored, and the usage was 244 vs 222 kW respectively. Despite the incline, which reduced the effect of the belt mass, a 9% reduction was measured.

End-customer	Yanzhou Coal Mine Corporation	Yanzhou Coal Mine Corporation
Mine	Baodian coal mine	Baodian coal mine
Country	China	China
Application	Transport in underground mine	Transport in underground mine
Ore/material	Coal	Coal
Belt manufacturer	Tangcun Industry	Tangcun Industry
System specification (According to O&M conveyor belt project)	Belt strength: 1600N/mm Belt width: 1200mm Running speed: 3.55 m/s Capacity: 1300t/h Power installed: 1x400kW Belt inclination: 6°	Belt strength: 2250N/mm Belt width: 1400mm Running speed: 0~4m/s Capacity: 2500t/h Power installed: 3x315kW Belt inclination: 0°
Customer goals	No corrosion from water; anti-slitting; good belt tracking; easy to transport and install	No corrosion from water; anti-slitting; good belt tracking; easy to transport and install
Belt Length (m)/ weight (kg/m) / cover thickness (mm)	666 / 21.8 / 7+5	3400 / 27.3 / 7+5
Date of aramid belt installation	March 2015	April 2016
Results		
Energy consumption	9% energy savings measured	Estimated energy savings: 30- 40%. Derived from ampere readings (40A vs. 70A full load). See explanation in text below.
Other	Higher trough ability, which leads to higher transport capacity	Higher trough ability, which leads to higher transport capacity
	No corrosion	No corrosion
	Easy to transport and install	Easy to transport and install
	Less maintenance. Saving mainly due to good running condition of aramid belt, with lower weight and better flexibility. Better belt tracking also contributed to less maintenance.	Very satisfied with initial results on energy savings and running behavior.

Table 2. Results of two aramid belts in China.

The mining company was very positive about the higher transportation capacity of the aramid belt which they attributed to the higher flexibility of the belt compared to the more rigid steel cord belt. Moreover, looking at the other features, such as ease

of installation, good troughability and running behaviour, the results from the first belt were regarded as extremely positive.

The mining company commented that the installation was easier compared to a steel belt. In addition, maintenance was less intensive with the aramid belt: the steel belt required four to five people, while the aramid belt only required three people. In addition, the aramid belt did not corrode, which was a critical issue for the mine.

Based on the first installation, the mining company decided to install an aramid belt on a newly built system. Two identical lines had been operating for some years, equipped with a steel reinforced ST2000 belt. In contrast to the first operating system described above, these lines have a zero inclination. The weight of the ST2000 reference belt is 47.6 kg/m vs the 27.3 kg/m of the DPP 2000 belt, a reduction of 42%.

Figure 7 illustrates the installation. Since the second aramid belt was installed on a new system, comparison with the existing lines is not straightforward, because it is not a replacement on the same conveyor system. However, the setup of the three lines (2 x ST2000, 1x DPP2000) is identical in terms of dimensions, capacity and running speeds. The readings of the current steel and aramid system showed 70A versus 40A during use, a reduction of 43%. The current is proportional to the power via the formula:

$$P = \eta \cdot \sqrt{3} \cdot V \cdot I \cdot \cos\varphi$$

- V = volts (constant for particular installation)
- I = Current (ampere) absorbed by motor
- η = efficiency of motor
- $\cos\varphi$ = power factor

Since the efficiency of the drive and the power factor are unknown, it is difficult to quantify the exact contribution of the aramid belt properties. However, the energy savings can be estimated based on the weight differences of the belt, the running speed and the capacity of the system. The difference between the ST2000 and DPP2000 belts is 20.3 kg/m. The reduction of the Total Motional Resistance component ($2m'_G + m'_L$) in the DIN formula is 15%. Idler weight is an unknown parameter, but is assumed to be equal for both cases (steel and aramid). Therefore, conservative energy savings between 12% to 15% can be estimated from the belt weight with zero incline. In addition, higher energy savings could be expected due to the lower friction coefficient caused by the thinner bottom cover³.



Figure 7. Aramid DPP 2000 belt in Baodian Coal Mine (YCMC), China.

CASE STUDIES: CUSTOMER BENEFIT MODEL

Air pollution, or smog, is a serious problem in various parts of the world, particularly in China. The production of electricity generates a vast amount of carbon dioxide (CO₂) and particulate matter (PM10), the levels depending on the source used (e.g., coal or oil). The aramid belt concept with its lower energy consumption compared to steel reinforced belts contributes to emission reduction. Teijin Aramid has developed a calculation tool to quantify the positive environmental impact of using an aramid belt¹.

The customer benefit model (CBM) aims to provide a comprehensive overview from the perspective of the end user, showing that environmental and financial best practices can go hand in hand. The model is based on ISO 14040 and 14044, and is TÜV-certified. The model analyses the eco-efficiency-related gains for end users, providing a complete overview of the environmental and financial impact of the belt in the use phase, benchmarked against traditional solutions. Based on energy use, energy prices, and belt costs, the CBM model calculates a wide range of key indicators for each situation: carbon dioxide (CO₂) and particulate matter (PM10) emissions, in addition to traditional financial indicators, such as payback period, net present value (NPV), and internal rate of return (IRR).

The CBM model was applied to the first (short) belt in the Yanzhou Coal Mine. In terms of energy consumption, a saving of 9% was measured, which can be completely attributed to the use of the aramid belt. The results of the CBM are shown in Figure 8. The carbon dioxide and particulate matter reductions are in the same magnitude as the power savings, i.e., 9%, since the source of the energy produced in this case was coal.

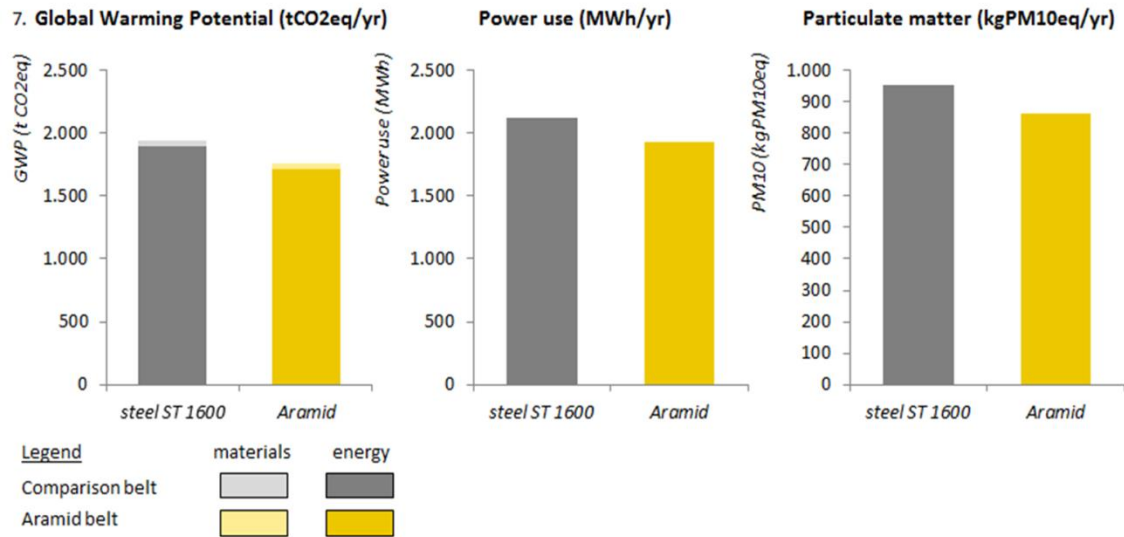


Figure 8. Results of CBM calculation of the 666 m Chinese belt in Baodian Mine.

The lower cost of ownership of the aramid belt vs the steel cord belt facilitates a more favourable payback period. In this particular case, the payback period is estimated at <1 year for a belt, assuming a 20% increase in initial financial outlay than the equivalent belt reinforced with steel cord.

SUMMARY

The case studies presented in this paper describe the performance of aramid reinforced conveyor belts compared to steel and textile EP alternatives.

Several belts running in crusher and stacker applications showed a significant extension of belt lifetime – up to four times the average of the original belts. This appears to be due to the greater flexibility of an aramid reinforced belt in combination with the straight warp construction of the fabric reinforcement. Energy savings and, consequently, a lower environmental impact were measured and demonstrated in two belts in an underground coal mine. The excellent running behaviour, ease of installation and less maintenance as reported by the end user also show that aramid reinforced belts offer a good alternative to the traditional steel cord reinforced belts in long haul conveying systems.

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