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Aspects of corrosion protective tape technology

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Corrosion protective tape coatings have been used for decades on all types and sizes of buried pipelines. Results thus obtained are as versatile as the available range of products. The following paper deals with important aspects that have to be considered to ensure long term performance of corrosion protective tape coatings.

Tape composition and structure

The proper choice of a suitable tape coating system starts with a basic requirement, which is valid for all pipe diameters and operating conditions. This requirement is related to material composition and structure. Regarding their composition the available plastics tape coatings can be assigned to the following main material classes and combinations thereof:

Carrier film material

- Polyethylene (PE)
- PVC

Adhesive material

- Butyl rubber
- Bitumen

Among possible tape compositions the combination of a PE carrier film with butyl rubber adhesive has proven the best corrosion protection performance [1], [2], [3]. In contrast to this PVC as carrier film material, particularly in case of contained plasticizers, is susceptible to embrittlement. Bitumen as material basis for corrosion protection tapes is a less performing material also as it provides a lower ageing resistance than butyl rubber based adhesives. This lower ageing resistance is expressed by a significantly lower electrical insulation resistance, compared to butyl rubber tapes, which further decreases after years of operation [4].

Having made the choice for polyethylene and butyl rubber as the material basis, the question of the most suitable tape structure comes up. As a minimum requirement the innerwrap tape or so called corrosion protection tape should always be of a three-ply structure with butyl rubber adhesive layers on both sides of the carrier-film [5], [6]. **Figures 1 a** and **b** show typical cross sectional views of high performance three-ply corrosion protection tapes.

Among these structures the asymmetrical one is to be preferred, because its thick inner adhesive layer ensures higher peel strength as well as better filling of surface irregularities and potential hollows, e.g. beside the weld bead. Having a detailed look on the tape structure shown in Figure 1 a, one can even recognize a four ply structure, which is typical für state-of-the-art asymmetrical corrosion prevention tapes like DENSOLEN-Tape AS40 Plus. The thin fourth ply between carrier film and the thick grey butyl rubber adhesive is a co-extruded ply from a blend of butyl rubber and polyethylene. The existance of such an intermediate ply can easily be determined by preparing a microtome cross section as shown in **Figure 2**. All tape plies indicated in the schematic view in Figure 1 a can also be seen in the real photography of such a cross section. State-of-the-art mechanical protection tapes like DENSOLEN-Tape R20HT (**Figure 1 c**) also contain a coextruded intermediate layer between carrier film and adhesive.

A co-extruded intermediate ply between backing and main adhesive layer provides a homogenous transition from butyl rubber to PE. Additionally, the well known delamination effect (**Figure 3**) and a potential long term permeability through the interface between carrier film and adhesive is avoided by using tapes comprising co-extruded plies. Same as in DENSOLEN-Tape AS40 Plus, the outer butyl rubber layer of asymmetrical three-ply tapes should also be manufactured by a co-extrusion process to also ensure perfect bonding between backing and outer adhesive layer. At this point it should be clearly distinguished between tapes of the DENSOLEN-type, where the backing is produced by a co-extrusion

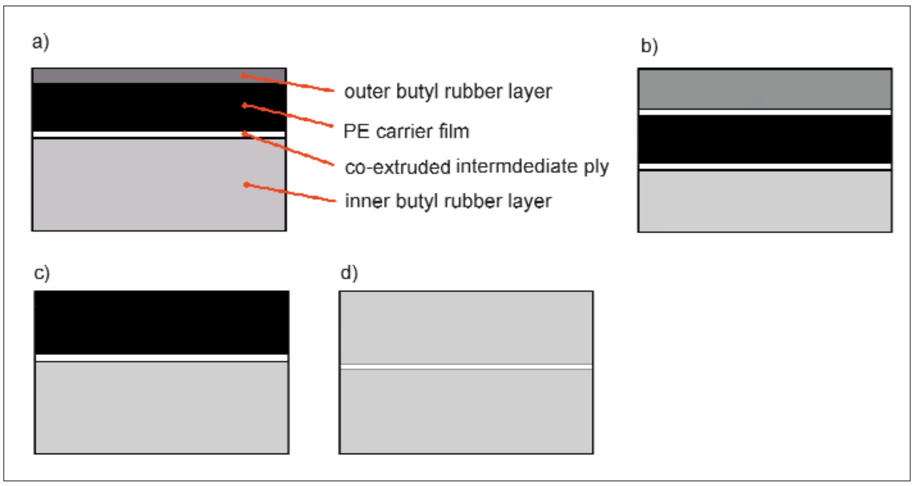

Fig. 1: Cross sectional view of a) asymmetrical 3-ply corrosion protection tape b) symmetrical 3-ply corrosion protection tape c) mechanical 2-ply protection tape d) butyl rubber tape

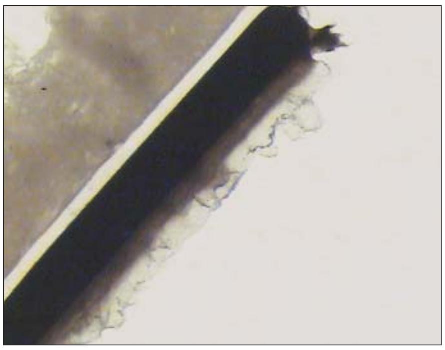

Fig. 2: Microtome cross section of DENSOLEN-Tape AS40 Plus/AS39P

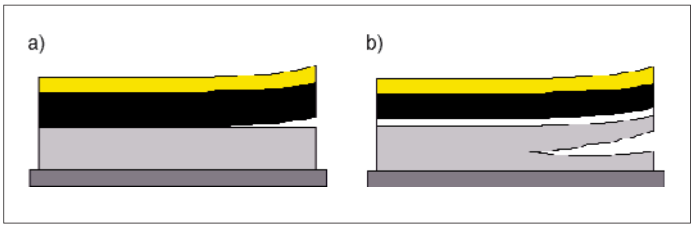

Fig. 3:
a) Delamination during peel-test
b) cohesive peel mode of tape with co-extruded intermediate ply

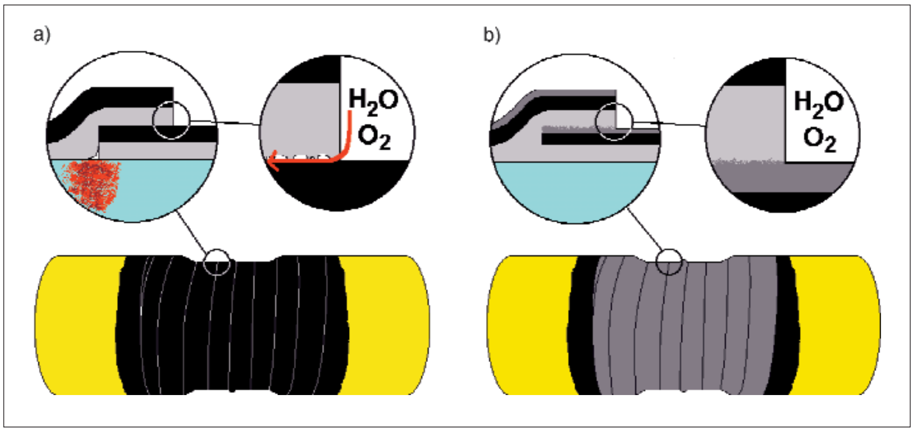

Fig. 4: a) Incompletely sealed tape overlap of two-ply tape wrapping with undermining corrosion along spiral tape overlap b) Completely sealed tape overlap by self-amalgamation of high performance three-ply tape

process and the main adhesive layer is laminated by a calender process, and between tapes, where the backing and the adhesive layers are manufactured in a one-step co-extrusion process. The latter type is accompanied by certain limitations concerning formulation and dimension of the main adhesive layers, while the two-step process offers a wider range of possibilities concerning adhesive composition and tape dimensions. Only this freedom in formulation allows to perfectly adjust the tape properties to its corrosion protection function.

Why is a three-ply structure of the innerwrap tape of such importance? As can be seen from **Figure 4 a**, an interface and potential penetration path for water and oxygen remains in the tape overlap, if an only two-ply tape is used for the innerwrap. After some time of operation the incompletely sealed tape overlaps inevitably lead to spiral corrosion first followed by complete undermining corrosion. A big percentage of bad experiences with tape coatings all over the world originate from and is linked with the effect shown in Figure 4 a. In contrast to this no interface or penetration paths remains in the overlap of high-performance three-ply tapes (**Figure 4 b**). The outstanding feature of butyl rubber is its ability to self-amalgamate in the overlap areas, resulting in a completely sealed, impermeable and sleeve-type coating.

Tape systems

Tape systems should always contain at least two layers of a self-amalgamating three-ply tape. The resulting and completely sealed innerwrap ist then normally overwrapped with a mechanically protecting outerwrap, which could be either a three-ply or a two-ply tape.

The even distribution of polyethylene and butyl rubber plies in a one tape system as shown in **Figure 5 a** and **b** affords a maximum resistance to mechanical stresses like indentation and impact. Additionally in a one tape system all tape layers self-amalgamate within their overlaps, forming a sleeve type coating throughout the whole tape system. In two tape systems using two-ply tapes for the outerwrap, the overlap between the third and forth tape layer does not self-amalgamate, which nevertheless is not detrimental to the corrosion protection performance of the whole system. Even contrary and beside the fact, that they are economically preferred, there may be also technical reasons to choose two-ply outerwrap tapes instead of three-ply outerwrap tapes. Particularly in hot climates it could be useful to employ two-ply tapes comprising a white polyethylene backing. Such tapes would show only a minor rise in temperature when exposed to sun irradiation. The well known effect of bubble formation under tape coatings, which are exposed to sunlight, would consequently be avoided. Moreover, there is lower friction between the smooth exterior of polyethylene two-ply tapes and soil, which is of benefit especially for high-temperature tape systems of the structure shown in **Figure 5 d** and described below.

Mechanically highly resistant tape systems according to stress-class C-50 (EN 12068) always have a structure as shown in Figure 5 a or b. An alternative two tape system makes use of a butyl rubber tape instead of a three-ply tape for the innerwrap. Such butyl rubber tapes, which may contain thin poylethylene films (usually 25 to 70 µm) to avoid overstretching of the tape during application, are highly conformable and therefore find use in wrapping of irregularly shaped objects like weld-on branch lines. In such fields of application the requirement for simple application predominates the importance of maximum mechanical resistance. Butyl rubber tape systems (**Figure 5 c**) afford minor indentation resistance than type 5 a or 5 b tape systems for the benefit of simple application.

A special attention has to be directed to tape systems for elevated operating temperatures, since tape coatings on pipes operating above +50°C are exposed to particular stresses. These stresses, which are further indicated below, can be compensated by taking the following measures:

The thermal elongation of the carrier film leads to wrinkle formation, which in combination with reduced peel and lap shear strength at elevated temperatures would partly lift off tape system from pipe surface.

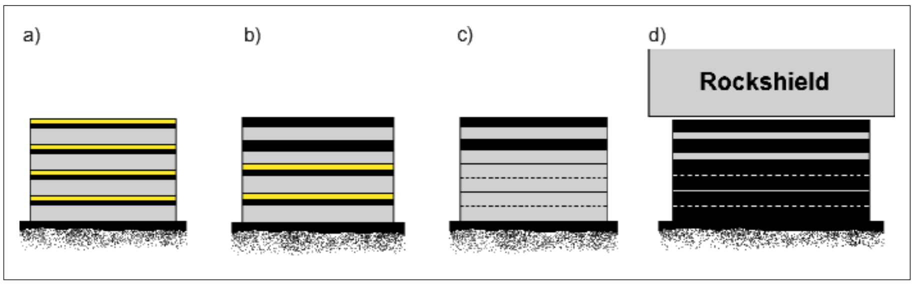

Fig. 5: Corrosion protection tape systems a) one tape system b) two tape system with two-ply outerwrap tapec) two tape system with butyl rubber innerwrap tape d) two tape system for elevated operating temperatures (> 50 °C)

Fig. 6: Typical field of application for type 5.b two-tape system: Coating of weld-on branch line

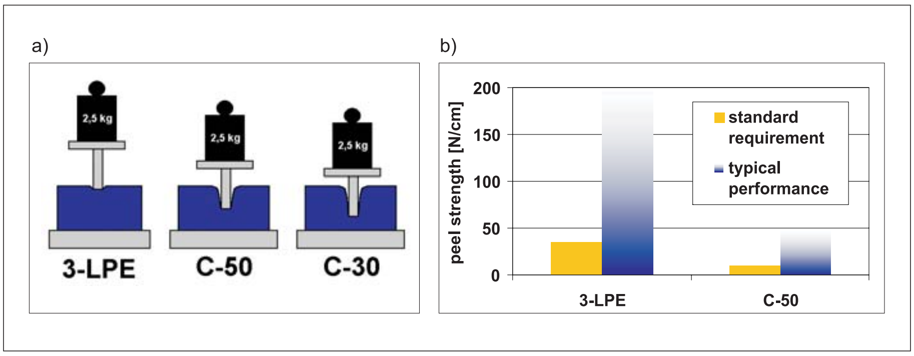

Fig. 8: a) Typical residual thickness of a three-layer polyethylene factory coating (3-LPE, DIN 30670) compared to stress-class C-50 and C-30 tape coatings (EN 12068) at 23 °C b) Peel Strength of 3-layer PE factory coatings (DIN 30670) and stress-class C-50 field coatings (EN 12068) at 23 °C

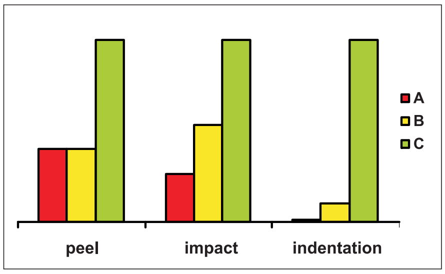

Fig. 7: Differences between stress-class A, B and C requirements for peel strength, impact resistance and indentation resistance according to EN 12068

→Recommendation: Use of a butyl rubber tape without carrier film as innerwrap.

Adhesives get smooth at elevated temperatures, which would result in reduced peel and shear forces.

→ Recommendation: Use of a special butyl rubber formulation, which is highly stabilised against thermal degradation and which is self-reinforcing by cross-linking at elevated temperatures.

Carrier film of the mechanical protection tape gets smooth at elevated temperatures, which would result in reduced resistance to load forces.

→ Recommendation: Use of a high density polyethylene carrier film and additional use of a load distributing non-woven rockshield.

Elevated operating temperatures are often accompanied with alternating temperatures, which could result in a longitudinal movement of pipe and increase the risk off the coating to be sheared off.

→ Recommendation: Use of a rockshield, which decouples moving pipe from surrounding soil by providing low friction between rockshield casing and outerwrap tape.

Standard requirements – stress classes

Technical properties of a corrosion protective tape coating are described in respective national and international standards [4]. It should be noticed that frequently employed ASTM standards contain well suitable test procedures to determine single tape properties. Nevertheless ASTM standards neither define acceptance criteria nor do they contain an adjusted or balanced set of requirements for tape coatings.

In contrast to this material standards like EN 12068 ([7], [8]) do not only describe test methods to determine the relevant tape and coating properties, they also give a well suitable tool for classification and comparison of tape coatings by using a concept of stress classes. The mechanical stress classes A, B and C essentially differ concerning requirements for peel strength, impact resistance and indentation resistance. Corresponding ratios for the mentioned properties are shown in **Figure 7**.

When choosing a suitable tape coating it has to be considered that the performance level of a standard factory applied coating, e.g. three layer polyethylene (3-LPE) according to DIN 30670, exceeds the performance level of a field coating by far. Especially the resistance to load stresses and peel forces, which are permanently affecting the pipe coating during pipeline operation, is generally lower in case of field applied coatings, which is clearly demonstrated in **Figure 8 a** and **b**. This different performance levels originates from the general demand for easy on site applicability, which makes it necessary to accept lower level of mechanical strength in case of field applied tape coatings.

Having in mind the different performance level of factory coatings and field applied tape coatings, it seems evident that a field coating with properties as close as possible to the performance level of the existing line pipe coating should be chosen. The only limiting factor, which should influence the decision for a cer-

Table 1: Tape systems guideline

operating temp.	field of application	recommended tape system	mechanical stress	stress-class	DENSOLEN-System
≤ 30 °C	Irregularly shaped objects (e.g. weld-on branch lines)	butyl rubber tape with mechanical protection tape	low	B-30	E15-PE3
			medium/high	C-30	N15-PE5
≤ 50 °C	all	one tape system or two tape system	high	C-50	AS40 Plus
					AS39P-R20HT
≥ 50 °C ≤ 100 °C	all	high temperature butyl rubber tape with mechanical protection tape and rockshield	medium/high	B/C	ET100-R20HT

Table 2: Tape width guideline for insulation of girth welds, bends and full pipe lengths

pipe ∅	tape width	application by	Wrapping Machine
Recommended			
1" – 2"	30 mm	hand	-
2 ½" – 11"	50 mm	small hand wrapping device	DENSOMAT 1
		hand	-
≥ 12"	100 mm	small to medium size hand wrapping device	DENSOMAT 1
			DENSOMAT KGR
		motor driven wrapping machine	DENSOMAT 11
possible			
≥ 28"	150 mm	small to medium size hand wrapping device	DENSOMAT KGR
			DENSOMAT 1 / 150
-	> 150 mm	only by line travel wrapping machines	-

Fig 9: a) Tape wrapping with DENSOMAT 1 hand wrapping machine b) DENSOMAT KGR Junior hand wrapping machine with extension arms c) DENSOMAT 11 motor driven wrapping machine for field joint coating on a 36" pipeline d) DENSOMAT KGR Junior with closed frame e) Easy mounting of DENSOMAT 11 wrapping machine on a 36" pipeline (girth weld insulation)

tain tape coating, should therefore be the issue of applicability. Consequently a stress-class C-50 tape system (e.g. DENSOLEN-System AS39P-R20HT) should be used for standard wrapping of welded joints, bends or full pipe length. Even if the pipeline is operated at temperatures below 50 °C, the higher performance level of a C-50 system provides a higher safety margin also at room temperature and narrows the gap to the performance level of the line pipe coating. Only in case of irregularly shaped objects, which require flexible and easy to apply tapes, the use of a more conformable but mechanically less resistant two-tape system according stress class C-30 or B-30 could represent a reasonable alternative.

Application

The performance of a corrosion protective tape coating can only be as good as the quality of its application. Therefore the corresponding properties and application equipment play a major role in corrosion protective tape technology. As a general requirement tape coatings should be applied

- without wrinkles and hollows
- with sufficient tape tension
- with constant tape overlap

Observance of the above requirements can as much as possible be ensured by

- use of appropriate (= pipe diameter dependent) tape width
- limitation to an upper limit of tape width even on large diameter pipes
- employment of wrapping machines whenever possible

Particularly the choice of a suitable tape width can influence the quality of a tape coating. In case of tape application by hand wrapping devices sufficient tape tension can only reliably be applied by limiting oneself to a maximum tape width of 150 mm. However, the recommended maximum tape width is 100 mm (4"), which allows proper wrapping also in case of more tough mechanical protection tapes. The seeming advantage of faster application when using a wider tape is more than compensated by the disadvantage of a sometimes questionable quality of wrapping due to poor adhesion and wrinkle formation.

The range of DENSOMAT hand or motor driven wrapping machines illustrated in **Figure 9 a** to **e** offers versatile important features for perfect site suitability and simple use.

- built-in break mechanism for constant tape tension
- integrated interleaving take-up mechanism
- low weight

- minimum clearance requirement
- possibility to attach extension arms (9 b) or circumferentially closed frames (9 c) to wrapping machine for large diameter pipes (DENSOMAT KGR)
- simple mounting and movement across pipe supports (DENSOMAT 11, 9 e).

It is unnecessary to mention that quality of surface preparation is another important factor, which affects quality of corrosion protective coatings. Cold applied tapes in general and DENSOLEN-Tapes in particular offer a high level of site suitability, since they tolerate a surface preparation according to ST2 [7] obtained just by wire brushing.

Conclusion

When taking into consideration important factors like tape composition and structure, mechanical performance issues and finally application technique and technology, tape systems offer a well suitable, durable and high performing solution for the corrosion protective coating of pipes and pipelines in rehabilitation and new construction, including insulation of girth welds and irregularly shaped structures. The combined use of DENSOLEN tape systems and DENSOMAT wrapping machines provides perfect applicability and optimised properties concerning corrosion protection performance, mechanical strength and durability.

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