



Three-Ply-Tapes- Two-Ply-Tapes Differences in function and structure

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

1. Tape composition and structure

The proper choice of a suitable tape coating systems starts with a general requirement for tape structure and composition. This requirement is valid for all pipe diameters and operating conditions.

Regarding composition all available tape coatings can be divided into following classes and combinations thereof:

Carrier film material

- Polyethylene
- PVC

Adhesive material

- Butyl rubber
- Bitumen

Among possible tape compositions the combination of PE carrier film with butyl rubber adhesive has proven best corrosion protection performance [1], [2].

In contrast PVC as carrier film material, particularly in case of contained plasticizers, is susceptible to embrittlement. Bitumen is a questionable material also as it provides a significantly lower ageing resistance than butyl rubber based adhesives.

Having made the choice for butyl rubber and polyethylene as the material basis, the question of the most suitable tape structure is brought up.

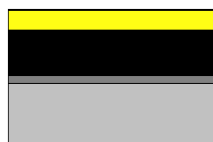
As a minimum requirement the innerwrap tape or corrosion protection tape should always be a three-ply structure with butyl rubber adhesive layers on both sides of a PE carrier-film [3], [4].

Figure 1 shows typical cross sectional views of high performance three-ply corrosion protection tapes.

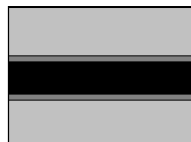
Fig. 1

Cross sectional view of corrosion prevention tapes

a) asymmetrical



b) symmetrical



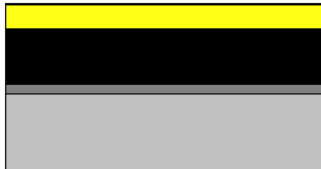
Among these structures the asymmetrical one is to be preferred, because its thick inner adhesive layer ensures better filling of surface irregularities and potential hollows. Furthermore state-of-the-art asymmetrical corrosion prevention tapes like DENSOLEN-Tape AS39P, AS40 Plus or AS50 have a four-ply structure, containing an additional layer between carrier film and adhesive. This intermediate layer is coextruded from a blend of butyl rubber and polyethylene and thus ensures a homogenous transition from butyl rubber to PE. The well known delamination effect (Figure 2) and a potential long term permeability through the interface between carrier film and adhesive is avoided by the tape structure shown in Fig 1a).



A co-extruded intermediate layer facilitates good bonding between carrier film and adhesive layer, which avoids delamination during peel test. Moreover, due to the nature of the intermediate layer (a blend form PE and butyl rubber), the tape cross section is characterised by a homogenous transition from butyl rubber to PE and to butyl rubber again. It should be mentioned, that the outer adhesive layer in asymmetrical three-ply DENSOLEN-Tapes is also manufactured in a co-extrusion process, which ensures perfect bonding between outer adhesive layer and carrier film.

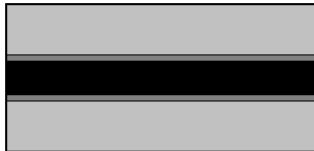
Cross sectional view of an asymmetrically structured "three-ply" tape (e.g. AS 39 P) with

- one PE-layer
- one inner adhesive layer
- one outer adhesive layer
- one co-extruded intermediate layer between carrier film and inner adhesive layer



Microtome cross section of DENSOLEN-Tape AS 39 P

Cross sectional view of a symmetrically structured "three-ply" tape



Cross sectional view of a DENSOLEN two ply tape



Fig. 2

a) Delamination during peel-test





b) Cohesive peel mode by co-extruded intermediate layer of high-performance tape



State-of-the-art mechanical protection tapes like DENSOLEN-Tape R20HT (Figure 3) also contain a coextruded intermediate layer between carrier film and adhesive.

Fig. 3

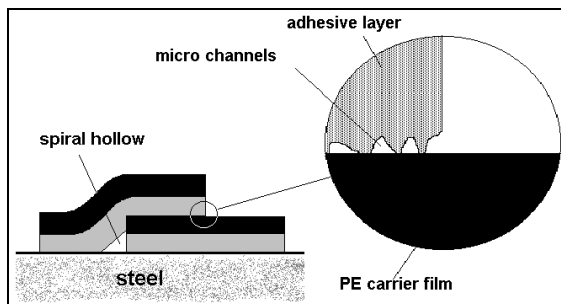
Mechanical protection tape with co-extruded intermediate layer



Why is a three-ply structure of the innerwrap tape such indispensable? As can be seen from Figure 4, 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.

Fig. 4

Incompletely sealed tape overlap of two-ply tape wrapping



After some years of operation the incompletely sealed tape overlaps inevitably lead to spiral corrosion followed by complete undermining corrosion. **A big percentage of bad experiences with tape coatings all over the world originate from the effect shown in Figure 4.**

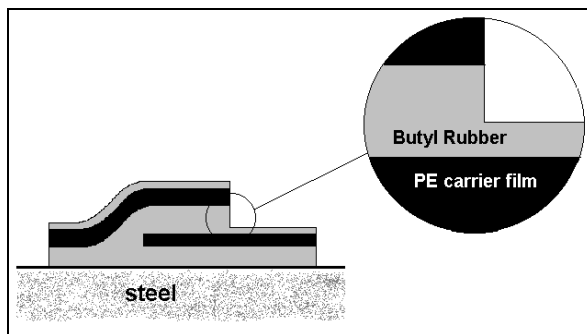


Fig. 5
Spiral corrosion



On the other hand, no interface with penetration paths remains within a wrapping from high-performance three-ply tapes. 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.

Fig. 6
Completely sealed tape overlap of high performance three-ply tape wrapping



The definition "tape layer" is used by DENSO to define the number of tape layers in a tape system. E.g. the four-layer DENSOLEN-Tape system AS 39 P contains 4 layers of tape, resulting in a coating thickness of 3,2 mm.

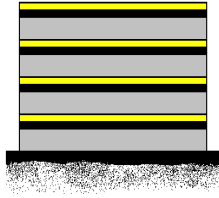
2. Tape Systems

Tape systems should always contain at least two layers of such three-ply tape. The completely sealed innerwrap, depending on mechanical stresses, is most often combined with a mechanically protecting outerwrap from a three-ply or two-ply tape.

Fig. 7
Creation of tape systems by combination of three-ply or three-ply and two-ply tapes



a) one-tape system



b) two-tape system



The even distribution of polyethylene and butyl rubber layers afford a maximum resistance to mechanical stresses like indentation and impact.

Mechanically highly resistant tape systems according to highest stress-class C-50 always show a structure as shown in 7 the latter one (e.g. DENSOLEN-System AS 39P - R20HT) being economically preferred. DENSOLEN-Tape system AS 39 P R 20 HT contains 4 layers of tape, resulting in a coating thickness of 2,6 mm.

Typical peel strength of DENSOLEN-Tapes

The following table shows typical peel strength values obtained for DENSOLEN-Tape AS 39 P according to DIN EN 12068.

Property	Unit	Typical value @	
		23 °C	50 °C
Peel strength on steel @	10 mm/min	25	3
	100 mm/min	45	5
Peel strength tape to tape	N / 10mm	45	5

In order to define minimum required peel strength values, other pipeline owners found it useful to require the doubled peel strength values of DIN EN 12068 and DIN 30672, which is as follows.

Property	Unit	Required minimum value @ 23 °C
Peel strength on steel @	10 mm/min	20
	100 mm/min	30
Peel strength tape to tape	N / 10mm	30

P.S. In the DENSO definition "ply" refers to the structure of one tape layer, whereas "tape layer" refers to the number of tape layers within a tape system.

In order to make it not too much complicated, the co-extruded intermediate layers between carrier film and adhesive are not included in the definition "three-ply" tape or "two-ply" tape. These plies only represent the visible plies within a tape. In the tape cross section, co-extruded intermediate layers are not visible with the naked eye. Nevertheless they could be made visible by microscopy.



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Accordingly, a three-ply tape is a tape with a carrier film and adhesive layers on both sides. Additionally, asymmetrical three-ply tapes like DENSOLEN-Tape AS39 P contain one additional co-extruded intermediate layer between carrier film and inner butyl rubber adhesive (to be very precise, one should talk about a "four-ply" tape in that case). Symmetrical three-ply tapes contain a co-extruded intermediate layer between carrier film and both adhesive layers (very precisely: "five-ply" tape).