Tape coatings

What are the differences in manufacturing technologies and which impact do they have on the material properties?

Pipeline Industries Guild Webinar, 08/04/2020

Agenda

1. Introduction
2. Lamination vs. Coextrusion
3. 3-ply Tapes vs. 2-ply Tapes
4. 3-ply Tapes: Coextruded & Asymmetrical
5. Comparison of Material Properties
6. How to simply test Coextrusion - Lamination
7. Long Term Experiences with 3-ply Tapes
8. Conclusions

1. Introduction

Introduction

Tapes differ in various aspects:

- Production technology (Lamination vs. Coextrusion)
- Material (e.g. PVC-Bitumen vs. PE-Butyl rubber)
- Structure (2-ply vs. 3-ply)
- Composition (Symmetrical vs. Asymmetrical)

➢ **Tape ≠ Tape**

Introduction

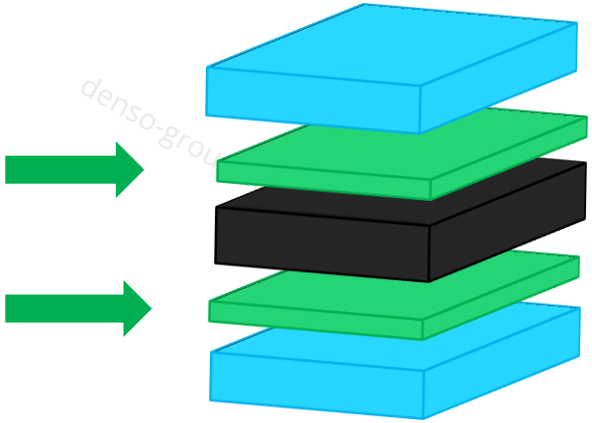
Questions to be answered:

- *Do different tape structures and **production technologies** have an impact on the **quality** and intrinsic **material properties** of tapes?*

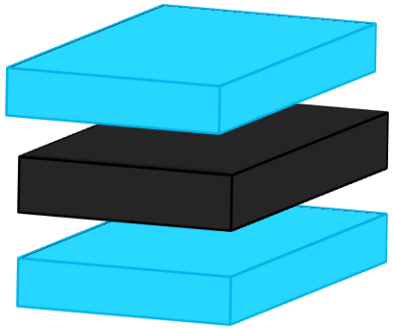
- *What are the impacts of tape structure and production technology on **long-term behaviour** of tape coatings?*

2. Lamination vs. Coextrusion

Objective: Bond different materials together



Using Adhesive (glue)



For Tape: Without Adhesive (glue):

- Lamination
- Coextrusion

Lamination

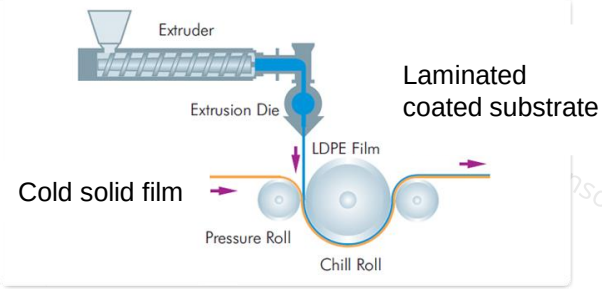
- 3 typical lamination technologies exist.

- For all technologies of lamination applies:

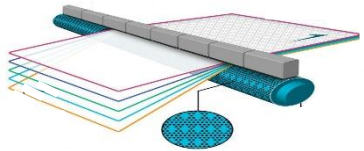
> At least **one layer** has already **cooled down** and is then covered with another layer.

3 Typical Lamination Technologies

1. Extrusion of a second layer on the first cold solid film



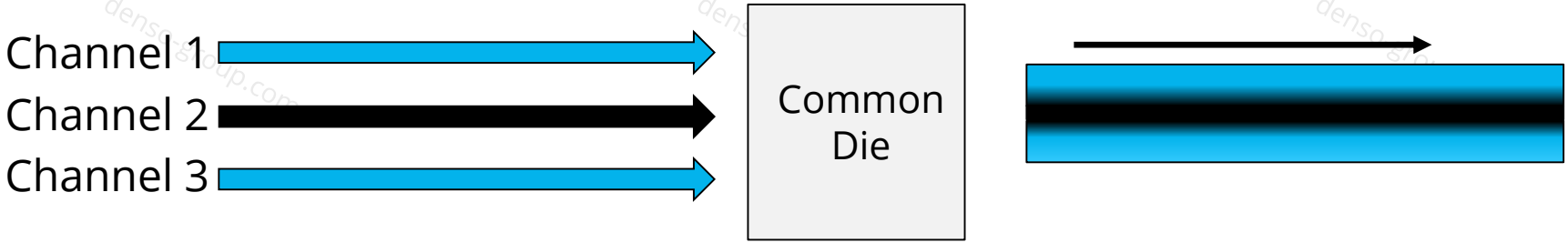
2. Heating and pressing cold solid films together



3. Liquid is distributed on a cold solid film.

The principle of real Coextrusion

- Coextrusion requires more than one polymer **melt stream**.
- Each melt stream is produced by its **own extruder**.
- Real coextrusion process: melt streams flow into different channels to and through **3 different entries into the Common Die**.
- The different molten polymers flow together to the outlet of the **common die**.



The principle of real Coextrusion

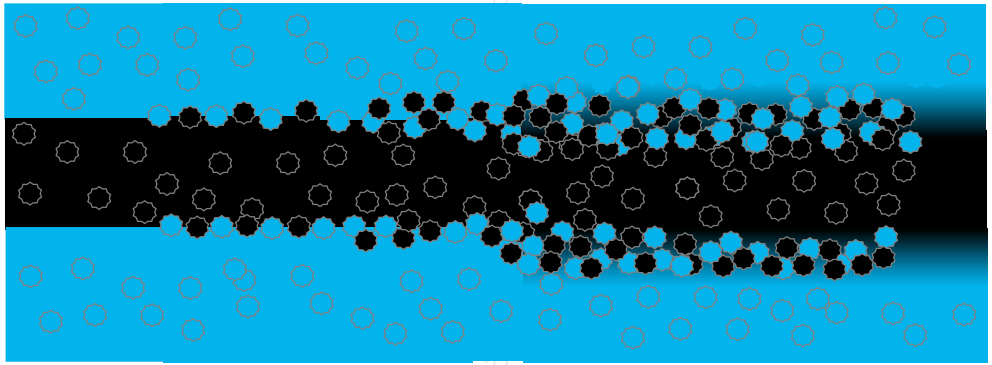
- Inside Common Die: Macromolecules of the molten polymers flow into each other and are **intermingling** in the border zones.

flow direction

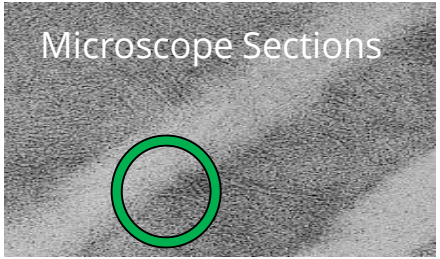
Melt Stream from Channel 1

Melt Stream from Channel 2

Melt Stream from Channel 3



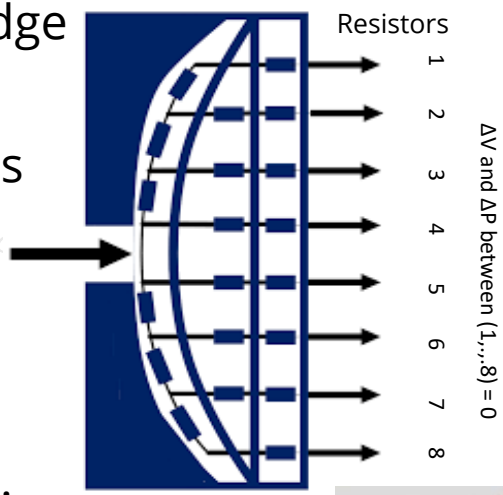
Along the flow path the melt streams flow into each other

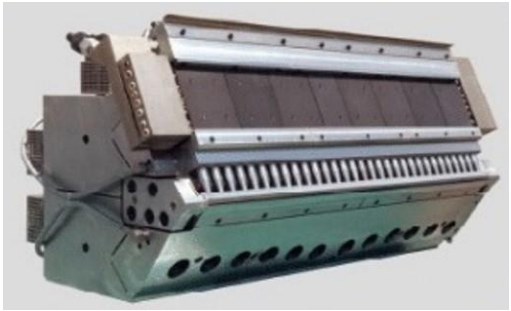


- Equivalent to "***welding components***" with very strong bonding/merging between the layers.

The principle of real Coextrusion

- Coextrusion requires expert knowledge and a lot of experience.
- Process Technology + Melt properties + “Recipes”: must fit together.
- Each melt must flow with the **same velocity** (speed) over the complete width of the die to ensure a **stable and correct thickness distribution**.
- A real coextrusion die has its own channel and a **Coat-Hanger Manifold** for each component. That ensures an **equal pressure loss** on each flow path.





Properties of real coextruded tapes

- Superior **Layer to Layer Adhesion**.

The layers never separate and delaminate from each other!

- Superior **Lap Shear Resistance**.

The layers do not move on each other!

- High **Elongation at Break** Resistance.

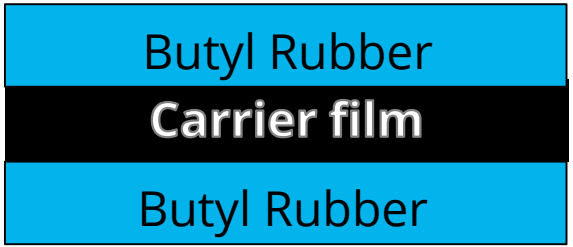
Poor values for *elongation at break* is an indication of inferior material quality or uncontrolled coextrusion proccess!

➢ **Real Coextruded Tapes = High Quality Tapes**

3. 3-ply Tapes vs. 2-ply Tapes

Material & Structure 3-ply vs. 2-ply Tapes

3-ply Tape:



- Structure: carrier film covered on **both** sides with adhesive.
- Material: **Butyl rubber only.**
- Lamination or Coextrusion.

2-ply Tape:

- Structure: carrier film covered only on **one** side with adhesive.
- Adhesive: Butyl Rubber ***or*** Bitumen.
  - Butyl Rubber: Lamination or Coextrusion.
  - Bitumen: only Lamination, **Coextrusion not possible!**

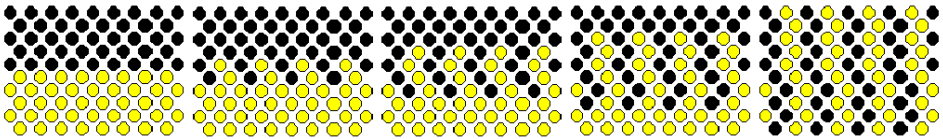
Characteristics of Butyl Rubber

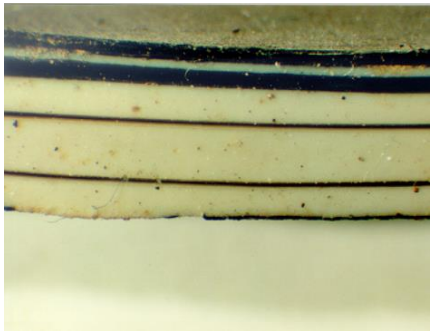
Ability to **„flow“** to a certain degree

- Small cavities of the steel surface are filled.

Butyl Rubber layers **self-amalgamate without any heat** (flame)

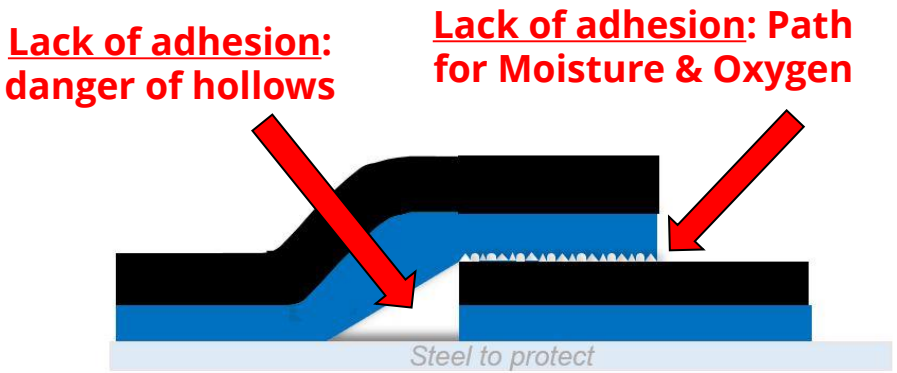
- Molecules migrate into each other to form an **homogenous structure**.





2-ply tapes: reliable corrosion prevention?

2-ply Tapes wrapped



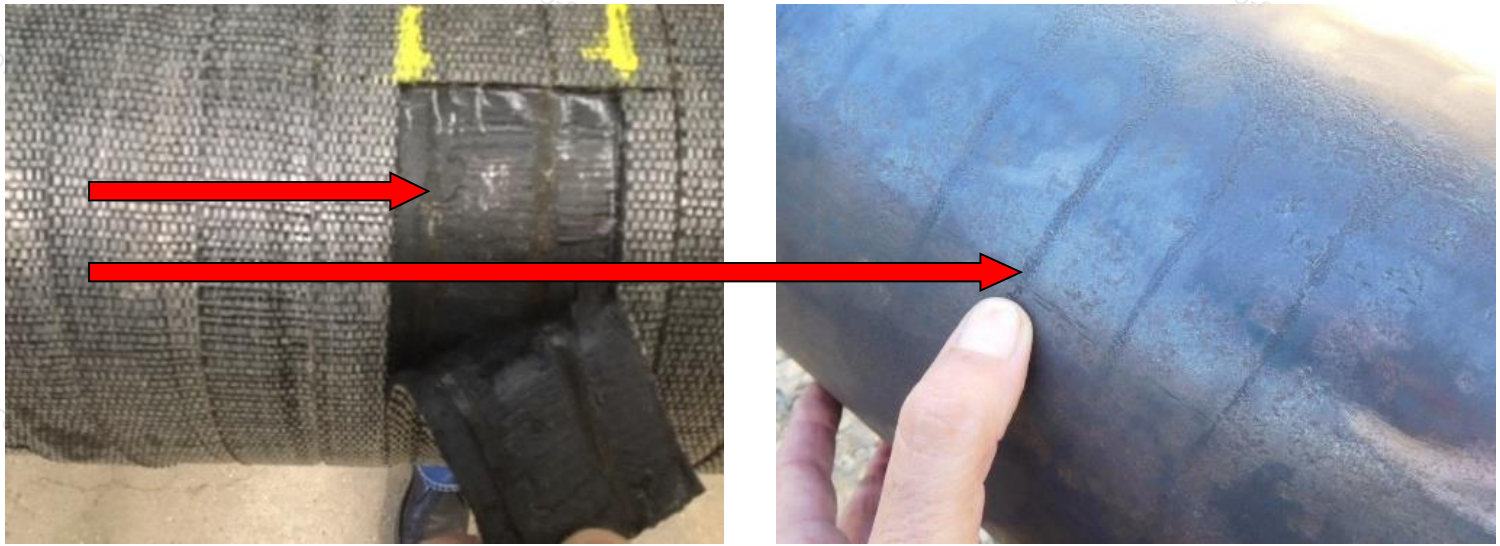
- In the remaining interface between the layers **micro channels** may occur!
- Possible **path** for moisture and oxygen!

➢ **SPIRAL CORROSION**

2-ply tapes: Risk of Spiral Corrosion!

SPIRAL CORROSION is frequently found on pipelines where **2-ply tapes** are used as **corrosion prevention** tape.

Spiral Corrosion



3-ply tapes: strong corrosion prevention

3-ply Tapes wrapped

- Butyl-Rubber layers **self-amalgamate** when tapes are wrapped.
- Molecules migrate into each other:
  - Tapes form a homogenous "**Impermeable Hose** Type Coating"
  - No interface, hollows or micro channels!

  - **NO SPIRAL CORROSION**

4. 3-ply Tapes:
Coextruded & Asymmetrical

3-Ply Tapes - Coextruded & Asymmetrical

1st step: Coextrusion:

Butyl Rubber real coextruded with Carrier film.

Intermediate Butyl Rubber real coextruded with Carrier film.

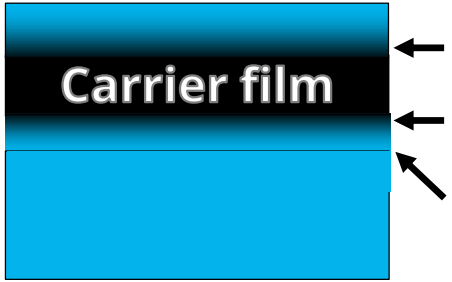
2nd step: Adding Butyl Rubber:

Chemical bond: Butyl-Rubber + Butyl-Rubber

Additional Butyl Rubber is building the required thickness.

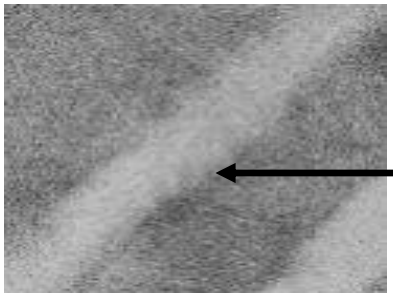
3-Ply Tapes - Coextrusion vs. Lamination

Coextrusion:



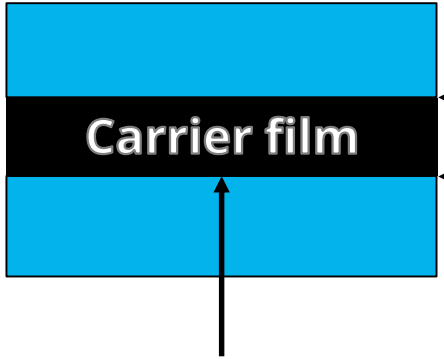
Strong **chemical bond** between Butyl-Rubber and PE!

Chemical bond: Butyl-Rubber + Butyl-Rubber



Penetration of macromolecules between layers:
Excellent Long-term properties!

Lamination:

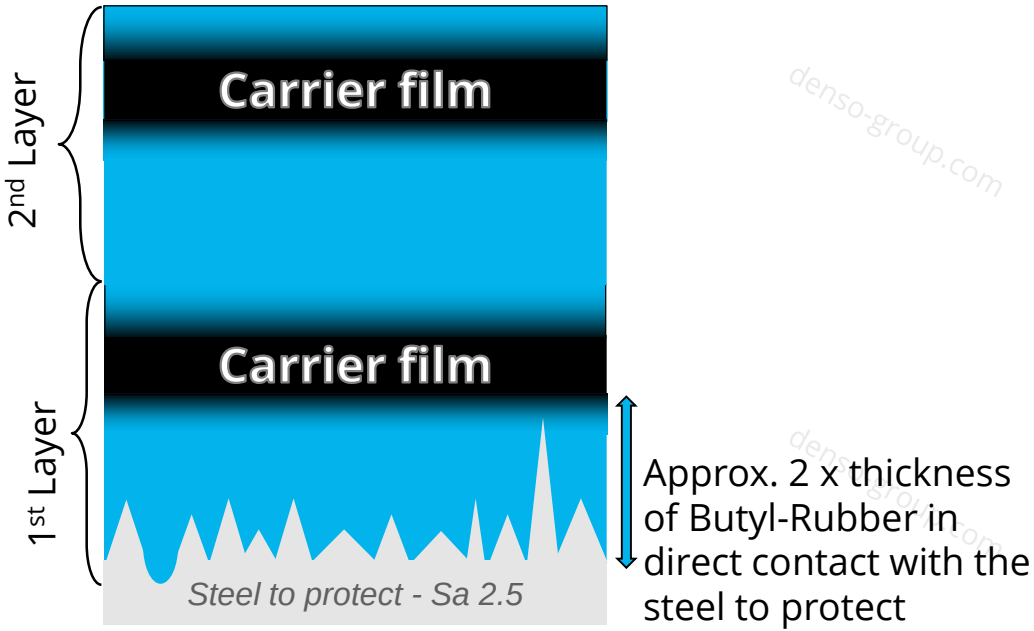


Only mechanical bond between Butyl-Rubber and PE

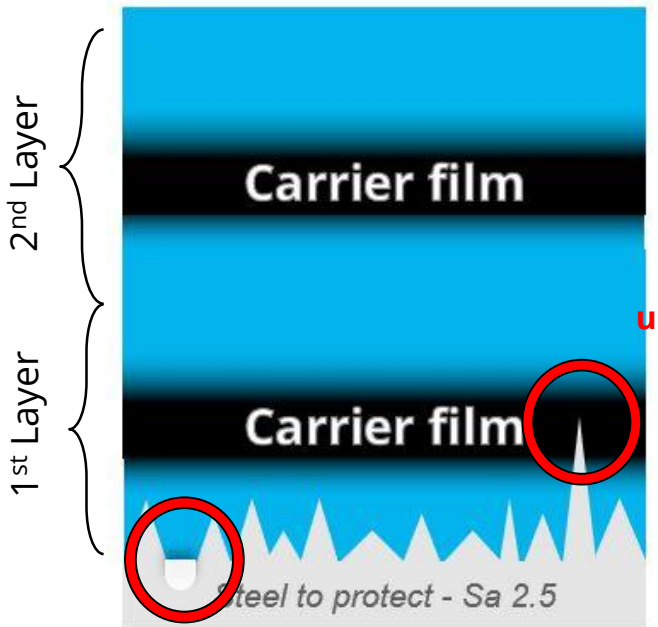
No Penetration of macromolecules between layers: **Long-term properties**, after aging, are significantly **reduced**.

3-Ply Tapes - Asymmetrical vs. Symmetrical

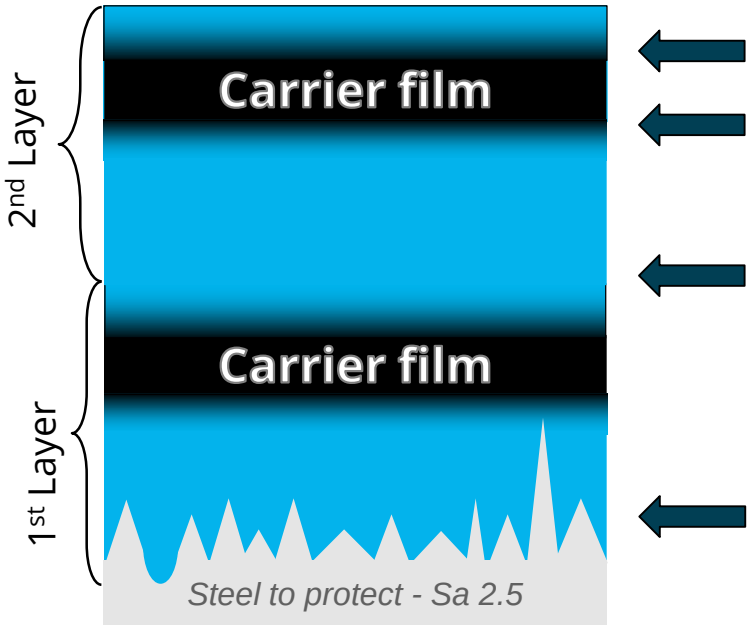
Asymmetrical:



Symmetrical:



3-Ply Tapes - Coextruded & Asymmetrical



Strong Chemical bonds:

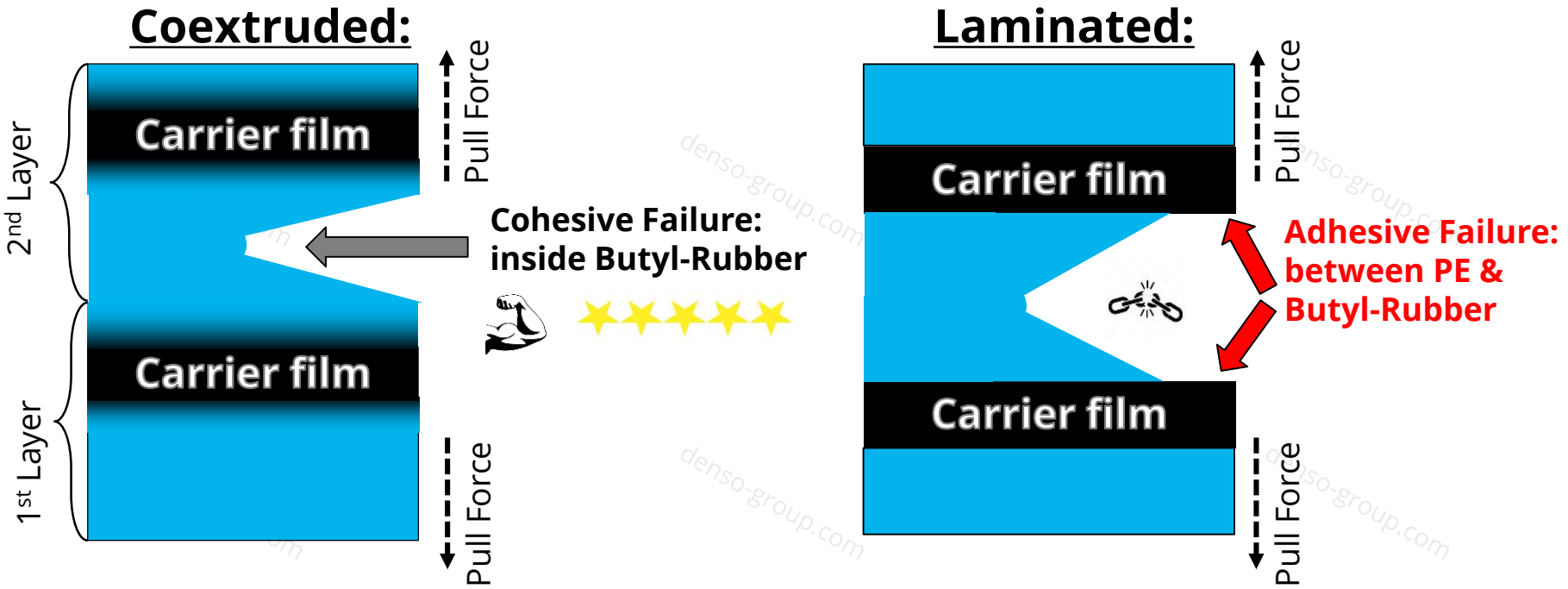
- Carrier film & Butyl Rubber
- Butyl Rubber & Butyl Rubber

Best Steel Coverage

Favorite Combination

5. Comparison of Material Properties

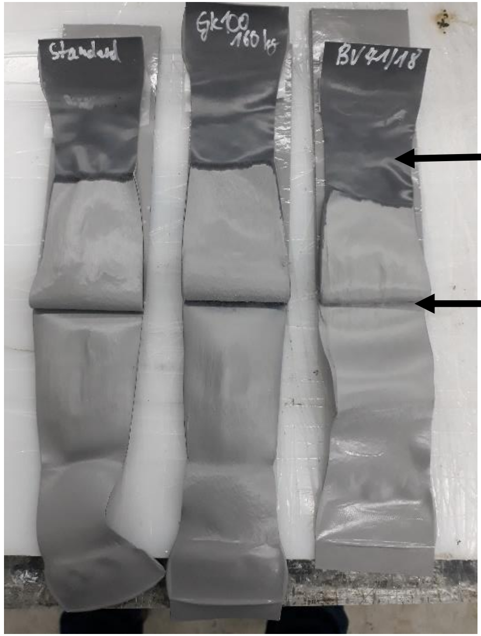
3-Ply Tapes - Layer to Layer adhesion



Certain risk of delamination with laminated tapes only.

3-Ply Tapes - Layer to Layer adhesion

3-Ply coextruded Butyl Rubber/PE:



Pull Force

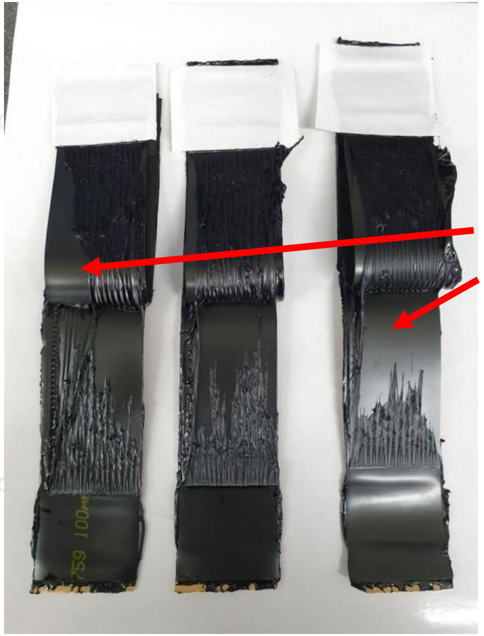
Elongation of PE

Cohesive Failure: inside Butyl-Rubber

★★★★★

Pull Force

2-Ply laminated Bitumen/PVC:



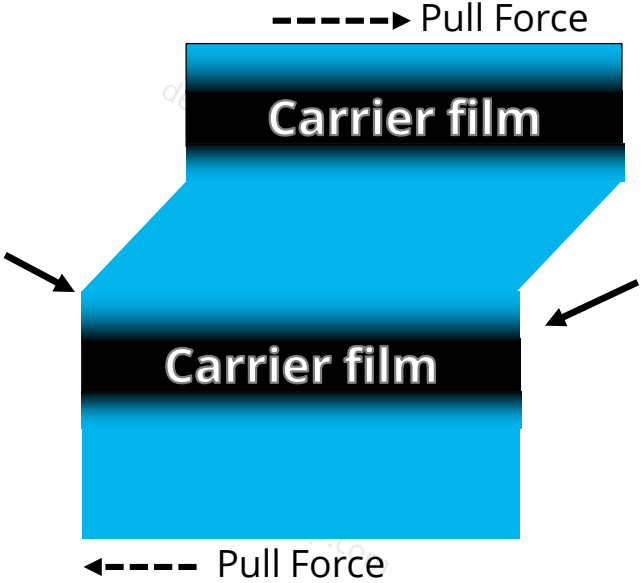
Pull Force

Adhesive Failure: between PVC & Bitumen

Pull Force

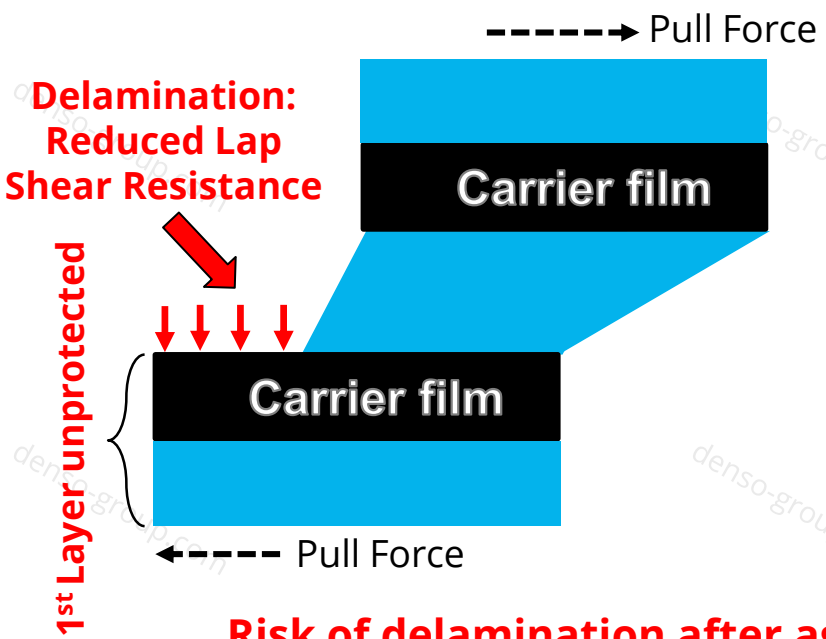
3-Ply Tapes - Lap Shear Resistance

Coextruded:



No delamination:
High Lap Shear Resistance

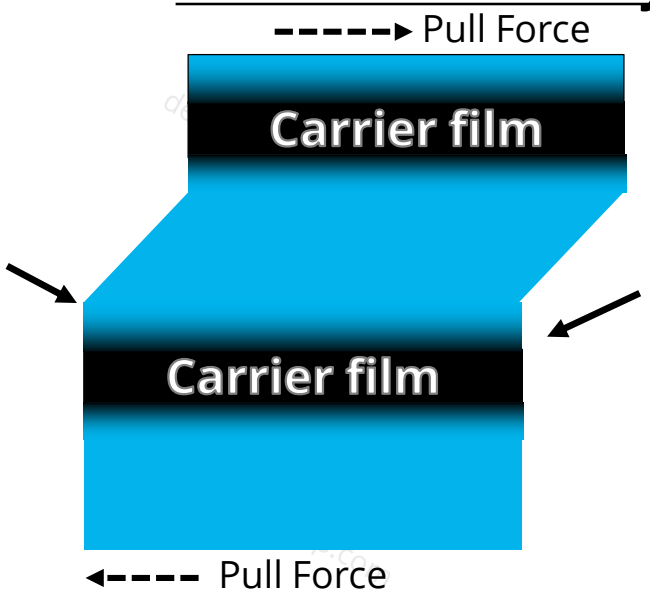
Laminated:



Risk of delamination after aging with laminated tapes only

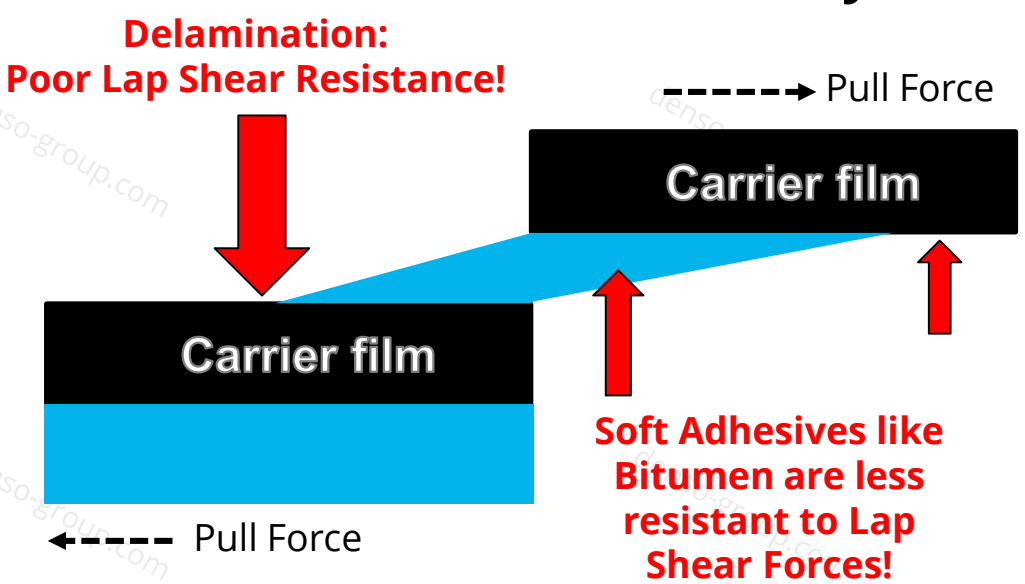
3-Ply vs. 2-Ply Tapes - Lap Shear Resistance

Coextruded – 3-Ply:



No delamination:
High Lap Shear Resistance!

Laminated – 2-Ply:



High Risk of delamination with laminated 2-Ply tapes!

Bad performance of laminated 2-Ply-Tapes

Poor Lap Shear Resistance: Poor Soil Stress Resistance

Overview of Tape Properties

Tape Properties	Real Coextruded 3-ply Tapes	Laminated 3-ply Tapes	Laminated 2-ply Tapes
Long term performances (ageing)	High	Low	Low
Layer-to-layer adhesion	Higher than EN-ISO	EN-ISO	Poor
Layer-to-layer failure mode	100% Cohesive	Adhesive-Cohesive	Adhesive
Lap Shear Resistance	Higher than EN-ISO	EN-ISO	Poor
Spiral Corrosion Risk	Very Low	Low	Very High
Equal Thickness	Perfectly uniform	Less uniform	Less uniform
Steel Coverage	Excellent	Limited	Limited
Flexibility at low temperature	Excellent	Poor	Poor

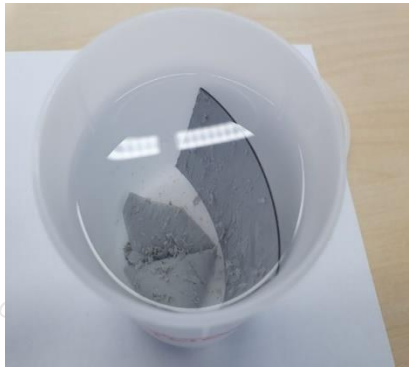
6. How to simply test Coextrusion - Lamination

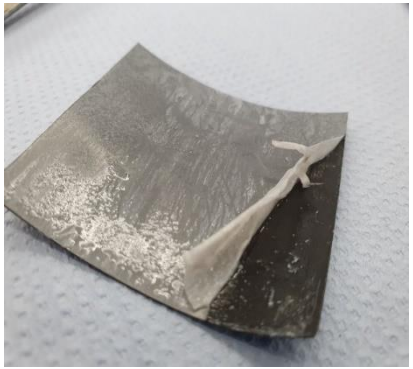
Petrol Immersion Test
Coextrusion - Lamination

Petrol Immersion : 2-Ply or 3-Ply tape for minimum 2 hours

- Residual adhesive is easily removed, Carrier film is smooth or glossy: **Lamination**
- Residual adhesive can only be removed with strong mechanical devices: **Coextrusion**

Adhesive easily removed: **Lamination**





Adhesive difficult to remove: **Coextrusion**

7. Long term experiences DENSOLEN®-3-Ply Tapes

Reference: Energienetz Bayern (Germany)

Energienetz Bayern GmbH (Munich/Germany)
Pipeline network of 9.500 km

<u>Moosburg – Straubing Pipeline</u>

- Year of Construction: 1976
- Used corrosion protection:
  coextruded DENSOLEN® 3-ply PE/Butyl-Tapes.
- Year of Excavation: 2015
  (after **39 years** in operation)

<u>*Field joint coating assessment after 39 years*</u>:

- No failure – No corrosion
- *Peel strength*: ≥1,83N/mm* – Cohesive break

**Requirements of EN 12068: ≥1,00N/mm*

Reference: Gascade STEGAL (Germany)

Gascade Gastransport GmbH - Germany
Pipeline network of 2.900 km

<u>36-inch STEGAL Pipeline</u>

- Year of Construction: 1992
- Used corrosion protection:
  coextruded DENSOLEN® 3-ply PE/Butyl-Tapes.
- Year of Excavation: 2012
  (after **20 years** in operation)

Field joint coating assessment:

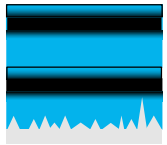
- No failure – No corrosion
- *Peel strength*: 6,40N/mm*
- Cohesive break: Res. Thick: 344 microns

**Requirements of EN 12068: ≥1,00N/mm*

8. Conclusions

Real Coextruded 3-Ply Tapes

- Self-amalgamation = "*Impermeable* ***Hose type coating***".
- **No spiral corrosion**.
- Best steel coverage.
- Superior **Layer to Layer adhesion**.
- Superior **Lap Shear Resistance**
  = "*Superior Soil Stress Resistance*".
- Excellent **long-term expectancy**
  proven by Coating Inspections.
- No other tape coating has a longer **proven track record in field**.



Conclusion

- **Tape Structure matters:**
  - 3-ply Tapes create a hose-like coating.
  - 2-ply Tapes risk to fail as corrosion prevention tape.
- **Tape Material matters:**
  - PE/Butyl-Rubber is superior to i.e. PVC/Bitumen.
  - PE/Butyl-Rubber successfully proven in field for decades!
- **Production Technology matters:**
  - Real Coextrusion is the superior production technology.
  - Laminated layers risk to fail on long term.

Thank you for your attention!

If you have any further questions please contact us!

Contact:
Michael Schad
Head of Sales International
Phone: +49 214 2602 260
Mobile: +49 171 77 88199
Mail: michael.schad@denso-group.com

denso-group.com

made in Germany since 1922