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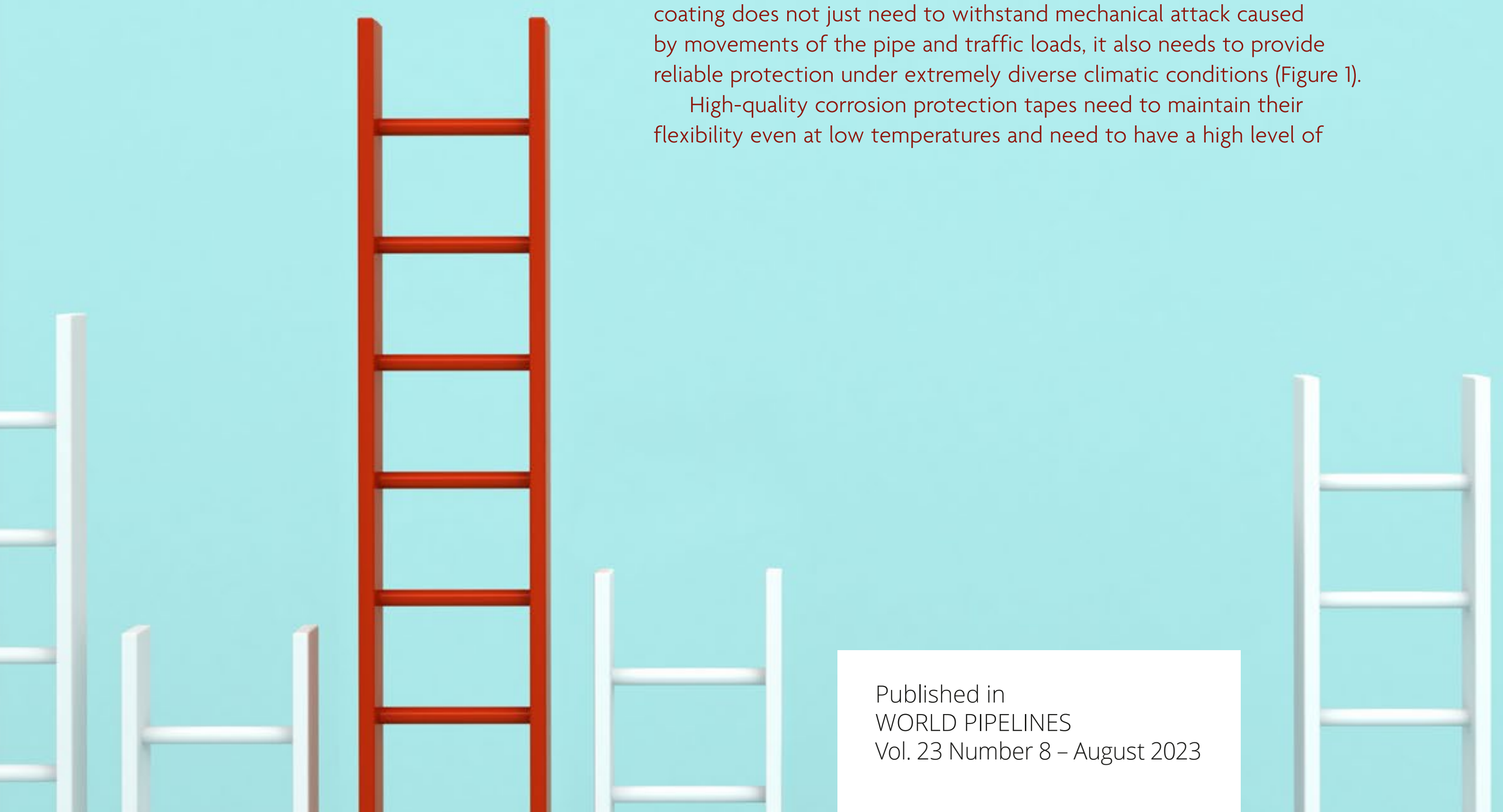
BITUMEN VS BUTYL: WHICH IS SUPERIOR?

Thomas Kaiser, Managing Director, DENSO Group Germany, considers whether PVC/bitumen or PE/butyl rubber is better suited for use in corrosion protection tapes.

Cold-processed polymer tapes are used all over the world either as welded joint coatings or complete pipe coatings for rehabilitation. For decades, there have been two different product designs, namely PVC/bitumen and PE/butyl rubber. But are these two versions equally well suited for use in corrosion protection tapes? Or is there a combination of materials that is more resistant and that can therefore provide the pipe with better long-term corrosion protection? Comparing the fundamental material properties of PVC/bitumen and PE/butyl rubber makes it crystal clear.

During installation and subsequent operation of the pipelines, the coating does not just need to withstand mechanical attack caused by movements of the pipe and traffic loads, it also needs to provide reliable protection under extremely diverse climatic conditions (Figure 1).

High-quality corrosion protection tapes need to maintain their flexibility even at low temperatures and need to have a high level of



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impact resistance. The material needs to be thermally stable and elastic, allowing it to react to an applied force before failing (plastic deformation). Looking at these requirements more closely shows a significant difference in the intrinsic material properties of PVC/bitumen and PE/butyl rubber.

Bitumen is only used in two-ply tapes

First, the way in which cold-processed polymer tapes are fundamentally structured is of key importance. While PVC or PE are used as the backing layer, bitumen or butyl rubber are used for the coating layer that bonds to the pipe after the tape-coating has been applied. It's important to note that bitumen is only used in two-ply tapes. There is no such thing as high-quality, three-ply tapes that have bitumen as the coating material. Three-ply corrosion protection tapes feature a stabilising PE carrier film with a coating on both sides that is only ever made from butyl rubber. This is an important first indication for the assessment of material suitability.

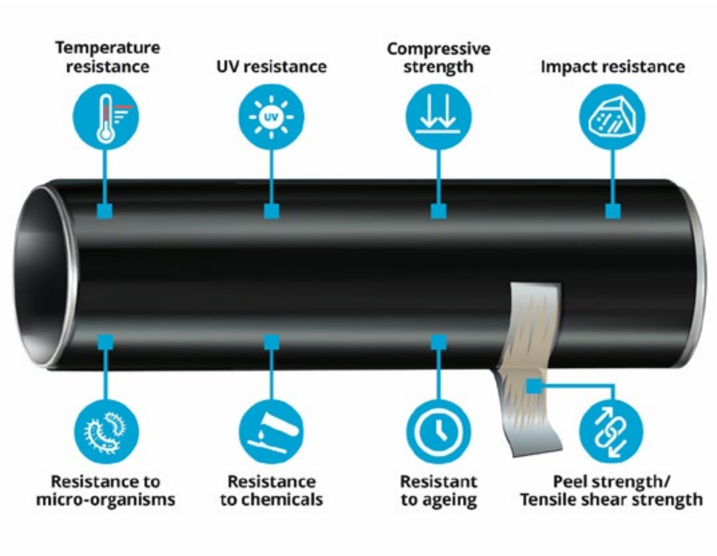

Figure 1. Loads affecting the pipe coatings.

Figure 2. Cracks in the coating due to aged bitumen.

PVC: ageing effect by exuding additives

In order to use polyvinyl chloride (PVC) as a layer or film for corrosion prevention, additives are added to the hard and brittle material to make it soft and thermally stable. Thanks to these additives, which have a material share of up to 40%, PVC is flexible down to -18˚C (-0.4°F). The problem with this, however, is that the additives, and above all the plasticisers, are not stable, but instead are lost again over time. An ageing effect occurs as a result of exudation, meaning the carrier material becomes brittle and cracks occur in the material.

This is also problematic from a corrosion-protection perspective. If PVC is exposed to higher temperatures, dehydrochlorination (i.e. the separation of hydrogen chloride) occurs from 80˚C (176°F). If this gas comes into contact with water, this will form hydrochloric acid, which is not only corrosive but also toxic. In order to curb or prevent this process, further additives such as thermal or UV stabilisers are also added to the material. Another detrimental effect is the risk posed to people and to the environment. If plasticisers get into the environment, this can lead to significant pollution of our groundwater. The source material for PVC, vinyl chloride, is also carcinogenic to humans.

In summary, PVC is less suitable as a base material for polymer tapes, because thermal stabilisers and plasticisers need to be added to the intrinsically hard material in order for it to be used in corrosion prevention. Because these additives do not have long-lasting resistance, a backing layer or carrier film made from this material would age and become brittle.

PE: flexible and temperature-resistant

Unlike PVC, polyethylene (PE) is flexible down to -40˚C (-40 °F) without any additives. As a material, it is very elastic while also being tough, so it can be deformed without breaking. These are important properties when filling a pipe trench, for example, when forces have an impact on the pipeline from the outside. PE also absorbs less water than PVC, does not require any thermal stabilisers, and has good insulating properties due to its high level of electrical resistance.

The properties of PE are temperature resistance up to almost 100˚C (212°F), good flexibility at low temperatures, and exceptional chemical and impact resistance. It also has outstanding tensile strength, is insoluble in organic solvents and does not crack under tension.

In conclusion, the fundamental properties of PE mean that the material is very well-suited for corrosion prevention tapes. Whereas PVC only achieves the desired properties with the addition of additives, PE already has these properties. Therefore, the evaporation of the additives, the resulting material ageing and the health risks seen with PVC do not apply to PE.

Bitumen: structural ageing unavoidable

When bitumen is used as a coating material for pipelines due to its adhesive properties, corrosion prevention experts often

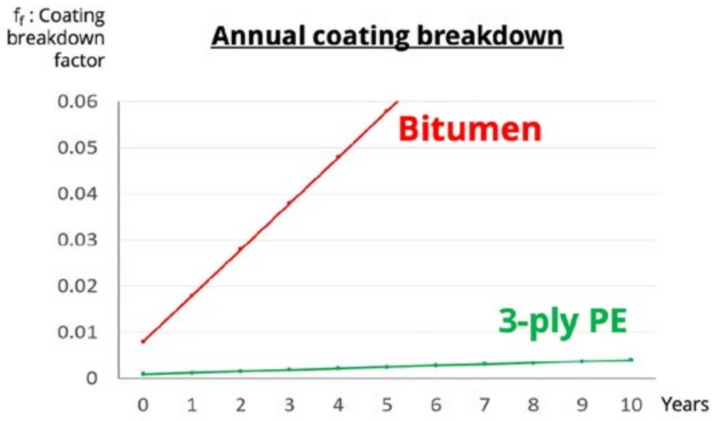

Figure 3. Annual coating breakdown.

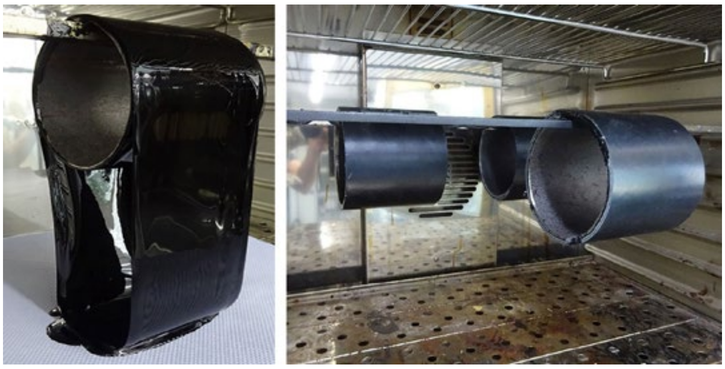

Figure 4. Material behaviour of PVC/bitumen tape (left) vs PE/butyl rubber tape (right).

Properties	PVC	Bitumen	PE	Butyl-Rubber
Lower temperature operating range	-18 °C (-0.4 °F)	-50 °C (-58 °F)	-40 °C (-40 °F)	-67 °C (-88.6 °F)
Upper temperature operating range	+80 °C (+176 °F)	+100 °C (+212 °F)	+100 °C (+212 °F)	+100 °C (+212 °F)
Electrical Resistance	10^{11} Ω cm		10^{16} Ω cm	
Water absorption	0.20 – 1.00 %		0.02 – 0.06 %	
Ageing	Poor	Poor	Stable	Stable
Effect	Cracks	Porous	HWI & Ageing tests	
CONCLUSION	X		✓	

Figure 5. Comparison of the properties of PVC and bitumen vs PE and butyl rubber.

Figure 6. Cohesive separation pattern of a DENSOLEN® PE/butyl tape after 40 years of project use.

discover pipelines have to be repaired after a short period because the bitumen has become hard, brittle and porous.

But why is this process unavoidable? The problem occurs due to the structural ageing of bitumen. In order to know why this happens, it's important to understand the chemical composition of bitumen.

Bitumen has what is known as a colloidal structure. A colloidal system, or colloid for short, refers to the fine distribution (dispersion) of a substance into another homogeneous and continual medium (dispersion medium).

The colloidal structure in bitumen is divided into a disperse phase (asphaltenes) and a coherent phase (maltenes). The asphaltenes (solid phase) are surrounded by oil resins, and form the micelles in the colloidal system. The temperature-sensitive maltenes (oily phase) are comprised of the oil resins and oils: in their original state, the asphaltene micelles are completely distributed and do not interact. But when bitumen ages, the micelles expand due to oxidation whereas the maltenes evaporate. The micelles clump together, form chain structures and take up a lot more space. During the ageing process, the solid phase gets bigger and bigger while the soft (oily) phase disappears. This results in the bitumen becoming hard, brittle and porous.

In summary, bitumen's weakness is its structural ageing, as shown in Figure 2. The speed of the ageing process depends on the temperature and the source of the crude oil. The addition of additives (polymers) can slow down the process but can't stop it altogether. The result is a porous coating and cracks.

Butyl rubber: age and weather resistant

Butyl rubber is barely permeable to air, gases and moisture, and maintains its elastic properties even at very low temperatures, making it suitable for use down to -67˚C (-88.6°F). It is also resistant to ageing and weathering, suitable for use at very high temperatures, and has very good hardness and tensile strength characteristics.

The properties of butyl rubber are temperature-resistance up to almost 100˚C (212°F), and outstanding acid resistance. It is a flexible and malleable material, typically used for mastic, adhesive and sealants.

In conclusion, due to its fundamental material properties, butyl rubber is very well-suited for corrosion prevention tapes. If the comparison of the backing layer or carrier films found PE to be superior to PVC, then butyl rubber is superior to bitumen as a coating material. Whereas butyl rubber is resistant to ageing, the ageing process of bitumen itself cannot be stopped by the addition of additives. This results in the pipeline becoming porous in the long-term and needing to be repaired.

Durability and load resilience comparison

The problem of porosity in pipeline coatings is measured by their degradation and recorded by a coating breakdown factor (f_f). Comparing coatings made from bitumen with those made from three-layer PE (3LPE) shows that the degradation factor of bitumen is much higher than that of 3LPE even right from the start, i.e. immediately after the coating is applied. The degradation of the bitumen coating reaches 25 times that of a 3LPE coating after just five years, as shown in Figure 3.

The different behaviour of the different material combinations at higher temperatures has been recreated at 75˚C (167°F) during tests: the PVC/bitumen tape no longer offers any protection after just 26 hours, whereas the PE/butyl rubber tape remains dimensionally stable and in perfect condition even after 100 days in storage (see Figure 4).

PE/butyl rubber: the more reliable option

From a historical perspective, tapes made from PVC/bitumen were initially a good choice because they could be given the properties necessary for corrosion prevention by the inclusion of additives. For longer-term project use, however, the product design is less suitable due to the problem of ageing and the increased level of environmental pollution: PVC requires plasticisers and stabilisers, which disappear as the product ages. Bitumen suffers from structural ageing, which makes it become hard, brittle and porous. PE/butyl rubber, on the other hand, already has the required properties and maintains them even over extended periods. PE is flexible and thermally stable, and does not require any additives. Butyl rubber has proven itself to be a stronger and more stable sealing adhesive. This product combination is undoubtedly more resistant, thereby providing the pipe with better long-term corrosion prevention (as shown in Figure 5).

Tried and tested over 50 years

In 1973, DENSO invented the world's first co-extruded three-ply tape using PE/butyl rubber. The 50-year anniversary isn't just a good time to highlight the material properties, but also a great opportunity to assess the long-term resistance of DENSOLEN® tapes in practice. A section of pipeline from the Isarschiene high-pressure natural gas pipeline in Germany, which was installed in 1976, represented a unique opportunity to put the tapes to the test. The section demonstrated very good bonding properties in the peel tests, even after 40 years of operation, as shown in Figure 6. The excellent quality of the DENSOLEN tapes was further emphasised by the cohesive separation pattern. The current standard requirements for corrosion prevention coatings were exceeded, even after four decades of use. PE/butyl rubber tapes are therefore able to prove their excellent suitability for corrosion prevention in practice too.

In the past ten years alone, DENSOLEN PE/butyl tapes have been successfully used over a square-meter area in the double-digit million range. The range of DENSOLEN tapes now includes 242 different products and is sold in over 60 countries. The DENSOMAT® wrapping devices have also been ensuring the simple, safe and efficient application of all DENSO tapes and tape systems for 50 years. They help the processor to consistently maintain the correct winding tension and the required overlapping width while doubling the processing speed compared to manual wrapping. The DENSOMAT wrapping devices have impressively proven their outstanding quality in major projects involving 24 hours of continuous application. All round the world, they are synonymous with high processing quality and cost-effective application.