(19) DANMARK

(10) DK/EP 2937214 T3

(12) Oversættelse af europæisk patentskrift

Patent- og Varemærkestyrelsen

(51) Int.Cl.: ***B 32 B 7/12 (2006.01)*** ***B 32 B 1/08 (2006.01)*** ***B 32 B 27/08 (2006.01)*** ***B 32 B 27/12 (2006.01)*** ***B 32 B 27/30 (2006.01)*** ***B 32 B 27/32 (2006.01)*** ***B 32 B 27/34 (2006.01)*** ***F 16 L 55/165 (2006.01)*** *E 03 F 3/06 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2022-05-09**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2022-02-09**

(86) Europæisk ansøgning nr.: **15167035.3**

(86) Europæisk indleveringsdag: **2013-12-10**

(87) Den europæiske ansøgnings publiceringsdag: **2015-10-28**

(30) Prioritet: **2012-12-10 DE 102012112024** **2013-01-11 DE 102013100272**

(62) Stamansøgningsnr: **13196518.8**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(54) Benævnelse: **INDFØRINGSSLANGE TIL UDGRAVNINGSFRI KLOAKRØRSRENOVATION**

(56) Fremdragne publikationer:
EP-A1- 0 592 732
EP-A1- 2 725 277
WO-A1-2010/075946
DE-A1-102010 023 764
US-A- 4 954 393
US-A1- 2006 048 834
US-B1- 6 210 765

[0001] The invention refers to an insertion hose (insertion tube) for trenchless sewage pipe rehabilitation by means of a pipe lining method.

[0002] The areas of application for films keep expanding. Among the areas of application, in which films with olefin homo- or copolymers are used, for example, is the tube lining process for trenchless sewage pipe rehabilitation. Here a pipe liner (also known as insertion hose or just liner) in the glass fiber pipe liner system with UV- or steam curing has typically an inner and outer tube. Between them, the glass fiber carrier material impregnated with reactive plastic resin is introduced. Examples of reactive plastic resins being used are commercially available UP resins (polyester and unsaturated polyester resins), VE resins (vinyl ester resins) or EP resins (epoxy resins). The curing of the resins is done in the case of the UP or VE resins with the help of photoinitiators, for example, but can also be done thermally.

[0003] The insertion tube (insertion hose) or pipe liner is inflated inside the pipe until it adheres to an external wall so the resin can subsequently be cured, for example, with UV light from a light source being pulled slowly through the pipe. At the end, the inner film of the insertion tube is peeled off and removed. The layer with the carrier material is then exposed to the substances that will flow through the pipe.

[0004] Often, the pipe liner – especially in the synthetic fiber pipe liner system with warm water or steam curing – does not make direct contact with the pipe's inner wall. Rather, a preliner (also known as preliner film), i.e. a thick-walled film lining the pipe completely, knowingly made of high-density polyethylene (HDPE), is introduced into the pipe to be renovated and placed tightly against the pipe's inner wall. Afterwards, the pipe liner is drawn (drawing-in process) or inverted (inversion process) into the pipe. The preliner prevents, for example, the plastic resin of the pipe liner from adhering to the pipe wall and dirt and water from making contact with the insufficiently cured resin. Furthermore, the preliner film also prevents the resin from leaking out of the sewage pipe rehabilitation system and contaminating the soil and ground water. The preliner film also protects the feeds from penetrating excess resin so no resin plugs and obstructions can form.

[0005] In the drawing-in process, a preliner can also have a similar function as known sliding films for the pipe liner to be drawn in. In this case, the low coefficient of friction between the sliding film and the external film of the pipe liner is essential. As a result of this, the insertion tube or pipe liner is not damaged by the inner wall of the pipe or objects inside the pipe when it is inserted into it; on the other hand, the friction between pipe liner and sliding film is very low and facilitates an insertion of the pipe liner.

[0006] A known preliner film that is very frequently used is known by the brand name of Valeron®. The extremely large mechanical stability of this film results from the cross-linking of two stretched HDPE layers running perpendicularly to one another. The stretching makes the film lose its elasticity and as a result of that, it acquires better tear resistance. The two transversally running layers ensure that the film will be equally resistant in all directions and particularly highly tear and puncture resistant. In addition, a single hole or tear that occurs will not keep expanding owing to the structure of the layer, because reduced film elasticity also results in high puncture resistance.

[0007] One disadvantage of the Valeron HDPE film mentioned above often used as preliner is that it cannot be easily turned inside out during the inversion procedure because of its very high inherent stiffness. Moreover, the Valeron film is not available in tubular shape owing to the way it is manufactured, so it must be sealed. However, since the film layers are oriented and stretched, the film cannot be sealed so easily. For this reason, it is necessary but undesirable to use a thermally-activated adhesive (e.g. hot melt) to seal the Valeron film. When doing so, the film overlaps the surface area to be sealed by about 3 to 5 cm, so that the seam or overlapping of the film in this location creates many problems during inversion. The disadvantage of such sealing lies not just in the additional and costly production step but particularly in the risk that the sealing seam will be porous. Therefore, if the sealing is incomplete, water can penetrate through the preliner foil from outside and greatly interfere with the curing of the resin. Another disadvantage of the Valeron film is its high affinity to the resins used and this manifests itself in clear resin adherence. This makes it very difficult to invert the pipe liner in the synthetic fiber pipe liner system, for example, in which the resin-impregnated side makes contact with the preliner. Finally, the Valeron film exerts virtually no barrier effect against the monomers and oils used in the resin. Consequently, a migration of noxious substances to the groundwater cannot be prevented.

[0008] An insertion tube is known from the subsequently published EP 2 725 277 A1, whose inner tube (or tubular) film has a three-layer structure with two outer layers based on polyamide and a core layer of thermoplastic elastomer. DE 10 2010 023764 A1 discloses an insertion tube comprising an inner tubular (tube) film in the form of a multilayer film, an outer film in the form of a tubular film, and a carrier material arranged between these two tubular films and impregnated with a reactive plastic resin, the inner tubular film containing at least one layer of a homo- or copolyamide and at least one layer of a thermoplastic, optionally modified, olefin homo- or copolymer.

[0009] It is the task of this invention to provide a film in an insertion tube that will comply with the high demands with regard to its mechanical stability with simultaneous high flexibility. It should also be possible to offer such a film without a seam, preferably in tubular form, so a seam-shaped predetermined breaking point can be prevented. Here, the goal is to limit as much as possible the film's affinity to the resins used and in particular its adherence to them. Apart from that, a film that is a very good barrier against monomers and oils should be made available.

[0010] This task is solved by the insertion tube according to claim 1. The inner tube film of the insertion tube according to the invention has at least one layer (a) – preferably forming one of the film's outer layers – that contains at least a homo- or copolyamide (hereinafter abbreviated as PA) in a proportional weight expressed in percent that exceeds 25% by weight. In addition, the film according to the invention has at least one layer (c) which comprises at least one thermoplastic elastomer. Additionally, the inner tube (or tubular) film according to the invention has at least one layer (b) wherein this further layer (c) comprises at least one thermoplastic, optionally modified, olefin homo- or copolymer.

[0011] The advantages of the invention can be seen especially in the fact that inner tube films according to the invention have good mechanical properties such as sturdiness, resistance and puncture resistance with relatively low inherent stiffness. Non-sealed inner tube films according to the invention that can be turned inside out very well during the inversion procedure in trenchless sewage pipe rehabilitation, for example, and that are also highly leak-proof against water penetration or monomer leakage from the resin of an insertion tube or pipe liner can also be made. The inner tube films according to the invention boast an overall outstanding barrier against monomers and oils and this significantly limits adherence to the resin.

[0012] Within the meaning of this invention, the term "tubular film" (or “tube film”) is a seamless, multilayered film manufactured by (co-)extrusion, preferably by blown film (co-)extrusion.

[0013] The multilayered inner tube film according to the invention contains at least one polyamide layer having more than 25% by weight. It can be a homo- and/or copolyamide or mixtures of various polyamides. Suitable homo- or copolyamides are preferably selected from the group of thermoplastic aliphatic, partially aromatic or aromatic homo- or copolyamides. These homo- or copolyamides can be manufactured from diamines, such as aliphatic diamines having 2-20 carbon atoms, especially hexamethylene diamine and/or aromatic diamines having 6-10 carbon atoms, especially p-phenylenediamines, and from aliphatic or aromatic dicarboxylic acids having 6-20 carbon atoms such as adipic acid, terephthalic acid or isoterephthalic acid, for example. Furthermore, homo- or copolyamides can be made from lactams having 4-20 carbon atoms, such as ε-caprolactam, for example. Polyamides that can be used according to the invention are preferably PA 6, PA 666, PA 12, PA 11, PA 66, PA 610, PA 612, PA 6I, PA 6T or corresponding copolymers or mixtures from at least two of the mentioned polyamides. Preferably, the at least one layer (a) of the inner tube film according to the invention contains more than 50% by weight, preferably more than 75% by weight, preferably more than 95% by weight and very preferably largely or approximately (i.e. almost or fully) 100% by weight of homo- or copolyamide.

[0014] The at least one layer (b) contains preferably more than 20% by weight, especially preferably more than 40% by weight and up to100% by weight of thermoplastic olefin homo- or copolymer.

[0015] Within the meaning of this invention, olefin homo- or copolymers are thermoplastic polymers of α,ß-unsaturated olefins having two to six carbon atoms, such as polyethylene (PE, especially LDPE or HDPE), polypropylene (PP), polybutylene (PB), polyisobutylene (PI) or mixtures from at least two of the mentioned polymers, for example. "LDPE" is low density polyethylene that has a density in the range of 0.86-0.93 g/cm^3 and is characterized by a high degree of molecular branching. "HDPE" is high density polyethylene whose molecular chains only have few branches and its density can lie between 0.94 and 0.97 g/cm^3.

[0016] The olefin homo- or copolymer is preferably polyethylene (PE), preferentially used in form of high density polyethylene (HDPE), but LDPE and/or LLDPE (linear low density polyethylene) can also be advantageously used. Also suitable are polyolefins, particularly polyethylenes polymerized with metallocen catalysts (mPE), such as mLDPE (metallocen LDPE) and mLLDPE (metallocen LLDPE). Polyethylene is classified into different categories, mainly with regard to its density and branching. Its mechanical properties depend considerably on variables such as the length and type of branching, crystalline structure and molecular weight. The most widely sold polyethylenes are HDPE, LLDPE and LDPE. Specifically, the order looks like this:

- Ultra high molecular weight polyethylene (UHMWPE)
- Ultra low molecular weight polyethylene (ULMWPE or PE-WAX)
- High molecular weight polyethylene (HMWPE)
- High density polyethylene (HDPE)
- High density cross-linked polyethylene (HDXLPE)
- Cross-linked polyethylene (PEX or XLPE)
- Medium density polyethylene (MDPE)
- Linear low density polyethylene (LLDPE)
- Low density polyethylene (LDPE)
- Very low density polyethylene (VLDPE)
- Chlorinated polyethylene (CPE)

[0017] VLDPE (very low density polyethylene) is defined by a density range from 0.880 to 0.915 g/cm^3. It is largely a linear polymer with a high proportion of short side chains, typically manufactured by linear copolymerization of ethylene with short-chained alpha olefins (e.g. 1-butene, 1-hexene, and 1-octene). VLDPE is manufactured very frequently using metallocen catalysts because they allow the incorporation of more co-monomers.

[0018] In accordance with another advantageous alternative, polypropylene (PP) is used as olefin homo- or copolymer.

[0019] Mixtures from various olefin homo- or copolymers are easily possible in the least one layer (b) mentioned, including the ones listed above.

[0020] The at least one layer (c) of the inner tube film preferably has more than 20% by weight, especially preferably more than 40% by weight and up to 100% by weight of a thermoplastic elastomer (TPE).

[0021] The at least one layer (c) contains as thermoplastic elastomer (TPE), in accordance with a preferred embodiment, thermoplastic polyurethane (TPU), i.e. a thermoplastic elastomer made of urethane (also known as TPE-U). Examples of it are Desmopan, Texin and Utechllan made by Bayer. Other examples are the products available under the trade names Elastollan, Estane, Morthane, Pellethane, Pearlthane, Skythane or Tecoflex.

[0022] Other TPE substances can be advantageously used as well,
in which case the following groups are differentiated in addition to TPU and TPE-U:

- TPE-O or TPO = Olefin-based thermoplastic elastomers, mostly PP/EPDM, e.g. Santoprene made by AES/Monsanto;
- TPE-V or TPV = Olefin-based cross-linked thermoplastic elastomers, mostly PP/EPDM, e.g. Sarlink made by Teknor Apex, Forprene made by SoFter;
- TPE-E or TPC = Thermoplastic polyester elastomers / thermoplastic copolyesters, e.g. Hytrel made by DuPont or Riteflex made by Ticona;
- TPE-S or TPS = Styrene block copolymers (SBS, SEBS, SEPS, SEEPS and MBS), e.g. Styroflex made by BASF, Septon made by Kuraray or Thermolast made by Kraiburg TPE;
- TPE-A or TPA = Thermoplastic copolyamides, e.g. PEBAX made by Arkema.

[0023] TPE silicon, made by Wacker and available under the trade name Geniomer, can also be used. Geniomer ® is a copolymer made of polydimethylsiloxane and urea and combines the good processing properties of an organic thermoplast with some typical silicone properties. Thus, Geniomer® has a property profile that so far could not be manufactured in this way neither with thermoplasts nor with silicones.

[0024] The TPE layer according to claim 1 can be specially structured as every one of the three layers (1), (2) and (3) described in EP 1 145 847 A1.

[0025] Preferably, the inner tube film according to the invention has at least one additional layer executed as adhesive promoter layer (d) (abbreviated AP). This adhesive promoter layer

(d) can – depending on the presence of the different layers and on the embodiment – be arranged between two layers (a), between one layer (a) and one layer (b), between two layers (b), between one layer (a) and one layer (c), between one layer (b) and one layer (c), or between two layers (c). To manufacture the adhesive promoter layer(s) mentioned above, conventional adhesive promoters can be used. Preferably, the adhesive promoter layer(s) is/are made independently from one another of at least one modified thermoplastic polymer, preferably of at least one modified olefin homo- or copolymer. The same olefin homo- or copolymers mentioned above can be used as olefin homo- or copolymers for this, only modified. Especially preferably, the adhesive promoter layer(s) is/are made independently of one another from at least one modified ethylene homo- or copolymer and/or at least one modified propylene homo- or copolymer modified with at least one organic acid or at least one preferably cyclical organic acid anhydride, preferably with maleic anhydride. Even ethylene vinyl acetate, ethylene vinyl alcohol (EVOH) and ethylene (meth)acrylate copolymers, in modified or non-modified form, are ideally suited to be adhesive promoters.

[0026] The adhesive promoter layer(s) of the multilayered film according to the invention has/have preferably, independently from one another, a layer thickness of 1 µm to 30 µm, very preferably from 2 µm to 20 µm.

[0027] In an advantageous embodiment of the inner tube film according to the invention, both external layers are executed as layer (a), in which case these two external layers consequently contain in each case at least one homo- or copolyamide with a proportional weight expressed in percent exceeding 25% by weight.

[0028] It is especially preferable if the polymers in the inner tube film are cross-linked by irradiation with beta or gamma rays. Irradiation cross-linking can impart the plastics typically used with the mechanical, thermal and chemical properties of high-performance plastics. The beta or gamma rays used here trigger cross-linking reactions in the polymers. Cross-linking is possible with olefin homo- or copolymers, homo- or copolyamides and also with thermoplastic elastomers. Irradiation cross-linking is easy, economical and flexible. The acceleration voltage can be between 25 and 25 kV, with an intensity between 5 and 500 kGy. Penetration depth is at least 1 µm, so the entire thickness of films and composite films can be penetrated.

[0029] Here, irradiation cross-linking between polymers can be done within one layer and/or between polymers of two adjacent layers, which leads to a stronger lamination between these layers.

[0030] Cross-linking of films by means of electron irradiation (□ rays), a well- known technique, has been described, for example, in the article "Electron Beam Technology for Converting Applications" by Stephen C. Lapin, Radtech Report; 23, 5; S. 44-47; 2009. Various kinds of information about irradiation cross-linking have also been published in *www.bgs.eu/strahlenvernetzung.html* by BGS Beta-Gamma-Service GmbH & Co. KG and in *www.ebeam.com/markets.php?.section=cross* by the Energy Sciences Inc. Co. of Wilmington, MA, USA. The content of these documents is explicitly included in this disclosure.

[0031] The inner tube film according to the invention has, in a advantageous embodiment, a thickness of 20 to 2000 µm, preferably of 40 to 1000 µm, very preferably of 60 to 400 µm and especially of 80 to 250 µm.

[0032] According to a preferred embodiment, the at least one layer (b) of the inner tube film according to the invention contains an olefin homo- or copolymer and/or – if present – a layer (d) intended as adhesive promoter layer with at least one ethylene (meth)acrylate copolymer in functionalized or non-functionalized form. The proportional weight expressed in percent of the at least one ethylene (meth)acrylate co-polymer lies in this case preferably in the range from 0.1 to 100% and is preferably at least 30% by weight. As a result of this, even better elasticity until the film splices or bursts can be achieved.

[0033] Preferably, the inner tube film according to the invention contains – depending on the specific application – one or several of the following substances in at least one of the film layers: polystyrene (PS); polyhalogenides such as PVC and/or polyvinylidene chloride (PVdC); ethylene vinyl alcohol copolymer (EVOH), polyvinyl alcohol (PVOH or PVAL), adhesive promoter, ethylene vinyl acetate (EVAc); one or several ionomers; one or several poly (meth)acrylates; poly (meth)acrylates containing ethylene, polyvinyl acetate (PVAc); polycarbonate (PC); polyacryl nitrile (PAN); additional polyesters such as polybutylene terephthalate (PBT), polyethylene naphthalate (PEN), polylactic acid (PLA) and/or polyhydroxyalkanoate (PHA); one or several ethylene acrylic acid copolymers (EAA); polyvinyl butyral (PVB); polyvinyl acetale;

cellulose acetate (CA); cellulose aceto butyrate (CAB); polysaccharides; starch; cyclic olefin copolymer (COC).

[0034] To improve film properties, the following substances or additives can be used in one or several layers during the course of the extrusion: Some of the additives that can be added are, for example, adhesive promoters, functionalized polymers such as EVOH, optical brighteners, thermal stabilizers, lubricants, antioxidants, oxygen scavengers, separators (e.g. silica particles, SAS), slip-/anti-blocking agents, dyes, pigments, foaming agents, antistatic agents, process aids, lubricating agents, flame retardants, flame suppressants, impact modifiers, impact resistance enhancers, anti-hydrolysis agents, UV absorbers, UV protection agents, stabilizers, antifogging additives, waxes, wax additives, release agents, sealing or peeling additives, nucleation agents, compatibilizers, flow agents, flow improvers, melt strength enhancers, molecular weight enhancers, cross-linking agents or softeners.

[0035] The inner tube films according to the invention can be manufactured in various ways. A preferred manufacturing method uses extrusion or co-extrusion, for example through blowing extrusion or cast extrusion. The favorite is the manufacturing as tubular blowing film.

[0036] Preferably, the inner tube film according to the invention is not oriented. Moreover, it is preferably capable of being sealed although it does not to have a sealing seam.

[0037] According to the invention, the inner tube film without sealing seam is used in an insertion tube in pipe rehabilitation that uses the pipe lining technique. The film according to the invention is therefore suitable for trenchless sewer rehabilitation, namely as an inner tube film (inner tubular film) of a pipe liner - preferably pretreated by means of irradiation cross-linking.

[0038] An additionally assembled sliding film is frequently used to protect the glass fiber reinforced plastic pipe liner from damage during its insertion and to minimize friction.

[0039] Possible application techniques in the insertion process mentioned above are both the turning inside out of the pipe liner and also its drawing in as well as the curing of the pipe liner's resins with heat or UV radiation. In this invention, the term "UV radiation" is understood to be electromagnetic radiation having a wavelength range from 200 to 400 nm. In a certain embodiment of the multilayered film according to the invention for use as inner tube film

of a pipe liner, it is at least partially transparent for UV radiation, preferably at least 80%, very preferably at least 90%. If the tubular film according to the invention is executed as inner tube film, then this film has been preferably treated with the irradiation cross-linking described above in order to further improve its mechanical and thermal properties.

[0040] The invention refers equally to a tube lining system that comprises a preliner or a sliding film and a pipe liner, the latter comprising an inner tube film shaped like a multilayered film according to the invention, preferably cross-linked with beta or gamma radiation, an outer film executed as tubular film that advantageously absorbs and/or reflects UV radiation and is intended for being placed tightly against a preliner or sliding film, as well as a carrier material (e.g. glass fiber fabric, felt, fleece, textiles) arranged between these two tubular films and impregnated with reactive plastic resin that forms the renovated inner sewage pipe after curing. Certain designs allow the inner tube film according to the invention to be peeled off after the resin has been cured. The preliner or sliding film is left in the renovated pipe. According to an advantageous embodiment, the inner tube film (preferably pre-treated with irradiation cross-linking) has, on the one hand, the same layer structure according to the invention as the preliner or sliding film, on the other hand.

[0041] The inner tube film according to the invention can also be foamed or contain at least one foamed layer.

[0042] Furthermore, powder(s) can be applied to the surface(s) of the inner tube film. Talcum powder is preferably used for this purpose.

[0043] In the context described above, it must likewise be pointed out that the friction value of a preliner should be preferably small compared to the outer film of the insertion tube (pipe liner) being inserted into the pipe to be renovated with the help of the sliding film or preliner. In this respect, according to an advantageous embodiment, a lowering of the coefficient of friction (COF) can be achieved with wax additives such as ethylene-bis-stearamide (EBS), erucic acid amide (EAA), etc. and release agents. These wax additives or release agents are preferably applied on the surface of the sliding film that faces the external film of the pipe liner.

[0044] Extrusion coating and a glazing roller process are also possible. In addition, lamination techniques can be used.

[0045] Moreover, it is advantageously possible to laminate the inner tube film according to the invention with a non-woven material, textile, needle felt, synthetic fibers or fleece, in which case thermal lamination or adhesive lamination can be used.

[0046] The inner tube film according to the invention can also be subsequently stretched or embossed. An imprinting is also possible.

[0047] The structuring of the film surface can also be done on a correspondingly structured roller through casting.

[0048] According to an advantageous embodiment, the inner tube film surface is roughened by adding separators (anti-blocking agents), for example by preparing a batch with coarser particles having a diameter of 0.01 to 10 µm. To do this, silica particles are used in at least one of the external layers, for example, to prevent the sliding film or preliner to adhere to the insertion tube or pipe liner.

[0049] Further processing options consist in bringing together the inner tube film according to the invention with a unidirectional weave or knitted fabric, e.g. a plastic net or a grid. Alternately, this grid, unidirectional weave or knitted fabric can be introduced into the inner tube film for the purpose of strengthening it further.

Application examples:

[0050] The following examples and comparative examples serve to explain the invention.

I. Chemical Characterization of the Used Raw Materials

[0051] Commercially available polyamides of the following companies (with the corresponding brand names in parentheses) can be used as polyamides (PA) for the at least one layer (a): BASF (Ultramid), Lanxess (Durethan), DuPont (Zytel), DSM Engineering Plastics (Akulon, Stanyl), EMS-Chemie (Grilamid, Grivory, Grilon), Evonik (Vestamid, Trogamid), Radici (Radilon, Radiflam, Raditer, Heraform, Heraflex), Rhodia (Technyl, Stabamid), UBE, DSM

(Novamid) and Atofina (Rilsan). In the example presented below, a pure PA layer of Durethan C38F (Lanxess) was used as polyamide layer.

[0052] Admer AT1955E of the Mitsui Co. was used as adhesive promoter. Admer® substances are PE copolymers with maleic anhydride groups (MA groups) that have a strong adhesion to PET, EVOH and PA. At the same time, they can be very well processed and have a thermal stability equivalent to conventional PE.

[0053] Polyolefins that can be typically used are, for example, Lupolen 2420 F, a LDPE made by the LyondellBasell Polymers Co., and Exceed 1327 CA made by the ExxonMobil Chemical Company, an ethylene copolymer manufactured by means of metallocen catalysis in whose polymerization hexane is used as additional co-monomer apart from ethylene.

II. Manufacturing of the Multilayered Films

[0054] The multilayered film according to the invention of example B11 consists of five layers. The individual layers of the multilayered films are immediately adjacent to one another in the sequence given below ("layer number"). The tubular films according to the invention were manufactured by means of blown film co-extrusion.

[0055] Pearlthane Clear 15N80, made by MERQUINSA, based on a TPU polyether copolymer and with a Shore hardness of 82 A (according to ASTM D-2240) was used as thermoplastic elastomer.

[0056] The film of comparative example V1 was a commercially available Valeron® film with a thickness of 108 µm made by the Valeron Strength Films Co. Valeron films can only be manufactured as flat films. By applying a thin strip with hot melt, the foil was thermally sealed into a tube.

[0057] The film of comparative example V2 was a 110 µm thick, one-layered LDPE film in tubular form with a PE melting point of 111°C.

[0058] The percentages given in the tables for the individual chemicals in the layers indicate percentages by weight.

Example 11: Preliner film, 5-layer blown film extrusion, 140 µm, asymmetrical

Layer number	Layer	Composition	Amount in the layer in %	Thickness in µm
1	(b)	• Lupolen 2420 F • Exceed 1327 CA	• 70 • 30	30
2	(b)	• Lupolen 2420 F • Exceed 1327 CA	• 70 • 30	30
3	(d)	• Admer AT1955E	• 100	10
4	(c)	• Pearlthane 16N85 UV	• 100	30
5	(a)	• Durethan C38 F	• 100	40
				Total thickness 140 µm

Testing methods and instruments

[0059] Blow-up tests were carried out for determining the elasticity of the two films of comparative examples V1 and V2 as well of the multilayered film according to the invention in form of a tubular film (B11). If a multilayered film to be tested is not a tubular film but a flat film, for example, it is sealed to become a tube to determine its elasticity afterwards. The tests that are part of the invention were done on tubular films.

[0060] In preparation, both ends of (a 5 m long tube or) a 5 m long tubular film having a tube diameter of 1175 mm to 1180 mm were hermetically sealed by two metal disks that had a suitable diameter. As is customary with such blow-up tests, lashing straps and commercially available fabric adhesive tape were used to achieve airtightness. Through a valve in one of the two metal disks, pressurized air was introduced into the tubular film until it burst but before this occurred, tears in the layers of the internal film layers could be recognized. These tears receive the name of splice.

[0061] From them, a strictly localized bubble formed in the multilayered film, which subsequently led to a film tear and the bursting of the tubular film as blowing continued. The maximum elongation (expressed in percent) was determined by measuring the maximum external circumference of the tubular film achieved until it burst and comparing it with the initial tube diameter. The following formula was used:

Maximum elongation at break = [(tube diameter after blowing / initial tube diameter before blowing) – 1] · 100

[0062] The same formula is used for the "film splice", i.e. the first recognizable tear of a tubular film's layer (without affecting the entire tube):

"Splice" = [(tube diameter after blowing and first recognizable layer tear / initial tube diameter before blowing) – 1] · 100

[0063] For the other tests, the films were stored 24 hours under normal climate conditions.

[0064] A universal testing machine 281813 made by the Frank Co. was used as test instrument for the stretching tests (tensile properties, Young's modulus, etc.) and the tear resistance tests. The force of the load cell was 200 N, testing speed was 300 mm/min and 15 mm wide strips were used for the stretching test.

[0065] The testing instrument used for the sliding friction was the BETEX Slipping Tester RK2 with a load cell of 10 N. A LINSEIS L120 E recorder was used. Two film pieces were loaded with a weight (1.96 N), pulled above one another and the force needed for this measured.

[0066] The testing instrument used for measuring the sealing seam strength was once again the universal testing machine 281813 made by the Frank Co. with a load cell of 200 N. Testing speed was set at 100 mm/min. 15 mm wide strips were sealed using the laboratory sealing instrument SGPE 20 made by the Kopp Co. with a sealing jaw width of 10 mm flat. Sealing time was 1 sec, sealing temperature 130°C and sealing pressure 300 N/m^2.

Measurement results

I. Elongation at break

[0067] The following table summarizes the result of the blow-up test:

Example / Comparative example	Splice [%]	Elongation [%] until bursting
B11	27.5	126.6
V1	5.9	25.2
V2	-	45.7

[0068] The blow-up tests for determining the elongation at break show that the film from comparative example V1 stretched only very little (5.9%) until it spliced or 25.2% until the film burst. This demonstrated that the use of this film as preliner for the tube lining process in trenchless sewage pipe rehabilitation or as inner tube film in pipe liners is hardly suited at all. Although the mechanical properties of the film from comparative example 1 are very good with regard to tear resistance and puncture resistance, they are accompanied by poor elasticity and therefore these films are only suited to a limited extent for trenchless sewage pipe rehabilitation.

[0069] The film from comparative example V2, a LDPE mono film in tubular form, showed no splice strictly speaking, as there was only one layer. This layer burst when it was stretched 45.7% and showed that the mechanical properties were completely insufficient and only very little resistance could counter the pressurized air applied. This film hardly has any mechanical strength and can be torn without a problem. Therefore, this film is unsuitable for use as preliner or inner tube film.

[0070] On the other hand, the film according to the invention from example B11 did not only have very good tear resistance and puncture resistance values (even if the corresponding values for the film from comparative example V1 were not reached) but could be stretched a good deal until the film spliced or burst. These advantageous properties are explained especially by

the fact that film B11 has at least one layer containing polyamide and also one layer with a thermoplastic elastomer TPE.

[0071] By the use of TPE (in this case a thermoplastic polyurethane TPU) made of soft ester or ether segments in one or several layers (example B11) extremely high elongation values until the film splices or bursts are obtained.

[0072] In the film according to the invention from example B11, the elongation until the films break or burst is more than 80%, in some cases even significantly more than 100%.

[0073] The use according to the invention of polyamide ensures not only the films' higher mechanical strength (e.g. tear strength and tear resistance) but also creates a barrier against oils and monomers from the resins with which the carrier material was impregnated during the pipe lining process. This protects the resin from drying out.

[0074] The following table lists the measurement results for the elasticity modulus (also known as e-modulus, tensile modulus, elasticity coefficient or Young's modulus). The elasticity modulus describes the relationship between tension and elongation during the deformation of a solid body in linear elastic behavior.

Example / Comparative example	Elasticity modulus in N/mm^2 md (machine direction)	Elasticity modulus in N/mm^2 cd (cross direction)
B11	105	106
V1	296	307
V2	110	115

[0075] The e-modulus of a film indicates how stiff or flexible it is. The bigger the e-modulus of a film, the stiffer it is. The high stiffness or associated lower flexibility is coupled with a clearly lower capacity of the film to allow being turned inside out. Yet this turning inside out is precisely very high in demand in a film when the intention is to use it as preliner in trenchless sewage pipe renovation, i.e. when the preliner is inverted inside the pipe with the pipe liner or when the preliner is already invaginated beforehand.

[0076] A clear reduction of elasticity moduli is achieved when thermoplastic elastomers (TPE) are used.

[0077] Example B11 is a film consisting of polyolefin, adhesive promoter, TPU (polyether-based) and polyamide. The approximate value of the elasticity modulus of 105 N/mm^2 is comparable to pure LDPE (see comparative example V2: approx. 112 N/mm^2) and low. In this way, the general increase of Young's modulus, which takes place by the layer containing polyamide in the films according to the invention, can be counteracted by incorporating TPE as extra material in an additional layer.

[0078] On the other hand, the product from comparative example V1 used so far as preliner has a much higher elasticity modulus. Compared to the film according to the invention from example B11, Young's modulus is about 3 times higher in the 108 µm thick Valeron film. Thus, the film from comparative example V1 cannot be easily inverted or turned inside out at all compared to the films according to the invention from example B11.

II. Friction

[0079] Below, the results from the friction properties, whose determination is a basic property of films and packaging, are listed. The coefficient of friction (adhesive friction/sliding friction) was determined according to DIN EN ISO 8295 and is also known as adhesive friction number or sliding friction number. Furthermore, the surface of the friction partners should be considered to establish whether it makes sense to perform a friction test of metal against film surface or film surface against film surface. The friction number is a ratio from friction force and bearing force of the slide and therefore has no dimensions. Owing to the standardized slide weight of 200 g, the actual friction force is about twice as large as the friction number.

Example / Comparative example	Sliding friction Side 1 against side 1 (material)	Sliding friction Side 2 against side 2 (material)	Film structure
B11	0.11 (PE)	0.22 (PA)	asymmetrical

V1	0.29 (HDPE)	0.33 (HDPE)	symmetrical
V2	0.12 (LDPE)	0.11 (LDPE)	symmetrical

[0080] As can be seen in the detail shown in the table, the films according to the invention from example B11 can be adjusted in such a way that their coefficients of friction are especially low. In example B11, a range from about 0.11 to about 0.22 has been achieved. The film from comparative example V1, on the other hand, whose average coefficient of friction is 0.31, has a higher value. The film from comparative example V2 has a lower coefficient of friction of 0.12.

[0081] The skilled person knows very well that many additives can be used to lower the coefficient of friction even more. However, their effect in comparative example V1 is very limited owing to this film's manufacturing process.

III. Sealing seam strength

[0082] Comparative film V1 is available only as flat film and must be sealed to become tubular, in which case 3.2 to 10.5 N/15 mm sealing seam strength must be reached. In the sealing conditions mentioned above, the film from comparative example V1 consequently has only poor sealing capacity. Since owing to its manufacturing it's only available as flat film, it is welded with hot melt adhesives for its required use as tubular film. The sealing capacity of this comparative film V1 is too low to ensure a high-strength sealing seam in the resulting tube. The use of hot melt adhesives for general sealing is very critical here too, as there is basically a problem of adherence between the hot melt adhesive and the film. In preliners or inner tube films, high sealing seam strength is especially important to prevent the penetration of water (preliner) or evaporation of resin (inner tube film). In this regard, it is very risky to use the film from comparative example V1.

[0083] Owing to what has been said above, it is generally recommended to use a tube obtained through extrusion because then it won't have a weak point in the form of a sealing seam. The films according to the invention preferably have no sealing seam and as a result of that these films no longer have a "weak point". The film tube of the film according to the invention from

example B11 is consequently fully homogeneous and capable of resisting the highest stresses. Maximum barrier function against water or monomers from the resins is guaranteed.

[0084] In the comparative film V2 in tubular form, sealing seam strength was above 30 N/15 mm; owing to the tubular form, however, a sealing to obtain a tube is basically unnecessary. Yet even if the film is available as flat film, the film from V2 can be easily sealed or welded to a tube.

[0085] If the film B11 according to the invention, which is preferably in the form of a tubular film, is however initially manufactured as flat film, their polyolefin side is preferably sealed. In this example film B11, sealing seam strength, as in comparative film V2, was also considerably higher than 30 N/15 mm, making these films fully sturdy and impermeable.

Summary of the measurement results

[0086] The following table finally shows the advantages of the film according to the invention from example B11 with the film from comparative example V1 used to date in the state of the art with regard to the properties relevant for use.

Name	Property – relevant for use as preliner/inner tube film							
	Tubular form	Sealing capacity	Barrier, impermeability	WRF	PR	Elasticity	Flexibility, turning inside out	COF
B11	++	++	++	+	+	++	++	0/+
V1	0	-	-/0	++	++	-	0	0
V2	++	++	-	-	-	-/0	++	0/+

Legend:

- : insufficient values

0: sufficient for the application

+: quite suitable for the application

++: very suitable for the application

WRF: tear resistance

PR: puncture resistance

COF: coefficient of friction

[0087] It follows from the table that the properties of the film according to the invention from example B11 is greatly emphasized compared to those of the films from comparative examples V1 and V2 with regard to their suitability as preliner, water protection film, sliding film, calibration film or – according to the invention – inner tube film as part of the pipe lining process in trenchless sewage pipe renovation. Thus, the films according to the invention constitute a clear improvement compared to the films of the comparative examples.

Patentkrav

1. Indføringsslange til udgravningsfri kloakrørsrenovation ved hjælp af slange-lining-metode, omfattende en indvendig slangefolie i form af en folie i flere lag, en udvendig folie udformet som slangefolie, der fordelagtigt absorberer og/eller reflekterer UV-stråling, og som er beregnet til at ligge an imod en preliner eller en glidefolie, samt et bæremateriale imprægneret med en reaktiv kunststofharpiks placeret imellem de to slangefolier, f.eks. glasfibervævning, filt, fiberdug, tekstiler, der efter hærdning danner det renoverede indvendige kloakrør, kendetegnet ved, at den indvendige slangefolie har mindst et lag (a), der mindst indeholder en homo- eller copolymer med en procentuel vægtandel på mere end 25 vægt-%, helst som udvendigt lag, mindst et lag (c) indeholdende mindst en termoplastisk elastomer (TPE) samt mindst et yderligere lag (b), hvor dette yderligere lag (b) indeholder mindst en termoplastisk, i givet fald modificeret, olefin-homo- eller copolymer.

2. Indføringsslange ifølge krav 1, kendetegnet ved, at det mindst ene lag (a) indeholder mere end 50 vægt-%, fortrinsvis mere end 75 vægt-%, helst mere end 95 vægt-% og allerhelst hovedsageligt 100 vægt-% homo- eller copolyamid.

3. Indføringsslange ifølge krav 1 eller 2, kendetegnet ved, at det mindst ene lag (b) indeholder mere end 20 vægt-%, fortrinsvis mere end 40 vægt-% og op til 100 vægt-% termoplastisk olefin-homo- eller copolymer.

4. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at det mindst ene lag (c) indeholder mere end 20 vægt-%, fortrinsvis mere end 40 vægt-% og op til 100 vægt-% termoplastisk elastomer (TPE).

5. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at det mindst ene termoplastiske elastomer (TPE) i det mindst ene lag (c) er valgt fra følgende gruppe, der omfatter følgende medlemmer:

a) TPE-U eller TPU, dvs. termoplastiske elastomerer baseret på uretan;

b) TPE-O eller TPO, dvs. termoplastiske elastomerer baseret på olefin, hovedsageligt PP/EPDM;

c) TPE-V eller TPV, dvs. sammenkoblede termoplastiske elastomerer baseret på olefin, hovedsageligt PP/EPDM;

d) TPE-E eller TPC, dvs. termoplastiske polyesterelastomerer / termoplastiske copolyester;

e) TPE-S eller TPS, dvs. styrol-blokcopolymerer (SBS, SEBS, SEPS, SEEPS og MBS);

f) TPE-A eller TPA, dvs. termoplastiske copolyamider;

g) TPE-silikone.

6. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at den indvendige slangefolie har mindst et yderligere lag udformet som hæftegrunderlag (d), der fortrinsvis indeholder en olefin-homo- eller copolymer, hvor hæftegrunderlaget (d) er placeret imellem to lag (a), imellem et lag (a) og et lag (b) ifølge krav 3, imellem to lag (b) ifølge krav 3, imellem et lag (a) og et lag (c), imellem et lag (b) ifølge krav 3 og et lag (c), eller imellem to lag (c).

7. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at begge den indvendige slangefolies udvendige lag er udformet som lag (a), der mindst indeholder et homo- eller copolyamid med en procentuel vægtandel på mere end 25 vægt-%.

8. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at den indvendige slangefolie har en tykkelse fra 20 til 2000 µm, fortrinsvis fra 40 til 1000 µm, helst fra 60 til 400 µm, især helst fra 80 til 250 µm.

9. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at der i det mindst ene lag (b) ifølge krav 3, der indeholder en olefin-homo- eller copolymer, eller i et hæftegrunderlag (d) er indeholdt mindst en ætylen-(met)akrylat-copolymer, i funktionaliseret eller ikke-funktionaliseret form, hvor den procentuelle vægtandel af den mindst ene ætylen-(met)akrylat-copolymer ligger i mindst et af lagene (b) eller (d) fortrinsvis i området fra 0,1 til 100 %, fortrinsvis ved mindst 30 vægt-%.

10. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at et eller flere af følgende stoffer er indeholdt i mindst et af den indvendige slangefolies folielag: polystyrol (PS); polyhalogenider, som f.eks. PVC og/eller polyvinylidenklorid (PVdC); ætylenvinylalkohol-copolymer (EVOH), polyvinylalkohol (PVOH eller PVAL), hæftegrunder, ætylenvinylacetat (EVAc); en eller flere lonomerer; en eller flere poly(met)akrylater; ætylenholdige poly(met)akrylater, polyvinylacetat (PVAc); polykarbonat (PC); polyakrylnitril (PAN); flere polyestere som polybutylenterephthalat (PBT), polyætylennaphthalat (PEN), polymælkesyre (PLA) og/eller polyhydroxyalkanoater (PHA); en eller flere ætylenakrylsyre-

copolymerer (EAA); polyvinylbutyral (PVB); polyvinylacetal; celluloseacetat (CA); celloloseacetobutyrat (CAB); polysaccharider; stivelse; cyklisk olefin-copolymer (COC).

11. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at følgende stoffer er blevet tilføjet som led i ekstruderingen af den indvendige slangefolie i et eller i flere af dens lag: hæftegrunder, funktionaliseret polymer som f.eks. EVOH, optiske blegemidler, termiske stabilisatorer, glidemidler, antioxidanter, oxygen scavenger, afstandsholdere (f.eks. silica-partikler, SAS), slip-/antiblokmidler, farver, pigmenter, skummidler, antistatika, proceshjælpemidler, smøremidler, flammebeskyttelsesmidler, flammehæmmere, impact modifier, slagmodstandsforbedrer, anti-hydrolysemidler, UV-absorbere, UV-beskyttelsesmidler, stabilisatorer, antifog-additiver, vokser, voksadditiver, skillemidler, forseglings- eller peel-additiver, iskrystalfremmende midler, combatibilizer (kompatibilitetsmager), flydemidler, flydeforbedrer, smeltestyrkeforbedrer, molekulærvægtforbedrer, sammenkobler eller blødgører.

12. Indføringsslange ifølge et eller flere af foregående krav, kendetegnet ved, at den indvendige slangefolie er lamineret med et ikke-vævet materiale, tekstil, nålefilt, syntetiske fibre eller fiberdug.

13. Anvendelse af en indføringsslange ifølge et eller flere af foregående krav ved udgravningsfri kloakrørsrenovation.