

LINING MATERIAL FOR PIPELINES

Introduction

The present invention relates to a lining material for pipelines, such as water, gas, or other fluids, which is capable of forming a lining thereof in the form of a strong inner pipe.

For a number of years, a tubular lining material was used for the purpose of repair and reinforcement of damaged or superannuated pipelines, which had been constructed and buried in the ground, since pipe-exchange works especially for underground pipelines involved much cost and difficulty. Pipe-lining methods developed at an early stage, for example, those disclosed in U.S. Pat. 3,132,062 and 3,494,813 were rather primitive and had a number of drawbacks in actual pipe-lining operations. Under the circumstances, various improvements were made in both pipe-lining methods and lining materials used therein.

Several improved lining methods have been proposed, for example, in U.S. Pat. Nos. 4,368,091, 4,334,943, 4,350,548; 4,427,480 and 4,334,943 have been noted as excellent methods for lining pipelines. According to these methods, a tubular lining material having a binder applied onto the inner surface thereof, is inserted into pipelines and allowed to advance therein while turning it inside out (evagination), whereby the lining material is bonded onto the inner surface of the pipelines with the binder.

In general, a lining material for pipelines is desirably provided on the inner surface thereof with an air-tight membrane or coating to impart water-proof and/or air impervious property to the lining material.

Various kinds of tubular lining materials have been used for relining pipes or pipelines. Usually the lining materials are made of felt and/or fabric and/or other porous, flexible or foamed material and have a water-proof and/or air impervious membrane or coating thereon.

The application of a tubular lining material is desired for the purpose of reinforc-

ing pipelines for transporting a high pressure fluid, for example, a gas conduit, (up to 64 kg/cm² service pressure on actual use), a city water pipeline (up to 18 kg/cm² service pressure on actual use), etc.

In the case of the city water pipeline, a pipeline of city water grade is frequently used which originally has a pressure resistance as high as 30 kg/cm² but gradually deteriorates with the lapse of time so that its pressure resistance ultimately drops to a few kg/cm². Besides the pressure-resisting property, a strong resistance to cracking or destruction of the pipeline caused by external shock or loads, or even earthquakes, is also desired for such pipelines including city water pipelines. In the case of pipelines for a high pressure fluid, damages caused by the destruction of pipelines will be serious. Thus, a tubular lining material used for such pipelines is required to possess such function that it should not be destroyed and can be substituted for pipelines even if the pipelines become degraded or broken. Similarly, the tubular lining material alone should desirably maintain the function of a passageway for the high pressure fluids even if the pipelines are superannuated and significantly cracked or destroyed. In such a case the lining material alone should withstand the pressure of the transported fluid and the demand on the lining material will become severe especially if the diameter of the pipelines is large. If the pipelines are cracked or broken off due to a strong external force caused, for example, by an earthquake, the tubular lining could peel off from the damaged pipelines, without being destroyed itself in order, to maintain the function of a passageway for high pressure fluid.

The term "structural-resistance" used herein means the specific mechanical characteristics of the tubular lining material. In other words, the term "structural-resistance" is herein used to mean a combination of external loads-absorbing property and internal pressure resistance property which assume the function of a passageway for a high pressure fluids using only the tubular lining material when the pipelines are cracked or broken off. In order to furnish a tubular lining material with structural-resistance, the tubular lining material should possess a sufficiently high tenacity in both the lengthwise and the crosswise direction and a satisfactory resistance to such a degree that the lining material should not be

broken down prior to external loads and/ or shearing destruction forces from a binding loss between the pipelines and the lining material. In case the pipelines are buried in soft ground or reclaimed land, the pipeline may be cracked or broken off because of a dip in the ground or an earthquake. Even if the pipelines are cracked or broken off, the tubular lining material possessing structural-resistance can be split off from the damaged pipelines by shearing destruction of the solidified binder and can still function as a passageway for the high pressure fluid. Thus, the structural-resistance of the lining material is one of the most important characteristics, where in addition to a (very) high internal service pressure resistance, the renovated pipelines is buried where external loads could occur as well, and/ or where there is soft ground or reclaimed land and/ or in a district where earthquakes could be anticipated. In the prior art tubular lining materials, however, no consideration has been given to such structural-resistance.

As the tubular lining material is applied onto the inner surface of the pipelines by evagination, it is important that the tubular lining material should be flexible and do not require a high fluid pressure for the evagination operation. In general, the evagination operation becomes more difficult as the thickness of the tubular lining material becomes greater. Consequently, good flexibility is also required before curing, in addition to the structural -resistance, for the cured tubular lining material.

US 5,186,987 discloses a lining material for pipelines which comprises a flexible tubular film, a sheet covering the outer surface of the tubular film and a second film capable of being split off covering the outer surface of the sheet. The sheet is comprised of a fabric and a mat of fibers of high tenacity impregnated with a thickened liquid thermohardenable resin to form a fabric-fiber-reinforced composite thanks to the high tenacity sheet having a sufficient length and a width greater than the inner circumferential length of a pipeline to be treated. Both lateral end portions of the single high tenacity sheet are slidably overlapped with each other to form a tube around the tubular film, the outer circumferential length of the tube being shorter than the inner circumferential length of the pipeline.

When the lining material inserted into the pipeline is inflated to bring the lining material evenly into intimate contact with the inner surface of the pipeline, the overlapping section of the lining slides over one another and the circumferential length of the lining material expands so that the lining material comes in tight contact with the pipeline.

However, the expansion of the circumferential length of the lining material is limited and a rather strong pressure may be required to overcome the frictional resistance of the lining material in the overlapping section.

Object of the invention

The object of the present invention is to provide a new type of lining material for pipelines which can be evenly applied onto the inner surface of the pipelines and is capable of forming a strong composite lining.

General description of the invention

In order to overcome the above-mentioned problems, the present invention proposes a tubular lining material for reinforcing pipelines, utilizable in a pipe-lining method. This tubular lining material, having a binder disposed on the inner surface thereof, is inserted into a pipeline and is allowed to advance within the pipeline as the tubular lining material is turned inside out under fluid pressure whereby the tubular lining material is applied to the inner surface of the pipeline with the binder being interposed between the pipeline and the tubular lining material. Said material is provided on the inside thereof with a reinforcing inner tubular jacket, wherein the inner reinforcing tubular jacket comprises at least two sheets of high strength and high modulus fibers and wherein the sheets overlap at least two locations and wherein said overlap portion extends in the lengthwise direction of the inner tubular jacket.

The proposed tubular lining material for reinforcing pipelines possesses a good binder absorption capacity, remains very flexible before curing for easy evagination, and has good circumferential expansion properties in order to fit the host pipe.

After the curing of the binder, the lining material becomes firm, shape stable and its structural-resistance and pressure-resistance is sufficient enough to maintain itself as having the function of a passageway even if the pipelines or joint parts thereof are cracked or broken off and if the tubular lining material is peeled off from the pipelines or joint parts thereof by an external force stronger than the bonding strength of the binder used.

One other advantage of the lining material according to the invention is that its circumferential expansion requires only a low pressure to overcome the overlap slipping needs.

The presence of at least two overlapped portions greatly enhances the expansion capacity because the expansion may take place at two separate locations and allows designing the tubular lining with a rather small initial circumferential size. The risk of wrinkle formation during relining is minimized or even avoided.

Furthermore, if, according to a preferred embodiment, the overlaps are extending across the two opposite edges of the flattened tubular lining material, even after diameter expansion, the previous flattening folds will remain in the double layer overlap zones.

One advantage of this embodiment is that the two overlaps extending across the two opposite edges of the flattened tubular allow to keep the total thickness, flexibility and weight of the lining material on rather low level in addition to an optimal homogeneous resistance of the composite material after impregnation and curing. This characteristic lead to an important saving of resin and makes this lining material more competitive and easier to process.

Thanks to those double layer reinforced zones covering the flattening folds, the negative effects of the physical folding on the high strength / high modulus textile material is overcome, and the tubular lining preserves its structural performances around its entire circumference, in spite of the use of folding and shearing sensitive reinforcement fibers or yarns into the composite structure.

Indeed, it has been found that lining materials such as disclosed in US 5,186,987, with only one single overlap portion do not withstand very high pressures even when a high strength / high modulus fabric is used in the lining

material.

Surprisingly, the lining material with two diametrically opposed high strength and high modulus fabric or mat overlap sections however has a much higher pressure resistance than a comparable lining material which has only one overlap section.

This surprising effect seems to be due to the fact that the lining material is folded during production, then stored and transported in a flattened state. Only when the lining material is introduced into the pipeline and applied to the inner surface of the pipeline, it returns to its round shape. It has been found that the high tensile strength and high modulus fibers used in the reinforcing inner tubular jacket have a tendency to break when the lining material is flattened. The fact that the reinforcing inner tubular jacket comprises at least two sheets or mats of high tensile strength and high modulus fibers or yarns, which overlap in the lengthwise direction at the locations where the lining material is folded, increases the number of fibers that are still intact dramatically and thus increases the structural strength and the pressure resistance of the cured lining material.

For example, a bursting test was carried on with a free 1.20 m long and DN 400 mm impregnated and cured lining. This lining was constructed with a 6.25 mm thick polyester coated felt, and a flat reinforcing E-CR glass fabric of 1500 g/m² (500 g/m² in warp & 1000 g/m² in weft), shaped to make a channel with a single overlapped zone outside the lateral folding edges. The short term bursting pressure was 16 bars allowing a long term service pressure of +/- 5.3 bars (long term resistance = 1/2 short term resistance, and security coefficient = 1.5).

With the same design, but where glass material channel was constructed with two separate layers of glass fabric, overlapping astride the folding edges areas on 160 mm, the short term bursting pressure was 37.5 bars, allowing a long term service pressure of 12.5 bars

The at least two sheets of fabrics or mats of high tensile strength and high modulus material overlap preferably by at least 5 cm each.

Advantageously, especially when "DN" is bigger than 320 mm, the at least two

sheets of fabrics or mats of high tensile strength and high modulus material overlap from about 2 X 0,10 DN (nominal diameter) to about 2 X 0,30 DN each, and most preferably by about 2 X 0.20 DN each, according the size of the liner in comparison with the pipeline diameter. Those skilled in the art will be able to determine the optimal value of the overlapping depending on the diameter of the pipeline to be renovated, by its expected service pressure, the type and quality of the sheets or mats, and the expected tubular lining expansion during implementation.

According to a further preferred embodiment, the tubular lining material further comprises either a flexible tubular jacket between the air-impervious outer layer and the inner reinforcing tubular jacket or a flexible tubular jacket on the inner reinforcing tubular jacket or a first flexible tubular jacket between the air-impervious outer layer and the inner reinforcing tubular jacket and a second flexible tubular jacket on the inner reinforcing tubular jacket.

This flexible tubular jacket preferably comprises a rather stretchable textile structure like a non-woven web or felt, a knitted layer, or an elastic woven fabric.

More particularly, the flexible tubular jacket(s) comprise(s) a textile non woven felt, a spunbonded mat or fleece, or a woven, braided or knitted textile structure or flexible, porous and absorbent layer such as an open cells foam.

The impervious material of the outer layer comprises preferably an elastomeric or flexible natural or synthetic material, which is chosen among the group consisting of natural and synthetic rubbers, polyester elastic polymers, polyolefin polymers, polyolefin copolymers, a polyurethane polymers or a mixture thereof. Preferably these materials are "food approved" materials.

Depending on the destination of the lining material, the outer layer is air impervious and/or watertight.

Generally, the outer layer has a thickness within the range of 0.2-2.0 mm, preferably 0.5-1.5 mm.

The inner reinforcing tubular jacket and the optional flexible tubular jacket(s) is

(are) preferably impregnated with a binder creating a hard composite material after curing or drying.

The binder may comprise a resin or a glue chosen from the group consisting of a heat setting or cold curing hardening material such as polyurethane, unsaturated polyester, vinyl ester, epoxy, acrylics, isocyanate, concrete or water glass or a mixture thereof.

The binder binds the overlapping edges of the high strength and high modulus reinforcing sheets after curing or drying.

According to a preferred embodiment, the at least two sheets of high tensile strength and high modulus material comprise a woven, braided or knitted structure or mat or a non woven sheet made of glass, para aramide, carbon or other high modulus fibers or yarns.

Preferably the high strength and high modulus material is chosen in order to overcome to a certain extend the loss of strength due to the folding operation during the tubular lining manufacturing process. "E" or "E-CR" Glass fiber and "E" or "E-CR" glass filaments having individual cross section of maximum 17 microns and selected sizing agent for epoxy resin compatibility are well suited for this application. Para aramide fibers and filaments sold under the trademarks Kevlar®, Twaron® or Technora® or carbon fibers and filaments could also be used.

Other objects, features and advantages of the present invention will become apparent more fully from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can more fully be understood from the following description taken in conjunction with accompanying drawings in which:

FIG.1. shows a cross section of a structural lining material before reversion

FIG. 2. shows a crossection through a preferred embodiment of a structural lining material before reversion.

Fig. 3 : cross section of a structural lining material after reversion.

Fig.1 shows a cross section of a structural lining material before reversion, comprising a flexible multilayer structure manufactured to be used for relining pipelines. This lining material is designed for structural reinforcement of a pipeline after impregnation with a hardenable resin or binder, evagination and curing inside the pipeline to be renovated.

The external layer 1 is made of an air-impervious coating material 1.a. applied on the outer surface of a flexible porous and absorbent substrate 1.b. The flexible porous and absorbent substrate 1b is most usually made of a non woven textile structure such as felt, mat, spun bond or web with continuous filaments or staple fibers. In some cases, it may also be a woven, braided or knitted structure; or any other kind of flexible porous absorbent material like an open cells foam. When a textile material is used for the porous, absorbent layer, synthetic or artificial fibers or filaments like polyamide, polyolefin, acrylics, glass, rayon, aramides or most usually polyester are used. In certain cases natural fibers, especially from vegetal origin, like flax, hemp, jute, kenaf or ramie may be used as well. The construction and the thickness of the flexible porous layer 1 is designed in accordance with the specific requirements, in relation to international standards, like ASTM F.1216, in order to guaranty the structural reinforcement of the total composite lining in relation to the mechanical properties (E Modulus) of the resin or binder used for the impregnation.

For example: A partly deteriorated pipe in DN = 500mm with an ovality reduction factor of 2%, submitted to a 1.5 m water column, and taking in account a ground enhancement factor $K = 7.0$ and a factor of safety $N = 1.5$ renewed with a composite lining material having a short term E-Modulus = 3500 Mpa need a layer of min. 5 mm.

The flexible porous and absorbent substrate 1 may be made of a single layer or of several layers of the same or from different material.

Inside this flexible porous and absorbent substrate, two separate sheets of high strength and high modulus textile material 2 & 3 are placed and folded with free overlaps on both edges in order to form an internal channel. The two overlaps are placed opposite to each other, creating a double layer of material along the

length of the lining material. The double layers are placed so as to cover the flattened edges of the lining 4a-a' and 4 b-b'.

The two sheets of high strength and high modulus material 2 & 3 may be made of non woven or woven, braided or knitted structures using staple fibers, continuous filaments or yarns. Structures like woven or warp and weft knitted fabrics, where longitudinal and cross yarns or filaments are in a perpendicular direction are preferably used. This arrangement allows to obtain a maximum reinforcement effect as far as the internal pressure resistance of the structural lining material is concerned. In practice continuous, high strength and high modulus multifilament yarns are used in sheets 2 & 3 where the warp yarns are in the longitudinal direction of the lining material and the weft yarns in the crosswise direction. Construction of the sheets 2 & 3 is designed in order to reach a tensile breaking strength twice as high for the crosswise direction as compared to the lengthwise direction. An optimal bursting pressure for the final structural lining material is thus assured.

Sheets 2 and 3 are made of high strength and high modulus material like carbon, para aramide, high performance polyethylene (HPPE) and for economical reasons preferably of glass.

When glass is used for sheets 2 & 3, the chemically and mechanically most resistant grades are selected in order to assume long term performance and to minimize the loss of strength during the lining manufacturing process and during storage. In this respect E Glass or preferably E-CR Glass, or Boron free grades are preferably selected.

Sheets 2 & 3 are normally made of the same kind of fiber or yarn, but different materials may also be combined.

Overlap location and widths on sheets 2 & 3 are normally equal on both side, but may be different.

FIG. 2. shows a crosssection through a preferred embodiment of a structural lining material before reversion.

Additional tubular layer(s) of flexible, porous and absorbent material 5 may be

inserted inside the channel constructed with sheets 2 & 3.

Such layer(s) is usually similar to the porous absorbent substrate 1.b. However, It may also be a water-proof and / or air impervious layer able to protect the heat setting resin or binder against wetting during implementation in the host pipe.

FIG. 3: is a cross section of a structural lining material after reversion.

After reversion, layer 1 is turned inside the lining material with its water-tight coated face 1.a. in contact with the fluid to be carried in the renovated pipe.

After curing of the heat setting resin or binder, the layer(s) 1.b. contribute in a major way to the structural reinforcement of the lining material, due to its design thickness and E-modulus.

The two sheets of high strength and high modulus textile material 2 & 3, are now around the inner tube 1, and are still overlapped on their edges to reinforce the previous folded zones 4 a-a' and 4 b-b'. It is the heat setting resin or binder which assumes after curing by mean of steam, hot air, hot water or UV light, the firm connection between the two overlapped areas and creates a reinforced, pressure resistant, composite tube.

Thanks to the high strength and high modulus reinforcement sheets 2 & 3, the cured lining is able to resist to high internal pressure and to maintain its size and shape in such conditions.

Unlike the prior art cured in place linings, this specific high modulus structural construction allows the lining material to accurately fit the renovated pipeline and also to restrain the pressure inside the composite lining itself.

Thanks to those specific properties, sensitive and / or damage host pipe are preserved against pressure forces after such structural relining.

On application of the tubular lining material of this invention onto the inner surface of pipelines according to any suitable pipe-lining method disclosed, for example, in U.S. Pat. No. 4,334,943, the tubular lining material is impregnated on the inner surface thereof with a sufficient amount of the binder held in the porous flexible layer and to secure integral bonding of the different reinforce-

ment sheets of the tubular lining material , and to bind it onto the inner surface of the pipelines. Various kinds of binders can be used like unsaturated polyester, vinyl ester but those of epoxy type are preferable. In case the binder is an epoxy type is used, an aromatic or aliphatic poly-amine may be selected as a curing agent.

The construction of the tubular lining material of the present invention will now be illustrated in more detail by way of a specific example with respect to the tubular lining material for a conduit working at a service pressure of 15 bars under a 6 meter water column, and having a nominal diameter of 400 mm :

The air-impervious tubular jacket is manufactured with a 7 mm thick flat non woven polyester felt of 1400 g/m² coated with a 1mm air impervious layer of polyethylene (LLDPE). After cutting at the width of 1159 mm, the coated felt is shaped and bonded in order to realize a hose, inside witch two layers 788 mm wide each of 1500 g/m² woven glass fabric are folded and create an internal tube with their two edges overlapping on the full length on a minimum width of 80 mm across the folds off the flattened lining.

The glass fabrics are made of 100% continuous multifilament Boron free yarns treated with an abrasion resistant, epoxy-compatible sizing agent.

The lining material is then impregnated with 10.35 kg/m² of an epoxy resin containing an aliphatic polyamine hardener.

After evagination with compressed air, in the pipe to be renewed, steam is circulated in contact with the internal coated face of the reverted lining during 5 hours at a temperature of 85 to 90°C. After complete curing of the resin, the air pressure is maintained until cooling up to 30°C. The lining is then able to assume a 38 bars (short term) bursting pressure, and an external load corresponding to 6 meters water table.

As many apparently widely different embodiments of the present invention may be made without departing from the spirit and scope thereof, it is to be construed that the present invention is not limited to the specific embodiments thereof except as defined in the appended claims.

CLAIMS:

1. A tubular lining material for reinforcing pipelines, utilizable in a pipe-lining method wherein the tubular lining material, having a binder disposed on the inner surface thereof, is inserted into a pipeline and is allowed to advance within the pipeline as the tubular lining material is turned inside out under fluid pressure whereby the tubular lining material is applied to the inner surface of the pipeline with the binder being interposed between the pipeline and the tubular lining material, said tubular lining material comprising an outer layer of an impervious material and provided on the inside thereof with an inner reinforcing tubular jacket wherein the inner reinforcing tubular jacket comprises at least two sheets of high tensile strength and/ or high modulus fibers and wherein the sheets overlap at least two locations and wherein said overlap portions extend in the lengthwise direction of the inner tubular jacket.
2. The tubular lining material of claim 1, wherein the overlap portions are situated at diametrically opposed locations.
3. The tubular lining material of claim 1 or 2, wherein the at least two sheets of high tensile strength and / or high modulus material overlap by at least 5 cm.
4. A tubular lining material according to claim 1 or 2 wherein the reinforcing sheets of high tensile strength and / or high modulus material overlap by between 2 X 0.10 DN and 2 X 0.30 DN.
5. A tubular lining materials according to any of the preceding claims, wherein the tubular lining material further comprises a flexible tubular jacket between the air-impervious outer layer and the inner reinforcing tubular jacket.
6. A tubular lining materials according to any of the claims 1 to 4, wherein the tubular lining material further comprises a flexible tubular jacket on the inner reinforcing tubular jacket.
7. A tubular lining materials according to any of the claims 1 to 4, wherein the tubular lining material further comprises a first flexible tubular jacket between

the air-impervious outer layer and the inner reinforcing tubular jacket and a second flexible tubular jacket on the inner reinforcing tubular jacket.

8. A tubular lining material according to any claim of the claims 5 to 7 wherein the flexible tubular jacket comprises a textile non woven felt, a spunbonded mat or fleece, or a woven, braided or knitted textile structure or flexible, porous and absorbent layer such as an open cells foam.
9. A tubular lining materials according to any of the preceding claims, wherein the impervious material of the outer layer comprises an elastomeric or flexible natural or synthetic material.
10. A tubular lining materials according to claim 11, wherein the impervious material of the outer layer is which is chosen among the group consisting of natural and synthetic rubbers, polyester elastic polymers, polyolefin polymers, polyolefin copolymers, a polyurethane polymers or a mixture thereof.
11. A tubular lining materials according to any of the preceding claims, wherein the outer layer is air impervious and/or water tight.
12. A tubular lining materials according to any of the preceding claims, wherein the outer layer has a thickness within the range of 0.2-2.0 mm, preferably 0.5-1.5 mm.
13. A tubular lining materials according to any of the preceding claims, wherein the inner reinforcing tubular jacket and the optional flexible tubular jacket(s) is (are) impregnated with a binder creating a hard composite material after curing or drying.
14. A tubular lining materials according to claim 13, wherein the binder comprises a resin or a glue chosen from the group consisting of a heat setting or cold curing hardening material such as polyurethane, unsaturated polyester, vinyl ester, epoxy, acrylics, isocyanate, concrete or water glass.
15. A tubular lining material according to any of the preceding claims wherein the binder binds the overlapping edges of the high strength and high modulus reinforcing sheets after curing or drying.
16. A tubular lining material according to any of the preceding claims wherein

the high strength and high modulus sheets comprise a non woven, a woven, a braided or a knitted structure or mat of glass, para aramide, carbon or other high modulus fibers or yarns

17. A tubular lining material according to claim 16 wherein the fibers or yarns comprise continuous multifilaments of glass like E, E-CR and / or Boron free glass.