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(54) Benævnelse: **Foringsrør til renovering af fluid-ledende systemer**

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Description

The invention relates to a lining tube for renovation of fluid-conducting systems comprising at least one resin-impregnated fibre tube.

Lining tubes for renovation of fluid-conducting systems are known per se and have been described in the literature.

In practice, what are called liners based on thermoplastic polymers comprising a fibre reinforcement have been found to be useful for this purpose. These are flexible lining tubes which are introduced into the pipe system to be renovated, then fitted to the inner wall of the pipe system to be renovated and subsequently brought into their final shape by curing the resin present in the fibre tube.

The manufacture of such lining tubes is described, for example, in WO 95/04646. In the process described therein, a film tape is initially helically wound onto a mandrel consisting of multiple parallel winding fingers which are adjustable in their distance to the mandrel axis to form an inner tubular film serving as protective film. Onto the inner tubular film thus obtained is wound at least one resin-impregnated fibre ribbon, onto which in turn is wound a second film tape which forms an outer tubular film.

Curable polymers with nanoparticulate fillers have been described in the literature for various applications.

For instance, EP A 1502727 describes composite moulded elements which are obtained by injection of a low viscosity polymer into a fibre base and subsequent curing by heating. Prior to injection, nanoparticles are added to the low-viscosity polymer. The products obtained are called pre-pregs, which are no longer flexible after curing. There is no disclosure or suggestion of use in lining tubes for renovating fluid-conducting systems.

EP A 1 634 921 and EP A 1 786 866 relate to polymeric compositions which, as well as an unsaturated polyester and a further copolymer with groups reactive towards the polyester, contain nanoparticles as fillers. These compositions can be used to obtain composite materials, coatings, encapsulating compounds, adhesives and dental materials with improved mechanical properties, in particular improved impact strength.

US 2010/0143701 describes a process wherein carbon nanotubes dispersed in a solvent are applied to a fibrous surface, then the solvent is evaporated, and the coated surface thus obtained is finally covered with a polymer to obtain a fibre-reinforced composite material with embedded carbon nanotubes.

WO A 2005/028174 relates to the production of polymer composites based on epoxy resins and comprising functionalized carbon nanotubes.

US 2008/0271802 describes tubular materials for renovation of pipelines, comprising a resin-impregnated felt with carbon nanotubes embedded within the resin impregnating the felt in an amount of 0.5% to 30% by weight.

US 2005/0194718 discloses lining tubes (liners) for renovation of pipelines, comprising a resin-absorbing material and an essentially impervious coating, wherein the coating includes a modified polymer with at least one added additive, wherein the coefficient of friction of the modified polymer is lower than that of the pure polymer without additive.

EP A 100029 discloses a coated composite material consisting of a layer composite composed of a reactive resin-absorbing textile layer and a gas- and water-impervious, at least bilaminar layer applied to the textile layer and composed of inextricably associated polyurethane-urea reactive coatings that may contain fillers. The composite material may be used for renovation of passages.

It was an object of the present invention to provide lining tubes for renovation of fluid-conducting systems that have advantageous mechanical properties and an abrasion-resistant surface.

This object is achieved in accordance with the invention by the lining tubes according to Claim 1. Preferred embodiments of the lining tubes according to the invention can be found in the dependent claims and in the detailed specification that follows.

A further aspect of the invention relates to a method of producing the lining tubes according to the invention, and to the use of the lining tubes according to the invention for renovation of water and wastewater conduit systems

In the context of the present invention, "fluid-conducting systems" are understood to mean any and all systems in which fluids, i.e. gases or liquids, can be transported. There are no particular limitations with regard to construction type, diameter or materials of the systems to be renovated.

The material selection is determined by the fluid media to be transported in the systems; their properties ultimately also determine the service lives of such systems and the need for renovation, which may be undertaken with the lining tubes according to the invention.

Accordingly, the invention provides a lining tube for renovation of fluid-conducting systems, comprising at least one resin-impregnated fibre tube, a reinforced or unreinforced inner film tube on the side of the resin-impregnated fibre tube facing the flowing medium, wherein 0.1% to 40% by weight, based on the weight of the resin or the weight of the inner film tube, of nanoparticles has been added to the resin used for impregnation or to the inner film tube or both, and said nanoparticles at the time of incorporation into the resin used for impregnation have a median particle size D_{50} or a greatest dimension in any spatial direction of less than 300 nm, and the lining tube has an outer film tube. This means that the resin used for impregnation may contain 0.1% to 40% by weight, based on the total weight of the resin, of nanoparticles or that an inner tubular film may contain 0.1% to 40% by weight, based on the total weight of the tubular film, of nanoparticles, or that nanoparticles may be present in both of these components in the amount stated. It is preferable that nanoparticles are present in the fibre tube which comes into direct contact with the flowing medium in the installed state. This may be the inner film tube if this remains in the lining tube after installation, or it may be the resin-impregnated tubular fibre tube if the inner tubular film is removed after installation.

The term "nanoparticles", as used herein in the context of the present invention, is intended to cover any and all particulate or fibrous particles having a greatest dimension in one or more spatial directions, or in case of spherical or ball-shaped particles a median diameter, of less than 300 nm, preferably less than 150 nm and especially less than 100 nm.

The term median particle diameter, as used herein in the context of the present invention, refers to the median diameter D_{50} based on the intensity-weighed particle size distribution as obtained in accordance with the so-called Contin data inversion algorithm. D_{50} divides the intensity-weighed particle size distribution into two equal fractions, of which the first fraction contains particles with a diameter below D_{50} and the second fraction particles with diameters exceeding D_{50} .

D_{50} is usually determined via dynamical light scattering in accordance with ISO 22412:2008. The determination is carried out at a temperature of 25°C. Refractive index and viscosity coefficient of the dispersion medium should be determined as precisely as possible or should be known from literature. After temperature calibration the position of the measurement cell is adjusted to obtain an optimum scattering signal. Details of the measurement can be taken from the ISO standard mentioned.

Spherical or ball-shaped particles have a more or less pronounced isometric structure, i.e. the dimensions in all three spatial directions are comparable in size.

The ratio of the dimensions of a particle in different spatial directions is characterized through the so-called aspect ratio, which describes the maximum ratio of the dimensions of the particle in two different spatial directions. The aspect ratio of ideally spherical particles is accordingly 1, whereas the aspect ratio is usually significantly higher than 1 for fibrous or platelet-shaped particles and often reaches values of 100 or more. Platelet-shaped or fibrous nanoparticles are therefore characterized via the statement of the dimension in the spatial direction in which the corresponding particle has its greatest measurement.

In principle, suitable nanoparticles are any types of inorganic or organic products which can be manufactured in the respective particle sizes and which may also be available commercially. Processes for producing such particles are known to the skilled person and have been described in the literature.

Spherical or ball-shaped fillers are, for example, metal oxides, metal carbonates, metal sulfates or the like. Preference is given to oxides of Ba, Al, Si, Zr, Ce and Ti, and mixed oxides of these metals. Carbonates and sulfates of alkaline or alkaline earth metals may be specified here with preference as sulfates or carbonates.

Platelet-shaped fillers have been described in great variety, for example in Plastics Additive Handbook (Hanser Verlag, 5th Ed.) in chapter 17.4.2 on pages 926 to 930, to which reference is made herewith for further details.

Needle-shaped or acicular particles have also been described in the literature in great variety. Preferred acicular additives for use in the resins used for curing have an aspect ratio in the range of from 2 to 100, preferably of 2-20.

Wollastonite, xonotlite, sepiolite, attapulgite and palygorskite may be mentioned as preferred acicular particles.

Fibrous fillers have an even higher aspect ratio compared to needle-shaped fillers. A preferred group of fibrous nanoparticles is that of carbon-based particles, which are also known as carbon nanotubes.

Further suitable fibrous nanoparticles which may be mentioned here are glass fibres or fibres based on Al, Ti, Mg, Al silicate or Si carbide or boron carbide fibres. Glass fibres are preferred here.

The nanoparticulate fillers are added to the resin used for impregnating the resin-impregnated fibre ribbons or to the inner film tube in an amount of 0.1% to 40%, preferably of 2-30% and more preferably of 3% to 25% by weight, based on the weight of the resin or respectively the weight of the inner film tube.

The addition of the nanoparticles to the resin used for impregnation prior to the impregnation is made according to methods known per se, and so no further information needs to be given here.

The aforementioned particle size of the nanoparticles refers to the time of incorporation into the resin used for impregnation. As a result of agglomeration in the course of the addition or during the impregnation of the resin-impregnated fibre tubes with the resin containing nanoparticles that is used for impregnation, a different, usually greater, particle size may result in the final lining tube.

Reactive resins used for impregnation of the fibre ribbons are preferably unsaturated polyester resins (UP resins) or vinyl ester resins (VE resins), which may be dissolved, for example, in styrene and/or an acrylic ester. Suitable reactive resins are known to the skilled person and commercially available in different grades.

For the production of UP resins, polybasic unsaturated dicarboxylic acids are esterified with diols to obtain low molecular weight products, which are polymerized, generally with vinyl compounds (in particular styrene) as comonomers, to give high molecular weight three-dimensional networks during curing.

Acid components used for UP resins may also be mixtures of unsaturated and saturated bifunctional carboxylic acids or their anhydrides. For instance, acid components used may be adipic acid, glutaric acid, phthalic acid, isopthalic acid and terephthalic acid or the reactive derivatives of these acids. Preferred unsaturated acids are maleic acid or its anhydride, fumaric acid and Diels-Alder adducts of maleic anhydride and cyclopentadiene. Diols used with preference are ethylene glycol, propanediol, dipropanediol, diethylene glycol, 2,2-dimethyl-1,2-propanediol, 1,4-butanediol, 2,2,4-trimethyl-1,3-pentanediol or bisphenol A. The comonomers needed for crosslinking of the UP resins may at the same time be solvents for the low molecular weight oligomers; a particular example for this purpose is styrene, which is used in many UP resins. Other examples of suitable comonomers are methylstyrene, vinyltoluene or methyl methacrylate.

Bifunctional monomers such as diallyl phthalate or divinylbenzene may likewise be added.

Other constituents of UP resins, such as hardeners, polymerization initiators, accelerators, plasticizers or the like are known to the skilled person and have been described in the literature, and so no further details need be given here.

Vinyl ester resins (also referred to as VE resins), another group of resins suitable for impregnating the fibre ribbons, are obtained by preparing, in a first stage, an epoxide oligomer which contains terminal vinyl ester groups such as acrylate or methacrylate groups and thus has reactive double bonds. In a second step, crosslinking is then effected, generally using styrene as solvent and crosslinking agent. The crosslinking density of VE resins is usually lower than for UP resins, as fewer reactive double bonds are present.

In VE resins, the base skeleton of the oligomer preferably has aromatic glycidyl ethers of phenols or epoxidized novolaks. These are preferably esterified at their terminal positions with (meth)acrylic acid.

The reactive resins used for impregnating the fibre ribbons may be cured thermally (typically by peroxide catalysts) or by radiation, for example by UV light with photoinitiators, as described, for example, in EP-A 23623. Also possible are what are called combination curings with a peroxide initiator used for thermal curing in combination with photoinitiators, and these have been found advantageous particularly in the case of high wall thicknesses of the lining tubes. A method for such a combination curing is described, for example, in EP-A 1262708.

After impregnation, the resin can be advantageously thickened, as described, for example, in WO-A 2006/061129. This increases the viscosity of the resin and improves the processibility and windability of the fibre ribbons used.

Usable fibre ribbons that are impregnated with the reactive resin containing nanoparticles in the lining tubes according to the present invention are all the products known to the skilled person in the form of weaves, knits, scrims, mats or nonwovens, which may comprise fibres in the form of long endless fibres or short fibres.

Corresponding products are known to the skilled person per se and are commercially available in great variety from various manufacturers.

The term “weaves” generally means sheet-like textile products composed of at least two orthogonally crossed fibre systems, wherein the so-called warp extends in the longitudinal direction and the so-called weft orthogonally thereto.

The term “knit” generally means textile products produced through the formation of loops.

Fibre scrims are a processing variant of fibres, in which the fibres are not woven but aligned parallel to each other and embedded in a chemical carrier material (the matrix) and which are generally fixed in place by cover foils on the top and bottom and optionally fixed in place with a thread or a glue. Fibre scrims, due to the parallel alignment of the fibres, show pronounced anisotropy of strengths the direction of the orientation and orthogonally thereto, which may be of interest for certain applications.

A nonwoven consists of loosely coherent fibres that are not bonded to one another. The strength of a nonwoven is based solely on the adhesion inherent to the fibres, but may be influenced by processing. In order to be able to process and use a nonwoven, it is generally consolidated, for which various methods may be employed.

Nonwovens differ from fabrics or knits, which are characterized by the laying of the single fibres or filaments determined by the processing method. Nonwovens, by contrast, consist of fibres whose position can only be described by statistical methods. The fibres are randomly oriented in the nonwoven. The term nonwoven thus clearly differentiates them from weaves. Nonwovens are differentiated, inter alia, by the fibre material (e.g. the polymer in case of manmade fibres), the weaving process, the fibre type (staple or endless fibres), the denier of the fibres and the fibre orientation. The fibres may be laid in a preferential direction or may be entirely stochastically oriented, as in the case of a random-laid nonwoven.

If the fibres do not have a preferential direction for their orientation, the term “isotropic nonwoven” is used. If the fibres are oriented in one direction more often than in another direction, the term “anisotropy” is used.

In the context of the present invention, felts should also be regarded as fibre ribbons in the sense of the invention. A felt is a sheet-like product based on unordered fibre material that can be separated only with difficulty. In principle, felts are thus textiles that have not been woven. Felts are generally obtained from manmade fibres or natural plant-based fibres through dry needling (called needlefelts) or through consolidation with water jets which exit from a nozzle bar under high pressure. The individual fibres in a felt are interlooped with each other in an unordered manner.

Needlefelts are generally manufactured mechanically with a multiplicity of needles with barbs, wherein the barbs are arranged in reverse direction compared to a harpoon. This presses the fibres into the felt and allows the needle to be easily pulled out. Through repeated stitching the fibres are interlooped with each other and thereafter optionally treated chemically or with steam.

Felts – like nonwovens – may be manufactured from virtually all natural or synthetic fibres. Besides needling or in addition thereto, it is also possible to hook the fibres with a pulsed water jet or a binder. The latter methods are particularly suitable for fibres without flake structure, such as polyester or polyamide fibres.

Felts show good thermal stability and are generally moisture-repellent, which may be an advantage in particular in the case of application in fluid-conducting systems.

Preference is given to using glass fibre weaves or glass fibre scrims for the lining tubes according to the invention.

In a preferred embodiment, the lining tubes according to the invention comprise, in radial direction, at least two different resin-impregnated fibre ribbons that have been wound one on top of the other.

In a preferred embodiment, the at least two different fibre ribbons differ from one another at least in one of the parameters of fibre incorporation, fibre orientation, fibre length or fibre type.

“Fibre incorporation”, as used in the context of the present invention, means the way in which the fibres are integrated into a carrier material.

The fibre ribbons used are selected in such a manner that the lining tube on one hand has an optimized property profile for the specific application, and on the other hand can be manufactured as simply as possible on available apparatus for the manufacture of such lining tubes.

Through the combined use of several different fibre ribbons with different constitution in terms of fibre type, fibre length, fibre bonding or fibre orientation, the property profile can be individually adapted to the specific application without any need for extensive modifications to the apparatus used for the manufacture. By virtue of the choice of the sequence in which the at least two different fibre ribbons are wound, it is possible to design the radial and longitudinal profile of the lining tubes according to the invention individually and optimally adapt to the specific application.

The length of the fibres used is not subject to any particular limitation, i.e. it is possible to use either what are called long fibres or short fibres or fibre fragments. The length of the fibres may be used to adjust and control the properties of the respective fibre ribbons over a wide range.

The type of fibres used is not subject to particular limitations either. The following are mentioned here merely by way of example: glass fibres, carbon fibres or polymer fibres such as aramid fibres or fibres based on thermoplastic polymers, such as polyesters or polyamides or polyolefins (e.g. polypropylene), these being known to the person skilled in the art with their properties and commercially available in great variety. For economic reasons, glass fibres are generally preferred; if, however, particularly good heat resistance is important, it is possible, for example to use, aramid fibres or carbon fibres, which may offer advantages over glass fibres with regard to strength at higher temperatures.

In some cases it has been found to be advantageous if a first resin-impregnated fibre ribbon is selected from weaves, knits, scrims, mats, felts or nonwovens, where the length of the fibres may be selected in accordance with the desired application. The first resin-impregnated fibre ribbon, for example, may be a fibre scrim of parallel-oriented endless fibres, preferably parallel-oriented endless glass fibres. The endless fibres are advantageously oriented substantially orthogonally to the longitudinal direction of the resin-impregnated fibre ribbon. Such a first fibre ribbon may be preferably combined with a second fibre ribbon in which the fibres are in an unordered arrangement in a random fibre mat. The first fibre ribbon imparts good strength to the lining tube in longitudinal direction, which is advantageous during the introduction into the pipe systems to be renovated. The second fibre ribbon with unoriented fibres in the form of a random fibre mat stabilizes the inner surface through its high resin uptake and prevents pores on the inner surface which can lead to damage in the case of prolonged contact with aggressive media. The use of the oriented fibre scrim, on the other hand, reduces the risk that the fibre mat on impregnation is drawn apart, thus resulting in inhomogeneous impregnation. Static requirements on the liner also make this execution seem preferable.

Particularly advantageously, in a first wound resin-impregnated fibre ribbon, the fibre scrim may already have been needled or sewed with a random fibre mat, i.e. the first fibre ribbon and also the subsequent fibre ribbons wound thereafter may also have a multilayer structure. In some cases it has been found to be advantageous here if at least one of the fibre ribbons wound onto a first fibre ribbon has a multilayer structure such that an interlayer with cut fibres arranged parallel to the longitudinal direction of the fibre ribbon is present between two layers with unordered fibres, said cut fibres preferably having a length in the range of 2 to 60 and preferably of 3 to 30 cm.

In a particularly preferred embodiment, the lining tubes according to the invention comprise a resin-impregnated fibre tube produced by winding at least one fibre ribbon having fibres oriented essentially perpendicularly to the longitudinal direction of the fibre ribbon and at least one further fibre ribbon having fibres oriented parallel to the longitudinal direction of the fibre ribbon.

In a third preferred embodiment, a nonwoven, preferably of polyolefin fibres, more preferred a propylene nonwoven, is used at least as a first resin-impregnated fibre ribbon, which may be combined with any other fibre ribbon of the types described above.

Finally, in a fourth preferred embodiment, a felt of the type described above is used as one of the fibre ribbons, and this may in turn be combined with at least one further fibre ribbon of the type described above.

As mentioned, it is possible in principle to combine any types of fibre ribbons which achieve the property profile desired for the planned application in the best possible way. For instance, it is possible to use fibre ribbons with homogenous fibre incorporation (e.g. two fibre scrims or two fibre weaves), which contain fibres of different chemical composition, different orientation or with different length. By way of example, it is possible to combine short fibres in one fibre ribbon with long fibres in at least one further fibre ribbon wound thereon, or it is possible to combine weaves with nonwovens, mats or knits. It is also possible to use two fibre weaves with fibres of identical incorporation and identical orientation and length but different chemical composition. This opens a great scope of variation for the skilled person within which he can effectively “tailor” the properties of the lining tube for the individual specific application.

Proceeding from the desired property profile, the skilled person will select the suitable fibre ribbons for the lining tubes according to the invention using his professional knowledge about the properties of the different types of fibre ribbons, and will thus be able to provide products optimally adapted to the individual application.

The width of the fibre ribbons is not subject to any particular limitations; for a variety of applications, fibre ribbons with a width of 20 to 150, preferably of 30 to 100 and especially of 40 to 80 cm have been found suitable.

The thickness of the fibre ribbons in the lining tubes according to the present invention is not subject to any particular limitation either and is determined by the thickness of the lining tube for the desired application. Thicknesses of the fibre ribbons in the range of 0.01 to 1 and preferably of 0.05 to 0.5 mm have been found to be useful in practice.

The lining tubes according to the invention have an optionally reinforced inner film tube based on a thermoplastic polymer, which may be removed after installation of the lining tube or which may remain in the pipe system to be renovated. This inner tubular film, if not removed after installation, contains 0.1% to 40% by weight, based on the total weight of the inner film tube, of nanoparticles as described above. It is also possible that both the inner film tube and the resin used for impregnation of the fibre ribbons contain nanoparticles.

Suitable thermoplastic polymers for the inner film tube are in principle all polymers which can be processed to foils or film tubes in the thickness needed for the particular application. If the curing is effected photochemically, it is additionally necessary to ensure that the products have sufficient transparency for the wavelength or wavelength range of the radiation used for curing. If the inner film tube is to remain in the system to be renovated after curing, sufficient stability towards the transported fluids and also towards the resin in the fibre tubes likewise has to be ensured. In the majority of cases, however, the inner film tube is removed after curing. Taking account of these criteria, polyolefins such as polyethylene or polypropylene, polyamides, polyesters such as polybutylene terephthalate, polyethylene terephthalate or polyethylene naphthalate, polyvinyl chloride, polyacrylonitrile or thermoplastic polyurethanes or any mixtures of these polymers are suitable in principle. Also suitable in principle are thermoplastic elastomers. Thermoplastic elastomers are materials in which elastic polymer chains are incorporated into thermoplastic materials. Despite the lack of vulcanization, which is necessary in conventional elastomers, thermoplastic elastomers have rubber-like elastic properties, which may be advantageous in some applications. By way of example, polyolefin elastomers or polyamide elastomers may be mentioned here. Corresponding products have been described in the literature and are commercially available from various producers, and so there is no need for further details here.

Particularly suitable and preferred thermoplastic polymers are for example polyolefins and/or polyamides, wherein film tubes based on composite foils of polyolefins and polyamides have been found to be advantageous in particular applications, since these have a better barrier effect than pure polyethylene foils towards styrene, which is usually used as solvent for the resins used. This allows better prevention of the escape of this solvent/monomer on the inside of the lining tube prior to curing.

In a preferred embodiment, the inner film tube has a reinforcement. This is selected in a manner such that on one hand an optimized property profile for the specific application case is obtained, and on the other hand manufacture of the lining tubes is as simple as possible.

More preferably, the inner film tube comprises a fibre-based reinforcement, in particular based on fibre ribbons as described above, or one based on nonwovens.

The thickness of the reinforcement, for example of the nonwovens, is advantageously in the range of 0.001 to 10 mm, more preferably in the range of 0.02 to 5 mm.

In a particularly preferred embodiment, the fibre-based reinforcement is a glass fibre weave or a glass fibre scrim.

In a further preferred embodiment, the inner film tube comprises a nonwoven lamination.

In the course of lamination, the reinforcement is physically bonded to the film forming the basis of the inner film tube. One example thereof is the lamination of the reinforcement onto the film, which leads to partial melting of the film. Corresponding processes for lamination are known to the skilled person and have been described in the literature, and so no further details need be given here.

In general, but without being limited thereto, the flat film from which the inner film tube is formed in the preferred embodiment has a thickness in the range of 40 to 800 µm, preferably of 50-500 µm and more preferably of 80 to 200 µm.

If the curing is to be effected after installation in the pipe system to be renovated through exposure to light, it has to be ensured that the materials used (both for the flat film from which the inner film tube is formed and for the film ribbon) are sufficiently transparent for the light used for irradiation in order not to impair or prevent curing. This is not important in the case of thermal curing

In addition, the lining tubes in accordance with the invention comprise at least one outer film tube based on a thermoplastic polymer.

Suitable outer film tubes for use in the lining tubes in accordance with the invention are known and have been described in the literature. By way of example, reference is already made to WO 95/04646 and WO 00/73692, and the reinforced outer film tubes according to WO 00/73692 are a preferred embodiment.

In principle, the at least one outer film tube should provide protection against light (to avoid premature and unwanted curing in case of photochemical curing) and in addition should prevent the escape of resin from the resin-impregnated fibre tubes into the pipe system to be renovated. Especially in the case of pipe systems to be renovated that have been laid in the ground, this is generally already desirable or required for reasons of protection of the environment. It is also advantageous if the outer film tube provides a certain degree of protection against mechanical damage when the lining tube is pulled into the pipe system to be renovated and roughness in the surface or fracture sites entail the risk of mechanical damage to the tube.

Useful materials for the at least one outer film tube b) are in principle any thermoplastic polymers, if necessary taking account of the individual requirements mentioned above for the individual case. The skilled person will select the suitable thermoplastic polymer in accordance with the profile of requirements defined. The same applies to the thickness and any use of reinforcement materials for the outer film tube, in respect of which the skilled person will decide on the basis of the individual case.

The lining tube according to the invention is preferably obtained by the winding of fibre ribbons onto or around the inner film tube with the aid of a winding mandrel or another suitable device.

In principle, however, it is also possible to obtain fibre tubes by aligning the longitudinal edges of flat foils and connecting these edges in a suitable manner. Corresponding processes are known to the skilled person and are described in the literature.

In a preferred embodiment, the lining tube is obtained by the winding of fibre ribbons with the aid of a device as described in WO 95/04646.

The fibre ribbons wound one on top of another in the lining tubes according to the invention overlap at their edges in this embodiment, for example by 5 to 300 mm.

The final lining tube, which usually has a length of 1 to 1000 m, in particular of 30 to 300 m, in the course of the actual pipe renovation, is introduced into the pipe system to be renovated, where it is inflated, for example, with pressurized water or preferably with air so that it closely fits the inner wall of the pipe system to be renovated. Finally, the resin is cured thermally with hot water or preferably by means of UV light, as described, for example in EP-A 122 246 and DE-A 198 17 413.

The lining tubes according to the invention are suitable for renovation of fluid-conducting pipe systems of any type and enable rapid renovation while minimizing the shutdown time of the systems for which they have to be taken out of use. Compared to the replacement of damaged parts, shutdown times are reduced. The lining tubes according to the invention may be particularly advantageously used for renovation of systems which are amenable only to a limited degree to conventional repair or renovation with replacement of parts because these, for example, are part of an overall system or because they are inaccessible, for example because they are laid underground. Examples of these include pipe systems for the transport of water or wastewater which are laid underground in cities and municipalities and often below streets or other traffic routes. In the case of renovation through replacement, these pipe systems first have to be exposed by appropriate digging and the traffic routes are not available for traffic for extended periods of time, which leads to significant disadvantages particularly in case of relatively high traffic volumes. By comparison, the renovation of such pipe systems with the lining tubes according to the invention can be carried out without digging in a few hours or days without extensive groundwork.

The nanoparticles in the reactive resins used for impregnation lead to an improvement of the surface structure of the side of the lining tube which is in contact with the flowing medium, after removal of any inner film tube present, whereby the friction and thus the abrasive effect of the flowing medium can be reduced. If the inner film tube is not removed, the nanoparticles therein improve the structure of the surface in contact with the flowing medium and reduce the abrasion caused by the flowing medium. In this case it is not absolutely necessary that the resin which is used for the impregnation of the resin-impregnated fibre tube also contains nanoparticles. The desired reduction in abrasion is already achieved by the providing of the inner film tube with nanoparticles.

Furthermore, the addition of nanoparticles to the reactive resin used for impregnation leads to an improvement in the mechanical properties, such as modulus of elasticity or strength.

The use of nanoparticles in the resin used for impregnation also has the advantage that the resins thus obtained generally have very good transparency for the radiation used for curing because the particle size of the nanoparticles is smaller than the wavelength of the radiation. This facilitates complete and homogenous curing of the lining tubes according to the invention compared to resins comprising larger particles.

PATENTKRAV

1. Foringsrør (-slange) til renovering af fluid-førende systemer, indeholdende mindst et harpiks-imprægneret fiberrør, et forstærket eller ikke-forstærket indre folierør på den side af det harpiks-imprægnerede fiberrør, som vender mod det flydende medium, hvorved 0,1 % til 40 %, baseret på totalvægten af harpikset eller totalvægten af det indre folierør, af nanopartikler er blevet tilsat til harpikset, der anvendtes til imprægnering, eller til det indre folierør, og nanopartiklerne på tidspunktet for inkorporeringen i harpikset, som anvendtes til imprægnering, har en gennemsnitlig partikelstørrelse D_{50} eller en største dimension i en hvilken som helst retning på mindre end 300 nm, og foringsrøret omfatter et ydre folierør.

2. Foringsrør ifølge krav 1, hvorved 0,1 til 40 vægt-% nanopartikler, baseret på harpiksets totalvægt, er blevet tilsat til harpikset, som er anvendt til imprægnering.

3. Foringsrør ifølge krav 1 eller 2, hvorved 0,1 til 40 vægt-% nanopartikler, baseret på det indre rørs totalvægt, er blevet tilsat til det indre folierør.

4. Foringsrør ifølge krav 1 eller 2, **kendetegnet ved, at** nanopartiklerne på tidspunktet for inkorporering i harpikset, der er anvendt til imprægnering, har en gennemsnitlig partikelstørrelse D_{50} eller en største dimension på 150 nm i en hvilken som helst rumlig retning.

5. Foringsrør ifølge et af kravene 1 til 4, **kendetegnet ved, at** det aktuelle harpiks er en umættet polyesterharpiks eller en vinylesterharpiks.

6. Fremgangsmåde ifølge et af kravene 1 til 5, **kendetegnet ved, at** fiberbåndet er en vævet vare, et knyttet stof, lærred, måtte eller vlies.

7. Foringsrør ifølge et af kravene 1 til 6, **kendetegnet ved, at** filterbåndet er et glasfibervæv eller et glasfiberlærred.

8. Foringsrør ifølge et af kravene 1 til 7, **kendetegnet ved, at** nanopartiklerne er metaloxider, metalcarbonater, metalsulfater, wollastonit, xonolit, sepiolit, attapulgit, palygorskit eller carbon-nanorør.

9. Foringsrør ifølge krav 8, **kendetegnet ved, at** nanopartiklerne er carbon-nanorør.

10. Foringsrør ifølge et af kravene 1 til 9, **kendetegnet ved, at** det indre folierør omfatter en forstærkning.

11. Anvendelse af foringsrørene ifølge et af kravene 1 til 10 med henblik på renovering af spildevands-ledningssystemer.