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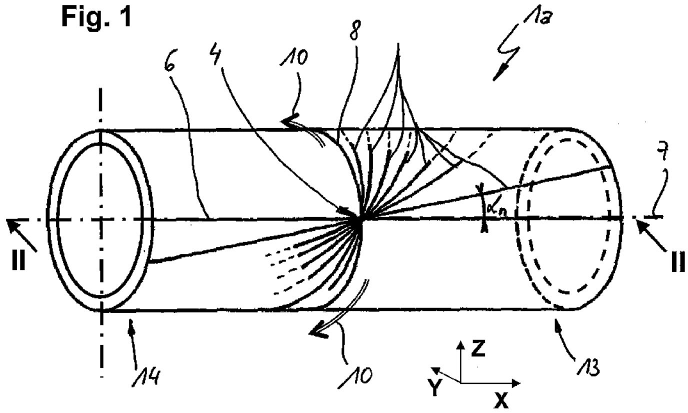
(54) Title: HOLLOW ELECTRIC INSULATOR AND MANUFACTURING THEREOF

Fig. 1



(57) **Abstract**: A hollow medium voltage or high voltage (composite insulator body comprising a plurality of layer portions of a first winding member wound in helical convolutions in a direction of a longitudinal axis defined by the insulator body, wherein a winding direction of the helical convolutions is tangentially with respect to the longitudinal axis and extends between a first end portion and a second end portion of the insulator body, wherein said winding direction is inclined to the longitudinal axis such that the longitudinal axis and said winding direction enclose a winding angle; the first winding member having a tensile strength in the winding direction which exceeds a tensile strength of the winding member transversely to the winding direction; the plurality of layer portions comprising a first layer portion being wound with a first winding angle and a second layer portion being wound with a second winding angle wherein an absolute value of the second winding angle differs from an absolute value of the first winding angle; and wherein the first winding member is fixed with a compound.

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DESCRIPTION

Hollow electric insulator and manufacturing thereof

TECHNICAL FIELD

The present invention refers to a hollow electrical insulation system based on composite composition. The electrical insulator tubular being in particular a high-voltage and/or medium voltage insulator body.

BACKGROUND OF THE INVENTION

Today, the use of fiber reinforced polymer compositions, hereinafter referred to as FRP's, as a suitable material for building electrical insulators for high and medium voltage applications is known. Commonly, these insulators are manufactured by winding strands of fibers through a polymer resin such as epoxy on a mandrel. The strands are wound on the mandrel by applying a predefined feed motion of the polymer strands back and fro along the mandrel in a longitudinal defined by the mandrel. This results in an insulating body comprising several layers of strands that are aligned in a positive winding angle during a forward motion and in a negative winding angle during a backward motion caused by an escapement. For manufacturing reasons the direction of the feed motion is changed in two opposed end sections of the future insulating body. After completing a curing process these end sections are cut off. Then, the cut section is finished such that the remaining intermediate portion becomes the desired insulating body.

The US-A-4,495,381 discloses an electrical insulator of such a type comprising an insulating section that is made of several layers of fiber band that is drawn through a liquid resin bath onto a rotating mandrel. Figure 6 and the correspondent description attend to the manufacturing process of the insulator. Winding the two successive layers of fiber bands are wound on a mandrel by the positive and negative winding angle in opposing convolutions results in a regular winding pattern.

Further, tubular electrical insulators are known in the art that are produced by winding a fiber glass filament on a cylindrical mandrel in a helical manner with respect to a longitudinal axis, i.e. the rotating axis of the mandrel, from a first end portion of the mandrel to the opposite second end portion thereof. Eventually, the plurality of helical convolutions of the fiber that are wound on the mandrel form a first layer. Once the second end portion is reached the pitch direction of the winding guide of the fiber supply is reversed and a second layer is wound on top of the first layer with a winding angle that is directing in the opposite direction towards the first end section. Once the first end section is reached the second layer is completed and a new, i.e. a third layer is wound in the same manner as the first layer until the desired wall thickness is achieved. After termination of a curing process the hollow FRP insulator is stripped off the mandrel.

Both prior art techniques have in common that they are suitable mainly for electrical insulators that are subject to static loads. An electrical insulator delimits a gas chamber, typically a pressurized gas comprising SF_6. An electrical insulator must not only be able to delimit the insulating gas in its interior at an about constant pressure but also at dynamic load conditions that attack its interior wall surfaces extending in the longitudinal direction. If the electrical insulator is integrated in a high current device, e.g. a generator circuit breaker, it must be able to endure two main situations. The first situation is known as short line fault (SLF) and the second situation is known as terminal fault (T100a).

Especially in the T100a case, a high gas pressure is generated within a comparatively short period of time. This results in a shock wave which has to be born by the structure of the insulator. When seen in the context of the present invention, said shock wave applies a dynamic load onto the insulator. Typically, the maximum pressure value of the shock wave, i.e. the burst pressure, exceeds the static load by far. The burst pressure may be in a range of about 60 bars or more.

Unfortunately known electrical insulators cannot be used for high end applications such as isolators of circuit breaker chambers of high or medium voltage applications, for example, since they have a comparatively poor sustainability if dynamic loads are applied. This is because such known insulators are usually made of epoxy resin, which is known to be a rather brittle material rather than having good mechanical stress values. Attempts to manufacture a reliable insulator being made of epoxy resin based FRP structures led to comparatively thick walled insulators. Such thick walled insulators are often that heavy such that can not be handled easily, e.g. lifted by one person only during the manufacturing process or during maintenance or repair.

BRIEF SUMMARY OF THE INVENTION

A first object of the present invention relates to a manufacturing method for creating hollow FRP insulators, in particular high voltage and medium voltage insulators, that are suitable for housing gas insulated electrical equipment in their interior in case that the insulation gas is under high pressure. A second object of the present invention relates to such electrical insulators.

These objects are solved by the subject-matter as set forth in the independent claims whereas particular embodiments are claimed by the dependent claims.

In a first aspect, a method for manufacturing a tubular high-voltage and/or medium voltage insulator body is disclosed. Said method comprises the following activities:

- Providing a winding device comprising a rotatable winding mandrel and winding guide for guiding an elongated winding member from a winding supply device to the winding guide in a winding direction tangentially towards the winding mandrel, wherein the winding mandrel defines a longitudinal axis and extends longitudinally between a first end portion and a second end portion, wherein said winding direction is inclined to the longitudinal axis such that the longitudinal axis and said winding direction enclose a winding angle;
- Forming a first layer portion of the insulator body by winding a first winding member in a coiled manner with respect to the longitudinal axis with a first winding angle, wherein the first winding member has a tensile strength in the winding direction which exceeds a tensile strength of the winding member transversely to the winding direction;
- Forming a second layer portion of the insulator body by winding the first winding member in a coiled manner with respect to the longitudinal axis with a second winding angle, wherein an absolute value of the second winding angle differs from an absolute value of the first winding angle;
- Fixing the first winding member with a compound in a curing process.

The winding angle is the key factor for mechanical performance of the insulator in terms of sustainability to stress. Commonly the strength of the FRP is approximately 20 times higher in direction of the fibers than in parallel direction. Thus, the first winding member has to be oriented to carry the mechanical stresses arising of the internal pressure, bending as well as torsion in the most effective way. An optimized winding angle of the FRP for carrying the stresses while loaded by internal pressure leads to a fully tailored electrical insulator.

The full extent of the present inventions becomes clear when focusing on the actual load/stress types and constraints that are present at the different longitudinal portions of the insulator body. When investigating the mechanical load distribution within the shell wall of the tubular, hollow electrical insulator one has to consider the boundary conditions. Commonly, the opposite end portions of the insulator having a cross-section of a circular ring are hold in place in a gas-tight manner by metallic ring-shaped clamps that are fixed to an adjacent metal housing such that the insulator shell acts as an insulating membrane. When focusing closer on the stress in the shell wall of the insulator in case of a high pressure applied by a shock wave, e.g. during the application of a burst pressure in the interior of the insulator, the membrane-like shell wall bulges convexly between the two end portions, such that the largest inner diameter of the insulator measured perpendicularly to the longitudinal axis is located somewhere in between the end portions in the direction of the longitudinal axis, presumed that the wall thickness is evenly distributed along the entire length of the insulator. At an insulator geometry of an even diameter and an even shell wall thickness, the following stresses are to be assessed. Proximate to the comparatively rigid, i.e. stiff clamps, the finite insulator wall elements are subject to internal pressure as well as to tensile stress acting in the direction of the longitudinal axis of the insulator tube. When considering also the thickness of the insulator wall, the finite insulator wall elements are also subject to bending relative to the longitudinal axis. In addition thereto are those finite insulator wall elements that are located in between the two end portions with respect to the longitudinal axis also subject to hoop stress running in a circumferential, i.e.

tangential direction with respect to the longitudinal axis whereas the hoop stress values exceed the tensile stress values by far.

The inventive concept addresses to these different requirements in stress handling of the winding member at the different locations along the longitudinal axis in the shell wall, hereinafter referred to simply as wall for enhanced readability, in that a more radial flexibility is conferred to the insulator by varying at least one of the first and second winding angle between the first and the second end portion when seen in the direction along the longitudinal axis at the time of forming one layer.

If the first as well as the second winding angle are changed monotonously for the successive layers, e.g. in that the winding angle is chosen to be small at the innermost layer and chosen to be large at the outermost, i.e. last layer, these different demands in regard of the stress to be born by the finite insulator wall elements that are located in between the two end portions in the direction of the longitudinal axis are satisfiable with a lower total number of winding layers than the total number of winding layers of a traditional insulator being wound by appliance of just one constant winding angle.

The somewhat contravening demands of a good axial tensile strength proximate to the end portions and a good hood strength longitudinally in between said end portions is achievable according to the present invention in a very effective manner without excessive undue compromises.

Although the main load is formed by the internal pressure in the above-mentioned description, additional loads originating from the clamps may cause additional tension stresses and/or bending moments in the radially inner layers or plies. However, good mechanical results are achievable if the first layer is wound with a minimal first winding angle.

If the electrical insulator is subject to additional loads such as axial pressure or tension, torsion and/or bending moments, the comparatively weak end portions of the insulator body may require a different handling and/or other measures to deal with.

Now let us return to the main load case originating of the internal pressure. In a basic embodiment, the first and second layers are tubular layers, in particular tubular layers having a cylindrical, ring shaped cross section.

Although the manufacturing process is demanding, the advantages conferred to an electrical insulator are manifold.

In a first embodiment, the increased mechanical performance of the inventive electrical insulator allows to reduce the overall mass of the electrical insulator by about 30% in an operating state of the electrical insulator, presumed that the mechanical load remains unchanged and presumed that its longitudinal end portions are fixed appropriately. As a result, such an insulator may be lifted and handled by one person only instead of two persons. In other words, the inventive insulator body contributes essentially to a more compact overall dimension of a medium voltage or high voltage installation since the insulator allows smaller insulation distances compared to a metallic housing.

In a second embodiment, the mass of the electrical insulator is comparable to the mass of a conventional one. However, the comparatively superior mechanical performance allows an increase of the sustainable inner gas pressure of about 30% in an operating state of the electrical insulator presumed that its longitudinal end portions are fixed appropriately.

Moreover, the variation in the winding angle allows manufacturing fully customized electrical insulators depending on the applicable demands. As an example, both the winding of insulators having a constant wall thickness and variable wall thickness along their length is feasible. The purpose of variable thickness of the tube is the clamping or optimal mechanical stress distribution. Thus, this also contributes to the freedom in design of the electrical insulator.

Moreover, the safety of the medium voltage or high voltage installation is improved in case of excessive pressure causing the housing to burst. In contrast to a metallic housing that has a latent danger of forming shrapnel-like metal projectiles when bursting does the FRP polymer insulator body according to the present invention burst softer in that the fibers maintain the insulator particles together even in a burst case. If it comes to the worst there are merely polymeric parts of the insulator body that are broken of the burst section. Thus the invention contributes at least to a reduced environmental damage in case of a burst due to internal pressure overload compared to known metallic installations.

In a further embodiment even winding with a varied winding angle in the same layer becomes possible leading to further applications that have not been possible before.

If the winding process produces irregularities in thickness it is possible to compensate them during the subsequent winding in that multiple transverse windings of the first winding member are used to create a locally thicker layer.

In addition or as an alternative to tailoring a bending stiffness versus a normal stiffness in different directions (X,Y,Z) by thickness variations during the winding process, the mechanical performance is customizable by winding the first (interior) layer or ply with a winding angle that is as small as possible as it is subject to axial stresses and winding a radially outer, in particular the outermost, layer or ply with a maximal winding angle. The technical effect is a reduced axial stress in the interior layer as well as a reduced hoop or membrane stress in the area between the end portions of the insulator.

The term medium voltage is understood hereinafter as a voltage being in a range between about 1 to about 72 kV whereas voltages higher than 72 kV are referred to as high voltage.

Electrical insulators manufactured according to the inventive method are particularly useful for housing high current equipment. The term high current is understood in this context as a current being more than 15 kA, in particular a current of about 30 kA or above.

For the following description, the term high pressure is to be understood as an internal gas pressure in the area of more than 20 bars up to 60 bars or more.

In the context of the present disclosure, the term winding member is to be understood in a broad sense not being limited to one single winding member such as a single fiber, but also enclosing several strands of fibers as well as fiber bundles or rovings. Furthermore it shall encompass also any kind of suitable fabrics having a predefined main orientation allocated to bear a maximum stress load.

The definition compound shall be understood broadly as a pourable, preferably liquid mixture of a dielectric material. As an example, a polymer compound of a polymeric resin, e.g. epoxy resin, plus additives, where necessary in an unsolidified state of the polymer compound. Said polymer compound is used and understood hereinafter to be the material resulting in a duroplastic material, also known as thermosetting plastic or thermosetting polymer. The polymer compound comprises a thermosetting compound typically comprising epoxy resin or acrylate resin or unsaturated polyester or other resins used for electrical insulations or a combination thereof.

Depending on the requirements and the feasibility during the manufacturing process, the operation of connecting the winding members of the different layers and convolutions with a compound, for example a polymer, is conducted prior to the step of forming the first and second layers. Depending on its purpose, the compound may be resinous, synthetic or polymeric. As an example, the wetting process may be performed by drawing the further winding member through a liquid polymeric bath prior to the step of forming the first and second layers, for example.

All thermosetting plastics, also referred to as thermosets, are polymer materials that irreversibly cure form. The step of curing is achieved through heat, e.g. at a temperature above 100 degrees centigrade, through a chemical reaction, i.e. a two-part epoxy, for example, or irradiation such as electron beam processing. Depending on their chemical compositions, acrylates and epoxies can also cure at room temperature, for example.

The curing process transforms, also referred to as fixing step, forms the resin into a plastic or rubber by a cross-linking process. Where applicable, energy and/or catalysts are added that cause the molecular chains to react at chemically active sites (unsaturated or epoxy sites, for example), linking into a rigid, three dimensional structure. The thermosetting epoxide polymer cures (polymerizes and crosslinks) typically when mixed with a catalyzing agent or hardener.

The present manufacturing method is not limited to the creation of tubular insulator bodies but shall also encompass cone-shaped, convex, concave longitudinal shapes, where necessary even with different wall thicknesses along the longitudinal axis, but also to non-circular cross-section shapes such as polygonal or rectangular cross-sections, where required.

Depending on the required mechanical properties of the insulator body to be produced, the at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied during the winding process from a radially inner layer to a radially outer layer of the insulator body. The variation may be realized at least partially by a gradual increase of the first and/or second winding angle. In example of the inventive insulator body, a radially inner first layer may feature a small winding angle and is thus well suited for carrying tensile stress in the direction of the longitudinal direction (Z) while a radially outer layer has a large winding angle such that is suited optimally for bearing hoop stress.

The selection of at least one of the first and the second winding angle depends on the diameter and/or the length in the direction of the longitudinal axis of the insulator body to be wound.

In an embodiment of the method, at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied between the first end portion and the second end portion in the direction of the longitudinal axis during the winding process of the first layer portion and the second layer portion, respectively. In other words, the winding angle is varied during the winding process of winding the very same layer portion. Such a winding angle variation can be performed by a controlled, preferably stepless escapement device or mechanism running essentially along the longitudinal axis. Such a manufacturing method leads to an insulator body whose pitch distance of two neighboring convolutions of at least one layer in the direction of the longitudinal axis is different.

Good mechanical values of an insulator body are achievable if at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a step-wise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body. The term monotone variation of winding angle between odd and even layer number, in particular the term monotone itself is to be understood in a mathematical sense/term in that several subsequent layers may have the same winding angle before the latter is increased/decreased again.

If the loads demand it, an inverse situation is also conceivable where the at least one of the first and the second winding angle of the inner layer is larger than the at least one of the first and the second winding angle of the outer layer.

Embodiments of the method comprise at least one of the absolute value of the first winding angle and the absolute value of the second winding angle that is varied monotonously increasingly or monotonously decreasingly, in particular in a step-wise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an odd layer number. By winding so, a gradual variation of winding angle between every odd layer can be realized, for example.

Where applicable, the method is characterized in that at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a step-wise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an even layer number. An insulator wound that way features a gradual variation of winding angle between every even layer, for example.

Good mechanical values of an insulator body are achievable in terms of wall thickness and weight if the at least one of the absolute value of the first winding angle and the absolute value of the second winding angle of a radially inner layer of the insulator body is smaller than the absolute value of the first winding angle and the absolute value of the second winding angle of a radially outer layer of the insulator body.

Embodiments of winding angles for the method are set for the at least one of the first and second winding angle to be in a range of about 2 degrees to about 90 degrees, in particular in a range of about 5 to about 70 degrees, more particular in a range of about 9 degrees to about 50 degrees. With such an insulator good mechanical load sustainability is achievable.

Depending on the manufacturing process and the demands on the insulator, the first winding member is a band or roving of plural strands of fibers, preferably continuous strands of fibers. At least one layer is wound such that two consecutive convolutions of the band are arranged at least partially in an overlapping manner with respect to the longitudinal axis.

In a basic embodiment, one of the first winding angle and the second winding angle is a positive winding angle and one of the second winding angle and the first winding angle is a negative winding angle with respect to the longitudinal axis.

In case of fiber reinforced insulators having winding members comprising epoxy soaked glass fibers, chemically aggressive gas particles such as acidic oxides, e.g. SiO_2, have a corrosive effect on the insulator body. For such or similar cases the corrosion sensitive first and second layers are protectable by a corrosion resistant protective layer. A convenient and economic method for producing such insulators is achieved if prior to the step of forming the first layer portion at least one base layer portion of the insulator body is formed by winding a second winding member in a coiled manner with respect to the longitudinal axis with a third winding angle on the mandrel. Where required the corrosion resistant radially innermost portion of the insulator tube comprises several layers or layer portions of the second winding member, e.g. if a certain minimal thickness of the protective base layer is required.

The third winding angle is selected to be positive or negative with respect to the longitudinal axis. Further he may be selected to be small, medium or large depending on the technical demands on the base layer as well as on subsequent first and/or second layer portions.

In an embodiment, the second winding member is a strip-shaped tissue, in particular a tissue comprising at least one of a fabric or a fleece. Good results are achievable with a polyester fabric or a polyester fleece.

In a basic embodiment of the method, a convolution of the second winding member is wound such that it contacts a neighboring convolution of the second winding member of the same layer in an overlapping manner.

Depending on the compound and its processability, the method employs a step of wetting at least one of the first winding member and the second winding member with a compound prior to the step of forming the first layer, the second layer and the base layer, respectively, in particular by drawing the first winding member through a liquid polymeric bath.

If the end portions of the insulator are still considered as too weak to sustain the mechanical stresses, these weak portions can be locally improved. In this case, the method comprises an additional step of embedding at least one local enforcement element between the layers, particularly in between the at least one of the first end portion and the second end portion of the insulator body. The local enforcement element can be a fabric, in particular a fabric having a predefined mechanical tensional strength in at least direction for structurally conferring or improving at least one stress withstand capability to/of the insulator body. One embodiment of such a local enforcement element comprises at least one pre-preg.

In a particularly advantageous manufacturing method, several electrical insulators are wound on the mandrel at the same time as one single tubular insulator body. Thereafter, the hollow tube in cut in longitudinal ring-like portions and their end surfaces machined and/or finished, if required. By doing so the inventive method contributes to an economical production of insulator bodies that may have different mechanical performance abilities depending on the location of the place with a local winding angle orientation where the cut is performed. In an embodiment where one common insulator body has been wound with varying winding angles of at least the first or second winding angle at least twice, two mechanical identical insulator bodies may be derived if the cut is placed in about the mid-length, provided the angle variation is equal in both longitudinal tube portions.

Moreover, the cutting allows an economic manufacturing of electric insulators having different wall thicknesses with respect to their longitudinal axis.

In a second aspect, a hollow high-voltage and/or medium voltage insulator body is disclosed that comprises a plurality of layer portions of a first winding member wound in helical convolutions in a direction of a longitudinal axis defined by the insulator body. A winding direction of the helical convolutions is tangentially with respect to the longitudinal axis and extends between a first end portion and a second end portion of the insulator body. Said winding direction is inclined to the longitudinal axis such that the longitudinal axis and said winding direction enclose a winding angle. The first winding member has a tensile strength in the winding direction which exceeds a tensile strength of the winding member transversely to the winding direction. The plurality of layer portions comprising a first layer portion is wound with a first winding angle and a second layer portion being wound with a second winding angle wherein an absolute value of the second winding angle differs from an absolute value of the first winding angle. Eventually, the first winding member is fixed with a compound, e.g. in a curing process.

Appointing different winding angles to certain fibers contributes essentially to an optimized exploitation of the stress bearing abilities of the fibers resulting in an insulator body that is able to withstand both a static load as well as a dynamic pressure shock wave originating from a pressurized medium present in the interior of the insulator body.

For further advantages and the technical effects of such an insulator body please see the description relating to the manufacturing method which applies likewise to the inventive insulator body.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the annexed schematic drawings, wherein:

Figure 1 shows a three dimensional view of first embodiment of a tubular electric insulator body having a ring-like cross section in its longitudinal direction;

Figure 2 shows a longitudinal section of the first embodiment as shown in figure 1, where the insulator body is clamped at its end portions and where no internal gas pressure is applied;

Figure 3 shows the longitudinal section as shown in figure 2 but where an internal gas pressure is applied;

Figure 4 shows a partial sectional view of the section IV in figure 3;

Figure 5 shows a simplified winding scheme using a minimal winding angle;

Figure 6 shows a simplified winding scheme using a larger winding angle than that shown in figure 5;

Figure 7 shows a simplified winding scheme using a maximal winding angle; and

Figure 8 shows a simplified winding scheme where different winding angles are applied at different longitudinal portions of the insulator body.

In the drawings identical and/or functionally identical elements parts and designated by identical reference numerals, unless indicated otherwise.

DETAILED DESCRIPTION OF THE INVENTION

A first embodiment of the inventive winding process of a tubular medium voltage or high voltage composite insulator body 1a is represented by **figure 1**. Figure 1 shows partially six convolution portions of the first winding member 2 which wound at six different winding angles $\alpha 1$ to $\alpha 6$ respectively of increasing absolute winding angle values but with the same positive first winding angle α. For easing the understanding, the six winding members are displayed in the very same tangential winding point 4 of an essentially cylindrical mandrel (not shown) in a place where a shell line 6 runs essentially parallel with a longitudinal axis 7 defined by the rotatable mandrel. The longitudinal axis 7 is at the same time the rotating axis of the mandrel 5 running in the direction X. Transversely thereto, a full circumferential, tangential line 8 runs about the longitudinal axis 7 on a shell surface of the mandrel. The ring-like cross section of the insulator body extends in a plane Y-Z that is extending perpendicularly to the direction X.

The strength of the composite insulator is approximately twenty times higher in the direction in which the first winding members runs than in a direction running transversely thereto. The first winding member is a fiber, in particular a glass fiber, but other fibers, such as carbon (graphite), polymer (aramid) or combination fibers, may be used with or without their occurrence in rovings, bundles and the like. Although a variety of glass fibers would be suitable, the preferred fiber is "E-glass". "E-glass" is an inexpensive, electrical grade fiber having high mechanical strength. According to the invention, the continuous strand of fibers forming the first winding member 2 is "wetted" in a controlled manner in a liquid resin bath (not shown). For example, the fibers are coated with a polyester, vinyl ester, epoxy, phenolic, thermoplastic polymer or other material having similar properties. The resin must provide a good mechanical bond and preferably be suitable for high temperature molding.

Then, the first winding member is repetitively wound from one end portion 13to the other end portion 14 by forming multiple loops or helix-like convolutions in case of the circle-cylindric cross section of the insulator body 1.

The maximum stress allowed by the first winding member 2 wound along the maximal angle $\alpha 6$ (the closest to 90 DEG of the full tangential line 8) is significantly larger than that of the first winding member wound under the angle $\alpha 5$, and much greater than that of the fibers wound along the angle $\alpha 4$, and so on. See also figures 5 to 7 for reference.

The mandrel 5 and the shell surface 9 of the mandrel are not shown in figure 1 but in **figure 5** where they are indicated by a dash double-dotted line in. The dominant hoop stress direction 10 is indicated by the arrows running in the circumferential direction.

Prior to winding a first layer with the first winding member, a cylindrical base layer (not shown) is formed by employing a second winding element 3 to a third layer 3 formed by a strip-like protective polyester fleece for the purpose of providing a corrosion resistant base layer (shown partially in the lower part of figure 2 as an option leading to an insulator body 1c). The wall structure of the insulator body 1c resulting of such a manufacturing method leads to a set-up as shown at the broken insulator wall 17b at the second end portion 14 of the insulator body 1c. The polyester fleece is applied on the mandrel in a helical manner by applying a maximized third winding angle and by winding a consecutive convolution of the second, strip-shaped winding member in a partially overlapping manner on the preceding convolution of the same base layer. The fleece is impregnated with the compound, e.g. an epoxy resin composition and afterwards wound around the rotating mandrel up to a predefined layer thickness. Immediately afterwards, a radially outer layer set comprising at least one of the first and second layer is formed by winding the first winding member around said base layer. Then, the winding is continued until a desired thickness and orientation of winding members is reached. The first winding member is impregnated with the same compound as the second winding member prior to the winding process. The polyester fleece is applied on the mandrel in a helical manner by applying a maximized third winding angle and by winding a consecutive convolution of the second, strip-shaped winding member in a partially overlapping manner on the preceding convolution of the same base layer.

This angle is the key factor for mechanical performance of the insulator. Commonly the strength of the FRP is approximately 20 times higher in direction of the fibers than in parallel direction. Therefore, the first winding member 2, e.g. the fibers have to be oriented to carry the stresses in the most effective way. Since the radially innermost first layer portion 11 is exposed to axial stresses, the first winding angle of said layer is selected to be as small as possible (such as indicated by figure 5), the e.g. radially outermost second layer portion 12 has to carry the hoop stress and therefore the second winding angle is as high as possible, i.e. maximal (values are nearly 90° as shown in figure 7. Winding angles of the layer located radially in between the innermost first layer and the radially outermost second layer have values between the initial first winding angle and the last second winding angle (see figure 6 for reference). The plurality of layers of the first winding element 2 leads to an insulator wall 17a such as indicated in figure 3 and the upper half of figure 2.

Together with **figure 5** and **figure 6** it becomes clear that after at least two helical wound tubular layer portions, e.g. a first layer portion 11 and a second layer portion 12 are developed with the first winding member 2, the winding pattern is changed to an almost circumferential/tangential winding with a large winding angle such as shown in **figure 7**. The first winding angles shown in figures 5 to 7 have the same orientation, i.e. are all positive angles for the purpose of easy understanding. In this embodiment, the first winding member has been brought back from the second end portion 14 to the first end portion 13 by winding a further first/second layer with the first/second winding angle remaining unchanged with respect to its absolute value but with a negative winding angle with respect to the longitudinal axis. With other words, these layers exist but have not been shown for clarity reasons.

Varying the winding angles during the winding process addresses specifically to the different mechanical stresses that are to be found in the shell wall elements of the insulating body along in the direction of the longitudinal axis 7. This is explained best in a most basic embodiment of the inventive insulator body of tubular shape with an even wall thickness, whereas the profile of the tube is symmetrical in respect to the longitudinal axis defined by the insulator such as shown in **figure 2**. For the sake of improved clarity, the insulator wall 17 is not displayed as a cross-hatched area in the sectional views of figures 2 and 3. The first layer and the second layer have not been displayed separately in the set of figures as it would be detrimental to the understandability. Said insulator body 1 is clamped in gas tight manner at each of its end portions, i.e. at its first end portion 13 and its second end portion 14 in particular by metallic clamps 15 having a much higher stiffness than the composite insulator body 1. Upon exposure of the insulator body 1 by an internal pressure caused by an insulating medium, in particular insulating gas such as SF6, for example, the insulator shell wall 17 deforms in between the first end portion 13 and the second end portion 14 sooner than at the clamps 15a, 15b, causing the insulator to deflect and/or deform to a barrel-shape. The internal pressure p_i causes the main load for the following explanation. **Figure 3** shows the longitudinal section as shown in figure 2 but where an internal gas pressure p_i is applied. The stress situation in an area IV at the clamp 15a is shown and explained with reference to figure 4. In this condition, the first winding member 2 of the first layer portion 11 is bent around an edge line of the circumferenting clamp 15 shown in an edge point 16 in **figure 4** such that the shell wall 17 is deflected off the longitudinal axis 7 the more it is distanced from the clamp 15a in the longitudinal direction Z. The force applied perpendicularly to the radially inner surface of the insulator wall 17 is indicated as force F_i. Hence, the tensile stress value in a finite wall element proximate to the clamps, i.e. at an end portion of the insulator body (indicated by double-headed arrow 18), exceeds the value of the hoop stress 10 running in a circumferential direction with respect to the longitudinal axis. Entirely different thereto is the stress situation in a finite wall element located at about equidistance between the first and the second end portions 13, 14 of the insulator body since there it is the hoop stress value that exceeds the tensile stress value by far. The hoop stress results mainly of the main load, i.e. the internal pressure in the hollow/cavity of the tubular insulator body 1.

Thus the inventive concept resides in orienting as many fibers as possible such that all or at least most mechanical stresses are carried in the most effective way. This is achieved by allocating fibers having a first winding angle to carry mainly the tensile stress and to allocate fibers being wound at a second, different winding angle to carry mainly the hoop stress leading to an insulator body that features an optimized stress distribution selected for each specific layer or portion thereof. As a result, the burden of stress in the fibers can be kept at a minimum which is positive in terms of an enhanced overall device security both during regular use as well as in case of a failure.

In addition, this gives the opportunity to find the optimal thickness for specific internal pressure loading.

An inventive variation of that inventive concept is shown in **figure 8** that discloses an insulator 1b where an absolute value of the first winding angle $\alpha1$ and an absolute value of the second winding angle $\alpha2, \alpha3, \alpha4, \alpha5, \alpha6 \ldots \alpha_n$ are varied between the first end portion 13 and the second end portion 14 in the direction of the longitudinal axis during the winding process of the first layer portion 11and the second layer portion 12, respectively. In figure 8 only a selected number of first winding elements 2 are displayed for showing the winding angle variation schematically only. Thus the lines representing the first winding member that is pulled in the winding direction with a certain winding angle are not shown in a detailed side view where the first winding member 2 would be visible as a curve rather than the schematic straight section shown in any of figures 5 to 8.

In addition, figure 8 shows that cutting a first longitudinal section 19 at the first cutting lines 20 leads to a first tubular electrical insulator in the second longitudinal section 21 whose mechanical performance is different to a second tubular electrical insulator in the second longitudinal section 21 that was derived by cutting the insulator body 1b along the second cutting lines 22 owing to the different orientation of the first winding angle convolutions with respect to the longitudinal axis 7 at both lateral ends of the respective longitudinal sections. The first and second cutting lines 20, 22 are displayed by a dash-double-dotted and a dotted line, respectively.

List of Reference Characters

1	tubular electrical insulator body
2	first winding member
3	second winding member
4	tangential winding point
5	mandrel
6	shell line
7	longitudinal axis
8	full tangential line
9	shell surface of mandrel
10	hoop stress direction
11	first layer portion
12	second layer portion
13	first end portion
14	second end portion
15	clamps
16	edge point / edge line
17	shell wall
18	tensile stress direction
19	first longitudinal section
20	first cutting line
21	second longitudinal section
22	second cutting line

Claims

1. A method for manufacturing a tubular high-voltage and/or medium voltage insulator body (1a, 1b), comprising the following steps:

a) Providing a winding device comprising a rotatable winding mandrel (5) and winding guide for guiding an elongated winding member from a winding supply device to the winding guide in a winding direction tangentially towards the winding mandrel, wherein the winding mandrel defines a longitudinal axis (7) and extends longitudinally between a first end portion (13) and a second end portion (14), wherein said winding direction is inclined to the longitudinal axis such that the longitudinal axis and said winding direction enclose a winding angle;

b) Forming a first layer portion (11) of the insulator body by winding a first winding member (2) in a coiled manner with respect to the longitudinal axis (7) with a first winding angle, wherein the first winding member (2) has a tensile strength in the winding direction which exceeds a tensile strength of the first winding member transversely to the winding direction;

c) Forming a second layer portion (12) of the insulator body by winding the first winding member (2) in a coiled manner with respect to the longitudinal axis with a second winding angle, wherein an absolute value of the second winding angle differs from an absolute value of the first winding angle;

d) Fixing the first winding member (2) with a compound in a curing process.

2. The method according to claim 1, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied during the winding process from a radially inner layer to a radially outer layer of the insulator body.

3. The method according to claim 1 or 2, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied between the first end portion and the second end portion in the direction of the longitudinal axis during the winding process of the first layer portion and the second layer portion, respectively.

4. The method according to any one of claims 1 to 3, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body.

5. The method according to any one of claims 1 to 3, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an odd layer number.

6. The method according to any one of claims 1 to 3, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an even layer number.

7. The method according to any one of claims 4 to 6, wherein the at least one of the absolute value of the

first winding angle and the absolute value of the second winding angle of a radially inner layer of the insulator body is smaller than the absolute value of the first winding angle and the absolute value of the second winding angle of a radially outer layer of the insulator body.

8. The method according to any one of claims 1 to 7, characterized setting the at least one of the first and second winding angle to be in a range of about 2 degrees to about 90 degrees, in particular in a range of about 5 to about 70 degrees, more particular in a range of about 9 degrees to about 50 degrees.

9. The method according to any one of claims 1 to 8, characterized in that the first winding member is a band or roving of plural strands of fibers, preferably continuous strands of fibers, and wherein at least one layer is wound such that two consecutive convolutions of the band are arranged at least partially in an overlapping manner with respect to the longitudinal axis.

10. The method according to any one of claims 1 to 9, wherein one of the first winding angle and the second winding angle is a positive winding angle and wherein one of the second winding angle and the first winding angle is a negative winding angle with respect to the longitudinal axis.

11. The method according to any one of claims 1 to 10, wherein prior to the step of forming the first layer portion at least one base layer portion of the insulator body is formed by winding a second winding member in a coiled manner with respect to the longitudinal axis with a third winding angle on the mandrel.

12. The method according to claim 11, wherein the second winding member is a strip-shaped tissue, in particular

a tissue comprising at least one of a fabric or a fleece, in particular a polyester fabric or fleece.

13. The method according to claim 11 or 12, wherein a convolution of the second winding member is wound such that it contacts a neighboring convolution of the second winding member of the same layer in an overlapping manner.

14. The method according to any one of claims 11 to 13, wherein the third winding angle is a positive winding angle with respect to the longitudinal axis.

15. The method according to any one of claims 1 to 14, characterized by wetting at least one of the first winding member and the second winding member with a compound prior to the step of forming the first layer, the second layer and the base layer, respectively, in particular by drawing the first winding member through a liquid polymeric bath.

16. The method according to any one of claims 1 to 15, wherein at least one local enforcement element is embedded between the layers, particularly in at least one of the first end portion and the second end portion of the insulator body, the local enforcement element being in particular a fabric, in particular a fabric having a predefined mechanical tensional strength in at least direction for structurally conferring or improving at least one stress withstand capability to/of the insulator body, more particularly the local enforcement element comprising at least one pre-preg.

17. The method according to any one of claims 1 to 16, wherein at least one tailored insulator section is derived by cutting a longitudinal section (19, 21) out of the cured insulator body along a cutting line (20, 22).

18. A hollow medium voltage or high voltage (fiber reinforced polymer) composite insulator body (1a, 1b) comprising a plurality of layer portions of a first winding member (2) wound in helical convolutions in a direction of a longitudinal axis (7) defined by the insulator body, wherein a convoluting direction of the helical convolutions is tangentially with respect to the longitudinal axis and extends between a first end portion and a second end portion of the insulator body, wherein said convoluting direction is inclined to the longitudinal axis such that the longitudinal axis and said convoluting direction enclose a winding angle;
the first winding member having a tensile strength in the winding direction which exceeds a tensile strength of the winding member transversely to the winding direction;
the plurality of layer portions comprising a first layer portion being wound with a first winding angle and a second layer portion being wound with a second winding angle wherein an absolute value of the second winding angle differs from an absolute value of the first winding angle;
and wherein the first winding member is fixed with a compound.

19. The insulator body according to claim 18, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle of a radially inner layer is different from at least one of the absolute value of the first winding angle of a radially outer layer of the insulator body.

20. The insulator body according to claim 18 or 19, wherein the first layer portion and the second layer portion belongs to the same layer such that a pitch distance of two neighboring convolutions of the same layer is different.

21. The insulator body according to claim 20, wherein the first layer portion is located at the first end portion and the second end portion of the insulator body and wherein the second layer portion is located in between the first end portion and the second end portion of the insulator body.

22. The insulator body according to claim 20 or 21, wherein the winding angle varies, in particular varies steadily, in between the first layer portion and the second layer portion.

23. The insulator body according to any one of claims 18 to 22, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle varies monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, in between a radially inner layer to a radially outer layer and/or within one layer of the insulator body.

24. The insulator body according to any one of claims 18 to 22, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle varies monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, in between a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an odd layer number.

25. The insulator body according to any one of claims 18 to 22, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle varies monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, from a radially inner layer to a radially outer layer and/or within one

layer of the insulator body at every layer having an even layer number.

26. The insulator body according to any one of claims 23 to 25, wherein the at least one of the absolute value of the first winding angle and the absolute value of the second winding angle of a radially inner layer of the insulator body is smaller than the absolute value of the first winding angle and the absolute value of the second winding angle of a radially outer layer of the insulator body.

27. The insulator body according to any one of claims 18 to 26, wherein the at least one of the first and second winding angle is in a range of about 2 degrees to about 90 degrees, in particular in a range of about 5 to about 70 degrees, more particular in a range of about 9 degrees to about 50 degrees.

28. The insulator body according to any one of claims 18 to 27, characterized in that the first winding member is a band or roving of plural strands of fibers, preferably continuous strands of fibers, and wherein at least one layer is wound such that two consecutive convolutions of the band are arranged at least partially in an overlapping manner with respect to the longitudinal axis.

29. The insulator body according to any one of claims 18 to 28, wherein one of the first winding angle and the second winding angle is a positive winding angle and wherein one of the second winding angle and the first winding angle is a negative winding angle with respect to the longitudinal axis.

30. The insulator body according to any one of claims 18 to 29, wherein at least one base layer portion of the insulator body is arranged under the first layer portion, and wherein said at least one base layer portion comprises a second winding member being wound in a

coiled manner with respect to the longitudinal axis with a third winding angle.

31. The insulator body according to claim 30, wherein the second winding member is a strip-shaped tissue, in particular a tissue comprising at least one of a fab-ric or a fleece, in particular a polyester fabric or fleece.

32. The insulator body according to claim 30 or 31, wherein two neighboring convolutions of the second winding member of the same layer contact one another in an overlapping manner.

33. The insulator body according to any one of claims 30 to 32, wherein the third winding angle is a positive winding angle with respect to the longitudinal axis.

AMENDED CLAIMS
received by the International Bureau on 07 July 2010

1. A method for manufacturing a tubular high-voltage and/or medium voltage insulator body (1a, 1b), comprising the following steps:

   a) Providing a winding device comprising a rotatable winding mandrel (5) and winding guide for guiding an elongated winding member from a winding supply device to the winding guide in a winding direction tangentially towards the winding mandrel, wherein the winding mandrel defines a longitudinal axis (7) and extends longitudinally between a first end portion (13) and a second end portion (14), wherein said winding direction is inclined to the longitudinal axis such that the longitudinal axis and said winding direction enclose a winding angle;

   b) Forming a first layer portion (11) of the insulator body by winding a first winding member (2) in a coiled manner with respect to the longitudinal axis (7) with a first winding angle, wherein the first winding member (2) has a tensile strength in the winding direction which exceeds a tensile strength of the first winding member transversely to the winding direction;

   c) Forming a second layer portion (12) of the insulator body by winding the first winding member (2) in a coiled manner with respect to the longitudinal axis with a second winding angle, wherein an absolute value of the second winding angle differs from an absolute value of the first winding angle, wherein the radially innermost first layer portion (11) of the insulator body is at least proximate to the end portions wound with a minimal winding angle for providing the insulator body with an axial tensile strength proximate to the end portions such that the insulator body sustains a pressure shock wave in its hollow of at least 20 bar in an operat-

ing state, and
wherein a radially outermost second layer portion (12) of the insulator body is in between said end portions wound with a maximal winding angle for providing the insulator body with a hoop strength longitudinally in between said end portions such that the insulator body sustains a pressure shock wave in its hollow of at least 20 bar in an operating state;

d) Fixing the first winding member (2) with a compound in a curing process.

2. The method according to claim 1, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied during the winding process from a radially inner layer to a radially outer layer of the insulator body.

3. The method according to claim 1 or 2, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied between the first end portion and the second end portion in the direction of the longitudinal axis during the winding process of the first layer portion and the second layer portion, respectively.

4. The method according to any one of claims 1 to 3, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body.

5. The method according to any one of claims 1 to 3, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a step-

wise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an odd layer number.

6. The method according to any one of claims 1 to 3, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle is varied monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, during the winding process from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an even layer number.

7. The method according to any one of claims 4 to 6, wherein the at least one of the absolute value of the first winding angle and the absolute value of the second winding angle of a radially inner layer of the insulator body is smaller than the absolute value of the first winding angle and the absolute value of the second winding angle of a radially outer layer of the insulator body.

8. The method according to any one of claims 1 to 7, characterized setting the at least one of the first and second winding angle to be in a range of about 2 degrees to about 90 degrees, in particular in a range of about 5 to about 70 degrees, more particular in a range of about 9 degrees to about 50 degrees.

9. The method according to any one of claims 1 to 8, characterized in that the first winding member is a band or roving of plural strands of fibers, preferably continuous strands of fibers, and wherein at least one layer is wound such that two consecutive convolutions of the band are arranged at least partially in an overlapping manner with respect to the longitudinal axis.

10. The method according to any one of claims 1 to 9, wherein one of the first winding angle and the second winding angle is a positive winding angle and wherein one of the second winding angle and the first winding angle is a negative winding angle with respect to the longitudinal axis.

11. The method according to any one of claims 1 to 10, wherein prior to the step of forming the first layer portion at least one base layer portion of the insulator body is formed by winding a second winding member in a coiled manner with respect to the longitudinal axis with a third winding angle on the mandrel.

12. The method according to claim 11, wherein the second winding member is a strip-shaped tissue, in particular a tissue comprising at least one of a fabric or a fleece, in particular a polyester fabric or fleece.

13. The method according to claim 11 or 12, wherein a convolution of the second winding member is wound such that it contacts a neighboring convolution of the second winding member of the same layer in an overlapping manner.

14. The method according to any one of claims 11 to 13, wherein the third winding angle is a positive winding angle with respect to the longitudinal axis.

15. The method according to any one of claims 1 to 14, characterized by wetting at least one of the first winding member and the second winding member with a compound prior to the step of forming the first layer, the second layer and the base layer, respectively, in particular by drawing the first winding member through a liquid polymeric bath.

16. The method according to any one of claims 1 to 15, wherein at least one local enforcement element is embedded between the layers, particularly in at least

one of the first end portion and the second end portion of the insulator body, the local enforcement element being in particular a fabric, in particular a fabric having a predefined mechanical tensional strength in at least direction for structurally conferring or improving at least one stress withstand capability to/of the insulator body, more particularly the local enforcement element comprising at least one pre-preg.

17. The method according to any one of claims 1 to 16, wherein at least one tailored insulator section is derived by cutting a longitudinal section (19, 21) out of the cured insulator body along a cutting line (20, 22).

18. A hollow medium voltage or high voltage (fiber reinforced polymer) composite insulator body (1a, 1b) comprising a plurality of layer portions of a first winding member (2) wound in helical convolutions in a direction of a longitudinal axis (7) defined by the insulator body, wherein a convoluting direction of the helical convolutions is tangentially with respect to the longitudinal axis and extends between a first end portion and a second end portion of the insulator body, wherein said convoluting direction is inclined to the longitudinal axis such that the longitudinal axis and said convoluting direction enclose a winding angle;
the first winding member having a tensile strength in the winding direction which exceeds a tensile strength of the winding member transversely to the winding direction;
the plurality of layer portions comprising a first layer portion being wound with a first winding angle and a second layer portion being wound with a second winding angle wherein an absolute value of the second winding angle differs from an absolute value of the

first winding angle,
wherein the radially innermost first layer portion (11) of the insulator body is at least proximate to the end portions being wound with a minimal winding angle for providing the insulator body with an axial tensile strength proximate to the end portions such that the insulator body sustains a pressure shock wave in its hollow of at least 20 bar in an operating state, and
wherein a radially outermost second layer portion (12) of the insulator body is at least in between said end portions being wound with a maximal winding angle for providing the insulator body with a hoop strength longitudinally in between said end portions such that the insulator body sustains a pressure shock wave in its hollow of at least 20 bar in an operating state;
and wherein the first winding member is fixed with a compound.

19. The insulator body according to claim 18, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle of a radially inner layer is different from at least one of the absolute value of the first winding angle of a radially outer layer of the insulator body.

20. The insulator body according to claim 18 or 19, wherein the first layer portion and the second layer portion belongs to the same layer such that a pitch distance of two neighboring convolutions of the same layer is different.

21. The insulator body according to claim 20, wherein the first layer portion is located at the first end portion and the second end portion of the insulator body and wherein the second layer portion is located in between the first end portion and the second end portion of the insulator body.

22. The insulator body according to claim 20 or 21, wherein the winding angle varies, in particular varies steadily, in between the first layer portion and the second layer portion.

23. The insulator body according to any one of claims 18 to 22, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle varies monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, in between a radially inner layer to a radially outer layer and/or within one layer of the insulator body.

24. The insulator body according to any one of claims 18 to 22, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle varies monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, in between a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an odd layer number.

25. The insulator body according to any one of claims 18 to 22, wherein at least one of the absolute value of the first winding angle and the absolute value of the second winding angle varies monotonously increasingly or monotonously decreasingly, in particular in a stepwise or continuous fashion, from a radially inner layer to a radially outer layer and/or within one layer of the insulator body at every layer having an even layer number.

26. The insulator body according to any one of claims 23 to 25, wherein the at least one of the absolute value of the first winding angle and the absolute value of the second winding angle of a radially inner layer of the insulator body is smaller than the absolute value

of the first winding angle and the absolute value of the second winding angle of a radially outer layer of the insulator body.

27. The insulator body according to any one of claims 18 to 26, wherein the at least one of the first and second winding angle is in a range of about 2 degrees to about 90 degrees, in particular in a range of about 5 to about 70 degrees, more particular in a range of about 9 degrees to about 50 degrees.

28. The insulator body according to any one of claims 18 to 27, characterized in that the first winding member is a band or roving of plural strands of fibers, preferably continuous strands of fibers, and wherein at least one layer is wound such that two consecutive convolutions of the band are arranged at least partially in an overlapping manner with respect to the longitudinal axis.

29. The insulator body according to any one of claims 18 to 28, wherein one of the first winding angle and the second winding angle is a positive winding angle and wherein one of the second winding angle and the first winding angle is a negative winding angle with respect to the longitudinal axis.

30. The insulator body according to any one of claims 18 to 29, wherein at least one base layer portion of the insulator body is arranged under the first layer portion, and wherein said at least one base layer portion comprises a second winding member being wound in a coiled manner with respect to the longitudinal axis with a third winding angle.

31. The insulator body according to claim 30, wherein the second winding member is a strip-shaped tissue, in particular a tissue comprising at least one of a fabric or a fleece, in particular a polyester fabric or fleece.

32. The insulator body according to claim 30 or 31, wherein two neighboring convolutions of the second winding member of the same layer contact one another in an overlapping manner.

33. The insulator body according to any one of claims 30 to 32, wherein the third winding angle is a positive winding angle with respect to the longitudinal axis.

Statement under Article 19 PCT

Herewith the applicant encloses an amended set of claims both in blank mode for the purpose of international publication as well as in amendment mode for the purpose of visualization of the amendments compared to the originally filed set of claims. The future procedure shall be based on the amended set of claims.

The amendments in the new claims 1 and 18 are supported by the original description as filed on page 19, line 32-37 and page 8, line 27-34 and page 9, line 12-14, for example.

The technical effect of the insulator body resides in an optimal design for carrying in an operating state of the insulator body the mechanical stress arising upon applying a shock wave in the hollow of the insulator body of at least 20 bar which may occur in case of a use of the insulator body as a chamber insulator of a circuit breaker, for example.

Since none of the documents cited in the International Search report anticipates the subject matter claimed in the new claims 1 and 18, the devices according to those new claims 1 and 18 are new in the sense of Article 33(2) PCT.

Moreover, the subject matter claimed in the new claims 1 and 18 is not rendered obvious by any one of the documents cited in the International Search report alone or in any combination thereof. Even if a person skilled in the art would combine the teachings of some documents cited, said person would not derive the subject matter claimed in the new claims 1 and

18. Hence, the devices according to those new claims 1 and 18 involve an inventive step in the sense of Article 33(3) PCT.

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Fig. 1

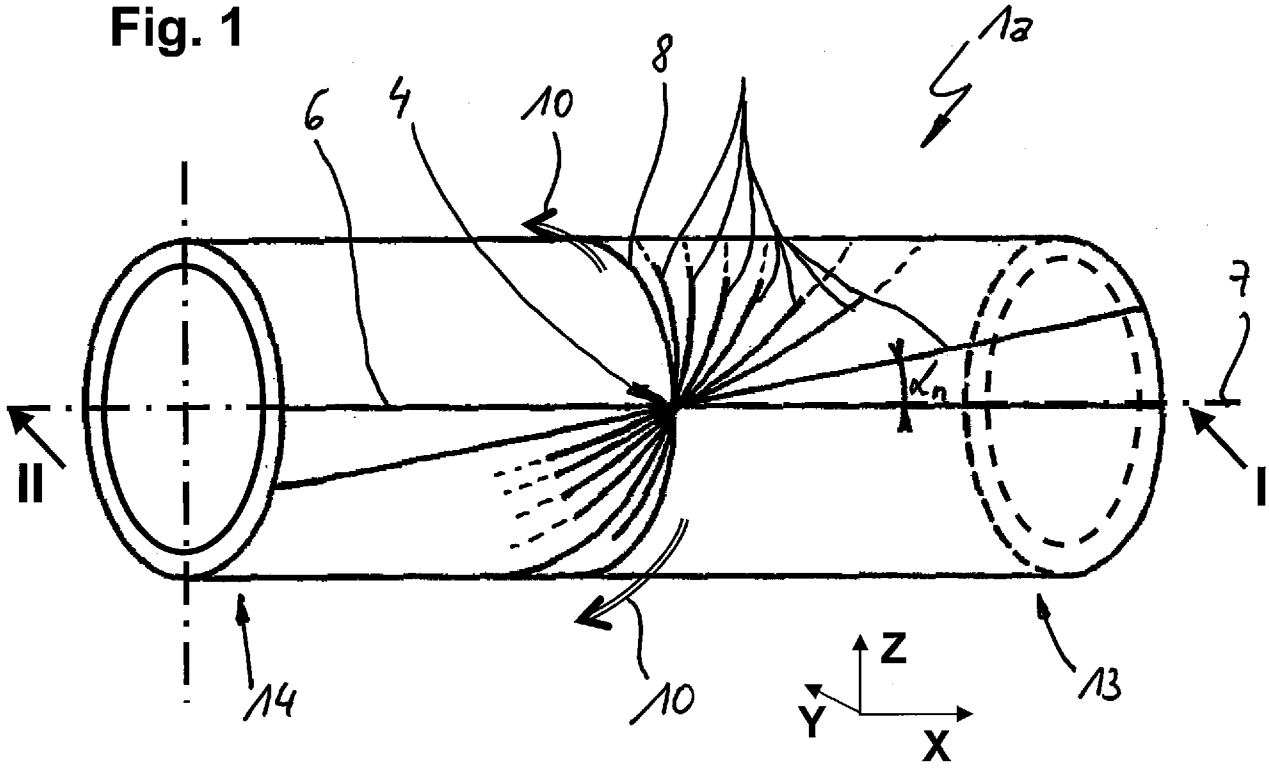

1a
8
4
6
10
7
α_n
II
II
14
10
Z
Y
X
13

Fig. 2

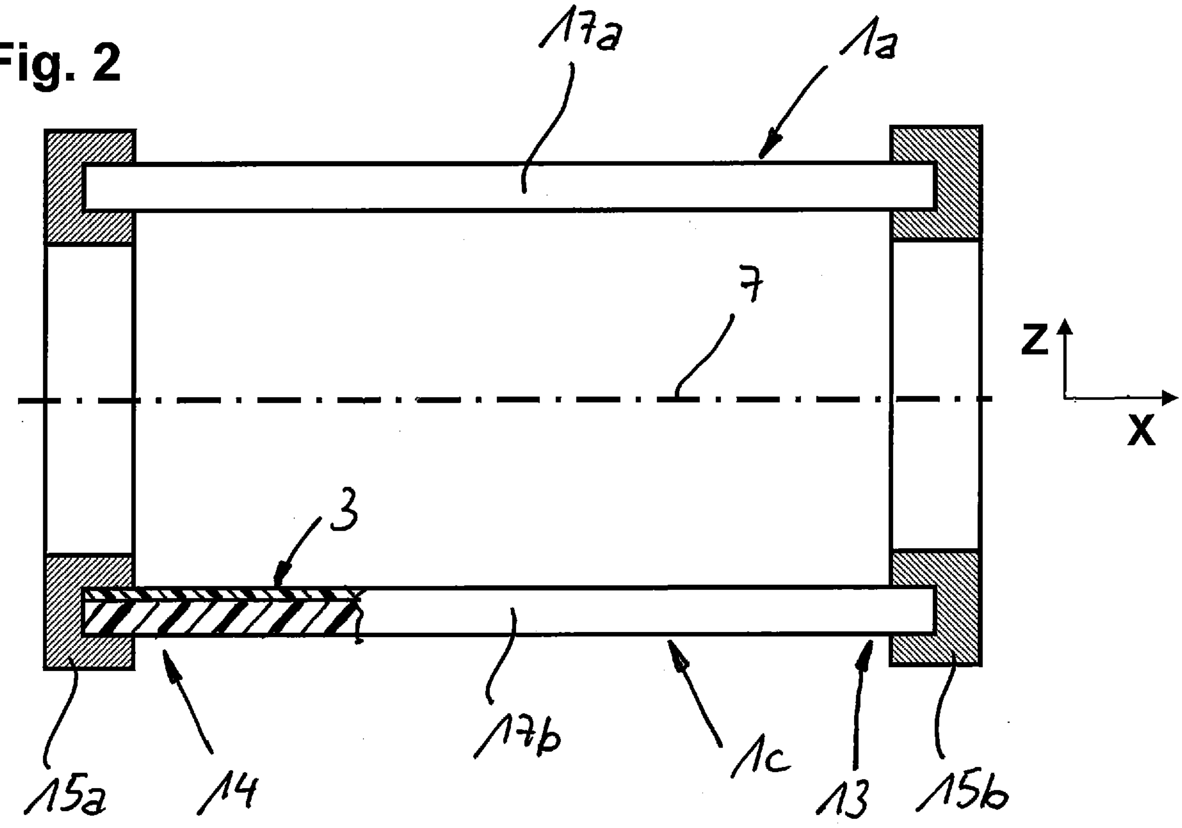

17a
1a
7
Z
X
3
15a
14
17b
1c
13
15b

Fig. 3

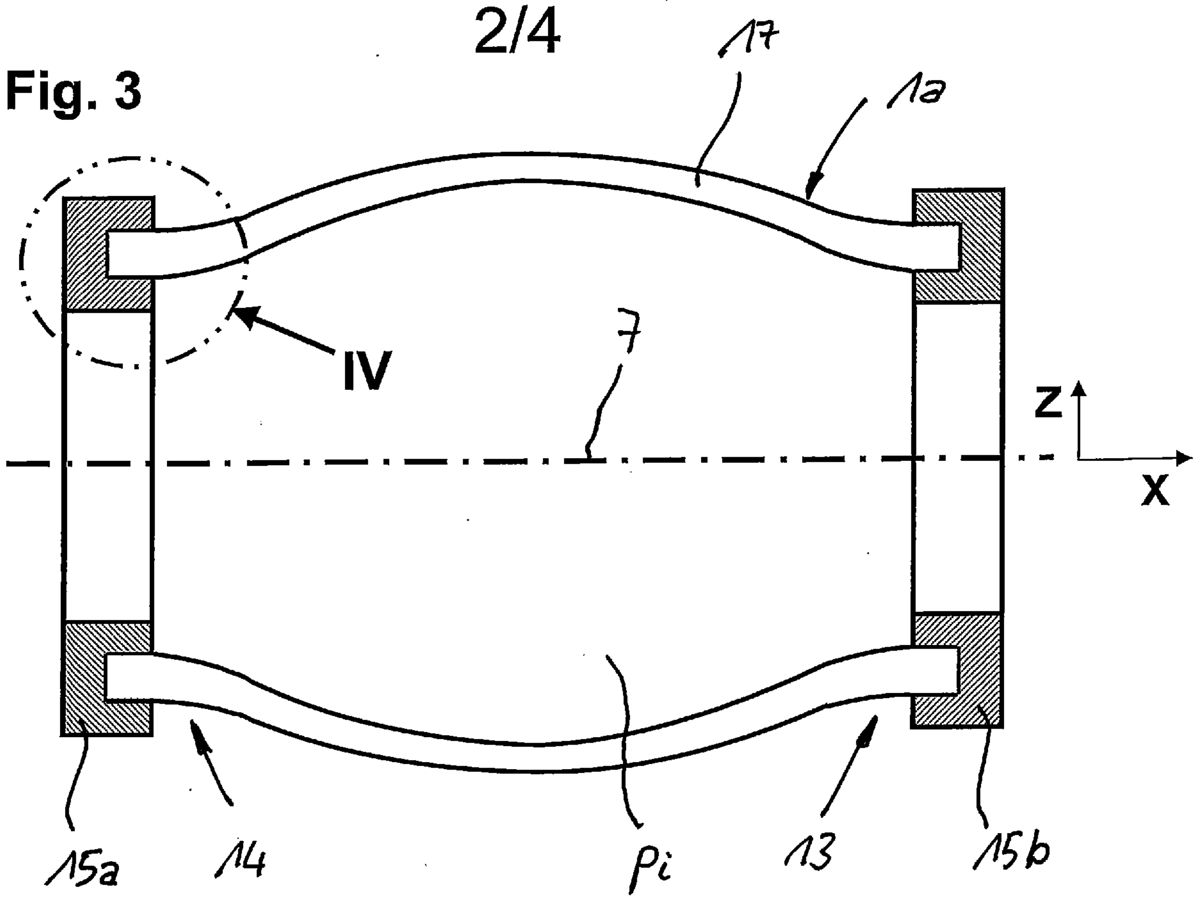


Fig. 4

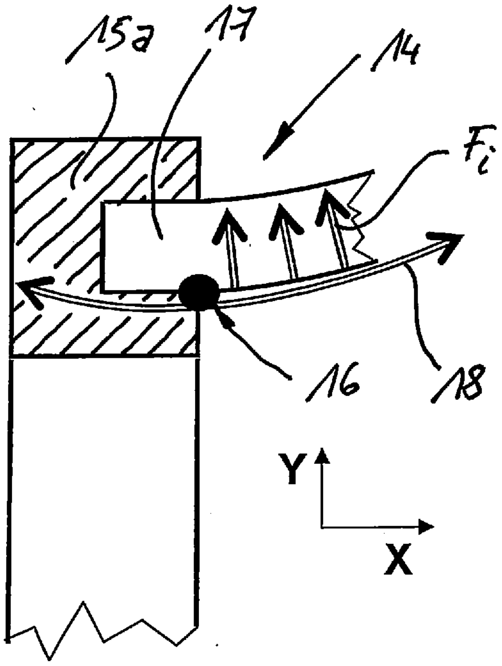


Fig. 5

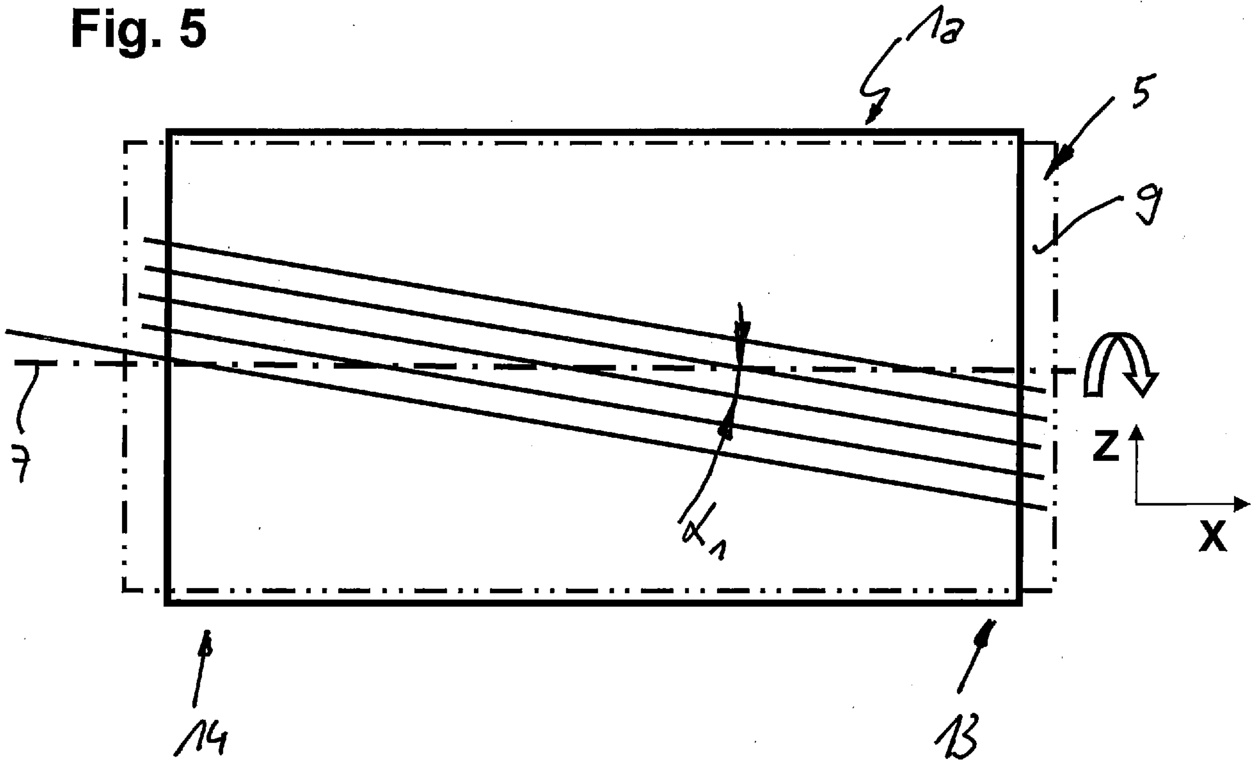


Fig. 6

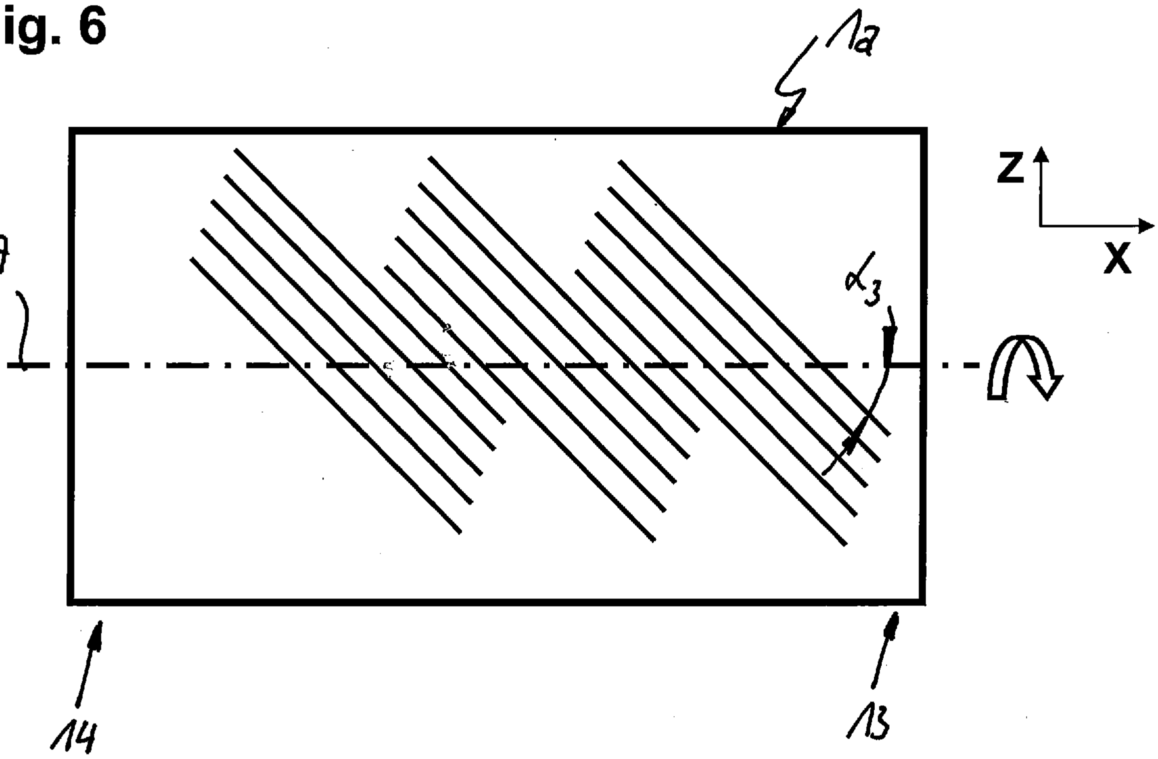


Fig. 7

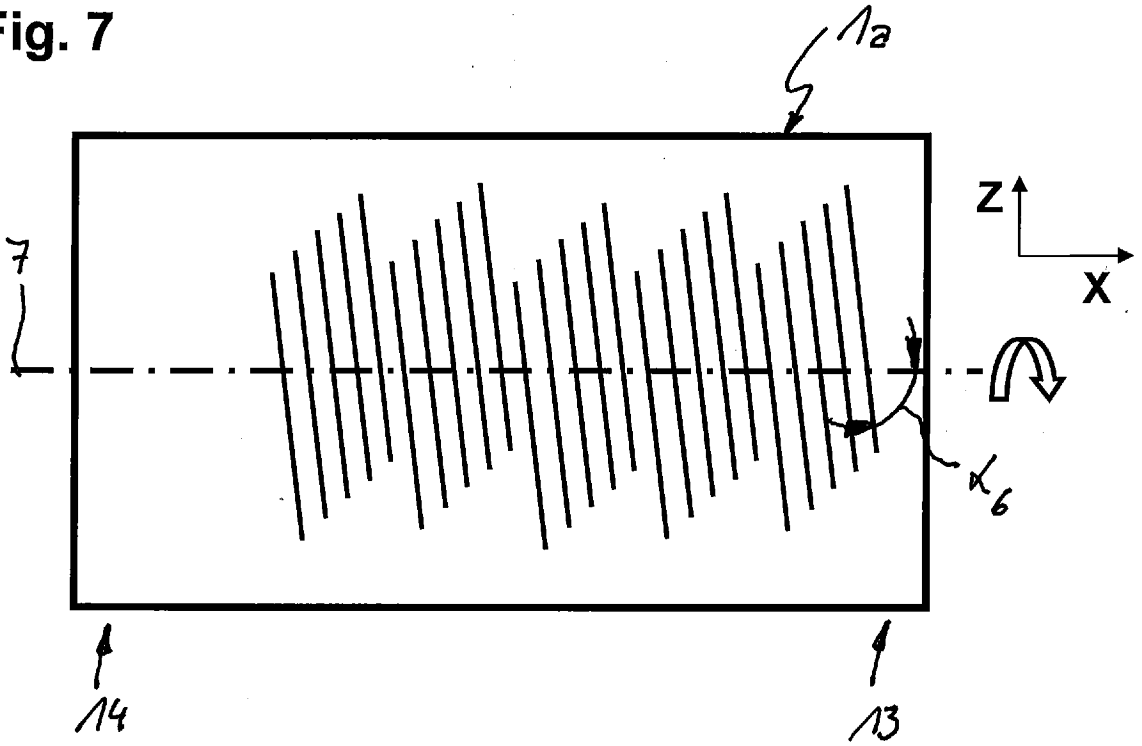
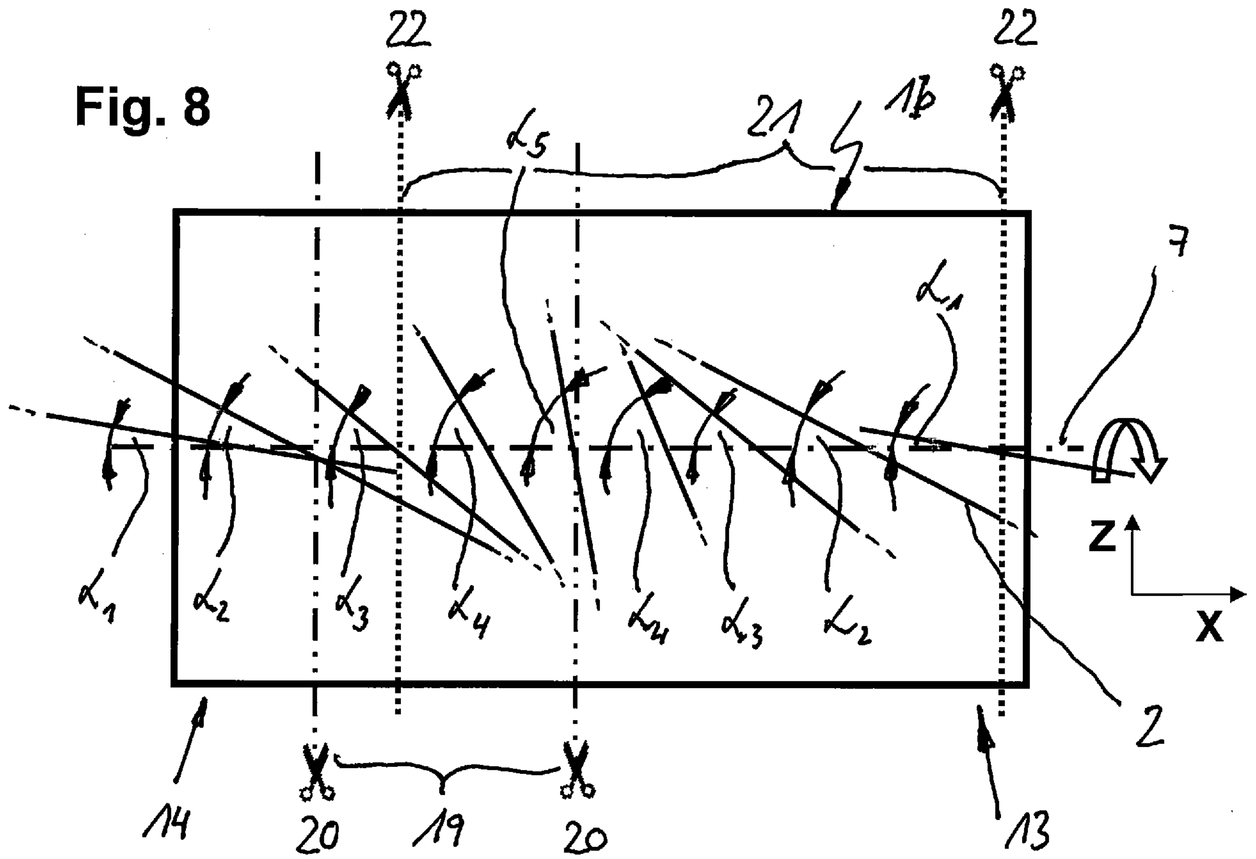

1a
Z
X
7
α6
14
13

Fig. 8


22
22
21
1b
α5
α1
7
α1
α2
α3
α4
α4
α3
α2
Z
X
2
14
20
19
20
13

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/061397

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01B17/56 H01H33/53

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01B H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001 266682 A (NGK INSULATORS LTD) 28 September 2001 (2001-09-28) paragraphs [0001], [0006], [0009] - [0015], [0018]; figures 1,3,5 -----	1,2,4-9, 11-19, 23-28, 30-33
X	WO 01/41161 A1 (ELECTRO COMPOSITES INC [CA]; GUILLEMETTE ROBERT [CA]; LEGRAND BERTRAND) 7 June 2001 (2001-06-07) page 1, lines 5-9 page 9, line 23 - page 11, line 4; figure 1 page 12, line 4 - page 13, line 21; figures 4,5 -----	1-33

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 April 2010	10/05/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tille, Daniel

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/061397

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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International application No
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