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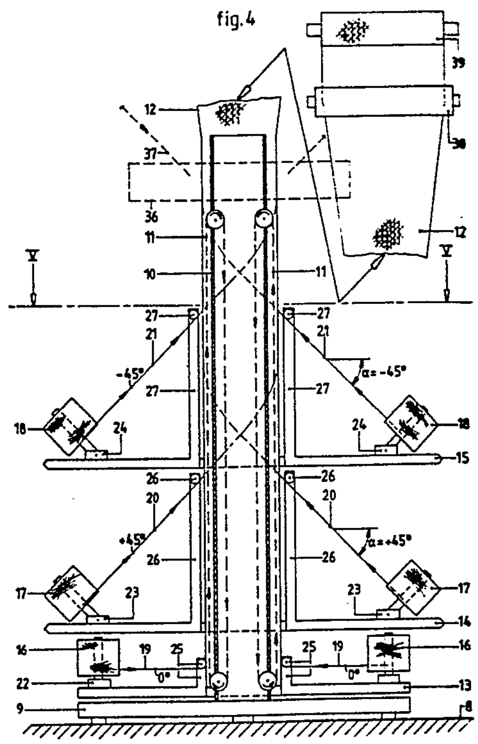
(54) **Process and apparatus for the manufacture of a tubular reinforcing material, more particularly for the reinforcement of a matrix, and the tubular reinforcing material and uses thereof.**

(57) The invention relates to a process for manufacturing a tubular reinforcing fabric (12) comprising one or more layers of parallel reinforcing yarns (19, 20, 21) which are optionally shiftable in axial direction while interconnected by binder yarns. The binder yarns are provided by knitting or stitching. In the former case a tubular inlay fabric is formed. In the case of a multilayer fabric it is preferred that subsequent layers of reinforcing yarns have different axial directions and, optionally, are also shiftable in different directions, e.g. through 0°, +45°, -45°, 90°. In tubular or opencut form said fabric can be used as fibre reinforcement for composites.

fig.4



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# Process and apparatus for the manufacture of a tubular reinforcing material, more particularly for the reinforcement of a matrix, and the tubular reinforcing material and uses thereof

The invention relates to a process and an apparatus for the manufacture of a tubular reinforcing fibre material or structure of reinforcing yarns, especially a knitted inlay fabric, more particularly for the reinforcement of a matrix material, in which reinforcing filaments or reinforcing yarns extending in one or more directions of the tube are provided, which are interconnected with binder or stitching yarns by a connecting unit, such as a circular knitting unit. Further, the invention comprises the tubular reinforcing material and uses thereof.

Such a tubular reinforcing material in the form of a knitted inlay fabric may be considered known from the paper "A new materials approach for providing transverse strength in pultruded shapes" by Rick Birsa and Paul Taft delivered at the 39th Annual Conference of The Society of the Plastics Industry, Inc. dated 16-19 Janary, 1984. In this article three knitted inlay fabrics manufactured on a circular weft knitting machine are described, viz. WEFTFAB® COFAB®, and WARPFAB®. Each of these three knitted inlay fabrics contains reinforcing yarns of glass. The knitted fabrics WEFTFAB and WARPFAB only contain reinforcing yarns in one single principal direction of the knitted fabric, viz. in the weft and in the warp direction, respectively. The knitted fabric of the COFAB type contains reinforcing yarns in two principal directions, viz. in both the warp and weft directions. As is indicated in said article, the various reinforcing yarns are interconnected to form a cohesive circular knitted inlay fabric by the knitting stitches formed by the stitching yarns. Although in principle favourable results may be attained for particular applications with such known knitted inlay fabrics, the reinforcing yarns extend only in one of the two principal directions of the circular knitted fabric or in both, i.e. in longitudinal direction of the tube and/or transverse to the longitudinal direction of the tube. Consequently, such known tubular knitted inlay fabrics can be used only on a limited scale for the manufacture of the nowadays increasingly used modern fibre-reinforced plastics of composite material.

It should be noted that for the manufacture of said modern fibre-reinforced plastics of composite material use is made successfully of a multi-axial, multi-ply laminate or structure of reinforcing yarns in the form of a flat warp knitted inlay fabric of the type described in Figs. 1 and 2 of Chemiefasern/Textilindustrie, Volume 38./90., March, 1988, p. T19 and in Chemiefasern/Textilindustrie, Volume 36./88. July/August 1986, pp. 579-580. This known flat inlay, however, is made by a relatively complicated manufacturing process, notably as a result of the various reciprocating movements needed to position the reinforcing yarns at the various desired angles relative to the machine direction. Further, the production rate for these known multi-axial flat knitted inlay fabrics is comparatively low. As regards the prior art, reference is further made to US 2 118 108 describing a flat knitted fabric for textile applications. In DE-A 33 04 345 is described a flat knitted fabric containing, int. al., reinforcing yarns of a high-strength material, such as glass, carbon, polyester, or the like extending diagonally across one another. GB-A 1 384 522 discloses a circular knitting machine for textile applications, showing knitted fabrics which beside the loops contain mutually perpendicular yarns in the machine direction and at right angles thereto. DE-A 33 39 205 describes a flat laminate of reinforcing yarns and a process and a machine for the manufacture of such a laminate. GB-A 970 939 describes a reinforced flexible hose comprising a tubular knitted fabric embedded in a plastic body, additional reinforcing strands being incorporated into the composite fabric.

The invention has for its object to provide a process of the type mentioned in the opening paragraph in which the drawbacks to said known reinforcing materials have been overcome. The process for the manufacture of a tubular reinforcing material is characterized according to the invention in that one, two or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of $+ 10^\circ$ to $+ 80^\circ$ and/or $10^\circ$ to $- 80^\circ$. According to the invention one or more groups of reinforcing yarns are with advantage positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of $+ 15^\circ$ to $+ 75^\circ$ and/or $- 15^\circ$ to $- 75^\circ$, more particularly an acute angle of a magnitude of $+ 30^\circ$ to $+ 60^\circ$ and/or $- 30^\circ$ to $- 60^\circ$. According to the invention at least two groups of reinforcing yarns are with advantage positioned at said acute angle $\alpha$ to the longitudinal axis of the tube, more particularly at equal but opposite angles, such as $\alpha = + 30^\circ$ and $- 30^\circ$ or $\alpha = + 45^\circ$ and $- 45^\circ$, or $\alpha = + 60^\circ$ and $- 60^\circ$. Optionally, the thus oriented groups of yarns can be combined with a group of reinforcing yarns positioned at a virtually right angle $\beta$, which differs from $90^\circ$ by less than $10^\circ$, relative to the longitudinal axis of the tube, and with a group of reinforcing yarns positioned virtually parallel to the longitudinal axis of the tube. According to the invention each group of reinforcing yarns is with advantage positioned in a separate ply and the several pies containing a group of reinforcing yarns are interconnected by the stitching yarns.

A simple method of manufacturing, in which the reinforcing yarns are fed from a feeding unit to the connecting unit, such as a circular knitting unit, to which the stitching yarns also are fed, and the completed tubular reinforcing material is discharged, for instance by being wound, is characterized according to the invention in that on a preferably cylindrical core upstream of the connecting unit and extending in longitudinal direction of the tube one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at said acute angle $\alpha$, and these obliquely positioned reinforcing yarns are conveyed along the core to the connecting unit, where they are interconnected by the stitching yarns. In this case according to the invention one or more groups of reinforcing yarns are with advantage fed to the core from a feeding unit with several supply packages of reinforcing yarns provided about the core, and the reinforcing yarns of a group on its feeding unit are fed to the core at said desired acute angle $\alpha$ via guide elements, with said feeding unit and the core rotating relative to each other at a rotational speed dependent on said acute angle $\alpha$ and the discharge rate of the produced tube. Preferably, each of said groups of reinforcing yarns is fed from its feeding unit rotating about the non-rotating core, and the reinforcing yarns of the various groups are deposited at the desired acute angle $\alpha$ on a surface moving in axial direction of the core, such as a number of conveyor belts moving in axial direction. According to the invention the reinforcing yarns employed can be selected from the following group of materials: aramid, more particularly polyparaphenylene terephthalamide (PPDT), carbon, and glass.

The invention also comprises an apparatus for the manufacture of a tubular reinforcing fibre material, more particularly a knitted inlay fabric, equipped with a frame with a feeding unit for the reinforcing yarns and a connecting unit, such as a circular knitting unit, for interconnecting the reinforcing yarns with the stitching yarns, and a discharge unit, such as a winding unit, for the discharge of the tubular reinforcing material, which apparatus is characterized in that the frame has a central core with provided about it from one end to the other one or more feeding units rotatable relative to the core, and on the outside of the core there are provided conveying elements for the reinforcing yarns than can move in axial direction of the core, which conveying elements extend at least from the feeding units to the connecting unit. The apparatus according to the invention is advantageously characterized in that the feeding units each consist of a platform provided with a number of pegs for packages of reinforcing yarns and yarn guides, and which is rotatingly mounted at its circumference and provided with a drive, said discharge unit being positioned downstream of the connecting unit in a direct line with the core. An effective embodiment of the apparatus is characterized according to the invention in that the platforms forming feeding units are mounted by means of cooperating virtually V-shaped grooves and rollers engaging therewith. The reinforcing yarns fed via the core can according to the invention be held against the core by a suitable subatmospheric pressure.

The process and the apparatus according to the invention permit a simple and effective manufacture at a relatively high production speed of multi-axial, multi-ply, reinforcing yarns-containing tubular knitted inlay fabrics or structures of reinforcing yarns. The platforms can rotate about the central core or column to the left as well as to the right, depending on whether the reinforcing yarns are to be positioned at a positive or a negative acute angle to the central axis of the tube. Alternatively, one or more platforms may be stationary for receiving reinforcing yarns in the production direction, which means an angle of 0° to the longitudinal axis of the tube. The reinforcing yarns deposited on the core or column can be interconnected with the stitching yarns by a warp knitting unit or a weft knitting unit to produce a tubular laminate in the form of a warp knitting or a knitted inlay fabric. Optionally, a web or a fabric may also be incorporated in the tubular laminate of reinforcing yarns in the manufacture. The number of platforms may range from one to in principle an unlimited number, depending on the desired number of plies. The orientation of the reinforcing yarns may vary from ply to ply and range from 0° to almost + 90° or - 90°.

The invention further comprises a composite or sheet material consisting of a matrix of a thermoplastic or a thermosetting synthetic material, into which the tubular laminate of reinforcing yarns according to the invention has been incorporated. The tubular laminate of reinforcing yarns according to the invention can be impregnated with a thermoplastic synthetic material, optionally with heating being applied. The laminate of reinforcing yarns can be impregnated with the thermoplastic synthetic material by one or more of the following techniques:

use of one or more films of thermoplastic synthetic material;

use of continuous reinforcing yarns optionally incorporated into a cloth, such as a woven fabric, a knitted fabric, or a web, impregnated with a powder of the thermoplastic synthetic material; use of con-

tinuous reinforcing yarns optionally incorporated into a cloth, such as a woven fabric, a knitted fabric, or a web, impregnated with a molten thermoplastic synthetic material;
use of continuous reinforcing yarns optionally incorporated into a cloth, such as a woven fabric, a knitted fabric, or a web, impregnated with a solution of the thermoplastic synthetic material;
use of continuous reinforcing yarns and separate yarns of a thermoplastic synthetic material;
use of combined or mixed yarns each preformed from a combination or a mixture of a reinforcing yarn and a thermoplastic yarn. Another favourable embodiment of the process for the manufacture of sheet material is characterized according to the invention in that the structure or layer of reinforcing yarns, which is for instance in the form of a sheet, is joined to molten thermoplastic material emerging from an extrusion head.
In this process the structure of reinforcing yarns can according to the invention be formed integral with the thermoplastic matrix material with heat and pressure being applied, preferably by using an apparatus of the double belt press type. It should be noted that according to the invention the sheet material to be manufactured may contain a flat or an opencut tubular structure of reinforcing yarns.

The invention also comprises shaped objects manufactured from said composite or sheet material.

The invention also comprises a tubular reinforcing fibre material or structure of reinforcing yarns, such as a knitted inlay fabric, more particularly for the reinforcement of a matrix material, in which reinforcing yarns extending in one or more directions of the tube have been provided, which are connected by stitching yarns, characterized according to the invention in that one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of + 10° to + 80° and/or -10° to - 80°. Preferably, the reinforcing material according to the invention is characterized in that one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of + 15° to + 75° and/or - 15° to -75°, more particularly an acute angle of a magnitude of + 30° to + 60° and/or - 30° to - 60°. According to the invention the reinforcing yarns preferably consist of yarns having a linear density of at least 20 Tex and preferably at least 40 Tex, and at most 500 Tex.

The invention will be further illustrated with reference to the schematic drawings.

Fig. 1 is a view of the tubular knitted inlay fabric according to the invention.

Fig. 2 is a view on an enlarged scale of a rectangular piece of the tubular knitted inlay fabric according to Fig. 1.

Fig. 3 is a further illustration of the several directions of the reinforcing yarns relative to the longitudinal axis of the tube.

Fig. 4 shows a front view of an embodiment of the apparatus for the manufacture of the tubular knitted inlay fabrics according to the invention.

Fig. 5 shows a cross-section along the line V-V of the apparatus according to Fig. 4.

Fig. 6 shows a detail of the guide of a platform.

The tubular knitted inlay fabric 1 shown in its entirety in Fig. 1 has a diameter of, say, 100 cm, so that its circumference is 314 cm. The longitudinal axis of the tube is indicated with 2. Fig. 2 shows the rectangular piece 3 of the tube 1 on an enlarged scale. Fig. 3 is a further illustration of the indication of the direction of the reinforcing yarns by the angles they make with the longitudinal axis 2 of the tubular knitted inlay fabric. In Fig 3 the 0° direction coincides with the longitudinal axis 2 of the tubular knitted inlay fabric, which longitudinal axis also coincides with the production direction of the knitted inlay fabric on the machine during manufacture. As shown in Fig. 2, the wall of the tubular knitted inlay fabric 1 consists of three layers or groups of reinforcing yarns 4, 5 and 6 of for instance carbon, aramid, or glass. The reinforcing yarns 4 are positioned relative to the longitudinal axis 2 of the tube at an acute angle $\alpha$ of a magnitude of + 45°. The reinforcing yarns 5 are also positioned relative to the longitudinal axis 2 of the tube at an acute angle $\alpha$ of a magnitude of -45°C. The reinforcing yarns 4 and 5 are therefore positioned at equal but opposite acute angles $\alpha$ to the longitudinal axis 2 of the tubular knitted inlay fabric. The reinforcing yarns 6 are positioned virtually at right angles to the longitudinal axis 2 of the tube. The reinforcing yarns 4, 5 and 6 form three piles, which are interconnected by stitching yarns 7 forming knitting stitches using a circular weft knitting machine.

Figs. 4 and 5 are schematic illustrations of an embodiment of the apparatus for the manufacture of a tubular knitted inlay fabrics according to the invention. On the support 8 is placed the frame 9, which has a vertical cylindrical core or column 10. Outside the core 10 there are a number of conveyor belts 11 moving in the direction of the arrow at a speed which corresponds to the winding and production speeds of the manufactured tubular knitted inlay fabric 12. About the core 10 are positioned three feeding units in the form of platforms 13, 14 and 15. On each platform are a plurality of packages 16, 17 and 18 with reinforcing yarns 19, 20 and 21, which are deposited on the conveyor belts 11 of the core 10. Each of the packages 16, 17, 18 is rotatably mounted on a base 22, 23 and

24 and the angle of the axis of rotation of each package to the plane of its platform is pre-settable. On each platform there are provided appropriate guide elements 25, 26 and 27 for each of the reinforcing yarns, by means of which the yarns are deposited on the conveyor belts 11 of the core 10. The platform 13 does not rotate relative to the core 10, and consequently the reinforcing yarns 16 of this platform are laid on the conveyor belts 11 in the production direction of the tube, i.e., at an angle of 0° to the longitudinal axis 2 of the tube, and as a result the reinforcing yarns 10 form a first inner group of filaments of the tube. The platform 14 rotates about the core 10 in positive direction, as indicated by the arrow 28. The rotational speeds of the platform 14, the packages 17, and the guide elements 26 are so set to the production speed in this case that the reinforcing yarns 20 originating from this platform are laid on the conveyor belts 11 at an acute angle $\alpha$ = + 45° and are introduced into the completed tubular knitted inlay fabric at that same angle. The platform 15 rotates about the core 10 in negative direction, as indicated by the arrow 29. The rotational speeds of the platform 15, the packages 18, and the guide elements 27 are so set to the production speed in that case that the reinforcing yarns 21 from this platform are laid on the conveyor belts 11 at an acute angle $\alpha$ = - 45°. Figures 5 and 6 show the means for rotatingly mounting the platforms 14 and 15. The platform 14 has on its outer circumference an edge 30 bevelled off on two sides, which co-operates with three pairs of supporting rollers 31, each provided with a V-shaped groove 32. The rollers 31 are attached to three columns 33 of the frame 9, which are not shown in Fig. 4.

On one of the columns 33 is provided a drive motor 40 to drive the platform at the desired pre-settable rotational speed by way of a shaft 34 with a pinion 35.

In the manner indicated three piles consisting of the reinforcing yarns 19, 20 and 21 are formed at the top end of the core 10 on the conveyor belts 11. The resulting three plies of yarn are then fed to and interconnected in the connecting unit 36 in the form of a circular weft knitting machine known in itself. Said three piles of reinforcing yarns 19,20 and 21 are interconnected with the stitching yarns 37 forming knitting stitches (not shown). Upon leaving the circular knitting unit 36 the tubular inlay 12 is obtained, which is discharged in the direction of the arrow by a pair of pulling-off rollers 28 and then wound into a roll 39.

In one embodiment for the manufacture of a tubular knitted inlay fabric using the machine depicted in Figs. 4 and 5 a production speed of 1,25 m/min may be employed, which is the speed at which the completed tube 12 is wound and also the speed at which the reinforcing yarns are fed to the circular knitting machine 36 by the conveyor belts 11 over the core 10. The circumference of the central column measured across the conveyor belts 11 is 1 m. On the central column are successively deposited three sub-plies of reinforcing yarns at angles to the production direction of 0°, + 45° and - 45°. The reinforcing yarns 19 of the first sub-ply deposited at an angle of 0° may consist of E-glass having a linear density of 240 Tex. The yarns 19 for the first sub-ply are unwound from 150 yarn packages 16 placed on the platform 13 which does not rotate relative to the column or core 10. The reinforcing yarns 20 of the second sub-ply deposited at an angle of + 45° may be of E-glass having a linear density of 120 Tex. The reinforcing yarns 20 for the second sub-ply are unwound from 200 yarn packages 17 arranged on the platform 14, which rotates about the core 10 at 1,25 rpm (rotational direction as indicated by arrow 28).

The reinforcing yarns 21 of the third sub-ply deposited at - 45° may be of E-glass also having a linear density of 120 Tex. The reinforcing yarns 21 for the third sub-ply are unwound from 200 yarn packages 18 arranged on the platform 15, which rotates about the core 10 at 1,25 rpm (rotational direction as indicated by arrow 29). The circular knitting machine operates at 60 rpm and has 150 needles. The stitching or knitting yarns may for instance be of polyparaphenylene terephthalamide 420 dtex/f250.

Within the scope of the invention various changes may be made. The connecting unit may be a circular weft knitting unit or a circular warp knitting unit. In the tubular knitting inlays described the reinforcing yarns in the piles of reinforcing yarns are regularly distributed in the entire surface of the tube. However, it is also possible according to the invention so to manufacture a tubular laminate of reinforcing yarns that in at least one layer of filaments the reinforcing yarns are positioned according to a secondary pattern repeating itself in the longitudinal direction of the tubular laminate, within which the reinforcing yarns are distributed irregularly in the surface, which secondary pattern corresponds to at least part of the desired total reinforcing pattern in an end product into which the tubular laminate of reinforcing yarns, opencut or not, should be introduced. The repeating secondary pattern will generally extend in the longitudinal direction of the tubular reinforcing laminate over a lenght of at least 3 cm and at most, say, 1000 cm. If it is desired that said patterns are provided, then reinforcing yarns should be unwound from only part of the bobbins on the platforms so that only a narrow tape is deposited on the conveyor belts of the core. The angle of the axis of the bobbins with reinforcing yarns relative to said central core or tube is variable. The reinforcing yarns or tapes may be pulled off either from the side of the packages or overhead.

Although in the illustrated machine for the manufacture of the tubular knitted inlay fabric the product moves vertically from the bottom towards the top, it is in principle also possible for the machine to be adapted so that it moves from the top downwards. Further, the machine shown may be turned through 90°, so that the product moves in horizontal direction.

The tubular knitted inlay fabric according to the invention may be cut open to form a flat knitted fabric, which may be wound or cut into sections of a particular length which may be stacked or processed straightaway.

Although it is preferred according to the invention that use be made of stitching yarns of a non-melting material, such as PPDT, this is not required. For, it is also possible according to the invention that in the manufacture of a composite material use is made of a matrix of some particular thermoplastic synthetic material and stitching yarns of some other thermoplastic synthetic material of which the mechanical properties are still sufficiently high at the manufacturing temperature of the composite material. In the case of a matrix of polypropylene (PP) use might for instance be made of stitching yarns of polyether sulphone (PES), Alternatively, in a composite material comprising a thermoplastic matrix use may be made of stitching yarns of the same polymer material as the matrix.

The tubular laminate of reinforcing yarns according to the invention provided with a special pattern may in principle be combined with a matrix in the form of a thermosetting synthetic material, such as unsaturated polyester resin or epoxy resin.

Preferably, however, the tubular laminate of reinforcing yarns according to the invention for the manufacture of a composite material is combined with a matrix in the form of a thermoplastic synthetic material. According to the invention the thermoplastic material can with advantage be selected from the following group of materials: polyolefins, such as polypropylene and polyethylene, polyamide 6, polyamide 66, polyvinyl chloride, acrylonitrile butadiene styrene, and polyester, more particularly polyethylene terephthalate. Alternatively, use may be made according to the invention of a substantially amorphous thermoplastic synthetic material having a glass transition temperature Tg above 80°C, more particularly a Tg above 160°, such as polyarylate (PAR), polysulphone (PSO), polyether sulphone (PES), polyether imide (PEI), or polyphenylene ether (PPE), more particularly poly-2,6-dimethyl phenylene ether.

Alternatively, according to the invention the synthetic material can advantageously be a semi-crystalline or para-crystalline thermoplastic synthetic material with a crystalline melting point $T_m$ above 130°C, more particularly a $T_m$ above 270°C, such as polyphenylene sulphide (PPS), polyamide-4,6, polyketone sulphide (PKS), polyether ketones, more particularly polyether-ether ketone (PEEK), polyether ketone (PEK), and polyether ketone-ketone (PEKK), or liquid crystal polymers, such as XYDAR of Dartco composed of the monomers bisphenol, terephthalic acid, and hydroxybenzoic acid. Alternatively, according to the invention the matrix can advantageously be composed of a thermoplastic aramid having a glass transition temperature Tg above 140°C.

Said glass transition point Tg of said substantially amorphous thermoplastic synthetic materials should be determined using a dynamic mechanical measuring apparatus of the RDA-700 type manufactured by Rheometrics at a frequency of 1 Hertz and a heating rate of at most 2°C/min. Tg is the temperature at which there is a maximum damping modulus G″.

Said crystalline melting point Tm of the semi-crystalline thermoplastic synthetic materials is determined by Differential Scanning Calorimetry (DSC). This determination is carried out with the DSC-7 type measuring apparatus of Perkin Elmer at a heating rate of 20°C/min. Tm is defined as the peak maximum of the endothermic peak in the DSC curve.

Although the stitching yarns are preferably provided in the manner described, use being made of a circular knitting machine, to form a knitted inlay fabric, they may in principle also be provided by using a special sewing machine passing these yarns right through the laminate composed of reinforcing yarns.

Although the structure of reinforcing yarns according to the invention is sometimes referred to in the description as a layer or laminate of reinforcing yarns, this does not imply that the successively provided groups of filaments form truly separate plies. Together the successively provided groups of filaments constitute a structure of reinforcing yarns.

According to the invention said laminate or structure of reinforcing yarns, more particularly knitted inlay fabric, can be built up wholly or in part of tapes instead of the conventional reinforcing yarns consisting of a plurality of filaments. Such tapes, for instance, may each have a width of about 12 mm and contain about 50 000 carbon filaments of 8 µm in diameter. The envisaged tapes may be impregnated or not with a polymer of a thermoplastic or a thermosetting synthetic material. Said tapes as a rule are very difficult to interweave, but surprisingly they can be processed without any problems in the manufacture of the multi-ply, multi-axial knitted inlay fabric according to the invention.

## Claims

1. A process for the manufacture of a tubular reinforcing fibre material, such as a knitted inlay fabric, more particularly for the reinforcement of a matrix material, in which reinforcing yarns extending in one or more directions of the tube are provided, which are interconnected with stitching yarns by a connecting unit, such as a circular knitting unit, characterized in that one, two or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magni tude of + 10° to + 80° and/or- 10° to -80°.

2. A process according to claim 1, characterized in that one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of + 15° to + 75° and/or - 15° to - 75°, more particularly an acute angle of a magnitude of + 30° to + 60° and/or - 30° to - 60°.

3. A process according to claim 2, characterized in that at least two groups of reinforcing yarns are positioned at said acute angle $\alpha$.

4. A process according to claim 3, characterized in that at least two or more groups of reinforcing yarns are positioned at equal but opposite acute angles $\alpha$ to the longitudinal axis of the tube, such as $\alpha$ = + 30° and - 30° or $\alpha$ = + 45° and - 45°, or $\alpha$ = + 60° and - 60°.

5. A process according to claim 4, characterized in that a group of reinforcing yarns is positioned at a virtually right angle $\beta$, which differs from 90° by less than 10°, relative to the longitudinal axis of the tube.

6. A process according to claim 4, characterized in that a group of reinforcing yarns is positioned virtually parallel to the longitudinal axis of the tube.

7. A process according to claim 3, characterized in that each group of reinforcing yarns is positioned in a separate ply and the several piles containing a group of reinforcing yarns are interconnected by the stitching yarns.

8. A process according to claim 1, in which the reinforcing yarns are fed from a feeding unit to the connecting unit, such as a circular knitting unit, to which the stitching yarns are also fed, and the completed tubular reinforcing material is discharged, for instance by being wound, characterized in that on a preferably cylindrical core upstream of the connecting unit and extending in longitudinal direction of the tube one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at said acute angle $\alpha$, and these obliquely positioned reinforcing yarns are conveyed along the core to the connecting unit, where they are interconnected by the stitching yarns.

9. A process according to claim 8, characterized in that one or more groups of reinforcing yarns are fed to the core from a feeding unit with several supply packages of reinforcing yarns provided about the core.

10. A process according to claim 9, characterized in that the reinforcing yarns of a group on its feeding unit are fed to the core at said desired acute angle $\alpha$ via guide elements.

11. A process according to claim 10, characterized in that the feeding unit and the core rotate relative to each other.

12. A process according to claim 11, characterized in that said feeding unit and the core rotate relative to each other at a rotational speed dependent on said acute angle $\alpha$ and the discharge rate of the produced tube.

13. A process according to claim 12, characterized in that each of said groups of reinforcing yarns is fed from its feeding unit rotating about the non-rotating core.

14. A process according to claim 13, characterized in that the reinforcing yarns of the various groups are deposited at the desired acute angle $\alpha$ on a surface moving in axial direction of the core, such as a number of conveyor belts moving in axial direction.

15. A process according to claim 1, characterized in that the reinforcing yarns employed are selected from the following group of materials: aramid, more particularly polyparaphenylene terephthalamide (PPDT), carbon, and glass.

16. A sheet material consisting of a plastics matrix with incorporated therein a reinforcing fibre material, characterized in that use is made of the reinforcing material manufactured according to claim 1.

17. A sheet material according to claim 16, characterized in that the matrix is of a thermoplastic synthetic material.

18. A sheet material according to claim 16, characterized in that the matrix is of a thermosetting synthetic material.

19. A process for the manufacture of the sheet material according to claim 17, characterized in that the reinforcing material is impregnated with the thermoplastic synthetic material.

20. A process according to claim 19, characterized in that the reinforcing material is impregnated with the thermoplastic synthetic material by one or more of the following techniques:

- use of one or more films of thermoplastic synthetic material;

- use of continuous reinforcing yarns optionally incorporated into a cloth, such as a woven fabric, a knitted fabric, or a web, impregnated with a powder of the thermoplastic synthetic material;
- use of continuous reinforcing yarns optionally incorporated into a cloth, such as a woven fabric, a knitted fabric, or a web, impregnated with a molten thermoplastic synthetic material;
- use of continuous reinforcing yarns optionally incorporated into a cloth, such as a woven fabric, a knitted fabric, or a web, impregnated with a solution of the thermoplastic synthetic material;
- use of continuous reinforcing yarns and separate yarns of a thermoplastic synthetic material;
- use of combined or mixed yarns each preformed from a combination or mixture of a reinforcing yarn and a thermoplastic yarn.

21. A process according to claim 19, characterized in that the reinforcing material, which is for instance in the form of a sheet, is joined to molten thermoplastic material emerging from an extrusion head.

22. A process according to claim 19 or 21, characterized in that the reinforcing material is formed integral with the thermoplastic matrix material with heat and pressure being applied, preferably by using an apparatus of the double belt press type.

23. A shaped object manufactured from the sheet material according to claim 16.

24. An apparatus for the manufacture of a tubular reinforcing fibre material, more particularly a knitted inlay fabric, equipped with a frame with a feeding unit for the reinforcing yarns and a connecting unit, such as a circular knitting unit, for interconnecting the reinforcing yarns with the stitching yarns, and a discharge unit, such as a winding unit, for the discharge of the tubular reinforcing material, characterized in that the frame has a central core with provided about it from one end to the other one or more feeding units rotatable relative to the core.

25. An apparatus according to claim 24, characterized in that on the outside of the core there are provided conveying elements for the reinforcing yarns that can move in axial direction of the core, which conveying elements extend at least from the feeding units to the connecting unit.

26. An apparatus according to claim 24, characterized in that the feeding units each consist of a platform provided with a number of pegs for packages of reinforcing yarns and yarn guides and which is rotatingly mounted, preferably at its circumference, and provided with a drive.

27. An apparatus according to claim 24, characterized in that said discharge unit is positioned downstream of the connecting unit in a direct line with the core.

28. An apparatus according to claim 26, characterized in that the platforms forming feeding units are mounted by means of co-operating virtually V-shaped grooves and rollers engaging therewith.

29. A tubular reinforcing fibre material, such as a knitted inlay fabric, more particularly for the reinforcement of a matrix material, in which reinforcing yarns extending in one or more directions of the tube have been provided which are interconnected by stitching yarns, characterized in that one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of + 10° to + 80° and/or - 10° to - 80°.

30. A tubular reinforcing material according to claim 29, characterized in that one or more groups of reinforcing yarns are positioned relative to the longitudinal axis of the tube at an acute angle $\alpha$ of a magnitude of + 15° to + 75° and/or - 15° to - 75°, more particularly an acute angle of a magnitude of + 30° to + 60° and/or -30° to -60°.

31. A reinforcing material according to claim 30, characterized in that at least two groups of reinforcing yarns are positioned at said acute angle $\alpha$.

32. A reinforcing material according to claim 31, characterized in that at least two or more groups of reinforcing yarns are positioned at equal but opposite angles $\alpha$, such as $\alpha$ = + 30° and - 30° or $\alpha$ = + 45° and - 45°, or $\alpha$ = + 60° and - 60°, relative to the longitudinal axis of the tube.

33. A reinforcing material according to claim 32, characterized in that a group of reinforcing yarns is positioned at a virtually right angle $\beta$, which differs from 90° by less than 10°, relative to the longitudinal axis of the tube.

34. A reinforcing material according to claim 32, characterized in that a group of reinforcing yarns is positioned virtually parallel to the longitudinal axis of the tube.

35. A reinforcing material according to claim 31, characterized in that each group of reinforcing yarns is positioned in a separate ply and the several piles containing a group of reinforcing yarns are interconnected by stitching yarns.

36. A reinforcing material according to claim 29, characterized in that the reinforcing yarns consist of yarns having a linear density of at least 20 Tex, preferably at least 40 Tex, and at most 500 Tex.

fig.1

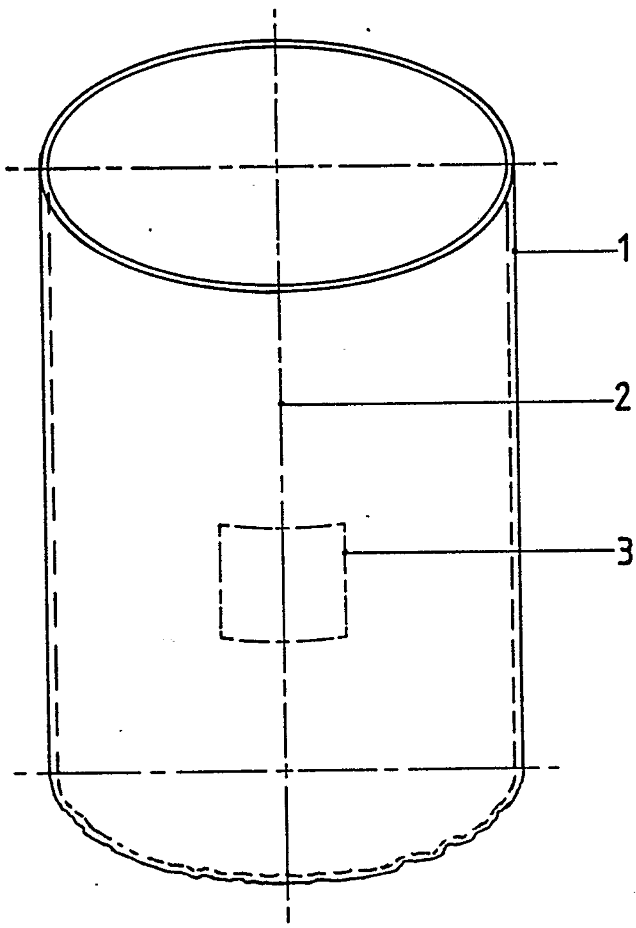


fig. 2

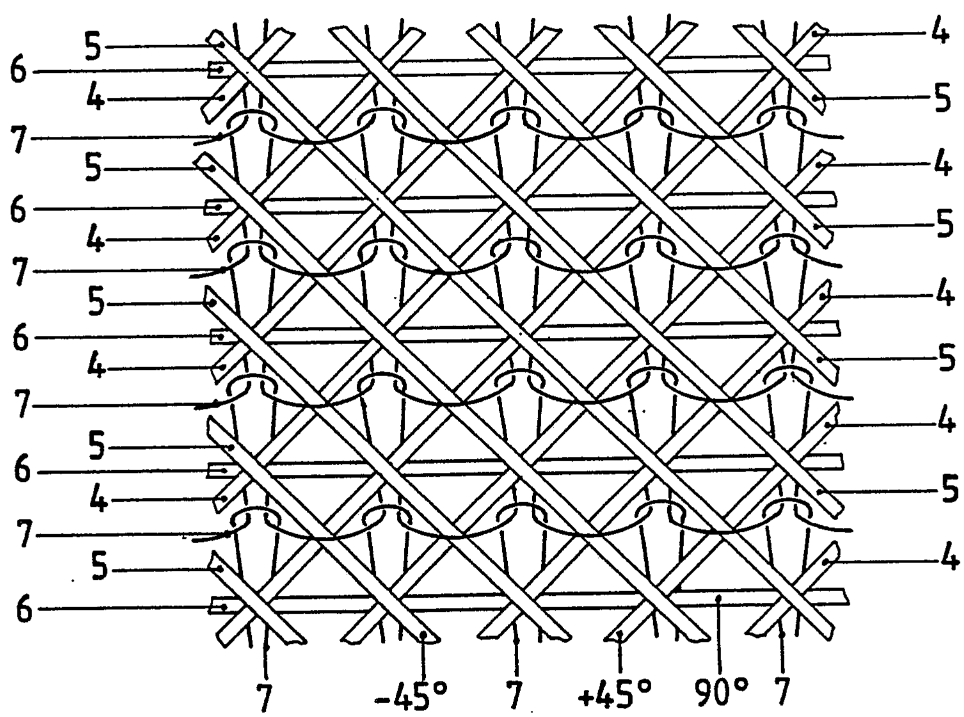

fig. 3

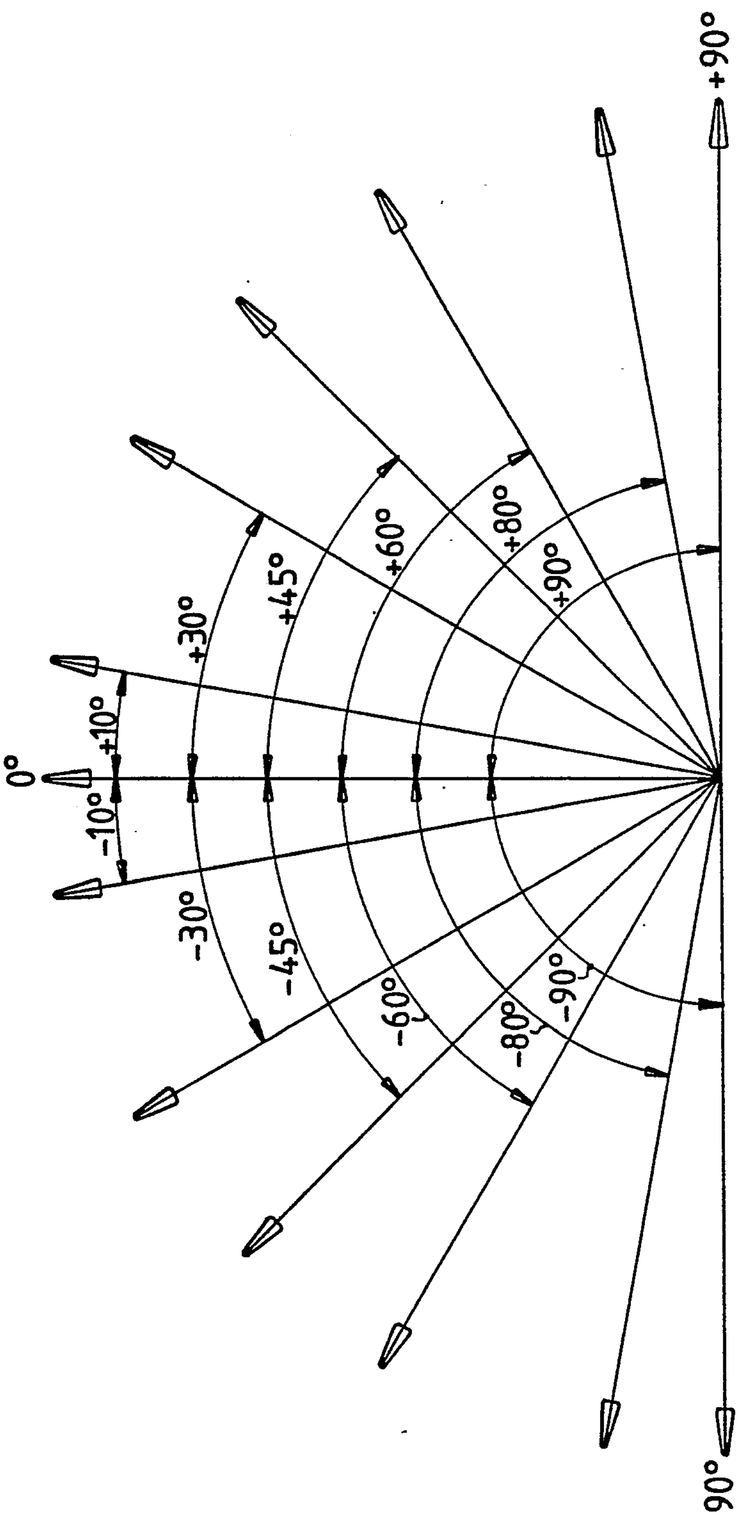


fig. 6

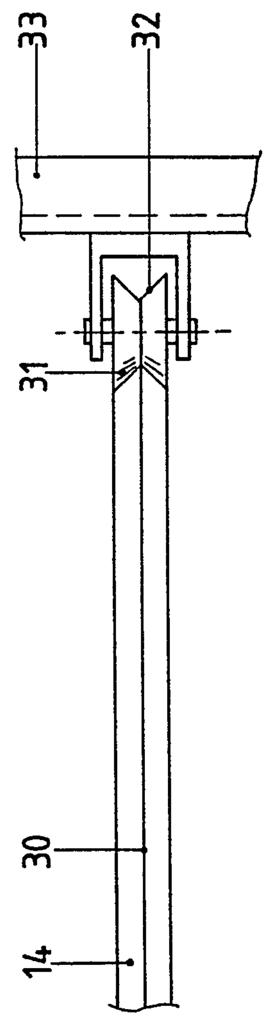

fig. 4

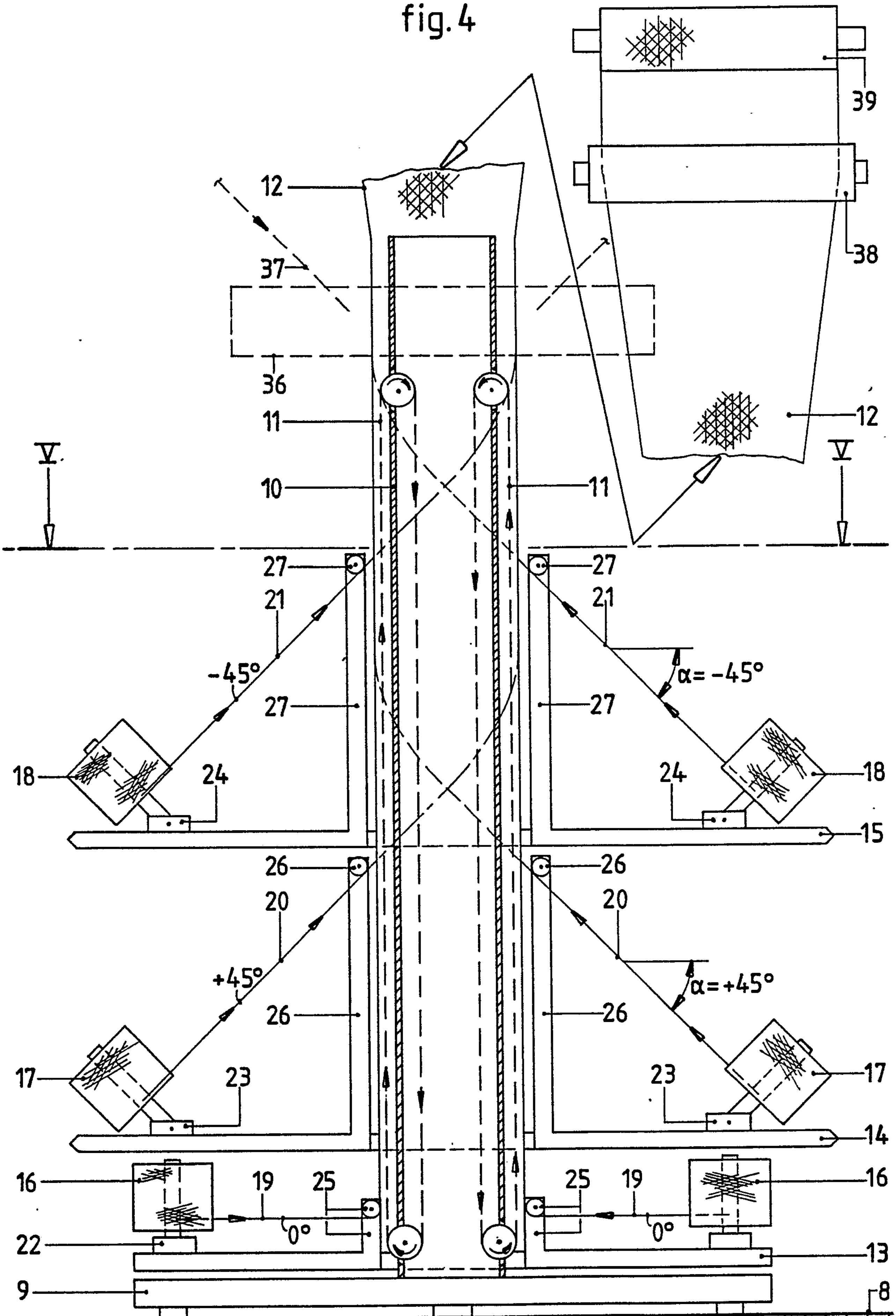

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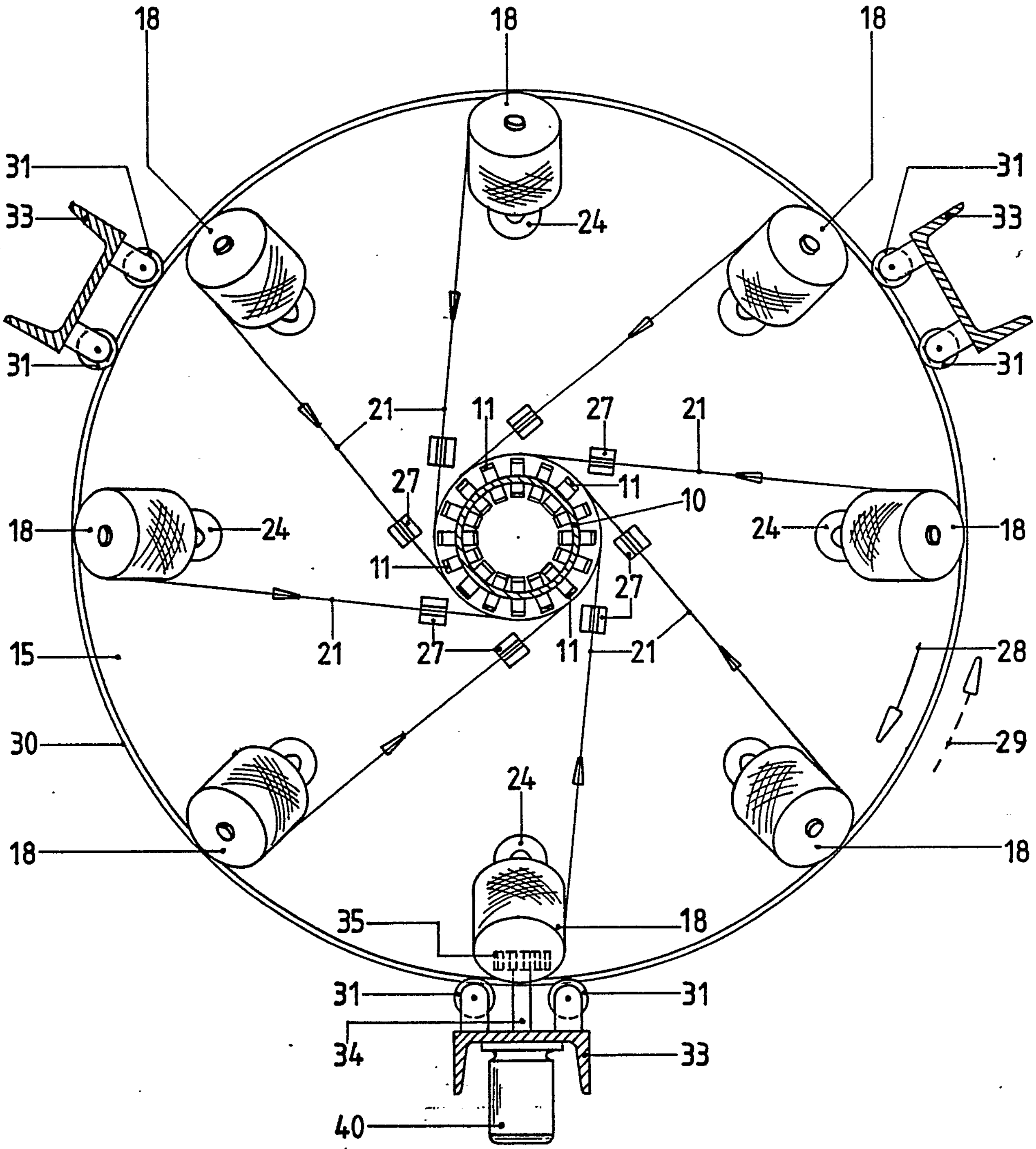
fig. 5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European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 89 20 2948

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5 ) |
|---|---|---|---|
| A | US-A-2118108 (RILEY)<br>* page 2, left-hand column, lines 12 - 47 *<br>* page 3, left-hand column, lines 13 - 28; figures 2, 6 * | 1-5, 7, 29-32, 34, 35 | D04B39/06 |
| A | DE-A-3304345 (KARL MAYER TEXTIL-MASCHINEN-FABRIK GMBH)<br>* page 3, lines 6 - 15; claim 1; figure 1 * | 1-7, 16, 29-36 | |
| A | GB-A-1384522 (KRYLOV) | | |
| A | DE-A-3339205 (POLYLOK CORP.) | | |
| A | GB-A-970393 (SINGER-FIDELITY INC.) | | |
| A | Chemiefasern/Textilindustrie<br>vol. 36, July 1986,<br>pages 579 - 580;<br>"Multiaxial-Magazinschuss-Wirkmaschine fuer Faserverbundwerkstoffe mit sehr hoher Festigkeit "<br>* pages 579 - 578 * | | TECHNICAL FIELDS SEARCHED (Int. Cl.5 )<br>D04B |
| A,D | Chemiefasern/Textilindustrie<br>vol. 38, March 1988,<br>page T19 P.Knobloch:<br>"ITMA-Bericht: Technische Textilien"<br>* page T19 * | | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 19 FEBRUARY 1990 | VAN GELDER P.A. |

CATEGORY OF CITED DOCUMENTS

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