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(54) Flat textile structure consisting of reinforcing fibres

(57) Flat textile structure comprising groups of parallel bundles (12) of reinforcing fibres that cross one another at a crossing angle (d). The structure contains fixation means for the bundles (1,2), which extend over part of the structure's surface, which fixation means (3) allow a change in the crossing angle (d) between the groups but prevent a change in the distance (x) between the bundles of a group in the structure's surface either completely or partially, relative to the change in distance in a corresponding structure that does not contain the fixation means.

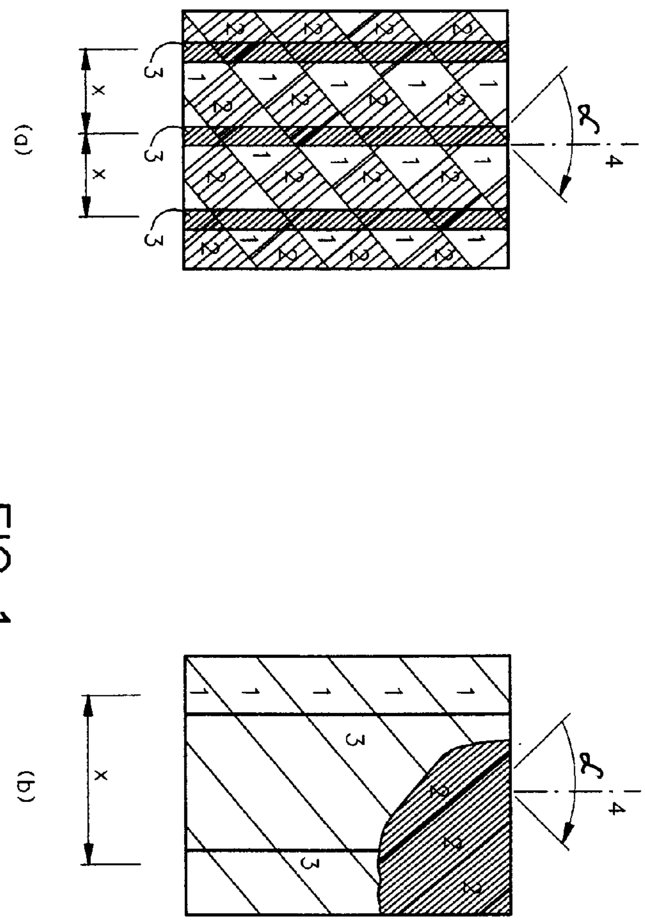

FIG. 1

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Description

The invention relates to a flat textile structure containing groups of parallel bundles of reinforcing fibres that cross one another at a crossing angle.

Such a textile structure, for example in the form of a fabric, is described in Section 8.5 of the 'Handbook of Composites, ed. George Lubin (1982)'. In the context of the present application, 'flat textile structure' is understood to be a structure of which one dimension (the thickness) is much smaller than the two other dimensions (length and width), which determine the structure's plane. The known structure is often used to manufacture objects containing reinforcing fibres. In such a manufacturing process a number of textile structures is usually applied in or against a mould (also known as 'draping') in a first step, after which, in a second step, the textile structures applied in more or less the shape of the object are wetted with a plastic in liquid condition (also known as 'impregnation'). In a third step the plastic is brought to a solid condition, for example by curing or cooling.

Draping the known textile structure in the shape of the object to be manufactured is usually a time-consuming and difficult task, on account of the structure's limited drapability. In the context of the present application 'drapability' is understood to be the possibility of causing the flat structure to assume a three-dimensional shape, without causing undesired geometric deformations of the structure. The fewer undesired geometric deformations, the better the structure's drapability. These undesired geometric deformations are known to a person skilled in the art and include for example wrinkling or local overlaps of the structure. A major drawback of the known structure is furthermore that gaps form between the bundles of reinforcing fibres during the draping, bundles splice or the structure even disintegrates. In many object shapes, because of the limited drapability of the known textile structure, cuts furthermore have to be made in the known structure before draping. Without making cuts it is usually entirely impossible to cause the structure to assume the shape of the object. This is for example the case with objects with doubly curved surfaces. The cuts are disadvantageous for the object's mechanical properties because the reinforcing fibres are interrupted at the cuts.

These problems are prevented according to the invention because the textile structure contains fixation means for the bundles of reinforcing fibres, which extend over part of the structure's plane, which fixation means allow a change in the crossing angle between the groups but prevent a change in the distance between the bundles of a group in the structure's plane either completely or partially, relative to the change in distance in a corresponding structure that does not contain the fixation means.

Surprisingly, with the textile structure according to the invention a drapability is obtained, which greatly exceeds that of the known structure.

A further advantage of the textile structure according to the invention is the improved ease of handling relative to the known structure. In the context of the present application 'ease of handling' is understood to be the possibility of handling the flat structure without it being partly undone, for example because of the angle between the bundles being permanently changed or fibre bundles being entirely or partly removed from the structure. 'Ease of handling' is also understood to be the structure's ability to retain a particular three-dimensional shape for a certain length of time without returning to its original flat shape.

The fixation means of the structure according to the invention may for example consist of strips of a thermoplastic or strips of a cured thermosetting adhesive. The strips constitute a link between adjacent bundles of a group and/or between the bundles of different groups. The link prevents a change in the distance between the bundles. This prevention is defined as 'complete' if the link has a high degree of stiffness, for example the stiffness of steel wire. The prevention is defined as 'partial' if the link exhibits a certain degree of elasticity, as a result of which the prevention is less than in the case of complete prevention but greater than in the case of an identical textile structure that does not contain the fixation means. The strips may be applied to one side or both sides of the structure's plane. A structure on which a layer of adhesive extends almost completely over the structure's plane, as is for example the case with a prepreg, which to a great extent prevents shearing, is not covered by the invention. 'Shearing' is here defined as a change in the crossing angle.

Preferably use is made of textile fixation means, for example yarn, thread or fibres. Such textile fixation means serve to link adjacent bundles in such a way as to ensure complete or partial prevention of a change in the distance between the bundles in the structure's plane. This is for example achieved by a thread that extends from bundle to bundle and is each time looped around a bundle.

Preferably the textile structure according to the invention is characterised in that the fixation means consist of stitching. It has been found that the drapability is further improved by using stitching. The best results are obtained when the stitching extends entirely or almost entirely linearly in a direction parallel to the crossing angle's bisector.

It is very advantageous to characterise the structure according to the invention in that the structure contains an upper and a lower layer, obtainable by flattening a circular braided fabric in a medial plane of the circular braided fabric, which layers are held on top of one another by the fixation means. This preferred embodiment is particularly suitable for fast and economic manufacture. One possible process for example comprises braiding a circular braided fabric using a mandrel in a manner known to a person skilled in the art, which circular braided fabric is then stitched longitudinally in a continuous process.

Any type of stitching is in principle suitable for use in the structure according to the invention. A survey of suitable types of stitching is for example described in the brochure 'Nähmaschinengruppierung nach technischen Merkmalen' of Dürkoppwerke GmbH in Bielefeld, Germany. The type of stitching is in principle determined by the stitch type, the stitch length and the thread type. Examples of suitable stitch types are for example a single chain stitch (100 series in the aforementioned brochure), a two-step stitch (300 series in the aforementioned brochure) or a double chain stitch (400 series in the aforementioned brochure). Suitable stitch lengths are for example 2, 4, 6, 8 or 10 mm. The thread type may be chosen from a wide range. For example, polyester or polyamide thread may be used as the material for the stitching. It is also possible to use for the stitching a fibre of the same material as that of which the reinforcing fibre is made.

Preferably use is made of a stitching that is longitudinally elastic. 'Elastic' is understood to mean that the length of the stitching changes when a force is exerted on it. This change in length may be an elongation (in the case of a tensile force) or a shortening (in the case of a compressive force). The stitching's degree of elasticity is determined by the stitch type, the stitch length and the stiffness of the type of thread used. Stitchings with the preferred elasticity for example consist of a single chain stitch of polyester thread having a stitch length of 2-8 mm, or of a double chain stitch of polyester thread having a stitch length of 2-6 mm.

The structure's drapability is further improved by using longitudinally elastic stitching. In particular, a greatly improved ease of handling is also obtained.

Preferably, the structure contains a number of linear stitchings, the distance between the linear stitchings being 4 to 25 mm. Besides a further improvement in the ease of handling, this preferred embodiment presents the possibility of fixing the drapability in a very simple manner. Very good results are obtained at a spacing of between 6 and 10 mm, although this is somewhat dependent on the structure's width and the bundles' weight per unit of length.

For the drapability it is advantageous that, in the structure's undeformed condition, the crossing angle between the bundles of reinforcing fibres is between 60 and 120 degrees. Preferably this angle is about 90 degrees.

Draping the known textile structure in the shape of the object to be manufactured is time-consuming because for most objects several such structures have to be draped on top of one another in order to obtain the desired mechanical properties and this draping is usually done by hand. The textile structure according to the invention presents the additional advantage that it is possible to use only a limited number of draping operations to this end. Preferably the structure's areal density is at least 400 g/m^2, more preferably it is between 800 and 3500 g/m^2. Most preferably the areal density is between 1200 and 2000 g/m^2. Because of this only one draping operation will in many cases be required.

In principle, all natural and synthetic fibres can be used as the reinforcing fibres. Suitable reinforcing fibres are for example inorganic fibres such as carbon fibre, glass fibre and ceramic fibre. Suitable organic fibres are for example aramid fibre, liquid crystalline polymer fibre and fibres of for example polyolefins, polyvinylalcohol and polyacrylonitrile, which polymers may optionally be highly oriented and may have an ultra-high molecular weight. The structure according to the invention may also contain several types of reinforcing fibre.

Any known fibre-containing structure may be chosen as the flat textile structure consisting of bundles of reinforcing fibres that cross one another at a crossing angle. It is for example possible to choose a flat woven fabric, for example a woven fabric with a satin or twill weave. Such fabrics usually contain two sets of bundles (the warp and weft bundles), which cross one another at a crossing angle. With such fabrics the crossing angle is usually 90 degrees. It is also possible to choose a fabric of a so-called unidirectional weave. Such a fabric of a unidirectional weave consists of a number of parallel bundles of reinforcing fibres which are held together by a limited number of transverse threads running at right angles to the direction of the bundles. The flat textile structure comprising crossed bundles is in this case obtained by stacking at least two such fabrics of unidirectional weave at a crossing angle. It is also possible to choose a braided fabric as the flat textile structure. A comprehensive description of the manufacture of braided fabrics and of the different kinds of braided fabrics - for example flat braided fabrics and circular braided fabrics - is given in the book 'Flechten, Rationelle Fertigung faserverstärkter Kunststoffbauteile' by J.U. Rosenbaum, Verlag TÜV Rheinland, 1991. The structure according to the invention may contain one, but optionally also several flat structures as described above.

The textile structure according to the invention can be used to manufacture a large number of fibre-reinforced objects (so-called composite objects). These objects are often used for example in the aircraft and automotive industries, the chemical industry and construction. In particular, the structure can also be used in those branches of industry in which objects of a complex shape and high requirements in terms of stiffness and/or strength are used.

The invention is further illustrated with reference to the example and the following figures, without being limited thereto.

Fig. 1 shows a schematic top view of two possible textile structures according to the invention.

Fig. 2 schematically shows which geometrical deformations are completely or partially prevented by the fixation means in the structure according to the invention.

Fig. 3 is a photograph of a top view of a structure according to the invention.

The textile structure in Fig. 1(a) comprises groups (1) and (2) of parallel bundles of reinforcing fibres that cross one another at a crossing angle α. Groups (1) and (2) are woven. Fig. 1(a) also shows a possible geometric pattern for the fixation means (3), in this case stitching in the form of three parallel lines. The stitching extends in a direction parallel to the crossing angle's bisector (4). In Fig. 1(a) the distance between the linear stitchings is indicated by x.

The textile structure in Fig. 1(b) comprises groups (1) and (2) of parallel bundles of reinforcing fibres that cross one another at a crossing angle α. In this case groups (1) and (2) lie on top of one another. In Fig. 1(b) group (1) has been drawn on top of group (2). The stitching (3), which links the groups of bundles locally, is linear, as in the case of the structure of Fig. 1(a). The stitching extends in a direction parallel to the crossing angle's bisector (4).

Fig. 2(a) represents a textile structure comprising groups (1) and (2) of parallel bundles of reinforcing fibres that cross one another at a crossing angle α. Groups (1) and (2) are woven. Fig. 2(a) shows stitching in the form of a single line. The stitching extends in a direction parallel to the crossing angle's bisector (4). Fig. 2(b) shows an enlargement of the square drawn in the structure of Fig. 2(a). If a textile structure identical to that shown in Fig. 2(a), but without the stitching (3), is loaded in direction A-A, the crossing angle α will readily be reduced. The distances X-X' and Y-Y', shown in Fig. 2(b), will also readily decrease. The structure according to the invention, which contains stitching (3), readily allows the change in the crossing angle, but partially prevents a change in the distances X-X' and Y-Y'. These distances will change until the maximum elongation of the stitching in direction A-A is reached. If the stitching is not elastic in direction A-A' the change in distance is completely prevented.

The structure of Fig. 3 was obtained by flattening a circular braided fabric in a medial plane of the circular braided fabric. Then the flattened circular braided fabric was provided with stitching, as indicated in the photograph.

Example

A circular braided fabric was produced using a standard circular braiding machine fitted with 144 carriers. Use was made of bundles of glass fibre with a weight per unit length of 9x300=2700 tex. At a mandrel diameter of 165 mm the circular braided fabric had a crossing angle of 45 degrees and a weight per unit length of 550 g/m.

The circular braided fabric was flattened by passing it over a flat mandrel. The flat mandrel was plate-shaped and had a width of 180 mm and a length of about a metre. The plate's edges were rounded to prevent damage to the braided fabric as it was passed over the flat mandrel. In the mandrel's downstream end, plate material had been milled away centrally over a length of about 150 mm so that the edges of the plate formed a fork there. This fork held the braided fabric flat at the desired width of 180 mm, while an open space was available for the application of stitching between the arms of the fork. The flattened circular braided fabric was stitched with the aid of a standard stitching machine fitted with 21 needles. The distance between the needles was 6.35 mm (0.25 inch). The thread type was 100% polyester thread with a weight per unit length of 100 Denier. This resulted in a structure according to the invention with a width of 180 mm in undeformed condition.

The structure was draped, in one operation, around a vertical round opening (diameter 500 mm) applied to a pipe (diameter 1500 mm), which served as a manhole. No cuts were required in the structure to cause the structure to assume the shape of the opening. The draped structure was then impregnated, with the aid of a brush, with a thermosetting resin, namely an unsaturated polyester resin, and cured. After curing a product with excellent properties was obtained.

Claims

1. Flat textile structure comprising groups of parallel bundles of reinforcing fibres that cross one another at a crossing angle, characterised in that the structure contains fixation means for the bundles, which extend over part of the structure's surface, which fixation means allow a change in the crossing angle between the groups, but prevent a change in the distance between the bundles of a group in the structure's surface either completely or partially, relative to the change in distance in a corresponding structure that does not contain the fixation means.

2. Textile structure according to Claim 1, characterised in that the fixation means consist of stitching.

3. Textile structure according to Claim 2, characterised in that the stitching extends entirely or almost entirely linearly in a direction parallel to the crossing angle's bisector.

4. Textile structure according to Claim 2 or Claim 3, characterised in that the stitching is longitudinally elastic.

5. Textile structure according to any one of Claims 1-4, characterised in that the structure comprises a bottom and a top layer, obtainable by flattening a circular braided fabric in a medial plane of the circular braided fabric, which layers are held on top of one another by the fixation means.

6. Textile structure according to any one of Claims 3-5, characterised in that the distance between the linear stitchings is between 4 and 25 mm.

7. Textile structure according to any one of Claims 1-6, characterised in that, in the structure's undeformed condition, the crossing angle between the bundles of reinforcing fibres is between 30 and 60 degrees.

8. Textile structure according to any one of Claims 1-7, characterised in that the structure's areal density is between 1200 and 2000 g/m^2.

9. Textile structure as described in the introduction and explained with reference to the examples.

10. Fibre-reinforced object entirely or partly made of the textile structure according to any one of Claims 1-9.

11. Process for the manufacture of a fibre-reinforced object, in which, in a first step, a number of textile structures according to any one of Claims 1-9 is applied in or against a mould, after which, in a second step, the number of textile structures applied is wetted with a plastic in liquid condition, after which, in a third step, the plastic is brought into solid condition by curing or cooling.

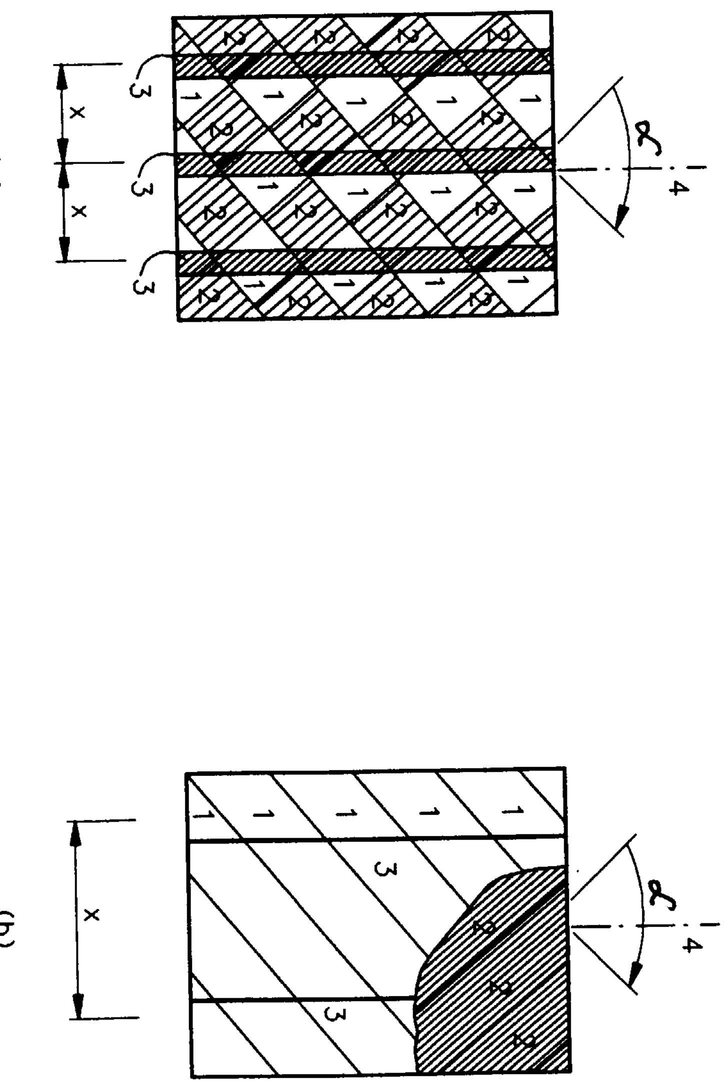


FIG. 1

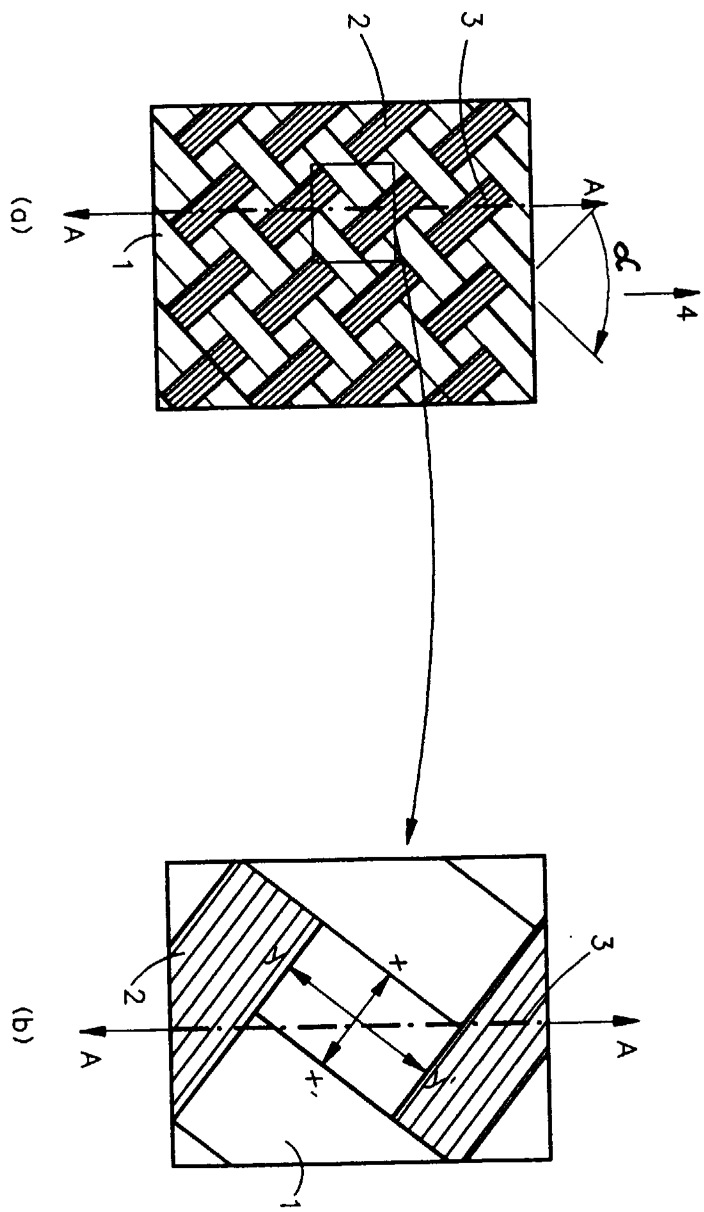
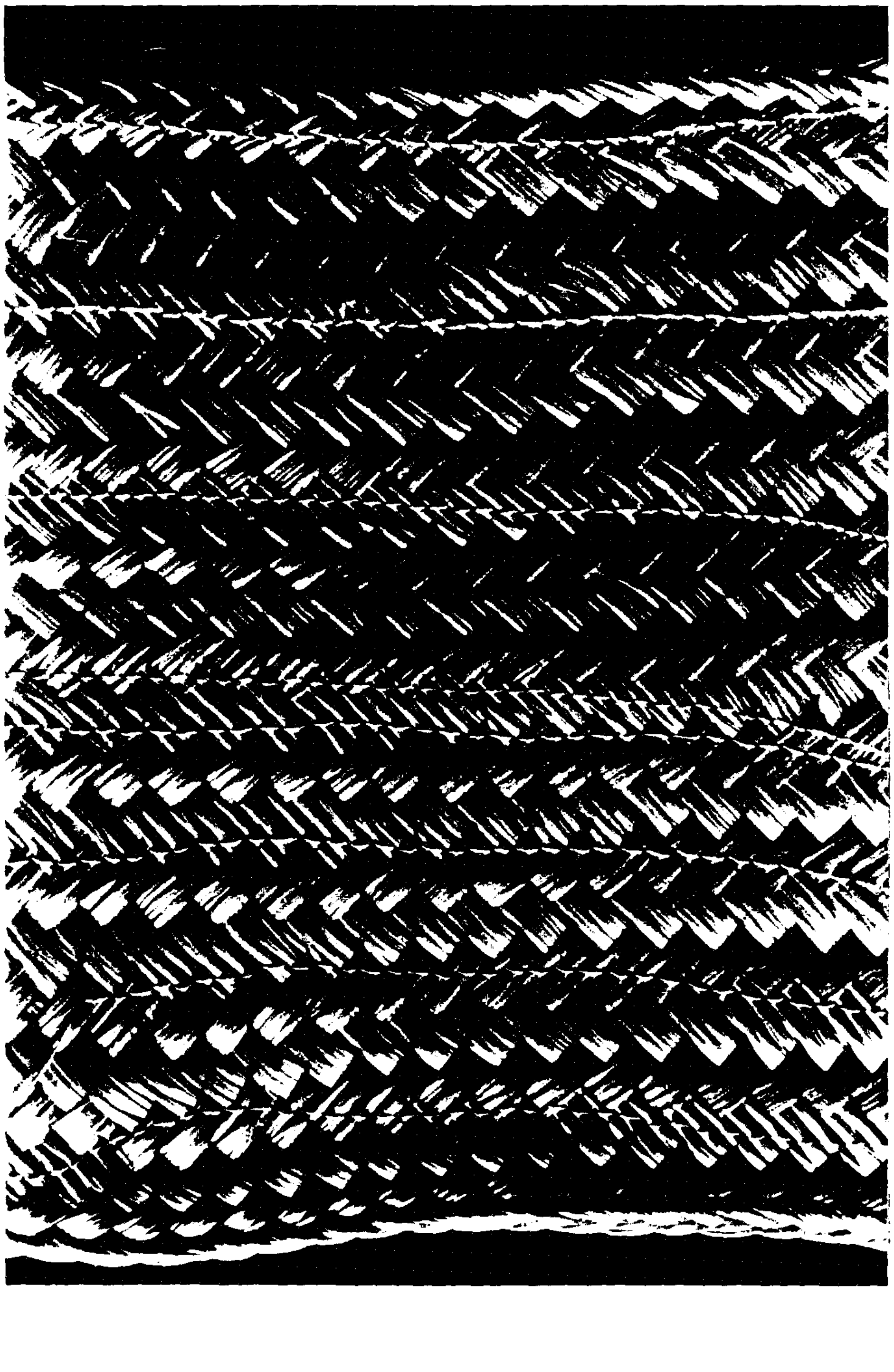


FIG. 2

FIG. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 96 20 1090

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.6)
X	EP-A-0 530 120 (C.R.S.T.(S.A.)) 3 March 1993 * column 1, line 30 - line 57; figures 1-5 *	1-3,7,9,10	D04C1/06
Y		11	
X	DE-A-38 22 188 (PENN ELASTIC GMBH) 11 January 1990 * claim 2; figure 4 *	1-4,7,9,10	
Y	DE-A-42 18 860 (FORSCHUNGSINSTITUT) 16 December 1993 * column 3, line 30 - line 47 *	11	
A	US-A-4 845 963 (PAREKH) 11 July 1989		
A	FR-A-2 568 275 (ETS LES FILS D'AUGUSTE CHOMARAT ET CIE) 31 January 1986		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

D04C
D04B
D05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 August 1996	Van Gelder, P

CATEGORY OF CITED DOCUMENTS

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