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(54) **REINFORCING TEXTILE STRUCTURE FOR
COMPOSITE MATERIALS**

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(57) **ABSTRACT**

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A reinforcing textile complex for composite materials, comprising a stack of textile layers with a view to their impregnation by a polymer resin, the including complex comprising: an assembly of weft threads (2); an assembly of warp threads (3, 4) associated in pairs, each pair comprising two threads of different type, at least one of which (3) is based on high toughness threads, the two threads of a given pair being woven with the weft threads in a “leno” weave.

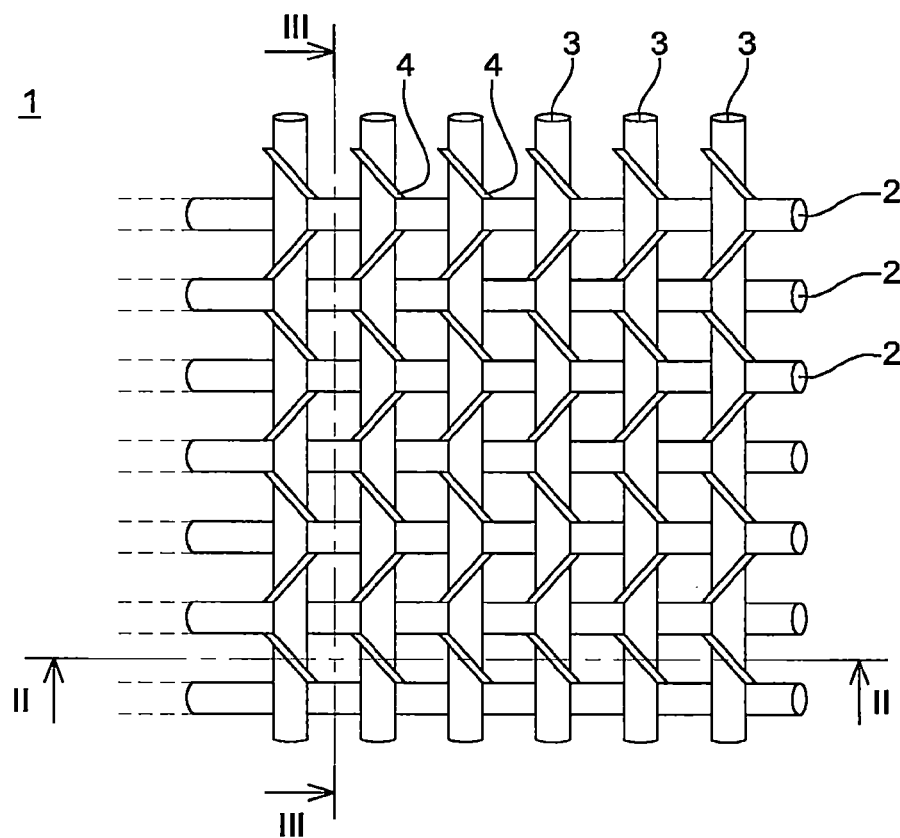


Fig. 1

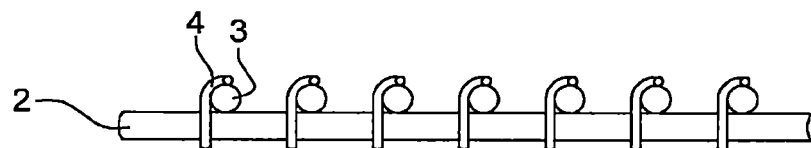


Fig. 2

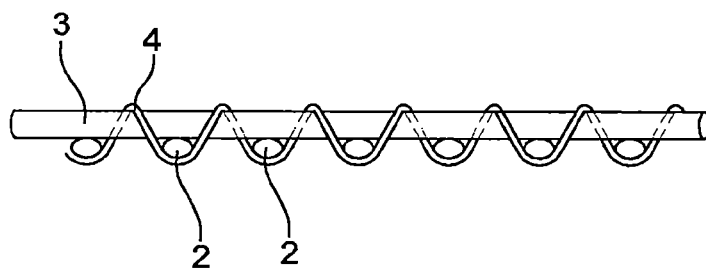


Fig. 3

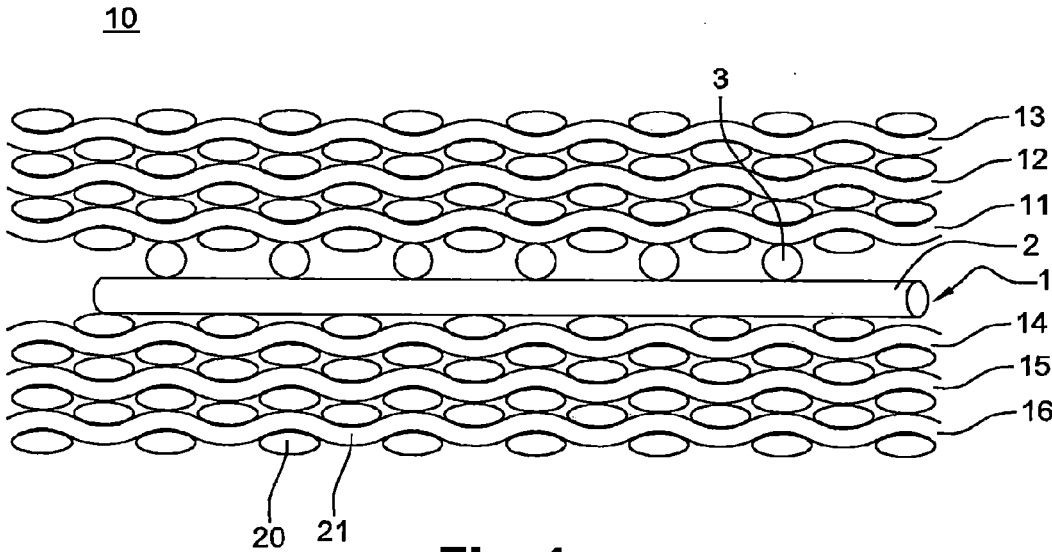


Fig. 4

REINFORCING TEXTILE STRUCTURE FOR COMPOSITE MATERIALS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a national stage application, filed under 35 U.S.C. §371, of International Application No. PCT/FR2015/050520, filed Mar. 4, 2015, which claims priority to French Application No. 1451734, filed Mar. 4, 2014, the contents of both of which are hereby incorporated by reference in their entirety.

BACKGROUND

[0002] Technical Field

[0003] The invention relates to the textile industry, and more particularly to textiles used as a reinforcement for composite materials. It more specifically aims at a complex formed by a stack of reinforcing layers to be impregnated by a polymer resin, especially a thermosetting resin.

[0004] It more specifically relates to a configuration of this type of complex enabling one of its layers to have a function both of mechanical reinforcement and of drainage of the impregnation resin for closed molds.

[0005] Description of Related Art

[0006] Generally, the manufacturing of composite materials based on fibrous reinforcements may be performed by infusion techniques, where the resin is introduced into a mold at specific points, and displaces within or around the fibrous layers towards suction points.

[0007] The infusion method is based on three fundamental physical principles, which are pressure difference, resin viscosity, and permeability. Indeed, the resin migration through the textile structure (impregnation) cannot occur if the permeability is not sufficient and if the pressure in the mold is constant.

[0008] The permeability of a reinforcement designates its ability to be crossed by a fluid, in the case in point, resin. At a microscopic scale, it is linked to the microporosities of the strands (fiber assemblies). At a mesoscopic scale, it is linked to the spaces which separate the strands forming the reinforcement weave. At a macroscopic scale, it depends on the reinforcement weave. The permeability is expressed in m^2 .

[0009] Conventional fabrics of roving type (twill weave, canvas, standard gauze . . .), or Non Crimp Fabrics (NCF) used in the infusion method have a permeability in the range from 10^{-10} to 10^{-11} m^2 for glass. Such a permeability is generally not sufficient to guarantee a correct filling of the part, which generally has a large size. To improve the permeability, two types of infusion may be used for monolithic structures.

[0010] An infusion with an external draining can thus be performed. In this case, the resin flows by means of a strongly permeable drainage fabric placed above the stack of preformed fibers. The pressure difference between the resin inlet, located at the draining level, and the vent, located on the base of the preform, causes the infusion of the resin, first in the drainage fabric, and then across the thickness of the dry preforms. The external draining fabric is then removed from the part by means of a peel ply. The main disadvantage of this method is the large amount of waste (peel ply, external drainage net) and the time necessary to install the consumables.

[0011] A method of infusion with an internal drainage is also known. In order to limit waste, the drainage fabric is positioned within the textile structure. It is a very porous layer allowing a good resin flow through the preform. It generally is a Continuous Filaments Mat or a synthetic net which will remain in the room. The major disadvantage of this type of product is the impact on the mechanical properties due to the increase in the resin rate in the final laminate.

[0012] Thus, the Applicant has described in document EP 0 395 548 a textile structure formed of a stack of two reinforcing layers, almost exclusively formed of high-tenacity yarns, for example, made of glass, imprisoning between them an aerated layer, formed from relatively thin and wavy synthetic yarns. The central layer, which forms the core of the stack, is thus relatively open-worked and provides a passage for resin between the two reinforcing layers, which are much less permeable to resin.

[0013] This solution, although it has significant advantages, however has the disadvantage of generating resin build-up areas which have much poorer mechanical properties than the external layers, and this all the more as the fibrous material which forms the core is not formed of high-tenacity yarns.

[0014] An alternative solution dedicated to infusion has been provided by the Applicant in document FR 2870861. This solution, deriving from the former, uses a polyester knitting as a core.

[0015] Another solution has also been provided by the Applicant in document EP 0 672 776.

[0016] In this solution, the fibrous plies are formed of unidirectional structures comprising high-count and high-tenacity yarns. Each of the plies is deformed so that the weft yarns have an inclination which is not perpendicular to the warp direction. A plurality of such plies is associated, by combining different inclinations of the reinforcing yarns.

[0017] The assembly is formed without inserting core layers to ease the flow. The inclination of the different yarns of the stacked plies enables the resin to flow. Although this solution has the advantage of not including fibrous materials other than those of the reinforcing layers, it however has the disadvantage of a relatively low permeability to resin in the warp direction.

[0018] It should thus be understood that a compromise has to be made between the mechanical performance of the obtained composites and the resin flow speed.

BRIEF SUMMARY

[0019] The invention thus intends to provide a solution which has both a good longitudinal permeability to resin for an easy impregnation during the infusion process, combined with a high mechanical performance for the obtained composite material.

[0020] For this purpose, the invention relates to a textile reinforcing structure for composite materials, intended to form an intermediate layer to be integrated in a textile complex formed of a stack of textile layers with a view to their impregnation by a polymer resin.

[0021] The intermediate layer is characterized in that it comprises:

[0022] an assembly of weft yarns;

[0023] and an assembly of warp yarns associated in pairs, each pair comprising two yarns of different type,

one of which at least is based on high-tenacity yarns, the two yarns of a same pair being woven with weft yarns in a leno weave.

[0024] In other words, the invention comprises forming an intermediate layer which has good mechanical properties, due to the fact that it is made of high-tenacity yarns, and which has a good permeability to resin along the warp and/or weft direction. This layer is thus used as a “structural internal drain”, thus combining the advantages in terms of permeability of a synthetic internal drain and of mechanical characteristics close to those of a standard reinforcement.

[0025] Indeed, the leno configuration with two yarns of different nature results in that some of these yarns, that is, the high-tenacity yarns, have a limited or even no crimp and define together channels where the resin can easily flow.

[0026] The channels are all the better defined as part of the warp yarns, that is, the high-tenacity yarns, all are on the same side of the weft yarn ply. Only the warp yarns of the second type hold the main yarns together.

[0027] The low crimp of high-tenacity warp yarns is all the more significant as the tension difference between the two types of warp yarns is significant. It is also by a lesser extent a function of the count difference between the two types of yarns. This indeed enables to work with tension differences on the two types of warp yarns, so that the yarn having the lowest count supports the greatest crimp.

[0028] In practice, it is now possible to modulate the reinforcement properties of the draining layer by using yarns which are also of high tenacity in the weft, thus providing a bidirectional reinforcement, both in the warp and in the weft direction. However, in certain applications, it may be useful to only use high-tenacity yarns in the warp direction.

[0029] For warp yarns, the yarns of the second type, that is, those having the lowest count, may be of different natures, that is, either organic synthetic yarns, or high-tenacity yarns similar to the main yarns. In this last case, the entire characteristic layer can thus be formed with high-tenacity yarns, which may be advantageous for certain compatibility or heat resistance properties, although the yarn of the second type does not take part in the mechanical resistance of the product.

[0030] Due to the construction of this layer, the mechanical reinforcement properties in the warp and weft direction may be very finely adjusted by accordingly selecting the masses per unit area of the weft and warp yarns.

[0031] In the case where the mass per unit area of the weft yarns is substantially equal to that of the warp yarns, the reinforcement is substantially balanced. This enables to create channels not only in the warp direction, but also in the weft direction, which provides a significant permeability in both directions. However, in the case where the permeability only needs to be increased in a single direction, that is, the warp direction, lower-count weft yarns may be used.

[0032] The influence of the binding yarns, that is, the warp yarns of the second type, may be all the smaller as the mass per unit area of the warp yarns of the first type is greater by more than eight or at least from three to four times that of the weft yarns of the second type.

[0033] The resin flow capacity may be modulated according to the width of the channels defined between the main yarns. Thus, in a first case, it may be provided for the channels between yarns to be of the order of magnitude of

the width of a yarn. Thus, the gap between the warp (and weft) yarns may be between two and three times the width of one of these yarns.

[0034] It is also possible to provide channels of greater width by providing a gap between yarns which is for example greater than four times the width of a yarn.

[0035] In practice, the size of the channels between the warp yarns of highest count may advantageously be in the range from 0.5 to 3 mm for a good permeability in the warp direction. Indeed, below 0.5 mm, the interval is not sufficient to give way to the resin and, above 3 mm, a phenomenon of interlocking of the reinforcements when vacuum is created can be observed. It can thus be observed that the textile structures placed on either side of the draining fabric may clog the channels as vacuum is applied and cause a drop in the permeability of the product.

[0036] The intermediate layer may be associated with one or a plurality of additional layers enabling to increase the flow capacity. Preferably, the additional layers are formed from high-tenacity yarns having a composition identical to that of the reinforcing layers of the complex. It may for example be a veil, or a mat of glass fibers, which by its bulk eases the flowing of resin during the molding, and improves the draining effect of the characteristic intermediate layer, with no added synthetic material. The use of a glass mat also improves the isotropy of the complex, by attenuating the anisotropy induced by the directions of the reinforcement yarns of the structural draining layer. It is possible to add an additional layer on one of the surfaces of the intermediate layer, or two additional layers, one on each surface of the intermediate layer, with identical or different compositions from one additional layer to the other. Of course, this additional layer may itself be formed of a stack of elementary layers if need be.

[0037] Such an intermediate layer has significant permeability properties at least in one direction, combined with high mechanical properties. It can thus be associated by lamination with as many reinforcement layers as necessary. In stacks of a large number of reinforcing layers, it may replace a reinforcing layer, thus gaining the draining effect while keeping a high mechanical performance level. The lamination may conventionally be performed by sewing, gluing or needle punching, possibly by assembly with one or a plurality of overlays.

BRIEF DESCRIPTION OF THE FIGURES

[0038] The way to implement the present invention, as well as the resulting advantages, will better appear from the description of the following embodiments, in relation with the accompanying drawings.

[0039] FIG. 1 is a top view of a textile structure forming the intermediate draining layer of a complex according to the invention.

[0040] FIGS. 2 and 3 are cross-section views respectively along planes II-II' and III-III' of FIG. 1.

[0041] FIG. 4 is a cross-section view of a complex according to the invention, including the intermediate layer of FIG. 1.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

[0042] Generally, the draining and structuring intermediate layer, such as illustrated in FIG. 1, comprises weft yarns

2 and warp yarns 3, 4. Weft yarns 2 are arranged parallel to one another and have almost no crimp. Warp yarns 3, 4 are associated in pairs.

[0043] The weaving is performed by using a leno weave between the two weft yarns 4 and 3 on the one hand, and weft yarn 2 on the other hand. The two warp yarns 3, 4 are interlocked around the frame.

[0044] Due to the tension difference between the two warp yarns, and to their count difference, a configuration where warp yarns 3 of the first type rest on the ply of weft yarns 2 is obtained. Each warp yarn 4 of the second type thus passes under a weft yarn 2 and over warp yarn 3, alternately on one side and the other of the main warp yarn 3 associated therewith.

[0045] Thus, as illustrated in FIG. 2, the main warp yarns 3 are all arranged on the same side as the ply of weft yarns 2, and the warp yarns 4 of the second type, that is, of lowest count, run from one surface to the other of the structure with a significant crimp.

[0046] Of course, the proportions of the different yarns illustrated in the drawings are given as an example only, and the various yarns may differ in reality from this representation.

[0047] It is further possible to modify the number of yarns per length unit, in the warp direction and in the weft direction to adjust the mechanical properties of the future reinforcement as well as the resin flow capacity.

[0048] Different practical embodiments have thus been formed.

EXAMPLE 1

[0049] weft yarn 2: a 1,200-tex glass yarn, with a 468-g/m² mass per unit area;

[0050] warp yarn 3 of the first type: a 1,200-tex glass yarn, with a 438-g/m² mass per unit area;

[0051] warp yarn 4 of the second type: a 28-tex polyester yarn, with a 16-g/m² mass per unit area;

[0052] 1-mm gap between weft yarns

[0053] gap between warp yarns: repeated pattern with two yarns separated by 4 mm and then 4 yarns separated by from 0.5 to 0.7 mm.

EXAMPLE 2

[0054] weft yarn 2: a 600-tex glass yarn, with a 240-g/m² mass per unit area;

[0055] warp yarn 3 of the first type: a 600-tex glass yarn, with a 240-g/m² mass per unit area;

[0056] warp yarn 4 of the second type: a 28-tex polyester yarn, with a 20-g/m² mass per unit area;

[0057] gap between weft yarns: 1.5 mm (approximately)

[0058] gap between warp yarns: 1.5 mm (approximately)

EXAMPLE 3

[0059] weft yarn 2: a 600-tex glass yarn, with a 276-g/m² mass per unit area;

[0060] warp yarn 3 of the first type: a 1,200-tex glass yarn, with a 280-g/m² mass per unit area;

[0061] warp yarn 4 of the second type: a 28-tex polyester yarn, with a 8-g/m² mass per unit area;

[0062] In this example, weft glass yarns 2 are thinner, but are arranged with a smaller pitch, to form a gap in the order of one millimeter, corresponding to the width of a weft yarn.

EXAMPLE 4

[0063] weft yarn 2: a 600-tex glass yarn, with a 276-g/m² mass per unit area;

[0064] warp yarn 3 of the first type: a 600-tex glass yarn, with a 240-g/m² mass per unit area;

[0065] weft yarn 4 of the second type: a 28-tex polyester yarn, with a 18-g/m² mass per unit area.

[0066] gap between weft yarns: 1 mm

[0067] gap between warp yarns: 1.5 mm

[0068] The properties of these different examples have been measured in comparison with a reference complex, constructed according to the teachings of patent FR 2870861, comprising two reference reinforcing layers formed of a 500-g/m² glass fabric, and a reference draining core formed of a warp knitting based on a 110-dtex polyester yarn, having a 110-g/m² general weight.

[0069] The performances of these four examples may be summed up in the following table:

	Reinforcing construction			Front infusion ID permeability			Mechanical properties *	
	(g/m ²)			Glass tx	Permeability	Thickness	traction 0°	
	Total weight	0° warp	90° weft				σ (MPa)	E (GPa)
Reference reinforcing layer	482	236	236	45	$6.86 \cdot 10^{-11}$	1.72	276.3	17.6
Reference draining core	110	/	/	/	$7.13 \cdot 10^{-9}$	2.87	96	7.9
Reference complex	620	265	240	19	$2.10 \cdot 10^{-9}$	4.39	243	12.4
Example Nr 1	916	432	468	39	$2.71 \cdot 10^{-9}$	2.76		
Example Nr 2	502	240	240	32	$3.43 \cdot 10^{-9}$	2.65	234.5	14.3
Example Nr 3	564	288	275	34	$2.98 \cdot 10^{-9}$	3.21	212.8	14.9
Example Nr 4	536	240	276	34	$3.74 \cdot 10^{-9}$	2.62		

* the mechanical tests are carried out with an identical standard stack (mat + Product to be tested + mat)

[0070] Permeability is a physical characteristic which designates the ability of a material to allow the transfer of fluid through a connected network. Darcy's law enables to link a flow rate to a pressure gradient applied to the fluid due to a characteristic parameter of the medium which is crossed, that is, permeability k .

[0071] Darcy's law can be expressed as:

$$k = \frac{Q}{S} \times \frac{\Delta L}{\Delta P} \times \eta$$

[0072] where:

[0073] k is the permeability (in m^2),

[0074] Q is the flow rate through the test piece (in m^3/s),

[0075] S is the cross-section of the test piece (in m^2),

[0076] η is the dynamic viscosity of the fluid (in $\text{Pa}\cdot\text{s}$)

[0077] ΔP is the pressure drop measured between the ends of the test piece (in Pa)

[0078] and ΔL , the length of the test piece

[0079] The permeability can be measured along 3 axes. The permeability indicated in the above table corresponds to the permeability measured in the plane of the reinforcement, along the warp direction.

[0080] The draining properties of this characteristic layer can be expressed in complexes used to manufacture composite parts. Such complexes include a plurality of reinforcing layers selected for their mechanical properties. Thus, as schematically illustrated in FIG. 4, draining layer 1 may be integrated within a stack of a plurality of reinforcing layers 11-16 formed by weaving of warp yarns 20 and weft yarns 21, and having numbers and orientations determined according to the general mechanical properties desired for the final composite part.

[0081] There appears from the foregoing that the reinforcement structure according to the invention enables to combine structural reinforcement properties with a good permeability, thus providing a draining structural reinforcement.

1-11. (canceled)

12. A textile reinforcement complex for composite materials, comprising:

a stack of textile layers with a view to their impregnation by a polymer resin,

the stack comprising an intermediate layer (1) comprising:

an assembly of weft yarns (2); and

an assembly of warp yarns (3, 4) associated in pairs, each pair comprising two yarns of different type, one (3) at least of which is based on high-tenacity yarns, the two yarns of a same pair being woven with the weft yarns in a "leno" weave,

wherein said intermediate layer (1) has a draining role within the complex.

13. The complex of claim 12, wherein the weft yarns (2) of the intermediate layer (1) are based on high-tenacity yarns.

14. The complex of claim 12, wherein:

the warp yarns (3, 4) comprise warp yarns (3) of a first type and warp yarns (4) of a second type; and the warp yarns (3) of the first type have a higher count than the warp yarns (4) of the second type.

15. The complex of claim 14, wherein the warp yarns (4) of the second type are based on organic synthetic yarns.

16. The complex of claim 14, wherein the warp yarns (4) of the second type are based on high-tenacity yarns.

17. The complex of claim 12, wherein the mass per unit area of the weft yarns (2) of the intermediate layer is substantially equal to the mass per unit area of the warp yarns (3, 4).

18. The complex of claim 12, wherein:

the warp yarns (3, 4) comprise warp yarns (3) of a first type and warp yarns (4) of a second type; a mass per unit area of the warp yarns (3) of the first type is more than three times greater than that of the warp yarns (4) of the second type.

19. The complex of claim 12, wherein:

the warp yarns (3, 4) comprise warp yarns (3) of a first type and warp yarns (4) of a second type; a mass per unit area of the warp yarns (3) of the first type is more than four times greater than that of the warp yarns (4) of the second type.

20. The complex of claim 12, wherein the gap between at least one of the weft or the warp yarns is between two and three times a width of a single weft yarn.

21. The complex of claim 12, wherein the gap between at least one of the weft or warp yarns is greater than four times a width of a single weft yarn.

22. The complex of claim 12, further comprising at least one layer formed by a mat of fibers, in contact with the intermediate layer.

23. The complex of claim 22, wherein the layer formed by the mat of fibers is made of a material identical to that of the reinforcement layers.

* * * * *