Title: FRP CONTINUOUS LAMINATE, LAMINATION METHOD AND LAMINATION DEVICE, BY INVERTED EXTRUSION TECHNIQUE

Abstract: The invention relates to a device for continuous lamination, a corresponding method and a FRP continuous laminate, comprising: a fiber reinforced plastic (FRP) structural core (15) comprising a composite filamentary premix of glassfiber (5) and unsaturated polyester resin composition (2) said core having a lower face and an upper face, a central area and two longitudinal edges, wherein said glassfiber (5) is formed of monofilaments, having a diameter of between 0.1 and 35 microns, that have been isolated and/or separated from standard glassfiber chopped strands and homogeneously and isotropically dispersed within said resin composition (2), said resin composition (2) contains curing agents that are been selected from a group including chemical curing agents and UV curing agents, and said longitudinal edges are straight, smooth, molded, uncut edges.
FRP CONTINUOUS LAMINATE, LAMINATION METHOD AND LAMINATION DEVICE, BY INVERTED EXTRUSION TECHNIQUE

FIELD OF THE INVENTION
The present invention relates generally to composite materials, and more particularly to a laminate of fiber reinforced plastic (FRP) and to its manufacturing. The FRP laminate of the invention comprises a FRP core produced by an innovative technique combining a doser/spreader system and an inverted extrusion system for processing a fluid premix composition made of resin and glassfiber monofilaments that were separated from chopped strands.

BACKGROUND OF THE INVENTION AND PRIOR ART
Fiberglass reinforced plastic (FRP) laminates have a long history of success in several applications, particularly in cladding, lighting and decoration systems. Over the next few years, the potential market for FRP laminates in the industry will be expanding rapidly since FRP is replacing other materials due to cost, durability and maintenance considerations. In 2015 the global demand for laminates will hit 230 billion square meters. This forecast includes competitor materials such as aluminum, steel, ceramic and a variety of wood and other plastics that can all be replaced by FRP, inasmuch as it achieves the proper combination of quality and price. FRP laminates are used for natural lighting, replacing glass in industrial areas, fagades, green houses, wall cladding, flooring, doors and roofing for architecture, cold vaults, corrosive areas, dielectric elements, thermal and acoustical insulation, sanitary rooms, tanks and reservoirs for industrial and food laminates having sanitary requirements, vehicle bodies, decoration, media, signs etc. The laminates can be either translucent or opaque, decorated or not. When decorated, the laminates can be applied in many settings, including residential, industrial, commercial and rural areas, schools, restaurants, hotels, hospitals, transportation, marine, media, useful for signs, leisure, corporate image etc. Corporations within the banking, oil, automobile, and retail chains sectors can make use of FRP laminates manufactured with built-in design, using their corporate image for walls, floors and partitions (internal and external) for both offices and stores, giving a corporate identity to these locations. The decoration can be changed rapidly without refurbishing costs for seasonal promotions and new product launches.
Technologies for manufacturing FRP laminates were disclosed in U.S. patents US 6,627,022 and US 7,160,605, in European Application EP 03704113.4, PCT Intl. applications PCT/BR03/00016, and PCT/IB2008/003778 and in Brazilian patents PI 9403679-9, PI 9802274-1 and PI 0201285-5, all in the name of the applicant of the present invention. In general, the technology outlined in these patents, although providing good manufacturing results, were either expensive, needed machinery difficult to operate and to control, required big working space and a large number of working steps, or, lastly, led to a lower efficiency, economy, production quality, and environmental friendliness as compared to the technology of the invention. The closest document to the present application seems to be that revealed in the PCT/IB2008/003778 application, also in the name of the inventor of the present invention, which is why it will be especially focused upon, showing throughout the description the main difference between both documents.

The continuous lamination technology known in the art provides machinery that is afe bulky and slow because it cuts and impregnates the fiber with resin entirely online and then polymerizes the composite by heating. These systems require time for wetting the fiber and time for hardening the resin, and these times determine the machine length and affect the operation speed. In machines using the technology known in the art, speed is substantially proportional to length, with the result that a normal production using conventional technology, if operating at a speed of 3 m/min, requires an average length of 50 m, and if operating at a speed of 6 m/min would require an average length of 100 m. The longer the machine, the more complex the machinery, the more the manpower required, and the higher the production costs, while a long machine reduces the quality of the laminate.

All the FRP laminates known in the art are made of glassfiber strands and all of them have their edges cut by tools, which means that all FRP laminates made using the technology known in the art will always present edges with irregular corners, will be rough, porous and brittle because of the stiffness of the strands, and the strands will always be laminated in layers parallel to the sheet plane, and therefore, vulnerable to delaminating or separation between the layers. In fact, the look of the protruding strands on the edges of FRP laminates when cut is similar to that of timber when cut across the grain, or plywood, fiberboards or any engineered woods, where the edges don't provide a good appearance nor mechanical strength.
The current technology of FRP lamination has several problems; one of these, which is very relevant considering the amount of FRP laminates produced worldwide, is the waste or scrap or leftover material created by cutting and trimming both sides of the laminate; the width of the waste (resin, fiber, additives etc.) is normally about 40 mm of FRP material on each side. Among several environmental problems, the problem that stands out is that when glassfiber is chopped and sprinkled onto the machine in the production line, as is done in the prior art machines, some of the glass particles float up and hover in suspension in the air, being ecologically undesirable and providing a hazardous working environment for the workers. Other problems relate to the laminates appearance; FRP laminates compete in a more and more demanding and selective global market, requiring improved features of quality, durability and price. In this context, FRP laminate surfaces must be even and uniform, free of any deformations such as undulations, irregular shrinkage of the resin causing plastic cellulite, orange peel, warping or embossed texture from the fiber strands. These properties are difficult to achieve in FRP sheets produced by the continuous lamination techniques currently known in the art, in light of the fact that:

a) the lamination is a continuous and mold and pressure-free process, opposite to static molding such as SMC (sheet mold compound), BMC (bulk molding compound), RTM (resin transfer molding) or injection, in which the material is pressed, stamped or injected between molds, thereby "copying" the molds surface;

b) the glassfiber used in the prior art FRP laminates are always formed by strands which are stiff and composed of a plurality of filaments bound together by a binder material.

When trying to release the filaments, this would require a very strong and prolonged agitation, something that is operationally impracticable in conventional processes, besides the fact that this operation would incorporate air bubbles into the composite as well; in particular, in the PCT/IB2008/003778 application short chopped-strands glassfiber are cut shorter than 10 mm and mixed with the resin forming a liquid putty; this liquid putty is made of strands which causes, in our production, some inconveniences such as:

- the strands, because of their stiffness, do not fill the corners properly, needing additional reinforcement directed specifically to the corners of the laminate and used along with and complementing the strands;

- when mixing the chopped strands with the resin by agitation, the viscosity of the composite increases undesirably, due to the partial separation of filaments which are on the strands outer surfaces;
- it is proven in the art that, for a still unexplained reason, when trying to dissolve the binder and disperse the filaments into the resin by agitation, the filaments entangle with each other interfering with the dispersing and the spreading of the putty, since it clots and forms lumps;

- the liquid putty formed by glassfiber strands is not an homogeneous putty, therefore causing irregularities such as undulations, irregular shrinkage of the resin due to the non-uniform concentration of resin and fiber, showing plastic cellulite or shaking or trembling surface, creating undesired texture of such strands marked and embossed on the surfaces of the laminate and a fibrous surface when cut, and warping when exposed to the sun;

- the strands make difficult the shredding and grinding of FRP in case this is the chosen manner of disposal;

- cut edges will always be brittle and vulnerable to delaminating;

- the liquid putty made of glassfiber chopped stands presents a serious operational problem of decantation of the glassfiber due to its bigger density (2.6 kg/l) as compared to the resin (1.1 kg/l); and

- lastly, the short length of the strands (lower than 10 mm) provides low mechanical strength insufficient for the intended applications of a laminate produced by continuous lamination, thus limiting the use of the product in the market.

OBJECTS OF THE INVENTION

One object of the invention is to obtain, through an improved continuous lamination technology, an innovative FRP laminate capable of giving new alternatives to the market, by providing one or more of the following benefits:

- a homogeneous FRP core comprising a premix of glassfiber monofilaments; the monofilaments preferably having a length of 15 mm or more and a diameter in a range of between 0.1 and 35 microns, preferably about 10 microns,

- a higher percentage of fiber in the FRP core than the conventional continuous lamination glassfiber products (about 40% as compared to the 25% of the conventional FRP laminates), high mechanical strength, derived from such higher content of fiber,

- glassy, smooth and even surfaces due to the homogeneity and isotropy of the premix core composition, being free of the typical FRP surface shrinkages or plastic cellulite caused from the non-uniform concentration of resin and fiber, extrusion finished longitudinal edges produced with no sharp corners or fibrous appearance caused by cutting tools, no warping when exposed to the sun, also due to the features of the premix material,
- ability of printing decoration by means of incorporation of multifunctional systems of films for linking, printing and finishing, on one or both sides of the core, with differentiated finishing, such that the laminate doesn't look like "plastic" but as if it were made of the material represented by the printed design, i.e. marble, stone, wood, cloth, cork, decorated metals and/or their combinations. The decoration is armored once it is made by printing on an internal layer, providing washable surfaces using regular solvents so as to easily remove graffiti or any other stains;

- capacity of having bent edges forming wings along their length, having superior splinter resistance, enabling uniform joints to be formed with adjacent laminates without the need for installation of molding strips to cover the joint between them, forming continuous and even surfaces,

- installation that is installer-friendly, with laminates having practically limitless length which eliminates end-to-end joints, and ability of the laminates to be installed side by side with another laminate without the need for installation of molding strips to cover the joint between them, avoiding dirt and bacteria,

- high abrasion and impact resistance, for uses as flooring, durability and resistance against UV rays and weathering, for outdoor applications; excellent total luminous transmission (TLT) enabling back-light applications, the possibility of packaging in reels, simplifying the storage, handling, transportation and installation, as well as customized product length that results in economical use of materials during installation; optional longitudinal embossments which form strips or grooves matching the joints and/or the printed design; unitary body formed using chemical fusion by cross-linking of layers composing the laminate; the feasibility of mass production; a low coefficient of thermal expansion (CTE); low cost per m².

- ability to be more easily disposed of than the FRP laminates know in the art, because of two reasons:
  a) the fiber monofilaments are capable of being more easily ground as compared to glassfiber strands, and
  b) the FRP premix can be cured by UV curing only, avoiding the necessity of chemical curing agents, such as catalysts and promoters, which are hazardous after grinding of the FRP containing such materials, as will be explained below.

Another object of the invention aims to create a continuous lamination device for producing FRP laminates, the device being economical, small and simple by eliminating steps required
in the machines known in the art, ecologically friendly, capable of producing with high quality FRP at high speed, and turning out a laminate that has smooth surfaces, longitudinal edges that are straight and smooth, eliminating cutting or finishing operations and, especially, generating no FRP waste or left over material, disposal of which is a worldwide ecological problem. As it is known, FRP polyester resin is a thermosetting resin, which cannot be melted and reused as thermoplastics resins do; on the other hand, FRP recycling involves grinding operations which are expensive and hazardous.

The device of the invention, uses an innovative technique combining a doser/spreader system and an inverted extrusion system for processing a fluid premix of glassfiber monofilaments and resin, thereby being capable of producing three types of FRP laminates as follows:

a) a plain laminate, either flat or corrugated, having naturally obtained smooth surface and edges, needing no lateral cutting or additional finishing operations;

b) a laminate as described in the preceding point a), additionally having bent longitudinal wings forming corners with the central area of the laminate;

c) an armored laminate comprising a laminate as described in the preceding points a) and b), further incorporating multifunctional films on one or both sides for protection, special mechanical and/or chemical performances and for decoration by printing on the internal side of such films.

Another object of the invention is to provide a method of manufacture to produce a laminate having the attributes described above. The method of manufacture involves:

- totally releasing and separating chopped strands glassfiber in monofilaments through an offline separation system, preferably vibratory, either mechanical, electric, pneumatic, hydraulic or ultrasonic, and homogeneously and isotropically dispersing the monofilaments into a resin matrix to form a fluid premix composition paste,

- dosing/spreading a pre-determined layer of the fluid premix onto a lower film as the lower film travels along a platform of the lamination device, by means of a doser/spreader mechanism,

- supplying an upper film on top of the premix layer, with the lower film, the premix core, and the upper film forming a laminate;

- consolidating the laminate by an system of inverted extrusion or funneling, for simultaneously shaping the thickness, width and edges of the premix core; this
inverted extrusion system eliminating the necessity of cutting and finishing the
longitudinal edges of the laminate, which impacts the cost of materials and
manpower required for the production, and avoids the problem of disposing of the
resulting waste;
- curing the so-formed laminate by one of:
  a) mixed curing system combining a partial curing the laminate core as it travels
  along a shaping mold or form for shaping its profile, and a chemical curing allowing the
  laminate to complete its full curing process offline by chemical curing agents, after removal
  of the laminate from the production line, or
  b) fully curing said laminate core in the production line by UV curing only,
avoiding hazards in case of grinding of the laminate, caused by the presence of chemical
curing agents;
the method of the invention further providing:
  - the elimination of the necessity of cutting and finishing the longitudinal edges of the
  laminate, which impacts the cost of materials and manpower required for the
  production, and avoidance of the problem of disposing of the waste resulting from
  the cutting and finishing;
  - the capacity of incorporating the step of bending the longitudinal edges, thereby
    forming wings, and the step of curing said wings; and
  - the ability of printing decoration by means of incorporation of multifunctional systems
    of films for linking, printing and finishing, on one or both sides of the core.

SUMMARY OF THE INVENTION
The above-mentioned problems in the prior art technology and the objects of the present
invention are solved by the invention according to the attached claims, by a technology
comprising:
  - offline separation system of monofilaments from glassfiber chopped strands, the
    separation system being preferably vibratory, either mechanical, electric, pneumatic,
    hydraulic or ultrasonic;
  - a dosing/spreading system for forming a predetermined size premix layer onto the
    production line, while slowly conveying the glassfiber monofilaments and the resin
    composition, with no agitation so as to avoid the entanglement or clotting of the
    monofilaments while providing a substantial homogeneity and isotropy in the filamentary
    putty.
- inverted extrusion of the premix for simultaneous shaping of its thickness, width, and edges of the laminated core,
- option to have a curing system that is both practical and ecological,
- elimination of cutting and finishing operations of the lateral edges,
- elimination of waste and the troublesome problem of its disposal,
- natural stretching of the laminate while curing,
- a simple molding system for bending the edges of the laminate to form lateral wings,
- a system for decorating the laminate and armoring the printed design,
- eliminating the generation of glass particles that can float up and hover in suspension in the air.

The chopped strands are separated into monofilaments by offline separation systems, preferably vibratory, either mechanical, electric, pneumatic, hydraulic or ultrasonic. The monofilaments, once released, isolated and/or separated from the chopped strands, lie still into the resin, dispersed in the same position as the original chopped strands were, and their very small diameter makes them practically impalpable and invisible allowing the fluid premix to be a homogeneous and isotropic fluid putty, capable of being spread, with no decantation of the glassfiber occurring despite its bigger density.

The combined technique provides important advantages as will be described below.

For simplicity of writing, the glassfiber monofilaments that are released, isolated and/or separated from the chopped strands, that lie still into the resin, dispersed in the same position as the original chopped strands were, and that their very small diameter makes them practically impalpable and invisible allowing the fluid premix to be a homogeneous and isotropic fluid putty, capable of being spread, with no decantation of the glassfiber occurring despite its bigger density, will be henceforth referred to as "monofilaments" or simply "filaments" and the fluid fiber/resin composition will henceforth be referred to as "premix".

THE PRODUCT
The laminate of the invention can be either flat or corrugated, can include bent longitudinal edges forming wings and can incorporate multifunctional films on one or both sides, providing interesting and innovative applications that will be described.
One embodiment of the FRP laminate of the invention is a plain laminate, either flat or corrugated, made by a FRP composite material comprising glassfiber monofilaments and polyester resin providing features comprising a glassy, smooth and naturally finished surface, including the edges surface, with no typical FRP irregularities, such as undulations, warping, fiber texture, shrinkages, porosity or plastic cellulite caused from the non-uniform concentration of resin and fiber, higher percentage of fiber in the FRP core than the conventional continuous lamination glassfiber products (about 40% as compared to the 25% present in conventional FRP laminates), high mechanical strength, resulting from such higher content of fiber, ability to be safely ground, excellent total luminous transmission (TLX), the feasibility of mass production, a low coefficient of thermal expansion (CTE) and low cost per m².

One embodiment of the armored FRP laminate of the invention has a lower film having a first plastic resin ink that is chemically bound to an upper face thereof; a fiber reinforced plastic (FRP) premix core, the core having a lower face that is lying on the first plastic resin ink, with the resin in the FRP premix core being chemically bound to the first plastic resin ink; an upper film having a lower side to which a second plastic resin ink is chemically bound, the second plastic resin ink being chemically bound to the resin in the FRP premix core as well; whereby the lower film, first plastic resin ink, FRP premix core, second plastic resin ink and upper film are fused to form a laminate having a unitary body. The plastic resin ink will be henceforth referred as "ink".

Another embodiment of the invention provides a laminate as described in any of the embodiments above, wherein the two longitudinal edges are bent such that they each form an angle of less of 180 degrees with the plane containing the central area of the laminate, thereby creating longitudinally extending corners at the bends formed where the central area and each of the longitudinal edges meet.

A further embodiment of the invention provides a laminate as above, where one or both of the upper and lower films are formed by a multifunctional film system including films for linking and finishing, where all these films are capable of being printed upon; the linking film layers being chemically bonded to the premix core and the finishing film layers have sufficient resistance to protect the laminate from scratches, cuts, and impacts thereto; where all films are bound to each other by one or more resins selected from a group consisting of
inks and an intervening adhesive resins, and each of the multifunctional film system can optionally be composed by a single polyvalent film layer adapted to be capable of linking, printing and finishing.

Yet a further embodiment of the invention provides a laminate wherein a decoration is made by silk-screening onto an exposed face of said FRP premix core after removal of one of the films.

Because of the innovative technique combining a doser/spreader and an inverted extrusion systems for processing the premix, the laminate of the invention is shaped directly to the final width, not showing the typical rough look of edges cut by tools; moreover, dispensing with the need for longitudinal cutting of the lateral edges, thus eliminating the waste of material that would otherwise be trimmed from the laminate's sides, thereby greatly improving the economy of the product and of the production machinery, further simplifying the production process. Also, this fact has an important beneficial impact on the environment, since there is currently no known environmentally friendly way of disposing of this waste. The laminate of the invention can also be produced so as to be capable te-be of being more easily and safely ground than the FRP products known in the art.

THE DEVICE
The present invention relates to a device for manufacturing the laminate of the invention on a continuous lamination system, the device having a structure comprising a platform and a driving system for hauling the laminate along the platform, further comprising a FRP supplying system including a doser/spreader set for forming a predetermined a layer of the premix material onto a lower film that travels along a platform of the device, with an upper film laying upon the premix layer so as to encapsulate it between both films; a funneling or inverted extrusion system for shaping the premix layer to a final thickness, width and surface finish, curing stations for curing the laminate as it travels along a profiling system including a form that can be either an arched form combined with a deflector (for creating flat laminates), or a corrugated form (for creating corrugated laminates), an optional bending mechanism for bending the edges of the laminate, and a transverse cutting system for separating a completed length of laminate.

The groups of the above-mentioned device are detailed as follows:
- the platform has a longitudinal axis;
- the driving system comprises cylinders located at a terminal end of the structure for continually hauling the laminate along the platform and through the device, the driving system being capable of hauling the laminate at a range of operational speeds;

- the lower and upper films for conveying and encapsulating the premix composition are respectively dispensed from a lower and an upper feeding reel system, both provided with a built-in brake, for continuously supplying at least one lower and at least one upper film onto the platform;

- the FRP premix supplying system comprises at least one tank, preferably pressurized, at least one valve, and at least one doser/spreader set for forming a layer having a predetermined width and thickness of fluid premix onto said at least one lower film;

- the inverted extrusion system for shaping the premix layer to a final thickness, width and surface finish, consolidates the lower film, the premix composite core and the upper film such that they form a continuous strip of fiber reinforced plastic (FRP) laminate, the laminate having a longitudinal axis substantially parallel to the longitudinal axis of the platform and a width that extends perpendicular to the longitudinal axis of the laminate, the laminate further including a pair of longitudinal edges; the inverted extrusion system comprises a rigid inclined spatula, a number of pairs of lateral rails and a lower flat surface on which the lower film travels;

- the profiling system comprises a form for shaping the transverse profile of the laminate; the form, when arched in the case of flat laminates, is combined with a deflector positioned just after the arched form, so as to press the laminate down against the arched form, and change the orientation of the laminate to a horizontal orientation;

- the curing stations can operate either by "mixed" curing combining a quick, partial curing by UV radiation on the lamination line and a slow, full curing by a room temperature chemical curing, made by chemical curing agents, once the laminate has been removed from the production line, or by a quick full UV curing only, occurring entirely on the production line; and

- the cutting system for separating a completed laminate includes any tooling capable of cutting.

Another embodiment of the machine for producing a laminate with bent edges or wings, positions the first UV curing station to partially cure the width of the laminate, with the exception of lateral strips that extend along the longitudinal edges of the laminate, with a
shutter system comprising a number of shutters positioned on respective side edges of the laminate for shielding the two lateral strips from UV exposure, and further comprises:

a bending system for bending the longitudinal edges of the laminate so that they each form an angle of less than 180 degrees with a central area of the laminate, wherein the bending system comprises a two-part mold having a fixed part comprising two corners, and a mobile part, comprising a number of mobile skates, each mobile skate pressing respective longitudinal edges of the laminate into a respective one of the corners of the fixed part of the bending system to form a respective one of the bent edges or wings; and

a second UV curing station for curing both bent edges or wings and, optionally, for further curing the whole laminate as well.

These and other features will be described in more detail below in the Detailed Description of the Drawings.

THE METHOD

The present invention also relates to a method of manufacturing a FRP laminate on a continuous production line. The method is based on an innovative technique combining a doser/spreader and an inverted extrusion systems for processing the premix composition. The premix is fed into the production line through a system, preferably hydraulic, comprising a doser/spreader mechanism where it forms a layer having a predetermined width and thickness of fluid premix which is hauled through an extrusion system, in this case being inverted extrusion, where it acquires a final thickness, width and surface finish, becoming a continuous strip of FRP laminated core, also referred to as "laminate".

The curing of the laminate of the invention can be either a "mixed" curing by a combination of quick, partial curing by UV radiation on the lamination line and slow, full curing by a room temperature chemical curing, made by chemical curing agents, once the laminate has been removed from the production line, or it can be a quick full UV curing only occurring entirely on the production line.

When glassfiber is chopped and sprinkled onto the machine in the production line, as is done in the prior art machines, the glass particles are released and float up and hover in suspension in the air, providing a hazardous working environment for the workers, and being ecologically undesirable. The current invention premixes the glassfiber with the resin off-line,
so that when the premix is deposited onto the machine in the production line, no glassfiber is free to move into suspension in the air.

One embodiment of the method of manufacturing the laminate of the invention includes the steps of:

- feeding a releasing lower film onto a platform at a first end of a continuous lamination line;
- dosing/spreading a layer having a predetermined width and thickness of fluid premix composition, such that it covers the exposed surface of the lower film, with the aggregate constituting a FRP premix core of the laminate;
- feeding an upper releasing film onto the exposed, upwardly-facing surface of the aggregate, whereby the aggregate is encapsulated between the lower film and the upper film, with the lower film, the premix core, and the upper film together forming a continuous strip of laminate;
- inverted extrusion of the laminate by means of a consolidating system having a lower flat platform, an upper spatula and lateral rails for shaping the premix core of the laminate to a final thickness, width, and surface finish,
- curing the laminate as it moves along on a mold or form, either arched or corrugated, depending on the embodiment, for shaping its transversal profile or section;
- cutting the laminate to a desired length, producing a plain laminate that is either flat or corrugated.

Another embodiment of the method of manufacturing the laminate of the invention includes the steps of:

- providing a lower film having an upper side which has been preprinted with a first ink that is chemically bound to the upper side of the lower film to form a composite therewith, the composite having a lower side and an upper side;
- feeding the preprinted lower film onto a platform at a first end of a continuous lamination line so that the lower side of the composite faces downwardly and travels on the platform, with the upper side of the composite facing upwardly to present an exposed surface;
- dosing/spreading a layer having a predetermined width and thickness of fluid premix composition, such that it covers the exposed surface of the composite, with the aggregate of
the premix constituting, when the laminate is completed, a fiber reinforced plastic (FRP)
structural premix core of the laminate;

feeding an upper film having a lower side that is preprinted with a second ink that is
chemically bound to the lower side of the upper film, the upper film being dispensed onto
the exposed, upwardly-facing surface of the aggregate such that the preprinted lower side of
the upper film contacts the exposed, upwardly-facing surface of the premix aggregate,
whereby the aggregate is encapsulated between the lower film and the upper film, with the
lower film, the premix core, and the upper film together forming a laminate having a lower
face, an upper face, and first and second longitudinal edges;

inverted extrusion of the laminate by means of a consolidating system having a lower
flat platform, an upper spatula and a number of lateral rails for shaping the premix core to
the desired thickness, width, edges and surface finish,

curing the laminate as it moves along a form, either arched or corrugated, depending
on the embodiment, for shaping its transversal profile or section; and

cutting the continuous strip to form a laminate of a desired length.

Another embodiment of the method of manufacturing is the one described in the above
embodiment further comprising the steps of:

partially curing only a substantially central area of the laminate as it travels along the
arched or corrugated form, the central area being defined as the area slightly smaller on
each longitudinal side than the full width of the laminate, leaving uncured the longitudinal
edges that fall outside the central area;

bending, with the use of a bending system, the still fluid longitudinal edges of the
laminate to form wings forming an angle of less of 180 degrees with the central area of the
laminate, thereby creating corners and wings extending along the laminate, and

fully curing the whole laminate.

The step of supplying the upper and lower films comprises supplying one or both of them in
the form of a multifunctional film system including films for linking and finishing, where all
these films are capable of being printed upon; the linking film layers being chemically
bonded to the premix core and the finishing film layers have sufficient resistance to protect
the laminate from scratches, cuts, and impacts thereto; where all films are bound to each
other by one or more resins selected from a group consisting of ink and an intervening
adhesive resin, and each of the multi-functional film systems can be optionally formed by a single polyvalent film layer capable of linking, printing and finishing.

Another embodiment of the method of manufacturing further comprises, after the laminate is removed from the lamination line, silk-screening at least one side of the premix core with a serigraphic ink. When this serigraphic ink is made of unsaturated polyester resin, there occurs a chemical fusion by cross-linking between the resin to be applied, which is in liquid form, and the partially dry substrate of the FRP core, just partially and sufficiently cured so as to allow its handling. The cross-linking requires a minimum amount of time for the chemical attack in the wet/dry interface, depending on the nature of the materials involved, on the environmental conditions, and on the degree of curing of the surface of the substrate. This minimum amount of time determining the curing system selected for use.

The cross-linking time must satisfy the main operational requirements innate in the continuous lamination technology, such as the speed of the line, the technology complexity, and the cost of the final product; the polyester ink used contains, essentially, a system of UV photoinitiators, a system of chemical curing agents, a system of inhibitor-drying retarders, and some performance additives.

Among the variety of possible combinations between the elements composing the mentioned systems the ones selected for use are only those that meet the commitment between both the chemical requirements and the operational requirements of the manufacture of the laminate. These requirements including:

- a sufficiently long gel-time to allow the laminate to be made economically by systematically mass-producing it with a continuous lamination technology, without the ink made of polyester resin hardening prematurely during the manufacturing process, including the pot-life (the length of time that a catalyzed resin system retains a viscosity low enough to be used);

- a sufficiently long operation time without the drying of the ink by evaporation and/or oxidation;

- a UV curing of the exposed surface of the ink up to a necessary and sufficient degree that enables handling of the laminate, in a tack-free condition;
- a necessary and sufficient time that the inner, or unexposed, portion of the ink is kept moist so as to allow chemical attack on the substrate, thereby fusing with it by cross-linking, and
- a sufficiently short time required for full polymerization of the ink, avoiding permanent sub-polymerization.

Both the resin to be applied and the substrate to which it is applied are cured by a mixed curing system combining UV curing and chemical curing, comprising two steps:
- in a first step, a partial UV curing of the ink made of unsaturated polyester, such that an exposed, outer surface of the ink layer cures sufficiently to form a skin that allows it to be handled, while leaving an inner, unexposed portion of the ink layer, that is in contact with the FRP core, sufficiently pasty and moist so as to allow it to chemically attack the substrate;
- subsequently allowing the applied ink and the resin of the substrate to fuse to each other by cross-linking during a second curing step by chemical curing, and allowing both to fully cure, forming a unitary body.

BRIEF DESCRIPTION OF THE DRAWINGS
In the following, the invention is described based on embodiments shown in different views. In particular, it is shown in:
Fig. 1 a schematic side view of the machine of the invention compared to the side view of a machine known in the market, in the same dimensional scale;
Fig. 2 a side view of one embodiment of the machine according to the invention setup for manufacturing a flat laminate;
Fig. 3 a top view, partially cut away, of the machine of Fig. 2;
Fig. 4 a side view of one embodiment of the machine according to the invention setup for manufacturing flat laminates having bent edges or wings;
Fig. 5 a top view, partially cut away, of the machine of Fig. 4;
Fig. 6 a cross section of the mold for bending the edges;
Fig. 7 a schematic view of the movable part of the mold for bending the edges;
Fig. 8 a side view of an embodiment of the machine where the laminate is corrugated;
Fig. 9 a top view, partially cut away, of the machine of Fig. 8;
Fig. 10 a cross-section of a mold for corrugation;
Fig. 11 a cross section of an end of a laminate having bent edge or wing;
Fig. 12 a cross section of an end of a laminate with no bent edge or wing;
Fig. 13 a cross section of one embodiment of a plain laminate made by the device of the
invention;
Fig. 14 a cross section of one embodiment of an armored laminate made by the machine
of the invention;
Fig. 15 a cross section of another embodiment of an armored laminate made by the
machine of the invention;
Fig. 16 a cross section of another embodiment of a laminate made by the machine of the
invention, showing silk-screening on the laminate that has been only partially
cured;
Fig. 17 a cross section of the embodiment of a laminate shown in Fig. 16, with the
laminate being fully cured;
Fig. 18 a detail of the lateral rails for shaping the width of the laminate in the molding
system through inverted extrusion;
Fig. 19 the cross section R-R of Fig. 18;
Fig. 20 another view of the lateral rails of Fig. 18, and
Fig. 21 a side view of one embodiment of the machine according to the invention setup
for manufacturing flat, plain laminates.

DETAILED DESCRIPTION OF THE DRAWINGS
The components of the technology according to one embodiment of the present invention
will be clearly understood from the following description of the figures, which contains the
same numeric references used in the drawings. Some figures have been intentionally drafted
off scale for better clarity.

Fig. 1 shows in schematic side view a dimensional comparison between the machine of the
invention (101) and a machine having technology known in the art (102), so as to make
evident the huge difference in size and logistic of both technological conceptions.

Fig. 2 and Fig. 3 show schematic views of one example of the production equipment of the
invention, also referred to a device of the invention, for producing flat laminates, where
some obvious parts of the equipment have been intentionally omitted for better clarity. In
particular, these parts being structure that supports the elements that are shown. The
machinery comprises the following components:
a lower film feeding system (1') including built-in brakes for controlling of the tension of feeding a lower film (1) from a coil onto the platform of the machine along which the lower film and all other components of the laminate being produced travel;

a guiding cylinder or axis (41) for guiding the lower film from feeding system (1) onto the platform;

a premix feeding system comprising a tank (55), preferably pressurized, containing the premix, a valve (57), and a doser/spreader mechanism (56) for forming a layer having a predetermined width and thickness of fluid premix as it is deposited by the premix feeding system onto the lower film;

an upper film feeding system (7') including built-in brakes for controlling of the tension of feeding an upper film (7) from a coil onto the layer of premix, thereby encapsulating the premix between the lower and upper films and forming an FRP laminate comprising the lower film, the premix of fiber and resin, and the upper film;

inverted extrusion system (6, 6a, 6b, 60 comprising the flat platform (60, the upper spatula (6) and the lateral rails (6a, 6b) for molding and consolidating the premix by inverted extrusion and shaping its thickness, width and surface finish as desired;

arched form (22);
UV curing station (21) for curing the entire laminate as it travels along the arched form;

deflector (23) for pressing the laminate down onto the arched form (22), using the tension of the films to stretch the laminate across the arched form;

driving system of cylinders (13, 14) for hauling the laminate through the device;

transverse cutting system (16) comprising, for example, electrical scissors, for severing the laminate when the desired length of laminate has been produced; and

exit cylinder or axis (42) for guiding the laminate to a collection system (not shown).

As can be seen in Figs. 2 and 3, the driving system of cylinders (13, 14) hauls the laminate throughout the steps of the machine. Being powered by motor-reducer (14a), assures that the driving system can operate at a range of operational speeds sufficiently large to give several operational options to the machine of the invention. This allows, for instance, switching to a minimum speed for allowing replacement of the films coils (1, 7) and for allowing transverse cutting (16) to separate the finished laminate with no need to stop the machine. Additionally, the correct set-up of the haul-off system avoids creation of lateral
forces that could displace the laminate strip sideways during its movement. A system of weights (13a) mounted on both ends of the upper axle (13) naturally and constantly equalizes the hauling pressure on the laminate by the force of gravity.

The upper spatula (6), the lower flat platform (6’) and the rails (6a, 6b) of the inverted extrusion system are made of a material having a low coefficient of friction (e.g. glass) that is sufficiently rigid to withstand the inverted extrusion pressure caused by the fluid premix density.

Figs. 4 and 5 show schematic views of one example of the machinery for producing flat laminates having bent edges or wings, where some obvious parts of the equipment have been intentionally omitted for better clarity. In particular, these parts being structure that supports the elements that are shown. Many elements of this machine are identical to those shown in Figs. 2 and 3 and described above, and bear the same reference numerals. Those elements of the machine will not be described again here.

The machinery of Figs. 4 and 5 comprises the following additional components:

UV curing station (21) for partially curing the laminate as it travels along with the arched form is identical to that described above except that in this embodiment, the UV curing station is positioned to cure only a central area of the laminate, leaving uncured the lateral strips "E" located along the longitudinal edges of the laminate located respectively on either side of central area, which edges are shielded from UV radiation by a shutter system (17);

bending system (8, 8’) for bending lateral strips "E" so that they form bent edges or wings at an angle of less than 180 degrees with the central area of the laminate;

UV curing station (10) for curing the wings and, additionally, the whole laminate;

In addition to lateral strips "E", more central or internal strips can be left uncured as well in the first UV curing station (21) by adding additional shutters, allowing for molding of longitudinal intaglios or grooves within the laminate in the next step for bending and second UV station (100, and providing additional resources for complementing the decoration or design.
When the laminate being produced is intended to be a flat laminate, as would be produced by the machinery of Figs. 2 to 5, the laminate needs to be stretched during the curing step so as to assure a smooth and even surface, avoiding deformations such as wrinkles made by the longitudinal stretching of the films by the driving system, the typical celluiite of the FRP made by the shrinkage of the resin, the marking of the fiber in the surface, and other deformations made by the conveyance of the material. To solve this, the laminate is pressed by a pressure "V" against arched form (22). The vertical pressure "V" is created by the combined action of the protruding arched form (22), and the deflector (23) positioned on the production line just after the arched form so as to press the laminate (15) down against the arched form (22), and the equal and opposite horizontal forces "H", applied on both films (1, 7) by the driving system of cylinders (13, 14) and the brakes (1', 7') built into the film cylinders, creating a tension in the films.

Deflector (23) serves, as well, to smooth the transition from the inclination angle of the arched form (22) to the horizontal orientation of the platform that follows in the production line.

In Figures 2 to 5 the laminate is cured by UV curing station (21) while it is stretched on an arched form (22), except, in the case of Figs. 4-5, for the two strips "E" which are not exposed to UV radiation (21), being shielded by means of the shutters (17). The arched form (22) can be transparent, made of glass or the like so as to allow optional UV radiation from below. Although the arched form (22) is preferably considered to be static, it can optionally be provided in the form of a sector of a cylindrical conveyor belt rotating together with the laminate so as to avoid friction between form and laminate. UV irradiators (21) can be located above the laminate and/or below the laminate. When located simultaneously above and below, this further increases the operational speed and/or further reduces the machine length. In this case the shutters (17) would be positioned on both sides, above and below the laminate.

[043] The UV curing system of the invention allows the FRP laminate to be hardened where and when needed. This allows those parts of the laminate which are exposed to UV light to set the elements of the laminate in place. For instance, applying UV curing while the laminate is stretched as it travels over the arched form (22) "freezes" the laminate irreversibly to a perfect flat and smooth surface shape.
Figs. 6 and 7 show one embodiment of how to shape the bent edges or wings (24), with the bending and aligning system (8, 80, and showing the curing station (10) in the form of reflectors, in this case, irradiating the edges from several positions. The strips "E" of the laminate (15) are partially cured by UV curing station (10) at the same time that the edges are bent. The bending and aligning system comprises a two-part mold (8, 8'), comprising a fixed part (8) and a movable part (8'). The fixed part (8) of the mold (8, 80 comprises a horizontal table and two laterals, or rails, siding the table and forming a gutter, preferably made of glass, within which the laminate (15) travels, and the movable part (8') of the mold (8, 80 comprises one or more pairs of skate-shaped tools mounted on the internal sides of such laterals so as to form a kind of forks or jaws working astraddle on the vertical parts of the bent sides of the laminate (15). Additionally, the skate-tools (80 can be rotated at an angle (a), as seen in Fig. 7, for pressing or deflecting the laminate (15) down into the corners of the fixed mold (8) to increase, if needed, the sharpness of the corners of the edges (24). The one or more pairs of skate-shaped tools (80 are intercalated with UV lamps (10) so as to work along with a progressive curing of the edges. Some parts of the upper mold (8) and the lower mold (80 are made of transparent material, e.g. glass, so as to allow the irradiation of the UV light to pass through and cure the formed edges. Alternatively, the UV curing of the edges (24) can be made by elliptical UV irradiators (10) positioned on the sides of the mold (8, 80 and/or above and/or below the edges of the laminate. The bending mold (8, 80 can obviously be set up to have the edges of the laminate bent in the opposite direction.

PRODUCING CORRUGATED LAMINATES
When the laminate (15) is corrugated instead of flat, it doesn't need to be particularly stretched when curing, since the corrugation itself, together with the premix homogeneity, eliminates any possible deformations.

Fig. 8 and Fig. 9 show views similar to Fig. 2 and Fig. 3, but for an alternative embodiment designed to produce a corrugated laminate (15). Instead of an arched form (22), this embodiment includes a two-part corrugation form (9-90, but all other features remain as described above for the embodiment of Figs. 2 and 3.
Fig. 10 is a cross section of Fig. 8 showing how the corrugation is shaped by an example of two-part mold (9-90).

DETAILS OF THE LAMINATES

By using different combinations of film systems and inks, it is possible to create laminates having a wide variety of appearances. Some of these, along with details of the materials of the laminates, will be discussed in detail below, and apply equally regardless of whether the laminate is flat or corrugated, and whether or not it includes bent longitudinal edges. For each of the embodiments, the surface of the films utilized in the process can be brilliant, matte or have any texture, and additional coating or resin layers can be applied on the faces of the laminate so as to give a differentiated finish to the laminate. Optionally, to increase the range of adhesives usable for bonding the laminate to different walls surfaces, prior to its introduction into the lamination line, the outermost film on the back of the laminate can have a resin or film comprising rough material laminated onto the side of the outermost film that will remain exposed on the finished laminate. The rough material can take the form of, for example fiber, fillers, paper, or textiles, as long as the material is compatible with the UV curing of the FRP laminate.

Fig. 11 shows a cross section of one end of a completed laminate showing core (15) bound by upper (7) and lower (1) films, respectively, and illustrating the longitudinal edge of laminate (15) which has been bent to a wing as described above.

Fig. 12 shows the same laminate with no bent wing, suggesting the different performance of both laminates when hit by lateral impacts represented by the dark arrows in the figure. The rippled surface on the edge of laminate represents the fibrous surface obtained when cutting the FRP laminate produced with conventional glassfiber strands by conventional systems.

As can be seen by comparing Figs. 11 and 12, a lateral impact to the laminate with bent edges or wings tends to be withstood without any negative effect on the laminate, because the impact hits a surface protected by upper film (7), whereas a lateral impact to the laminate with no wing can cause delaminating and chipping.
**Fig. 13** shows a cross-sectional view of a premix laminate of the invention, as a plain laminate, that may be either flat or corrugated. The laminate is made of a FRP composite premix providing naturally and with no additional operations, glassy, smooth and finished surfaces, including the surface of the edges, with no irregularities such as the typical FRP surface shrinkages or plastic cellulite caused from the non-uniform concentration of resin and fiber, the texture of the fiber strands, the warping when exposed to the sun and weather etc. Particularly, the edges are formed by longitudinally parallel glassfiber filaments, providing a superior impact strength and have the typical molded, straight and smooth surface obtained by extrusion, free of spikes or fibrous appearance as a consequence of the use of glassfiber strands cut by cutting tools. Additionally, the laminate has a higher percentage of fiber than do the conventional continuous lamination glassfiber products (about 40% as compared to the 25% present in conventional FRP laminates), high mechanical strength derived from such higher content of fiber, the ability to be easily and safely ground, excellent total luminous transmission (TLT), the feasibility of mass production, a low coefficient of thermal expansion (CTE) and a low cost per m². In a plain laminate such as this, the upper and lower film systems are provided in the form of release films that are:

a) removed at the end of the production, or

b) are endless loops of films such that they are not cut but re-circulated in the lamination process, or

c) are left in place so as protect the laminate, being removed by the end user.

**Fig. 21** shows a side view of the device of the invention that illustrates a variation of machine that uses the endless loops of release films described in b) above. The device is similar to the machine of **Fig. 2**, except that it includes additional guiding cylinders (43, 44, 45, 46) for supporting and guiding the endless loops of recirculation films acting as a kind of conveyor belts.

**Fig. 14** shows a cross-sectional view of the central area of an embodiment of the laminate of the invention that comprises a double-faced laminate. The laminate can have images, text, or design visible on each of a lower face of the laminate and an upper face of the laminate. Starting from the lower face of the laminate, this embodiment comprises a lower film (1), at least one layer of ink (25), a FRP premix core (15), at least one layer of ink (25), and an upper film (7).
If one wanted to make the laminate of the embodiment of Fig. 14 to be a one-faced laminate, all the layers above or below FRP core (15) could simply be omitted. Similarly, if it were preferred, one could produce images using serigraphic ink (34) to silk screen a design on the side of the FRP core of Figs. 13 and 14.

Fig. 15 shows a cross-sectional view of the central area of another embodiment of the laminate of the invention. It can have images, text or design visible on one or both faces of the laminate. Starting from the lower side of the figure, this embodiment comprises a finishing film (lb), at least one layer of ink or adhesive resin (25 or 26), a linking film (la), ink (25), an FRP premix core (15), ink (25), a linking film (7a), at least one layer of ink (25) or adhesive resin (26), and finally, a finishing film (7b). Each of these layers will be discussed in more detail below. The combination of films and intervening ink and/or adhesive resin (lb, 25 or 26, la) or (7b, 25 or 26, 7a) are bound to each other and create a multi-functional film system, this multi-functional film system optionally being replaced by a single polyvalent film layer properly adapted for linking, finishing and printing.

While the laminate of Fig. 15 can have images visible when looking at either the front or the back side of the laminate, if only a one-faced laminate with an image only visible on the front side of the laminate were desired, then all of the printed layers positioned either above or below the FRP core (15) could be omitted, resulting in a laminate composed only of finishing film (lb or 7b), at least one layer of ink (25), a layer of adhesive resin (26), linking film (la or 7a), ink (25), and FRP core (15).

If, instead of using the adhesive resin (26) to physically bond the ink (25) on the inner, inked side of the finishing film (lb, 7b), respectively, to the outer side of the linking film (la, 7a), the bonding were a chemical fusion bond by virtue of another ink (25) cross-linking with the outer surface of the linking film (la, 7a), both previously treated, then the layer of adhesive resin (26) could be omitted from this embodiment. In all cases, it is a matter of choice as to which ones of the inks (25) would be pigmented and which ones would be transparent.

According to a further embodiment, at least one of films (la, lb, 7a, 7b) can be a white opaque film or a film colored in any color.
Fig. 16 illustrates a cross-section of the laminate after partial UV curing, made intentionally out of scale, of a laminate of the invention decorated by silk-screening on a side of the premix core, using at least one ink layer (34) made of unsaturated polyester resin, cured by mixed curing combining UV curing with chemical curing; the figure shows schematically the variation of the polymerization along the thickness of the ink layer (34), evidencing that the outer surface of the ink layer is sufficiently cured so as to form a tack-free skin that allows the handling of the laminate, while the portion of the ink in contact with the premix core (15) remains, for a sufficient time, pasty and humid so as to allow the ink to chemical attack the substrate, fusing with it by cross-linking. The core (15) is also partially cured by the UV curing (21). The thickness and density of the lines in the cross-sectional view graphically represents the evolution of the polymerization at one particular moment in time during the hardening process.

Fig. 17 shows the same cross-section of the laminate illustrated in Fig. 16 after reaching full polymerization (hardness of around 50 Barcol degrees) by the action of chemical curing agents or by the action of a sequence of UV expositions, and suggests the total cross-linking or chemical fusion between ink and core. The higher density of the lines in the cross-section as compared to Fig. 16 graphically represents the bigger polymerization grade of the resin of the ink and the resin of the core. How long this process takes depends upon the room curing conditions, and it can take days to complete.

Figs. 18, 19 and 20 show how the thickness, width and edges of the laminate are shaped using upper spatula (6), lateral rails (6a, 6b), and flat platform (60, in an example in which the upper spatula has been intentionally made of glass so as to be shown in transparency.

For practical reasons, the examples of the machinery of the invention shown throughout the figures can be unified in the longer version shown in Fig. 4 and 5, in which all parts are present, although only the ones needed for the production of the particular type of laminate being produced are used.

MATERIALS BEING USED

Finishing films (lb and/or 7b) can be made from any of the transparent films available on the market, including PET, PETG, PVC, PC, Acrylic, EVA, PP, PTFE (Teflon ®) Nylon, PS, ABS, PEEK, PEI, PES, PVDF, PMP, PSO, ECTFE, Acetate, and/or PU. Each of films (lb and/or 7b)
can be treated on its inner, internal, or unexposed side to enhance its ability to bond, either by chemical fusion via cross-linking, or by physical bonding such as by adhesive, to the adjacent layer of ink (25) or adhesive resin (26). Treatments to improve chemical fusion comprise, for example, the lamination and/or co-extrusion of the film with at least one layer of a resin composition comprising acrylic, vinyl, polyester, PET, APET, and/or urethane resin. Treatments to improve physical bonding comprise increasing surface tension of the film(s) before printing and/or lamination by, for example, any of the following: electronic corona high voltage discharge, gas flaming, plasma, flourination, or oxyfluorination. All of these treatments are known to one of ordinary skill in the graphic art. While chemical fusion bonding via cross-linking is preferred because it provides a unitary body between the layers being joined, physical bonding, which securely attaches adjacent layers but does not produce a unitary body, is an acceptable alternative. In either case, the joining is permanent and irreversible.

Ink (25), which composes several of the layers throughout the laminate, can be made to be either transparent, or pigmented in any desired color, depending upon what the desired purpose of that particular layer is. The ink (25) comprises resin composed of any of vinyl, acrylic, polyurethane, polyester, PET, APET and/or nitro-cellulose resins or their combinations. When pigmented, ink (25) is adjusted to the desired rheology, viscosity, drying time, coverage, pigment concentration and light-fastness. This ink can form images, text or design, visible through the transparent finishing films (lb and/or 7b). In the case where ink (25) is transparent, then it serves the function only of cross-linking the films to which it is applied to the adjacent layer in the laminate, and does not serve to additionally provide a color or design. The printing of the films is made preferably by flexography and/or rotogravure.

Adhesive resin layer (26) is either transparent or pigmented and has light-fastness. It serves to physically bond finishing films (lb and/or 7b), that has been printed with ink (25), to linking film (la and/or 7a) to form a multilayer film (lb, 25, 26, la) or (7b, 25, 26, 7a) which forms the outer, decorative and/or protective surface of either the upper or lower side of the laminate.

To fulfill one object of the invention, the texture of the glass fiber in the FRP laminate should not be visible on the outer surface of the laminate. Usually, in conventional technologies
know in the art, a layer of gel-coat made of unsaturated polyester resin is applied on the side of the FRP core so that it acts as a barrier. In the present invention, both the ink (25) and adhesive resin (26) are capable of serving as a gelcoat layer, if at all.

Linking film (la and/or 7a) can be made of any plastic material compatible with the polyester resin, for example, polyester, PET PVC, acrylic, PC, PS or nylon. In this embodiment, both the respective outer sides of linking films (la and 7a) (meaning the side of each film that faces away from the FRP laminate that forms the core of the laminate), and the respective inner sides of linking films (la and 7a) (meaning the side of each film that faces toward the FRP core (15) of the laminate) are treated by any of the methods discussed above with respect to films (lb and/or 7b) in order to enhance their ability to bond to the respective adjacent layers of adhesive resin (26) and/or ink (25). The inner, treated, side of at least one of films (la, 7a) is always cross-linked to ink 25 to form a unitary body therewith. The multilayer film (lb, 25, 26, la, 25) and/or (7b, 25, 26, 7a, 25) overlays the entire side of the FRP core (15), including its folded longitudinal edges (24), in the event it has any.

FRP (fiber-reinforced plastic) (15) forms the structural core of the laminate, comprising a premix composite made from resin (2) and structural fiber (5) wherein the fiber (5) is composed of glassfiber monofilaments that have been previously separated from chopped strands glassfiber, preferably by means of an offline separation system, preferably vibratory, either mechanical, electric, pneumatic, hydraulic or ultrasonic.

The very small diameter of the glassfiber monofilaments in a range of between 0.1 and 35 microns (preferably about 10 micron), makes them practically impalpable and invisible, and allows the fluid premix to be a homogeneous paste, capable of being pumped and thus enabling it to be fed onto the production line by hydraulic means, eliminates separation or decantation of the glassfiber despite its bigger density (2.6 kg/l) with respect to the resin (1.1 kg/l), allows the easy inverted extrusion of the premix in the continuous line, eliminates the previously unsolved and well-known problem of surface marking of the fiber on the laminates, allows a high percentage of fiber in the fiber/resin core (about 40% against the average 25% of conventional glassfiber laminates) providing a laminate with high mechanical strength, is ecological since it avoids having glass particles in suspension in the air, allows better workability than FRP made of strands glassfiber, allows a glassy surface
with no irregularities or deformations, such as the typical plastic "cellulite", the fiber strands marking etc., due to the features of the premix composition of the invention. As known by those skilled in the art, all fiber-glass/resin currently known in the art is made with strands manufacturing and presents a shaking or trembling surface because of the non-uniform distribution of the fiber strands, creating some areas richer in resin than others so that the resin shrinkage is not equal everywhere in the laminate. Use of the monofilament glassfiber/resin premix of the invention eliminates this problem.

The resin (2) is selected from a group comprising unsaturated polyester, polymethyl methacrylate, vinyl ester, epoxy, phenol, fumaric, urethane, melamine, and/or formaldehyde, with unsaturated polyester resin being preferred. Resin (2) is either transparent or contains added pigments and/or fillers. The resin (2) can contain one or more of UV photoinitiators selected from a group comprising surface-curing and through-curing photoinitiators, including CIBA IRGACURE® 819, 369, 184, 907, and 651, a room temperature chemical curing system, such as MEKP-cobalt and CHP (Cumene Hydro Peroxide) catalysts, a hot chemical curing system, such as BPO (benzoyl peroxide) and DBPB (DiButyle Per Benzoate), an inhibitor system including TBC, and additives comprising, for example, air-releasing, fiber wetting and dispersing and self-extinguishing agents and/or fillers. Additives, such as cetearyl alcohol, cetrimonium chloride, behentrimonium methosulfate, methylchloroisothiazolinone methosulfate, methylisothiazolinone, citric acid, methylparaben, popryparaben, hydroxyethyl, lactic acid, cetearamidopropylidimmonium chloride, behenyl alcohol, trihydroxypropane, isocetyl alcohol, and tocopheryl acetate are also used for dispersing the glassfiber monofilaments from the chopped strands.

Rather than allowing the full curing to take place at room temperature, which requires the inclusion of catalysts and promoters in the premix, it is possible to cure the laminate substantially entirely on the production line, using only UV curing, as described above. This enables elimination of the catalysts and promoters, making grinding of any FRP product more practical and safe, for the reasons discussed below.

OFFLINE PREPARATION OF PREMIX COMPOSITE

All embodiments of the invention include the use of a premix composite of glassfiber monofilaments (5) separated from chopped strands glassfiber by offline separation systems, preferably vibratory, either mechanical, electric, pneumatic, hydraulic or ultrasonic, and
substantially homogeneously and isotropically dispersed into a resin matrix (2). This premix is prepared off-line, preferably using chopped strands available in the fiberglass market, and it is mixed and placed in tank (55), which is preferably pressurized. Because of the features of the premix, it can be conveyed to the production line through hydraulic tanks, pipes, valves, and through a doser/spreader mechanism, forming a predetermined premix layer in accordance with both the desired section (area) of the laminate and the operational speed of the device.

ADVANTAGES OF THE TECHNOLOGY OF THE INVENTION

The present continuous lamination system and machine for producing FRP laminates, and the laminates produced thereby, have the following advantages as compared to the technology known in the art:

The innovative technique combining a doser/spreader system and an inverted extrusion system for processing a premix composition of monofilamentary premix with the premix core made of glassfiber monofilaments that are released and separated from glassfiber chopped strands and homogeneously and isotropically dispersed into a resin composition matrix improves the quality and cost of the production, simplifies the manufacturing process, allows higher operation speed, avoids failures in applying, distributing and impregnating the fiber and avoids entrapped air in the laminate, avoids release of glass fiber particles in the air, and turns out a laminate that has smooth surfaces, longitudinal edges that are straight and smooth, eliminating cutting or finishing operations and, especially, generating no FRP waste or left over solving the worldwide ecological problem such as the waste disposal.

The UV curing increases the operation speed, enables the laminate to be hardened exactly when and where it is stretched, thereby assuring a flat and smooth surface, allows curing of the resin only where it is needed by using shutters to block exposition to UV light of areas not ready for curing, allows the longitudinal edges to be bent, allows the machinery to be safely stopped whenever it is convenient with no risk of drying the resins, shortens the machinery's length, reduces the cost of installation and operation, as well as exhaust, pollution and controls, increases the quality of the product, reduces the width of the machine thereby eliminating lateral stretchers, and make easier the grinding and/or recycling of the FRP laminates for end-of-life reasons, since it avoids the necessity of chemical curing
agents, such as catalysts and promoters, which are hazardous after grinding of the FRP products containing such materials.

The alternative system of "mixed" (UV + chemical) curing also increases the operation speed since allows fast UV curing online while allowing slow chemical curing to act after the laminate is removed from the production line and stored, and provides a more compact and economical machinery than using chemical curing by heating.

[Extruded or bent edges created by the machine and manufacturing method of the invention are advantages over the fibrous edges produced by the technology of the prior art because they improve the appearance of the finished laminate, allow installation of adjacent laminates with uniform joints with no trim needed between laminates, reduce the risk of accidents by eliminating sharp fibrous edges, avoid the formation of mold and bacteria on the edges by eliminating porosity there, and eliminate the main point of weakness in laminates, since the fibrous edges allow infiltration and delaminating.

Using films instead of a gelcoat layer on the outer surface shortens the machinery, simplifies the production process, improves the coloring of the laminate, improves surface smoothing, eliminates surface micro-porosity, eliminates warping due to the shrinking of the gelcoat in heat curing, allows decoration by printing, allows laminates to be washable by regular solvents and allows laminates to be backlit without the typical irregularities and stains of the gelcoat layer.

Using gravity pressure haul-off instead of fixedly mounted cylinders provides advantages because it equalizes the pressure along the driving cylinder, avoiding deviations in the laminate strip.

The most evident advantage of the technology of the invention is the size of the device. It is so short that it makes everything easy, even the packaging for delivery or export.

Additionally, most of the time, wide laminates can be replaced with smaller modular laminates having straight and perfectly fitting edges, with lower cost and easier production, handling, transport and installation than is possible with wider laminates.
The working area required for the machine according to the invention is much smaller than that required for prior art machines, while at the same time producing a higher quality laminate more quickly and inexpensively than previously possible, and minimizing energy consumption and pollution generated.

The cost of the machinery using the inverted extrusion of the invention is very low as compared to the machinery known in the prior art. On average, a machine according to the invention costs as little as 20,000 USD instead of the 350,000 USD of the known machines, for a 1 m width laminate basis.

The versatility of the technology according to the invention allows customizing the laminates.

The machine and process of the invention provides substantial energy conservation as compared with today’s industry standard. Additionally, the technology of the invention is non-polluting, since there is no exposed resin, no gas emission due to polymerization heating, non-ozone producing UV lamps, and no glassfiber particles in suspension in the air.

**FRP RECYCLING**

As with all FRP manufacturing methods, continuous lamination generates solid scrap. The scrap is typically in the form of overspray, trimmings, non-compliant parts or end-of-life products. Currently, this solid scrap is landfilled, costing the fabricators both in disposal costs (transport and landfill fees), and in the opportunity cost of the scraped material, since it cannot be used to make a saleable product.

Scrap reduction is the best way to deal with scrap, for both economic and financial reasons. The innovative technique combining a doser/spreader system and an inverted extrusion system for processing a premix composition of monofilamentary premix of the invention eliminates the scrap of the materials by manufacturing the laminate directly to its final width, so eliminating the need to trim extra (scrap) material from its longitudinal edges.

However, referring to non-compliant parts or end-of-life products, the present invention allows for recycling of the FRP more easily and safely than the systems known in the art.
The simpler and more technically proven method of recycling is mechanical recycling, but it does have two main drawbacks:

a) A first problem is the safety hazards involved with mechanical recycling and the low value of the end-product. Mechanical recycling involves shredding and grinding of the scrap FRP material with subsequent use of the ground material in a new product. The factor that most seriously impacts mechanical recycling is that most FRP products made worldwide use a room-temperature cure to reduce the capital cost of FRP manufacturing. Use of this method creates the potential for excess catalyst and promoters to exist in the scrap. Safety is a serious concern when grinding FRP scrap and the primary safety issue is fire. Grinding any material increases the surface area exposed to air. FRP scrap can become more flammable, if not explosive, when ground. Adding to this problem is the fact that FRP cured at room temperature often contains excess catalyst. This catalyst, once released by the grinding process, can react with the freshly exposed polymer surfaces generating heat and potentially starting a fire. Another disadvantage for the recycled product would be the inconsistent chemical properties of the ground material. Specifically, the finely ground FRP product could contain varying amounts of catalysts and/or promoters. This would lead to difficulties if the ground material were to be added to a resin mixture affected by these chemistries (e.g. premature cure of resin in a mixing tank). It is unlikely that fabricators would be willing to assume the risk of adding recycled FRP fillers to their products when the economic reward for doing so couldn't be worth it.

b) A second problem of mechanical recycling is the cost of grinding.

The curing technology of the invention allows the FRP material of the present invention to be entirely UV cured, thereby eliminating the need for the catalysts and promoters that create the problems in the mechanical recycling process and the resultant ground materials, thereby making recycling of the FRP material safer and the product produced by the recycling process to be more readily useable. Also, the use of glassfiber filaments makes grinding easier and less expensive.

While the invention has been described in detail with reference to the embodiments, modifications and variations of those embodiments will now be apparent to those skilled in the art. Accordingly, the scope of the invention is not to be limited by the details of the foregoing detailed description, but only by the terms of the appended claims.
Claims

1. A FRP continuous laminate comprising:
   a fiber reinforced plastic (FRP) structural core (15) comprising a composite
filamentary premix of glassfiber (5) and unsaturated polyester resin composition (2) said
core having a lower face and an upper face, a central area and two longitudinal edges,
wherein
   said glassfiber (5) is formed of monofilaments, having a diameter of between 0.1 and
35 microns, that have been isolated and/or separated from standard glassfiber chopped
strands and homogeneously and isotropically dispersed within said resin composition (2),
said resin composition (2) contains curing agents that have been selected from a group
including chemical curing agents and UV curing agents, and
   said longitudinal edges are straight, smooth, molded, uncut edges.

2. The laminate according to claim 1, further comprising:
   a lower film (1) having a lower face and an upper face, said upper face of said lower
film being covered with a first ink (25) that is chemically bound thereto;
   said lower face of said core (15) being chemically bound to said first ink (25);
   an upper film (7) having a lower side and an upper side, said lower side of said upper film
having a second ink (25) thereon that is chemically bound thereto, as well as to the resin in
the FRP core (15);
   whereby said lower film (1), first ink (25), FRP premix core (15), second ink (25)
and upper film (7) are fused to form a laminate having a unitary body.

3. The laminate according to claims 1 or 2, wherein each of said longitudinal edges (24)
are bent such that they each form longitudinal wings at an angle of less than 180 degrees
with the central area of said laminate, thereby creating longitudinally extending corners at
the bends where opposite edges of said central area and each of said longitudinal wings (24)
meet.

4. The laminate according to claim 2 or 3, wherein each of said upper and lower films
(1, 7) are formed as a multifunctional film system (la, 1b and 7a, 7b) with film layers for
linking (la, 7a) and film layers for finishing (lb, 7b), all these films being capable of being
printed upon,
said linking film layers (la, 7a) being chemically bonded to said core (15) and
said finishing film layers (lb, 7b) have sufficient resistance to protect the laminate
from scratches, cuts, and impacts thereto,

wherein all films that are bound to each other are bound by one or more resins
selected from a group consisting of ink (25) and an intervening adhesive resin (26), and
each of said multi-functional film systems (la, lb) and (7a, 7b) is formed as a
single polyvalent film layer adapted to be capable of linking, printing and finishing.

5. A device for continuous lamination using a technique combining a doser/spreader
system and an inverted extrusion system for processing a premix composition of
monofilamentary premix to produce a FRP laminate, the device comprising:

a structure, having a longitudinal axis, said structure supporting a platform (60)
located at an initial end of such structure and a driving system (13, 14) located at a terminal
end of such structure for hauling the laminate along said platform and through the device;

a lower feeding system (10, for continuously supplying at least one lower film (1)
onto said platform;

a premix feeding system, comprising a doser/spreader mechanism (56), for forming
onto said at least one lower film (1) a layer of fluid premix composite that is made of a
plurality of glassfiber monofilaments (5), previously isolated and/or separated from chopped
strand glassfiber, dispersed substantially homogeneously and isotropically into an
unsaturated polyester resin composition (2);

an upper feeding system (70, for continuously supplying at least one upper film (7)
onto said platform such that it lies on top of said premix composite, thereby encapsulating
said premix composite between said at least one lower film (1) and said at least one upper
film (7);

an inverted extrusion system (6, 6a, 6b, 60 for consolidating said at least one lower
film, said premix composite, and said at least one upper film such that they form a
continuous strip of fiber reinforced plastic (FRP) laminate (15), said laminate having a
longitudinal axis substantially parallel to said longitudinal axis of said structure and a width
that extends perpendicular to said longitudinal axis of said laminate, said laminate further
including a pair of longitudinal edges (24), for shaping the premix layer thickness, width and
surface finish, including the edges; said inverted extrusion system comprising a spatula (6),
a lower flat surface (60 of said platform on which said lower film (1) travels and lateral rails
(6a, 6b) positioned to limit the lateral spread of said premix composite so that the laminate
produced by the machine is produced with a desired final width and requires no cutting or trimming of its longitudinal edges or additional operations for its finish;

a first UV curing system (21) positioned for curing said laminate as it travels along a mold (22-23 or 9-90 supported by said structure; and

a transverse cutting system (16) for separating a desired length of completed laminate.

6. The device according to claim 5, wherein said mold (22-23 or 9-90 for shaping the cross section of the laminate is selected from a group including an arched mold or form (22), for shaping flat laminates, with a deflector (23) positioned just after said arched form (22) so as to press said laminate (15) down against said arched form (22) so that said laminate is stretched even and smooth, and a corrugation mold or form (9, 90 for shaping a laminate that is corrugated, said molds being positioned on said structure with said first UV curing station (21) positioned to project UV rays onto said laminate as it travels through said molds.

7. The device according to claim 5 or 6, further comprising:

a shutter system (17) positioned for shielding from UV exposure two lateral strips "E" of said laminate that extend along respective longitudinal edges (24) of said laminate (15);

a bending mold (8, 80 for bending said longitudinal edges (24) of said laminate so that they each form an angle of less than 180 degrees with a plane containing the central area of said laminate between said two strips "E", thereby forming bent longitudinal edges (24) or wings on said laminate, wherein said bending mold (8, 80 comprises a two-part mold (8-80 having a fixed part (8), comprising two corners, and a mobile part (80, comprising one or more pairs of mobile skates (8'a) and (8%), each mobile skate pressing the laminate into a respective one of said fixed corners of part (8) to form one of said bent edges or wings (24);

a second UV curing system (10) positioned for curing both strips "E" forming bent edges or wings (24) of the laminate while said edges are bent.

8. The device according to one of claims 5 to 7, wherein at least one of the films (1, 7) are re-circulated films, and they work as endless loops of release films or conveyor belts, guided by guiding cylinders (41, 42, 43, 44, 45, 46) for supporting and guiding the endless loops of re-circulated films.
9. A method of manufacturing a FRP continuous laminate using a technique combining a
doser/spreader system and an inverted extrusion system for processing a premix
composition of monofilamentary premix, said method comprising the steps of:

- providing a device having a platform (60 located at an initial end and a driving
  system (13, 14) located at a terminal end for hauling the laminate along said platform and
  through the device;

- dispensing a lower releasing film (1), having a lower side, **and** an upper side, and
  first and second longitudinal edges (24), onto said platform (60 so that the lower side of
  said lower film (1) faces downward and travels on said platform (60, with the upper side of
  said film (1) presents an upwardly facing surface;

- dosing/spreading a layer of a premix composition (2, 5), made of a substantially
  homogeneous and isotropic mixture of glassfiber monofilaments (5) dispersed into a
  composition of unsaturated polyester resin (2), said mixture having the consistency of a fluid
  putty, such that said layer covers the upwardly facing surface of said lower film (1), with the
  aggregate of said unsaturated polyester resin (2) and dispersed fiber monofilaments (5)
  together constituting, when the laminate is completed, a fiber reinforced plastic (FRP)
  structural core (15) of the laminate;

- dispensing an upper releasing film (7) having a lower side and an upper side, said
  upper film (7) being dispensed onto the upwardly-facing surface of said aggregate such that
  said lower side of said upper film contacts said upwardly-facing surface of said premix
  aggregate (15), whereby the aggregate is encapsulated between the lower film (1) and the
  upper film (7), with the lower film, the aggregate, and the upper film together forming a
  laminate (1, 15, 7) having a lower face, an upper face, and first and second longitudinal
  edges (24);

- hauling the laminate (1, 15, 7) through an inverted extrusion system (6, 6a, 6b, 60
  for shaping the filamentary premix composite (2, 5) to its desired layer thickness, width and
  surface finish, including its edges (24);

- further hauling said laminate through mold (22-23 or 9-9') for shaping the cross
  section, or transverse profile, of the laminate, said mold being selected from a group
  including an arched mold or form (22), for shaping flat laminates, having a deflector (23)
  positioned just after said arched form (22) so as to press said laminate (15) down against
  said arched form (22) so that said laminate is stretched planar and smooth, and a
  corrugation mold or form (9, 90 for shaping a laminate that is corrugated;

- curing (21) said laminate as it travels through the selected one of said molds;
transversally cutting a desired length of completed laminate.

10. A method of manufacturing a FRP continuous laminate using a technique combining a
doser/spreader system and an inverted extrusion system for processing a premix
composition of monofilamentary premix, said method comprising the steps of:

- providing a device having a platform (60) located at an initial end and a driving
  system (13, 14) located at a terminal end for hauling the laminate along said platform and
  through the device;

- providing a lower film (1) having first and second longitudinal edges (24) and a lower
  side, and further having an upper side which has been preprinted with a first ink (25) that is
  chemically bound thereto to form a composite (1, 25) having a lower side and an upper side;
  said ink (25) being capable of acting as a gelcoat layer;

- feeding said composite (1, 25) onto said platform (6) at a first end of a continuous
  lamination line so that the lower side of said composite faces downward and travels on said
  platform (60), with the upper side of said composite presenting an upwardly facing surface;

- dosing/spreading a layer of a premix composition (2, 5), made of a substantially
  homogeneous and isotropic mixture of glassfiber monofilaments (5) dispersed into a
  composition of unsaturated polyester resin (2), said mixture having the consistency of a fluid
  putty, such that said layer covers the upwardly facing surface of said lower film (1), with the
  aggregate of said unsaturated polyester resin (2) and dispersed fiber monofilaments (5)
  together constituting, when the laminate is completed, a fiber reinforced plastic (FRP)
  structural core (15) of the laminate;

- dispensing an upper film (7) having a lower side and an upper side, said lower side
  being preprinted with a second ink (25) that is chemically bound thereto, said upper film (7)
  being dispensed onto the upwardly-facing surface of said aggregate such that said
  preprinted lower side of said upper film contacts said upwardly-facing surface of said premix
  aggregate (15), whereby the aggregate is encapsulated between the lower film (1) and the
  upper film (7), with the lower film, the aggregate, and the upper film together forming a
  laminate (1, 25, 15, 25, 7) having a lower face, an upper face, and first and second
  longitudinal edges (24);

- hauling the laminate (1, 25, 15, 25, 7) through an inverted extrusion system (6, 6a,
  6b, 60) for shaping the filamentary premix composite (2, 5) to its desired layer thickness,
  width and surface finish, including its edges (24);
further hauling said laminate through mold (22-23) or (9-90) for shaping the cross section, or transverse profile, of the laminate, said mold being selected from a group including an arched mold or form (22), for shaping flat laminates, having a deflector (23) positioned just after said arched form (22) so as to press said laminate (15) down against said arched form (22) so that said laminate is stretched planar and smooth, and a corrugation mold or form (9, 9') for shaping a laminate that is corrugated; curing (21) said laminate as it travels through the selected one of said molds; and transversally cutting a desired length of completed laminate.

11. The method according to claim 9 or 10, further comprising the steps of:
curing (21) only a substantially central area of the laminate while it travels through the mold (22-23) or (9-90), said central area being defined as the area slightly smaller on each of two longitudinal sides than the full width of the laminate, leaving uncured the area "E" of said first and second longitudinal edges (24);
bending said first and second longitudinal edges (24) of said laminate to form bent longitudinal edges or wings (24) which form an angle of less of 180 degrees with said central area of said laminate, said bending step creating longitudinal corners extending along said laminate where said planar central area meets each of said bent edges or wings (24), curing (10) said longitudinal wings.

12. The method according to one of claims 9 to 11, wherein said steps of curing utilize a system comprising one or more of the group consisting of a mixed curing of the laminate by a combination of quick, partial curing by UV radiation on the lamination line and a slow, full, room temperature curing made by chemical curing agents once the laminate has been removed from the production line, or it can be a quick and full UV curing only, occurring entirely on the production line.

13. The method according to one of claims 9 to 12, wherein, after the step of cutting a desired length of said plain FRP laminate (15), the method further comprises the additional steps of:
removing one of said upper and lower films (1) or (7) to create a newly exposed face of said FRP structural premix core (15), and
silk-screening the newly exposed face of the core (15) with a serigraphic ink (34).
INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/001791

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29C70/08 B32B27/04 C08J5/04

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)
C08J B32B B29C

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

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search
7 December 2010

Date of mailing of the international search report
20/12/2010

Name and mailing address of the ISA:
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Puttins, Udo

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