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(54) **FOIL OR FILM LAMINATED ENHANCED
NATURAL FIBER/POLYMER COMPOSITE**

(76) Inventors: **James Przybylinski**, Corvallis, OR
(US); **Douglas G. Mancosh**, Warwick,
RI (US); **Paul Brestelli**, Stanfield, NC
(US)

Correspondence Address:
FISH & RICHARDSON PC
P.O. BOX 1022
MINNEAPOLIS, MN 55440-1022 (US)

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(57) **ABSTRACT**

A natural fiber/polymer composite product that includes a core (preferably with a textured surface) and a film or pigment surface layer applied to that textured core surface. The core comprises at least one natural fiber and at least one polymer intimately admixed together to form a composite.

FOIL OR FILM LAMINATED ENHANCED NATURAL FIBER/POLYMER COMPOSITE

RELATED APPLICATION

[0001] This application claims priority under 35 USC § 119(e) to U.S. Patent Application Ser. No. 60/641,308, filed on Jan. 1, 2005, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] This invention is in the general field of natural fiber/polymer composites, which are used (for example) in all-weather products such as decking, railing, fencing, siding, roofing and other outdoor products.

BACKGROUND

[0003] Wood products used in demanding environments, such as all-weather floorings, are subjected to a number of conditions, including detrimental environmental elements and physical abrasion and impact that can limit product lifetime and degrade its appearance. More durable materials, such as natural fiber/polymer composites, improve product performance and lengthen their useful life, but they may be aesthetically objectionable or have other undesirable properties and degradation issues.

[0004] Nishibori U.S. Pat. No. 5,869,138 and U.S. Pat. No. 6,066,367 (each of which is hereby incorporated by reference in its entirety) disclose a process in which a synthetic wood board is formed by mixing wood meal with a resin (such as polycarbonate, nylon, acrylonitrile butadiene styrene (ABS), polyvinyl chloride, nylon, polyethylene or polypropylene). The mixture is heated, kneaded and squeezed by extruding it with a screw into a molding die. The resulting synthetic wood board is then processed by sanding a surface, applying a colorant, sanding (or grinding) again to form "wound stripes" with the remaining colorant in a recessed layer, and then printing a wood pattern on the ground surface, so that the ink enters the wound stripes.

[0005] Velin et al. U.S. Pat. No. 6,106,654 discloses a decorative thermosetting laminate with a wear-resistant and a scratch resistant surface layer. The laminate can be paper impregnated with a melamine-formaldehyde resin. The top side of the wet paper is sprinkled with particles to impart abrasion resistance.

[0006] Sjölin et al. U.S. Pat. No. 6,375,777 discloses a process for making a laminate in which dry paper webs are fed through a continuous double belt press.

SUMMARY

[0007] The invention generally features a natural fiber/polymer composite product that includes a core having a surface and a film or foil layer applied to that core surface. The core comprises at least one natural fiber and at least one polymer intimately admixed together to form a composite.

[0008] A first aspect of the invention generally features a natural fiber/polymer composite having such a core with a mechanically or chemically prepared (textured) surface. At least one layer is positioned on the mechanically or chemically prepared core surface. That layer may be a film laminated onto the mechanically or chemically prepared

core surface, or it may be a layer that has been hot stamped from a foil onto the mechanically or chemically prepared core surface.

[0009] In a second aspect of the invention that specifically features the use of a layer that has been hot stamped from a foil onto the core surface. Mechanical or chemical preparation of that core surface is optional.

[0010] In a third aspect of the invention that specifically features the use of a layer that has laminated onto the core surface. Mechanical or chemical preparation of that core surface is optional.

[0011] In a fourth aspect of the invention, the composite product is made by first extruding at least one natural fiber and at least one polymer to form a composite core having a smooth surface. During extrusion or thereafter, a core surface is prepared by mechanical or chemical preparation. Finally at least one layer is added to the mechanical or chemical prepared surface, either by film lamination or by hot stamping the layer from a foil to the core surface.

[0012] In preferred embodiments of any of the above aspects of the invention, the polymer is a thermoplastic, such as polyvinyl chloride, polyethylene, polypropylene, ABS, or styrene. The polymer may be virgin polymer or recycled polymer. The layer may be a pattern that has been transferred from to the core surface from a foil by hot stamping, or it may be a pattern on a film that is laminated to the core surface.

[0013] More than one of the above-described layers may be included in the product. For example, one layer may be on a first core surface and a second layer may be on a core surface opposite the first core surface.

[0014] Preferably, the core comprises by weight less than 92% but greater than 25% polymer and less than 75% but greater than 8% natural fiber.

[0015] The layer may be essentially free of abrasive material.

[0016] The layer may provide visual enhancements and surface design to mimic natural or man made material surface. It may also include a material that deflects or reflects ultraviolet radiation away from the core to enhance product resistance to ultraviolet radiation. The core may include a UV resistant pigment. The core, the layer or both may include a substance that resists mold and/or mildew.

[0017] The layer may provide a number of advantageous physical characteristics. It may reduce water absorption as determined either by at least a 10% reduction either in weight gain or physical expansion of the product as compared to the core without the layer, wherein weight gain or physical expansion are measured by either the room temperature or elevated temperature test methods of ASTM D1037-99. It may exhibit extractive bleeding from the natural fiber in the composite core when subject to moisture that is at least 10% less than the extractive bleeding of the core without the layer, as determined by analysis of tannins, tannic acid and their derivative in a water solution. It may control surface temperature by a minimum of 3% as measured using ASTM D4803-97. It may increase wear resistance at least 10% compared to the core without the layer, as measured by ASTM D968-93 Standard Methods for Abrasion Resistance tests. It may provide an increase in strength

and stiffness compared to the core without the layer, as measured by ASTM D790-03 Standard Test Method for Flexural Properties. It may exhibit color inconsistency of less than 1-E as demonstrated by ASTM E805-01a Standard Method. Finally, the product may reduce color fade or change from environmental exposure, as compared to the core without the layer, by a minimum of 20% as measured by ASTM D6864-03a1 Standard Specification.

[0018] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DETAILED DESCRIPTION

[0019] Extrusion Process for the Core

[0020] Any of a number of extrusion processes may be used to produce a composite product or core that is then laminated to one or more decorative surface layers. One such process is direct extrusion, in which the raw materials (a natural fiber product and polymer) are added to the extruder, which melts the polymer and mixes the natural fiber into the polymer them together. The extruder then forces the molten composite through a die where it forms a finished product.

[0021] Another process is indirect extrusion, in which the raw materials (a natural fiber and polymer) are added to the extruder to melt the polymer and mix it with the fiber to produce a pellet. This pellet is then re-melted by a second extrusion process that forces the molten composite through a die where it forms a profile.

[0022] The finished product produced by either direct or indirect extrusion becomes the composite core, which is then laminated to a foil or other thin layer that imparts the desired decorative effect and physical property enhancements.

[0023] Exemplary extrusion processes are described in greater detail below with reference to specific examples, without limiting the invention. Generally, a composite of a polymer and natural fiber flour is extruded into a shape and then decorated using transfer foils and wraps. These extruded shapes have use in decking products, railings, fencing, windows, doors, doorframes, flooring, and similar applications. The composite material used in these applications is the result of mixing, blending, or compounding polymers with fibers such as wood, rice hulls or other fibrous materials reduced in particle size. The polymers used are polyethylene, polypropylene, PVC, ABS or styrene. Other thermoplastic materials capable of being extruded to a desired shape would also be used for specific applications.

[0024] The raw materials are received in both packaged and bulk containers and are prepared for processing in a variety of methods. The fiber flour is received in 40 or 60 mesh. The flour is then dried to a moisture content of 0-4%, using either drying kilns or air circulation silos or bins. For kiln drying, the fiber flour is introduced from either a bulk storage unit or packaged storage container into an air stream to the kiln, where it is dried then transferred to dry storage units or containers. Air circulation drying takes place in larger bulk storage units with the capability of circulating the fiber using hot air to reduce the moisture content of the fiber.

In addition to the fiber flour and polymer, a number of additives such as process aids, process stabilizers, color, anti-fungal agents, blowing agents, weather and aging protectors, etc. can be added to the blend or compound to obtain the desired physical properties for any appropriate application.

[0025] The fiber flour used is typically wood, both hardwood and softwood. The choice of wood species is dependent on the polymer used and the intended application. For polyolefin (HDPE)/wood compounds the wood species is usually oak or maple. These hardwood species are preferred, because they provide the extruded profile with a high degree of stiffness, a Modulus of Elasticity of greater than 500,000 psi. Additionally, maple is preferred over oak, because maple has a lower tannin content. The lower tannin content results in less organic acids being produced during the extrusion process. Further, the lower tannin content allows for higher extrusion process efficiency and less finished product problems such as moisture staining on the surface of the extruded product. For PVC/wood compounds pine is the usual species used. This softwood offers a smoother exterior surface to the extruded core of the product. The polymer or polymer compound is blended with the fiber flour and the additive materials (described above) using physical mixing units or compounding extruders. The materials are transferred pneumatically or by vacuum from the bulk storage units or transferred mechanically/pneumatically from the receiving containers. All ingredients are then mixed or compounded to a specific formulation for specific extruding equipment and specific end products. In some compounding situations, the polymer and additives are pre-compounded and the fiber flour is introduced as a secondary step in the blending operation.

[0026] The blended material is processed into a finished composite material shape or profile using an extruder or can be processed into a pellet and then reprocessed through a second extrusion operation to form a shape or profile. The processes are applicable to single screw extrusion or to twin-screw extruders with either co-rotating screws or counter-rotating screws. The extruder will have a temperature profile, temperature settings at various zones of the extruder, allowing for the melting, final mixing, pumping, and forcing of the material through the die. The temperature profile is dependent on the extruder, polymer used, die selection, and the physical properties required for the finished product. Whether extruding polyolefin (HDPE)/wood compounds or PVC/wood compounds a "reverse temperature profile" typically is used. The highest temperature is at the entry to the extruder to facilitate melting and mixing, and the temperature is reduced in the barrel going toward the die. The die temperature reflects the melt temperature of the extrusion as it exits the extruder. The combination of materials and equipment determines the specific temperature profiles. The temperature of the individual heating zones on the extruder, adapter zone, and die will vary from 88° C. to 240° C. The temperature will be controlled by zone to give the overall temperature profile required for optimum extrudability of the blend being used.

[0027] The pressures inside the extruder and at the die are controlled by feed rates, extruder speed, melt pumping where applicable, and die design. The feed rate control is determined by the method of introduction. The raw material is introduced to the extruder by loss-in-weight feeders that

measure the amount of material fed to the extruder. The material may be transferred from the feeder to the extruder by gravity. An alternative method introduces blended material into the extruder using a cramming device to insure the appropriate amount of material entering the extruder. Once the raw materials have entered the extruder further pressure control is accomplished by adjusting the speed of the extruder screws, measured in revolutions per minute, moving the material through the barrel of the extruder. If a melt pump is used the pressure is adjusted further by the speed, rpm, of the melt pump. The final pressure determination is accomplished by the internal cavity shape of the die. The pressure in combination with the temperature profile determines the control of the extruded shape or profile.

[0028] After the extrudate exits the die it may be calibrated for final dimensions using a sizing or calibration device to reach exacting dimensional requirements. Depending on the cooling characteristics of the material and the shape of the end product calibration devices may or may not be used. The calibration device is part of the overall cooling system used to bring the extruded shape from elevated extrusion temperatures to ambient temperature. After exiting the die, the extruded shape or profile is introduced to a cooling medium such as water or air to remove the internal heat of the shape or profile. In addition to cooling, the calibration device may also apply vacuum to the extrudate to assist in the forming of the shape or profile to the desired dimensions. When employing a sizing or calibration procedure, a pulling device is used to control the speed of the extrudate through the calibration system. This technique further allows for the control of the dimensions of the final shape or profile.

[0029] The cooled and formed shape or profile is cut to desired lengths using automated cutting devices. The most commonly employed device is a traveling saw that is calibrated to move at the same speed as the extrudate thereby giving a consistent length to the cut shape.

[0030] The formed shape or profile may be further processed using secondary mechanical operations. These operations may include molding the part to provide surface alteration or shape tolerance improvement or embossing the surface with heat pressure devices that leave surface impressions and visual features.

[0031] As described above, many different profiles are extruded to create the basic profiles covered by this invention. A very wide range of materials and formulations have been utilized and tested. A generic formulation that describes this range of materials and formulations follows:

Material description	Percent of material in formula
Natural fiber	0%–75% (preferably 8–66.5%)
Virgin polymer	0%–92% (preferably 0–71%)
Merchant recycled polymer	0%–65% (preferably 0–26%)
Internal recycled composite material	0%–65%
Lubricants (Internal & external)	2%–7%
Blowing agents	0%–6%
Process aids & other additives such as compatibilizers	0%–1%
Color concentrate	0%–2.5%

[0032] The following formulations are non-limiting examples to document utilization of high-density polyeth-

ylene (HDPE) and natural fibers to produce the basic composite profile. Those skilled in the field will understand that numerous other combinations of formulations appropriate for various product and applications are covered by this invention.

Material description	Weight of material in formula
Hard wood (40 mesh) (Typical formula)	47%
HDPE - Pellets or Powder	27%
HDPE - Merchant recycled	9%
Internal recycled HDPE composite material	9%
EBS wax	3%
Zinc Stearate	3%
Color concentrate	2%
Rice Hulls (20/80) (Typical formula)	47%
HDPE - Pellets or Powder	18%
HDPE - Merchant recycled	18%
Internal recycled HDPE composite material	9%
EBS wax	3%
Zinc Stearate	2%
Coupling Agent	1%
Color concentrate	2%

[0033] The following formulations are examples to document utilization of polyvinyl chloride (PVC) and natural fibers to produce the basic composite profile.

Material description	Weight of material in formula
Soft wood (60 mesh) (Typical)	16%
PVC - Dry blend or pellets	71%
PVC - Merchant recycled	0.0
Internal recycled PVC composite material	0.0
Other fillers	4%
Process aids	0.0
PVC capstock	9%
Rice Hulls (20/80)	24%
PVC - Dry blend or pellets	48%
PVC - Merchant recycled	16%
Internal recycled PVC composite material	7%
Other fillers	0.0
Blowing agent	5%
PVC capstock	0.0

[0034] The following formulations are examples to document utilization of polypropylene (PP) and natural fibers to produce the basic composite profile.

Material description	Weight of material in formula
Hard wood (40 mesh)	47%
PP	34%
HDPE - Merchant recycled	11%
Lubricants	7%
Color concentrate	Less than 1%
Calcium stearate	Less than 1%

Applying the Layer

[0035] Once the composite shape or profile has been manufactured, it then acts as the composite core to which decorative and protective layer(s) may be hot stamped from a foil or film laminated, to achieve the improved physical

and visual enhancement over the current inventions. Two methods of decoration/protection can be utilized to accomplish this process step: a) heat/pressure transfer of a design from a foil to the core; or b) lamination of a layer containing a pigmented design to the core.

[0036] The layer may be added either inline and continuous with the extrusion process, or off line as a secondary operation.

[0037] The layer may provide one or more functional benefits. For example, the layer may carry a desired pigmented decorative image and/or variety of performance chemical additives. The foil or laminate material can be specially designed to transfer a wide variety of images using highly stable outdoor color pigment for long-term outdoor exposure. Additionally the foil or laminate material may contain a variety of product performance enhancing materials such as heat reflective pigments or materials, mold and mildew inhibitors, surface hardening materials and others.

[0038] With the inline process, the profile shape exiting the extrusion process may retain sufficient residual heat to support the necessary reaction with the foil to adhere the decorative pigment and chemical additive composition to the profile. In the offline secondary operation a reheating of the surface through flame, infrared heat, or direct contact heat transfer will create sufficient surface temperature. A roll(s) of heat transfer foil is loaded onto a profile-specific transfer table.

[0039] We now describe the two basic transfer process—hot stamped foil transfer and film lamination.

[0040] Hot Stamped Foiling

[0041] The first process is the transfer of the layer from a foil to the composite core using heat and pressure.

[0042] The surface of the extruded part may be (but is not required that it be) prepared mechanically or chemically, or using both methods, to accept the transfer of decorative materials from the foil. This preparation creates an improved surface in which to adhere the hot stamp foil. The mechanical preparation may include molding, planing, sanding, or some other method of mechanical abrasion to the intended decorative surface. These techniques expose additional natural fiber and reduce the surface content of polyethylene or other extrusion process materials that impede foil adherence. As an alternative procedure, chemical abrasion may be used to accomplish similar results, using a chemical such as (but not limited to) acid wash or corona discharge for polyethylene or other polymer core materials.

[0043] Once the surface is prepared the foil is placed on the surface and with the application of heat the decorative materials are transferred to the surface of the composite core. The heat of application also activates the adhesive allowing the decorative materials to bond to the surface of the composite core. As the decorative materials are transferred the carrier foil is removed and discarded.

[0044] The foil is shaped to the profile of the core using a series of rollers that force the foil to cover the shape of the composite core profile.

[0045] Subsequent to the application of the foil a topcoat, or protective layer, may be applied for enhanced physical properties. The choice of topcoat materials, polyurethane or acrylics for example, is dependent on the end use of the decorated product.

[0046] Film Lamination

[0047] A second decorative method involves the use of a film laminated to the composite core. The film wrap is a polymeric sheet material which has had the decorative materials and patterns applied to it.

[0048] The composite core profile surface may be (but is not required that it be) prepared in the same manner as described above. For example, surface of the extruded part is prepared mechanically or chemically, or using both methods, to accept the lamination of the film wrap material. This preparation creates an improved surface in which to adhere the film wrap. The mechanical preparation may include molding, planing, sanding or some other method of mechanical abrasion to the intended decorative surface. These techniques expose additional natural fiber and reduce the surface content of polyethylene or other extrusion process materials that impede film wrap adherence. As an alternative procedure, chemical abrasion may be used to accomplish similar results using chemical such as but not limited to acid wash or corona discharge for polyethylene or other polymer core materials.

[0049] After the composite core has been mechanically or chemically readied and primed for the film wrap, the profile passes through a wrapping device. This device takes the film wrap from a coil then applies the adhesive to the wrap material. In a continuous process the film wrap is then passed over the composite core. Again using equipment using a series of rollers the film wrap is shaped to the composite core profile.

[0050] The film wrap may incorporate in addition to its decorative elements an integral topcoat material for physical property enhancement. This integrated element may be polyurethane, acrylic or other protective materials.

[0051] If the film wrap integrates only the decorative elements, then the wrapped product next has a topcoat applied to enhance the physical properties of the entire decorative system. The topcoat can be polyurethane, acrylic, or other protective material that will impart better physical properties to the wrapped finished part.

[0052] The topcoat may be spray applied or hot melt applied. If spray applied, the wrapped product will pass through a spray applicator and then may or may not pass through a curing device such as ultra-violet radiation curing.

[0053] If the topcoat is hot melt applied, then a layer of polyurethane is applied to flat surfaces of the decorated part. The cure process for this type of material is time dependent and could take several days depending on the hot melts topcoat chosen for a specific end-use application for the completed finished product.

[0054] A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A natural fiber/polymer composite product comprising:
 - (a) a core comprising at least one natural fiber and at least one polymer intimately admixed together, said core comprising a mechanically or chemically prepared surface; and
 - (b) at least one layer on said mechanically or chemically prepared core surface, said layer comprising either: a) a film layer laminated onto said mechanically or chemically prepared core surface; or b) a layer that has been hot stamped from a foil onto said mechanically or chemically prepared core surface.
2. A natural fiber/polymer composite product comprising,
 - (a) a core comprising at least one natural fiber and at least one polymer intimately admixed together, and
 - (b) at least one layer hot stamped from a foil onto a surface of said core.
3. A natural fiber/polymer composite product comprising,
 - (a) a core comprising at least one natural fiber and at least one polymer intimately admixed together; and
 - (b) at least one layer laminated onto a surface of said core.
4. A natural fiber/polymer composite product formed by,
 - (a) first extruding at least one natural fiber and at least one polymer to form a composite core having a smooth surface;
 - (b) providing a mechanical or chemical preparation to said surface of said core; and
 - (c) performing a process to add at least one layer to said mechanical or chemical prepared surface by a process, said process being film lamination or hot stamping of the layer from a foil to the core surface.
5. The composite product claim 1 in which said polymer is a thermoplastic.
6. The composite product of claim 5 in which the polymer comprises polyvinyl chloride, polyethylene, polypropylene, ABS, or styrene.
7. The composite product claim 1 in which the layer is a pattern that has been transferred from the core surface from a foil by hot stamping.
8. The composite product of claim 1 in which the layer is a pattern on a film that is laminated to the core surface.
9. The composite product of claim 1 comprising more than one of the layers.
10. The composite product of claim 1 in which the core comprises by weight less than 92% but greater than 25% polymer.
11. The composite product of claim 1 in which the core comprises by weight less than 75% but greater than 8% natural fiber
12. The composite product of any of claim 1 in which the layer is essentially free of abrasive material.
13. The composite product of claim 1 in which the layer provides visual enhancements and surface design to mimic natural or man made material surface.
14. The composite product of claim 1 in which the layer comprises a material that deflects or reflects ultraviolet radiation away from the core to enhance product resistance to ultraviolet radiation.
15. The composite product of claim 14 in which the core comprises a UV resistant pigment.
16. The composite product of claim 1 in which the core, the layer, or both comprises a substance that resists mold and/or mildew.
17. The composite product of claim 1 in which the layer is a first layer on a first core surface and the product comprises a second layer on a core surface opposite the first core surface.
18. The composite product of any of claim 1 in which the layer reduces water absorption as determined either by at least a 10% reduction either in weight gain or physical expansion of the product as compared to the core without the layer, wherein weight gain or physical expansion are measured by either the room temperature or elevated temperature test methods of ASTM D1037-99.
19. The composite product of any of claim 1 in which the product exhibits extractive bleeding from the natural fiber in the composite core when subject to moisture that is at least 10% less than the extractive bleeding of the core without the layer, as determined by analysis of tannins, tannic acid and their derivative in a water solution.
20. The composite product of any of claim 1 in which the layer controls surface temperature by a minimum of 3% as measured using ASTM D4803-97.
21. The composite product of any of claim 1 in which the layer increases wear resistance at least 10% compared to the core without the layer, as measured by ASTM D968-93 Standard Methods for Abrasion Resistance tests.
22. The composite product of any of claim 1 in which the layer provides an increase in strength and stiffness compared to the core without the layer, as measured by ASTM D790-03 Standard Test Method for Flexural Properties.
23. The composite product of any of claim 1 in which the layer exhibits color inconsistency of less than 1 ΔE as demonstrated by ASTM E805-01a Standard Method.
24. The composite product of any of claim 1 in which the layer reduces color fade or change from environmental exposure, as compared to the core without the layer, by a minimum of 20% as measured by ASTM D6864-03a e1 Standard Specification.

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