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(54) **REINFORCED ACOUSTICAL MATERIAL HAVING HIGH STRENGTH, HIGH MODULUS PROPERTIES**

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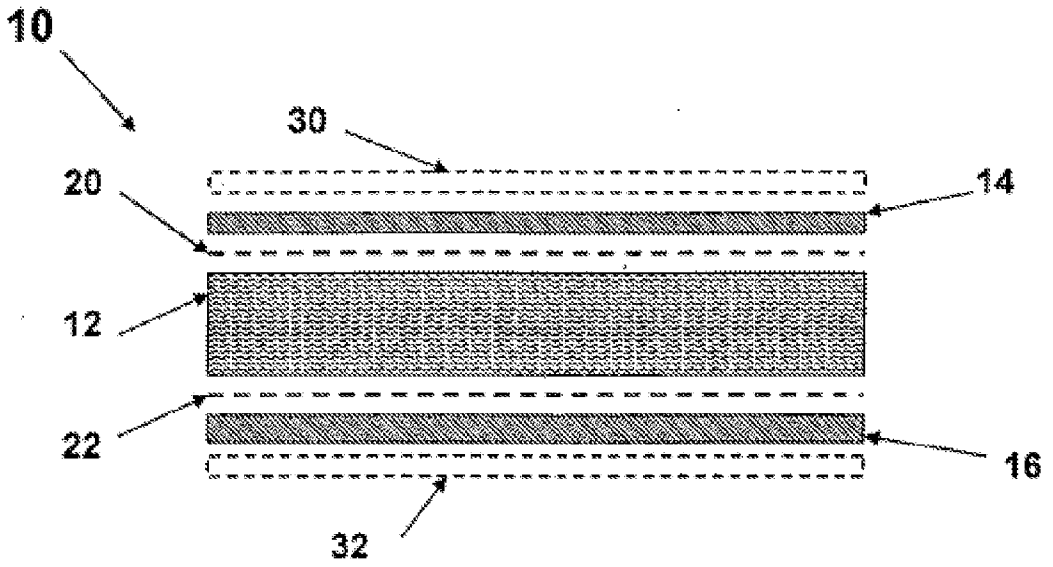
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(57) **ABSTRACT**

A multilayer composite material is formed of an acoustic core layer and at least one outer strengthening layer. The acoustic composite material has desirable high strength and high flexural modulus properties.



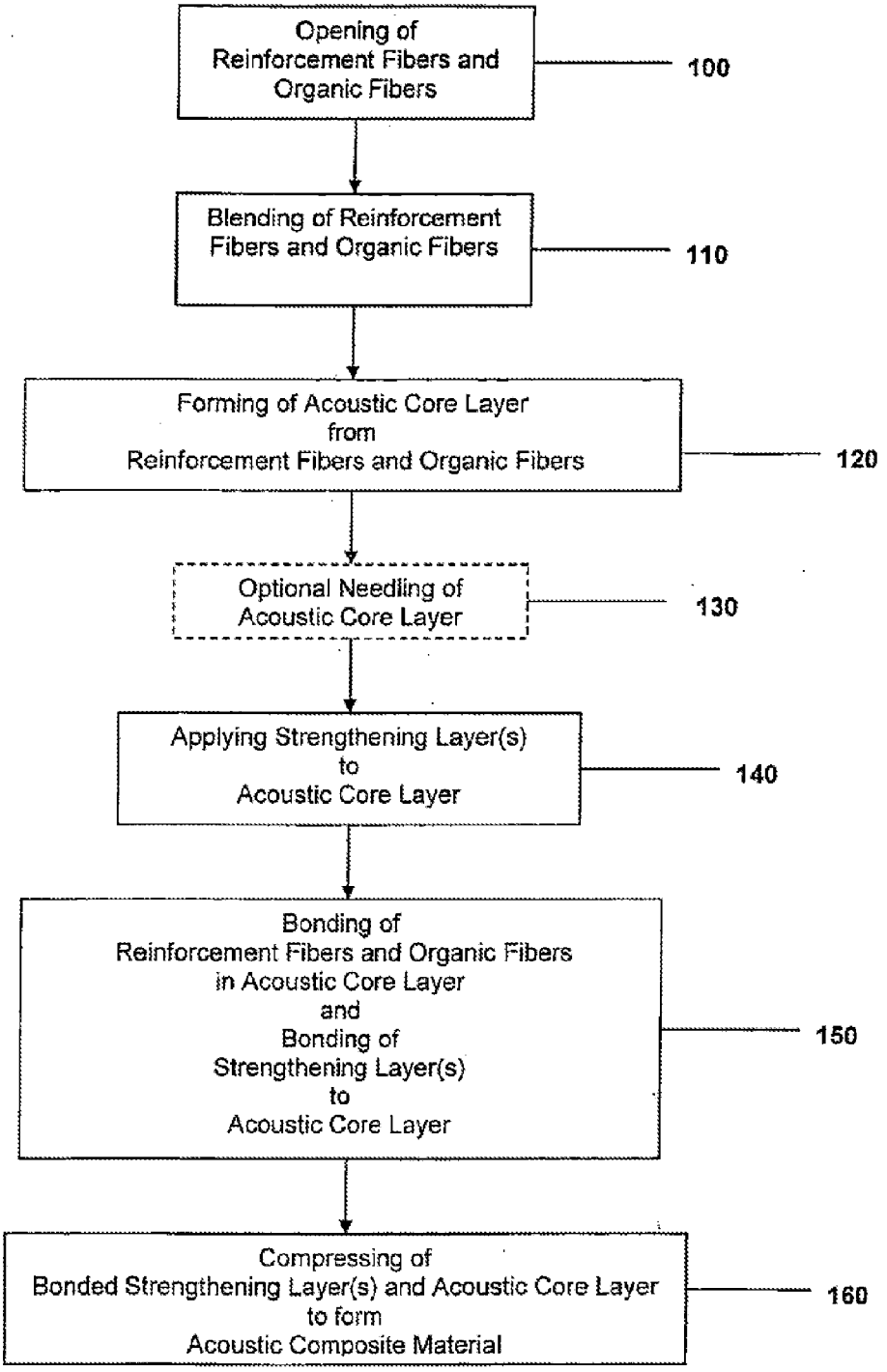

Opening of Reinforcement Fibers and Organic Fibers
100
Blending of Reinforcement Fibers and Organic Fibers
110
Forming of Acoustic Core Layer from Reinforcement Fibers and Organic Fibers
120
Optional Needling of Acoustic Core Layer
130
Applying Strengthening Layer(s) to Acoustic Core Layer
140
Bonding of Reinforcement Fibers and Organic Fibers in Acoustic Core Layer and Bonding of Strengthening Layer(s) to Acoustic Core Layer
150
Compressing of Bonded Strengthening Layer(s) and Acoustic Core Layer to form Acoustic Composite Material
160

FIG.1

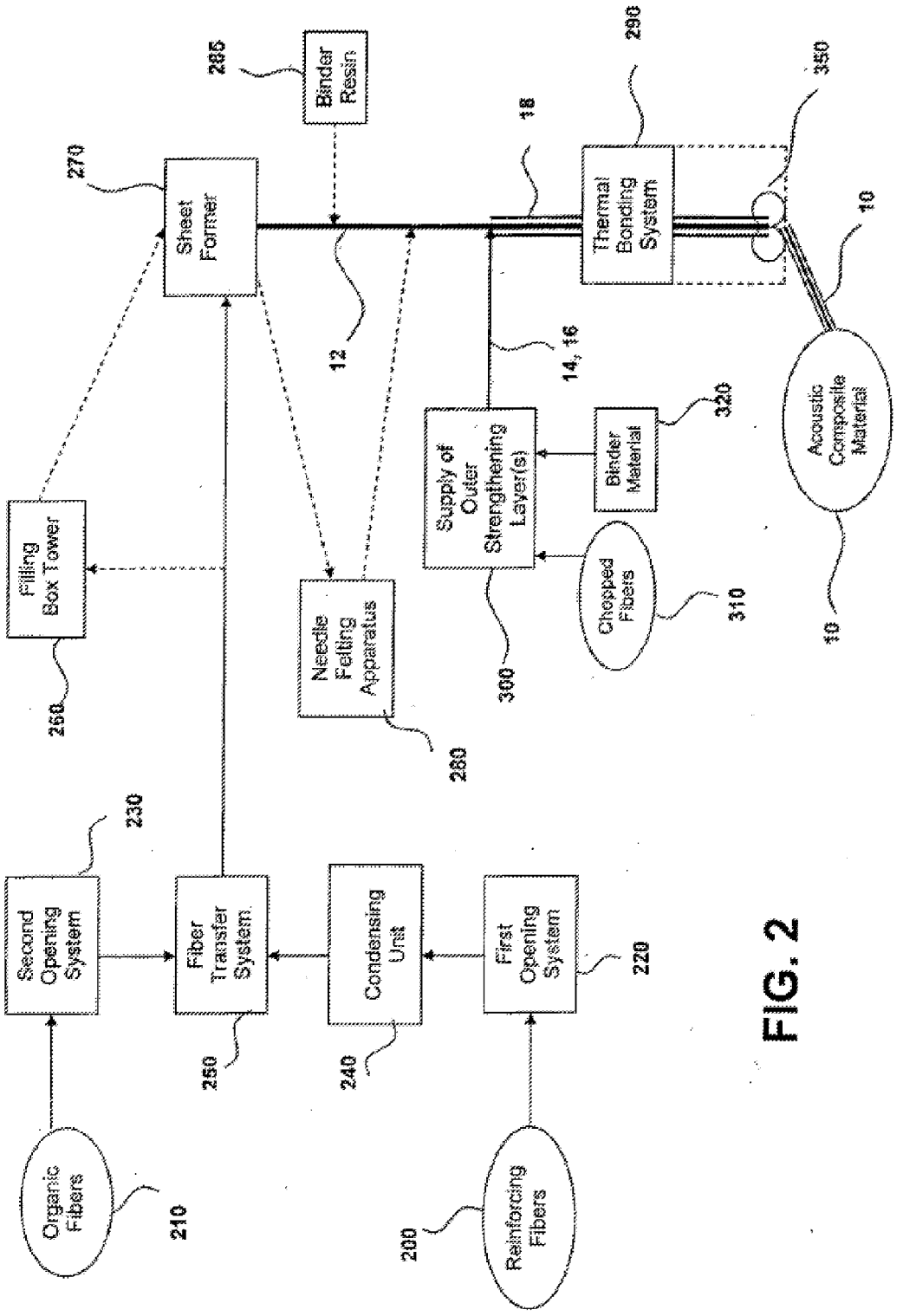

Organic Fibers
210
Reinforcing Fibers
200
Second Opening System
230
First Opening System
220
Fiber Transfer System
250
Condensing Unit
240
Filling Box Tower
260
Needle Felting Apparatus
280
Supply of Outer Strengthening Layer(s)
300
Chopped Fibers
310
Binder Material
320
Acoustic Composite Material
10
Sheet Former
270
Binder Resin
285
12
14, 16
18
Thermal Bonding System
290
350

FIG. 2

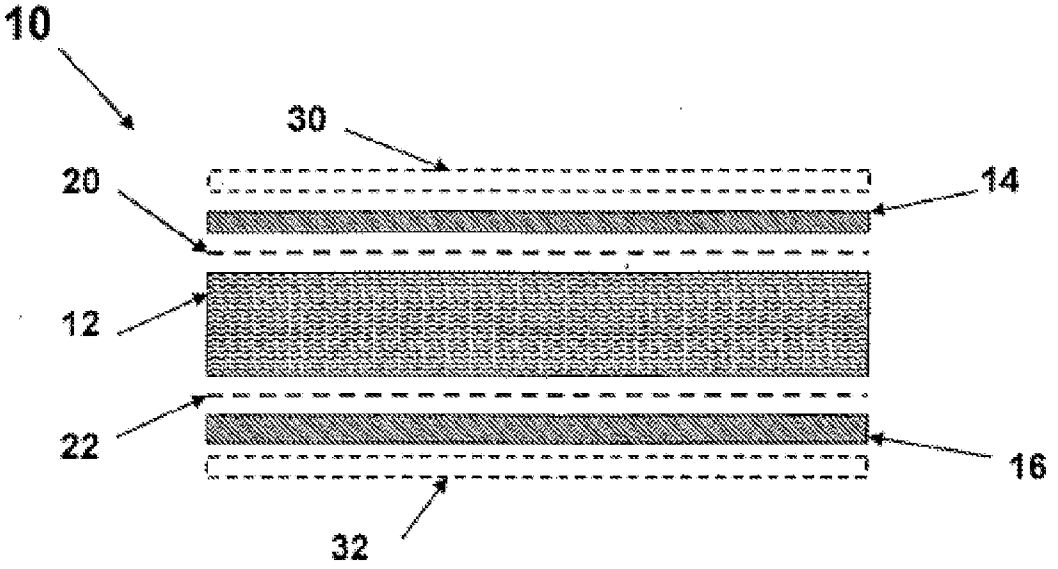


FIG. 3

Table 1

"A" Amax 1400 g/m² + (2 GMat x 200 g/m²) Total: 1800 g/m²		"B" Amax 1400 g/m² + (2 GMat x 100 g/m²) Total: 1600 g/m²		"C" Amax 1200 g/m² + (2 GMat x 200 g/m²) Total: 1600 g/m²	
MD	TD	MD	TD	MD	TD
43.43	38.38	33.20	35.93	36.53	31.54
43.58	32.25	31.47	26.88	27.61	29.24
51.44	33.69	34.81	30.90	39.07	38.26
52.08	45.41	47.06	26.35	39.82	24.39
47.63	**37.43**	**36.64**	**30.02**	**35.76**	**30.86**
42.53		**33.33**		**33.31**	

"D" Amax 1200 g/m² + (2 GMat x 100 g/m²) Total: 1400 g/m²		"E" Amax 1000 g/m² + (2 GMat x 200 g/m²) Total: 1400 g/m²		"F" Amax 1000 g/m² + (2 GMat x 100 g/m²) Total: 1200 g/m²	
28.76	24.87	22.7	20.44	28.76	24.87
36.53	24.45	19.12	21.45	36.53	24.45
32.14	23.96	21.04	16.44	32.14	23.96
27.14	34.55	20.33	20.17	27.14	34.55
31.14	**26.96**	**20.80**	**19.63**	**31.14**	**26.96**
27.46		**29.05**		**20.21**	

AMax Stiffness (N/mm) Molded @ 5mm					
Compar. #1 1000 g/m²		Compar. #2 1200 g/m²		Compar. #3 1400 g/m²	
MD	TD	MD	TD	MD	TD
16.9	13.47	23.54	11.37	24.06	18.45
14.82	12.19	20.16	5.46	21.08	23.50
21.41	16.47	23.55	13.3	23.77	14.50
12.07	16.58	19.03	15.08	22.67	13.85
14.4	17.7	12.12	17.78	13.32	18.05
16.94	19.59	20.97	18.33	18.50	18.26
22.95	15.57	15.5	14.96	24.66	14.14
23.34	14.09	12.89	13.67	23.79	14.66
17.85	**15.71**	**18.47**	**13.74**	**21.48**	**16.93**
16.78		**16.11**		**19.20**	

FIG. 4

REINFORCED ACOUSTICAL MATERIAL HAVING HIGH STRENGTH, HIGH MODULUS PROPERTIES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional application of and claims priority to and any other benefit of U.S. patent application Ser. No. 11/512,017, filed on Aug. 29, 2006, and titled "Reinforced Acoustical Material Having High Strength, High Modulus Properties," which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD AND INDUSTRIAL APPLICABILITY OF THE INVENTION

[0002] The present invention relates generally to acoustical products, and more particularly, to a high strength, high modulus acoustic composite material.

BACKGROUND OF THE INVENTION

[0003] Sound insulation materials are used in a variety of settings where it is desired to dampen noise from an external source. For example, sound insulation materials have been used in applications such as in appliances to reduce the sound emitted into the surrounding areas of a home, in automobiles to reduce mechanical sounds of the motor and road noise, and in office buildings to attenuate sound generated from the workplace, such as from telephone conversations or from the operation of office equipment. In automobiles, the insulation material also relies upon thermal shielding properties to reduce or prevent the transmission of heat from various heat sources in the automobile (e.g., engine, transmission, exhaust, etc.) to the passenger compartment of the vehicle. Acoustical insulation typically relies upon both sound absorption (i.e., the ability to absorb incident sound waves) and transmission loss (i.e., the ability to reflect incident sound waves) to provide adequate sound attenuation.

[0004] Conventional acoustical insulation materials include materials such as foams, compressed fibers, fiberglass batts, felts, and nonwoven webs of fibers such as melt-blown fibers. Although there are numerous acoustical insulation products in existence in the art, there is still a need for insulation products that have sufficient structural properties so that the insulation products can be employed in end-use applications that require high strength, high modulus insulation materials.

[0005] There is also a need for acoustical insulation materials that exhibit superior sound attenuating properties, improved structural and thermal properties, and that are lightweight and low in cost.

[0006] The invention will be more readily understood from the following descriptions thereof given, by way of example, with reference to the accompanying drawings.

SUMMARY OF THE INVENTION

[0007] The multilayer composite material is formed of a core acoustical composite layer and at least one outer strengthening layer. The acoustic composite material has desirable high strength and high flexural modulus properties.

[0008] A method of forming an acoustic composite material includes the steps of: positioning a core layer next to a major surface of at least one outer strengthening layer, the core layer being formed of a composite material comprising dehydrated reinforcing fibers and organic fibers, and bonding the core layer to the outer strengthening layer to form an acoustic composite material.

[0009] The method can further include the step of forming the acoustic core layer prior to the positioning step. The forming step can include: removing water from wet reinforcing fibers to form dehydrated reinforcing fibers; blending the dehydrated reinforcing fibers with the organic fibers to form a substantially homogenous mixture of the dehydrated reinforcing fibers and the organic fibers; and forming the mixture into the acoustic core layer. The outer strengthening layer can comprise a chopped strand mat.

[0010] The acoustic composite material has a core layer next to a major surface of at least one outer strengthening layer where the core layer is formed of a composite material comprising dehydrated reinforcing fibers and organic fibers.

[0011] In one embodiment, the fibrous material forming the core acoustical composite layer includes polymer based thermoplastic materials such as polyester and polypropylene and reinforcing fibers such as glass fibers. The fibrous material may contain from 40-60% glass fibers, by wt.

[0012] In certain embodiments, the reinforcing fibers in the core acoustic layer are wet use chopped strand glass fibers. Wet reinforcing fibers are typically agglomerated in the form of a bale, package, or bundle of individual glass fibers. To form the core acoustical composite layer, wet reinforcing fibers are opened and at least a portion of the water present in the wet reinforcing fibers is removed.

[0013] In addition, wet use chopped strand glass fibers are less expensive to manufacture than dry chopped fibers because dry fibers are typically dried and packaged in separate steps before being chopped. Therefore, the use of wet use chopped strand glass fibers allows composite products to be manufactured at lower costs.

[0014] The foregoing and other objects, features, and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description that follows. It is to be expressly understood, however, that the drawings are for illustrative purposes and are not to be construed as defining the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The advantages of this invention will be apparent upon consideration of the following detailed disclosure of the invention, especially when taken in conjunction with the accompanying drawings.

[0016] FIG. **1** is a flow diagram illustrating steps for making an acoustic composite material.

[0017] FIG. **2** is a schematic illustration showing an air-laid process using wet reinforcing fibers to form an acoustic core layer, in combination with a process for making an acoustic material having an acoustic core layer and at least one outer strengthening layer.

[0018] FIG. **3** is a schematic illustration of an acoustic composite material.

[0019] FIG. **4** is a table with data on different multilayer acoustic composite materials and acoustic core layers.

DETAILED DESCRIPTION AND PREFERRED EMBODIMENTS OF THE INVENTION

[0020] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the

invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are described herein. All references cited herein, including published or corresponding U.S. or foreign patent applications, issued U.S. or foreign patents, or any other references, are each incorporated by reference in their entireties, including all data, tables, figures, and text presented in the cited references.

[0021] In the drawings, the thickness of the lines, layers, and regions may be exaggerated for clarity. It is to be noted that like numbers found throughout the figures denote like elements. The terms "top", "bottom", "side", and the like are used herein for the purpose of explanation only. It will be understood that when an element such as a layer, region, or panel is referred to as being "on" another element, it can be directly on the other element or intervening elements may be present. If an element or layer is described as being "adjacent to" or "against" another element or layer, it is to be appreciated that that element or layer may be directly adjacent to or directly against that other element or layer, or intervening elements may be present. It will also be understood that when an element such as a layer or element is referred to as being "over" another element, it can be directly over the other element, or intervening elements may be present.

[0022] Referring initially to FIG. **3**, a multilayer acoustic material **10** is schematically illustrated as having an acoustic core layer **12** that includes reinforcing fibers and organic fibers, and at least one outer strengthening layer **14**. For ease of illustration, the multilayer acoustic material **10** is shown as having two opposing outer strengthening layers **14** and **16**; however, it is to be understood that the multilayer acoustic composite material **10** can have one outer strengthening layer. One or more types of fiberglass materials may be used to form the first and second outer strengthening layers **14** and **16**. The fibers forming the first and second outer strengthening layers **14** and **16** may have the same or different lengths and/or diameters. For example, the first and second strengthening layers **14**, **16** may be formed of a single glass fibrous material in which the fibers have different lengths and/or diameters.

[0023] In certain embodiments, the acoustic composite material **10** may include an adhesive material **20** positioned between the first outer strengthening layer **14** the acoustic core layer **12** and a second adhesive material **20** positioned between the acoustic core layer **12** and the second outer strengthening layer **16**. In certain embodiments, the adhesive materials **20**, **22** can be, for example, a spunbonded adhesive or a PTFE sheet.

[0024] In certain embodiments, the acoustic composite material **10** may include one or more surface coverings **30**, **32** bonded to an exposed major surface on one or both of the first and second outer layers **14**, **16**. The surface coverings **30**, **32** may be formed of fabrics, wall paper, vinyl, leather, aluminum foil, thin copper sheets, thermoplastic olefins (TPO), or films having various constructions, including monolayer films such as polypropylene, polyethylene, and polyamide, or multilayer films such as ethylene/acrylic acid (EAA), ethylene vinyl acetate (EVA), and polypropylene/polyamide (PP/PA). The surface coverings **30**, **32** may assist in altering the acoustical properties of the acoustic composite material **10** so that it can be tuned to meet the needs of a particular application. In addition, depending on the material of the surface layers, the surface layers may provide other properties of the acoustic composite material such as, but not limited to, water permeability or non-permeability, abrasion resistance, and/or heat resistance.

[0025] It is to be understood that the nomenclature for the acoustic core layer **12** and the first and second strengthening layers **14**, **16** are used for ease of discussion herein and that outer strengthening layers **14**, **16** may also provide acoustical properties.

[0026] As schematically illustrated in FIG. **2**, the outer strengthening layers **14**, **16** are comprised of randomly oriented chopped glass fiber strands **310** that are bonded together with a thermoplastic or thermoset binder material **320**. The outer strengthening layers **14**, **16** are fed from a supply **300**, such as a roller or reel. While not shown, the binder material **320** is commonly applied in a powdered form and the mat having binder material **320** applied is then taken through a curing process. During the curing process the chopped fibers **310** are bonded together where they intersect to form a mat with a certain amount of structural rigidity.

[0027] Also as schematically illustrated in FIG. **2**, the acoustic core layer **12** is comprised of reinforcing fibers **200** and organic fibers **210**.

[0028] The reinforcing fibers **200** used in the composite material **10** may be any type of organic or inorganic fiber suitable for providing good structural qualities as well as good acoustical and thermal properties. Non-limiting examples of reinforcing fibers that may be used in the composite material include glass fibers, wool glass fibers, natural fibers, cellulosic fibers, metal fibers, ceramic fibers, mineral fibers, carbon fibers, graphite fibers, nanofibers, or combinations thereof. The term "natural fiber" as used herein refers to plant fibers extracted from any part of a plant, including, but not limited to, the stem, seeds, leaves, roots, or bast. In the composite material, the reinforcing fibers may have the same or different lengths, diameters, and/or denier. In one embodiment, the reinforcing fibers are glass fibers, although other fibers can be used.

[0029] The reinforcing fibers **200** used in the acoustic core layer **12** may have a length of from approximately about 5 to about 100 mm, and even in certain embodiments, a length of from about 10 to about 50 mm. Additionally, the reinforcing fibers may have diameters of from about 8 to about 25 microns, and can have diameters of from about 12 to about 18 microns. The reinforcing fibers may have varying lengths, aspect ratios and diameters relative to each other within the composite material. The reinforcing fibers may be present in an amount of from about 20 to about 80% by weight of the total fibers, and, in certain embodiments, are present in an amount of from about 40 to about 60% by weight.

[0030] The organic fibers **210** present in the acoustic core layer **12** may include one or more of polymer based thermoplastic fibers such as, but not limited to, polyester fibers, polyethylene fibers, polypropylene fibers, polyethylene terephthalate (PET) fibers, polyphenylene sulfide (PPS) fibers, polyvinyl chloride (PVC) fibers, ethylene vinyl acetate/vinyl chloride (EVA/VC) fibers, lower alkyl acrylate polymer fibers, acrylonitrile polymer fibers, partially hydrolyzed polyvinyl acetate fibers, polyvinyl alcohol fibers, polyvinyl pyrrolidone fibers, styrene acrylate fibers, polyolefins, polyamides, polysulfides, polycarbonates, rayon, and nylon. The organic fibers may be functionalized with acidic groups, for example, by carboxylating with an acid such as a maleated acid or an acrylic acid, or the organic fibers may be functionalized by adding an anhydride group or vinyl acetate. The

organic fibers may alternatively be in the form of a flake, granule, or a powder rather than in the form of a polymer fiber. In some embodiments, a resin in the form of a flake, granule, and/or a powder is added in addition to the organic fibers.

[0031] One or more types of organic fibers **210** may be present in the acoustic core layer **12**. The organic fibers may have the same or varying lengths, diameters, and/or denier within the composite material. The acoustical behavior, stiffness, load deflection, and strength of the composite material may be tuned by altering the lengths and/or denier of the organic fibers. In addition, the ratio of the different organic fibers present in the composite material can be varied to achieve specific mechanical, acoustic, and thermal properties.

[0032] The organic fibers **210** may have a length of from approximately 10 to about 100 mm, and can have a length of from about 10 to about 50 mm. Additionally, the organic fibers may have a denier of from about 2 to about 25 denier, and in certain embodiments, from about **2** to about 12 denier. The polymer fibers may be present in the composite material in an amount of from about 20 to about 80% by weight of the total fibers, and, in certain embodiments, are present in an amount of from about 40 to about 60% by weight.

[0033] One or more of the organic fibers **210** may be multicomponent fibers such as bicomponent polymer fibers, tricomponent fibers, or plastic-coated mineral fibers such as thermoplastic coated glass fibers. The bicomponent fibers may be arranged in a sheath-core, side-by-side, islands-in-the-sea, or segmented-pie arrangement. In certain embodiments, the bicomponent fibers are formed in a sheath-core arrangement in which the sheath is formed of first polymer fibers that substantially surrounds the core formed of second polymer fibers. It is not required that the sheath fibers totally surround the core fibers. The first polymer fibers have a melting point lower than the melting point of the second polymer fibers so that upon heating the bicomponent fibers, the first and second polymer fibers react differently. In particular, when the bicomponent fibers are heated to a temperature that is above the melting point of the first polymer fibers (sheath fibers) and below the melting point of the second polymer fibers (core fibers), the first polymer fibers will soften or melt while the second polymer fibers remain intact. This softening of the first polymer fibers (sheath fibers) will cause the first polymer fibers to become sticky and bond the first polymer fibers to themselves and other fibers that may be in close proximity.

[0034] Numerous combinations of materials can be used to make the bicomponent polymer fibers, such as, but not limited to, combinations using polyester, polypropylene, polysulfide, polyolefin, and polyethylene fibers. Specific polymer combinations for the bicomponent fibers include polyethylene terephthalate/polypropylene, polyethylene terephthalate/polyethylene, and polypropylene/polyethylene. Other non-limiting bicomponent fiber examples include copolyester polyethylene terephthalate/polyethylene terephthalate (coPET/PET), poly 1,4 cyclohexanedimethyl terephthalate/polypropylene (PCT/PP), high density polyethylene/polyethylene terephthalate (HDPE/PET), high density polyethylene/polypropylene (HDPE/PP), linear low density polyethylene/polyethylene terephthalate (LLDPE/PET), nylon 6/nylon 6,6 (PA6/PA6,6), and glycol modified polyethylene terephthalate/polyethylene terephthalate (6PETg/PET).

[0035] The bicomponent polymer fibers may have a denier from about 1-18 denier and a length of from about 2 to about 4 mm. In certain embodiments, the first polymer fibers (sheath fibers) have a melting point within the range of from about 150 to about 400° F., and in certain embodiments, within the range of from about 170 to about 10° F. The second polymer fibers (core fibers) have a higher melting point, and, in certain embodiments, above about 350° F. Bicomponent fibers may be used as a component of the composite material or they may be used as the organic fibers present in the composite material.

[0036] The acoustic core layer **12** may be formed of an air-laid, wet-laid, or meltblown non-woven mat or web of randomly oriented reinforcing fibers and organic fibers. In at least one exemplary embodiment, the acoustic core layer **12** is formed by a dry-laid process, such as the dry-laid process described in U.S. patent application Ser. No. 10/688,013, filed on Oct. 17, 2003, to Enamul Haque entitled "Development Of Thermoplastic Composites Using Wet Use Chopped Strand Glass In A Dry Laid Process", which is expressly incorporated herein by reference in its entirety. In certain embodiments, the reinforcing fibers used to form the acoustic core layer **12** are wet reinforcing fibers, and may be wet use chopped strand glass fibers. Wet use chopped strand glass fibers for use as the reinforcing fibers may be formed by conventional processes known in the art. It is desirable that the wet use chopped strand glass fibers have a moisture content of from about 5 to about 30%, and can have a moisture content of from about 5 to about 15%.

[0037] The use of wet use chopped strand glass fibers as the reinforcing fibers **200** provides a cost advantage over conventional dry-laid glass processes. For example, wet use chopped strand glass fibers are less expensive to manufacture than dry chopped fibers such as dry use chopped strand glass fibers (DUCS) because dry fibers are typically dried and packaged in separate steps before being chopped. As a result, the use of wet use chopped strand glass fibers allows the composite material and subsequent acoustic composite material to be manufactured with lower costs.

[0038] An exemplary process for forming a composite material **10** is generally illustrated in FIG. **1**, and includes

[0039] at least partially opening the reinforcing fibers and the organic fibers (step **100**),

[0040] blending together the reinforcing fibers and the organic fibers to form a substantially homogenous mixture of the dehydrated reinforcing fibers and the organic fibers (step **110**),

[0041] forming the blended mixture of the reinforcing fiber and the organic fibers into an acoustic core layer (step **120**),

[0042] optionally, needling the acoustic core layer (step **130**),

[0043] applying at least one outer strengthening layer to at least one major surface of the acoustic core layer (step **140**), and

[0044] bonding together:

[0045] i) the organic fibers to the reinforcing organic fibers in the acoustic core layer, and

[0046] ii) the outer strengthening layer(s) to the acoustic core layer (step **150**),

[0047] and, in certain embodiments, compressing the acoustic core layer and the outer strengthening layers(s) (step **160**).

[0048] The reinforcing fibers **200** and the organic fibers **210** are typically agglomerated in the form of bundles or strands of fibers or filaments. Wet glass or wet chop reinforcing fibers are typically packaged and shipped in the form of "boxes" of individual fibers. In forming the composite material, bales of reinforcing fibers and organic fibers may be opened by opening systems, such as a bale opening systems, which are common in the industry. The opening system serves both to decouple the clustered bundles or strands and to enhance fiber-to-fiber contact.

[0049] Turning now to FIG. **2**, the opening of the reinforcing fibers **200** and organic fibers **210** can be seen. The reinforcing fibers **200** and the organic fibers **210**, typically in the form of bales, are fed into a first opening system **220** and a second opening system **230**, respectively, to at least partially open and/or filamentize (individualize) the wet reinforcing fibers **200** and organic fibers **210**. Although the exemplary process depicted in FIGS. **1** and **2** show opening the organic fibers **210** by a second opening system **230**, the organic fibers **210** may be fed directly into the fiber transfer system **250** (embodiment not illustrated) if the organic fibers **210** are present or obtained in a filamentized form, and are not in the form of a bale.

[0050] In alternate embodiments where the organic fibers **210** are in the form of a flake, granule, or powder (not illustrated) and not in a fibrous form, the second opening system **230** may be replaced with an apparatus suitable for distributing the flakes, powders, or granules to the fiber transfer system **250** so that these resinous materials may be mixed with the reinforcing fibers **200**. A suitable distribution apparatus would be easily identified by those of skill in the art. In embodiments where a resin in the form of a flake, granule, or powder is used in addition to the organic fibers **210** (and not in place of), the apparatus distributing the flakes, granules, or powder may not need to replace the second opening system **230**.

[0051] The first and second opening systems **220**, **230** can be bale openers, but may be any type of opener suitable for opening the bales of wet reinforcing fibers **200** and organic fibers **210**. The design of the openers depends on the type and physical characteristics of the fiber being opened. Suitable openers for use in the present invention include any conventional standard type bale openers with or without a weighing device. The weighing device serves to continuously weigh the partially opened fibers as they are passed through the bale opener to monitor the amount of fibers that are passed onto the next processing step. The bale openers may be equipped with various fine openers, one or more licker-in drums or saw-tooth drums, feeding rollers, and/or or a combination of a feeding roller and a nose bar.

[0052] The partially opened wet reinforcing fibers **200** may then be dosed or fed from the first opening system **220** to a condensing unit **240** to remove water from the wet fibers. In exemplary embodiments, greater than about 70% of the free water (water that is external to the reinforcing fibers) is removed. In certain embodiments, however, substantially all of the water is removed by the condensing unit **240**. It should be noted that the phrase "substantially all of the water" as it is used herein is meant to denote that all or nearly all of the free water is removed. The condensing unit **240** may be any drying or water removal device, many of which are known in the art, such as, but not limited to, an air dryer, an oven, rollers, a suction pump, a heated drum dryer, an infrared heating source, a hot air blower, or a microwave emitting source.

[0053] After the reinforcing fibers **200** have passed through the condensing unit **240**, the fibers may be passed through another opening system, such as a bale opener as is described above, to further filamentize and separate the reinforcing fibers **200** (embodiment not shown).

[0054] The reinforcing fibers **200** and the organic fibers **210** may be blended together by a fiber transfer system **250**. In certain embodiments, the reinforcing fibers **200** and the organic fibers **210** are blended in a high velocity air stream. The fiber transfer system **250** serves both as a conduit to transport the reinforcing fibers **200** and the organic fibers **210** to a sheet former **270** and to substantially uniformly mix the reinforcing fibers **200** and organic fibers **210**. It is desirable to distribute the reinforcing fibers **200** and the organic fibers **210** as uniformly as possible.

[0055] The ratio of reinforcing fibers **200** to organic fibers **210** entering the fiber transfer system **250** may be controlled by a weighing device such as described above with respect to the first and second opening systems **220**, **230** or by the amount and/or speed at which the fibers are passed through the first and second opening systems **220**, **230**. In certain embodiments, the ratio of reinforcing fibers **200** to organic fibers **210** present in the air stream is 50:50. However, it is to be appreciated that the ratio of fibers present within the air stream will vary depending on the desired structural and acoustical requirements of the final product.

[0056] In some embodiments of the invention, other types of fibers such as chopped roving, dry use chopped strand glass (DUCS), natural fibers (such as jute, hemp, and kenaf), aramid fibers, metal fibers, ceramic fibers, mineral fibers, carbon fibers, graphite fibers, polymer fibers, or combinations thereof may be opened and filamentized by additional openers (not shown), added to the fiber transport system **250**, and mixed with the reinforcing fibers **200** and organic fibers **210**, depending on the desired composition of the composite material. When such additional fibers are added, up to approximately 25% of the fibers in the fiber transfer system **250** consist of these additional fibers.

[0057] The mixture of reinforcing fibers **200** and organic fibers **210** exiting the fiber transfer system **250** may be transferred to a sheet former **270** where the blended fibers are formed into the acoustic core layer **12**. The blended fibers may be transported by the fiber transfer system **250** to a filling box tower **260** where the reinforcing fibers **200** and organic fibers **210** are volumetrically fed into the sheet former **270**, such as by a computer monitored electronic weighing apparatus, prior to entering the sheet former **270**. The filling box tower **260** may be located internally in the sheet former **270** or it may be positioned external to the sheet former **270**. The filling box tower **260** may also include baffles to further blend and mix the reinforcing fibers **200** and organic fibers **210** prior to entering the sheet former **270**. In one exemplary embodiment (not shown), the mixture of reinforcing fibers **200** and organic fibers **210** are blown onto a drum or series of drums covered with fine wires or teeth to comb the fibers into parallel arrays prior to entering the sheet former **270** (not illustrated), as in a carding process.

[0058] In addition, the acoustic core layer **12** formed by the sheet former **270** may be transferred to a second sheet former (not shown). The second sheet former assists in distributing the reinforcing fibers **200** and organic fibers **210** in the acoustic core layer **12**. The use of an additional sheet former may increase the structural integrity of the formed acoustic core layer **12**.

[0059] In some embodiments, a sheet former **270** having a condenser and a distribution conveyor may be used to achieve a higher fiber feed into the filling box tower **260** and an increased volume of air through the filling box tower **260**. In order to achieve an improved cross-distribution of the opened fibers, the distributor conveyor may run transversely to the direction of the acoustic core layer **12**. As a result, the reinforcing fibers **200** and the organic fibers **210** may be transferred into the filling box tower **260** with little or no pressure and minimal fiber breakage.

[0060] In at least one exemplary embodiment, the lengths of the organic fibers **210** are substantially the same as lengths of the reinforcing fibers **200**. The use of substantially similar lengths of the reinforcing and organic fibers **200**, **210** assists in uniformly distributing the fibers during the mixing of the reinforcing fibers **200** and organic fibers **210** in the fiber transfer system **250**, filling box tower **260**, and sheet former **270**.

[0061] The acoustic core layer **12** contains a substantially uniform distribution of reinforcing fibers **200** and organic fibers **210** at a desired ratio and weight distribution. The acoustic core layer **12** formed by the sheet former **270** may have a weight distribution of from 400-2500 g/m^2, and in certain embodiments, have a weight distribution of from about 800 to about 2000 g/m^2.

[0062] In one or more embodiments, the acoustic core layer **12** exiting the sheet former **270** may be subjected to a needling process in a needle felting apparatus **280** in which barbed or forked needles are pushed in a downward and/or upward motion through the fibers of the acoustic core layer **12** to entangle or intertwine the reinforcing fibers **200** and organic fibers **210** and impart mechanical strength and integrity to the acoustic core layer **12**. The needle felting apparatus **280** may include a web feeding mechanism, a needle beam with a needleboard, barbed felting needles ranging in number from about 500 per meter to about 7,500 per meter of machine width, a stripper plate, a bed plate, and a take-up mechanism. Mechanical interlocking of the reinforcing fibers **200** and organic fibers **210** is achieved by passing the barbed felting needles repeatedly into and out of the acoustic core layer **12**. An optimal needle selection for use with the particular reinforcing fibers **200** and organic fibers **210** chosen for use in the inventive process would be easily identified by one of skill in the art.

[0063] Either after the acoustic core layer **12** exits the sheet former **270** or after the optional needling of the acoustic core layer **12**, the outer strengthening layers **14**, **16** are fed from the supply **300** onto at least one major surface of the acoustic core layer **12** to form a multilayered intermediate **18**.

[0064] The first and/or second outer strengthening layers **14**, **16** are positioned on a major surface of the acoustical composite layer **12**, and may be attached to the acoustical composite layer **12** such as by a nip-roll system or by using a laminator (not shown).

[0065] The multilayered intermediate **18** is passed through a thermal bonding system **290**. During the bonding step, the reinforcing fibers **200** and organic fibers **210** of the acoustic core layer **12** are bonded together and the thermoplastic material of the outer strengthening layers **14**, **16** are bonded to at least one of the reinforcing fibers **200** and the organic fibers **210** in the acoustic layer **12**.

[0066] In the thermal bonding step, the thermoplastic properties of the organic fibers **210** are used to form bonds with the reinforcing fibers **200** upon heating. Also, in the thermal bonding system **290**, the multilayered intermediate **18** is heated to a temperature that is above the melting point of the organic fibers **210** but below the melting point of the reinforcing fibers **200**. When bicomponent fibers are used as the organic fibers **210**, the temperature in the thermal bonding system **290** is raised to a temperature that is above the melting point of the sheath fibers, but below the melting point of the reinforcing fibers **200**.

[0067] Heating the organic fibers **210** to a temperature above their melting point, or above the melting point of the sheath fibers in the instance where the organic fibers **210** are bicomponent fibers, causes the organic fibers **210** (or sheath fibers) to become adhesive and bond the organic fibers **210** and reinforcing fibers **200**. If the organic fibers **210** completely melt, the melted fibers may encapsulate the reinforcing fibers **200**. As long as the temperature within the thermal bonding system **290** is not raised as high as the melting point of the reinforcing fibers **200**, these fibers will remain in a fibrous form within the thermal bonding system **290** and composite material **10**.

[0068] Although the organic fibers **210** may be used to bond the reinforcing fibers **200** to each other, in certain embodiments, a thermoplastic or thermosetting binder resin **285** may be added to assist in the bonding of the fibers prior to passing the acoustic core layer **12** through the thermal bonding system **290**. The binder resin **285** may be in the form of a resin powder, flake, granule, foam, or liquid spray. The binder resin **285** may be added to the acoustic core layer **12** by any suitable manner, such as, for example, a flood and extract method or by spraying the binder resin **285** onto the acoustic core layer **12**. The amount of binder resin **285** added to the acoustic core layer **12** may be varied depending on the desired characteristics of the composite material **10**. A catalyst such as ammonium chloride, p-toluene, sulfonic acid, aluminum sulfate, ammonium phosphate, or zinc nitrate may also be used to improve the rate of curing and the quality of the cured binder resin **285**.

[0069] Simultaneously, the thermal bonding causes the binder material **320** in the outer strengthening layers **14**, **16** to be heated to a temperature above its melting point and causes the outer strengthening layers **14**, **16** to become adhesive and bond to the acoustic core layer **12**.

[0070] The thermal bonding system **290** may include any known heating and bonding method known in the art, such as oven bonding, oven bonding using forced air, infrared heating, hot calendaring, belt calendaring, ultrasonic bonding, microwave heating, and heated drums. Optionally, two or more of these bonding methods may be used in combination to bond the fibers in the acoustic core layer **12** and the outer strengthening layers **14**, **16** to the acoustic core layer **12**. The temperature of the thermal bonding system **290** may vary depending on the melting point of the organic fibers **210** used and whether or not bicomponent fibers are present in the acoustic core layer **12**.

[0071] Also, in certain embodiments, the acoustic material **10** passes through a compression system **350** to reduce the thickness of the acoustic core layer **12**. In certain embodiments, the acoustic core layer **12** can be reduced from a thickness of about 3 ½ inches to about ¼ inches. In certain embodiments, the compression system can be incorporated into or be within the thermal bonding system **290**, if desired.

[0072] The composite material **10** that emerges from the thermal bonding system **290** contains a uniform or nearly uniform distribution of organic fibers **210** and reinforcing

fibers **200**. The uniform or nearly uniform distribution of reinforcing fibers **200** and organic fibers **210** in the composite material **10** and the presence of the outer strengthening layers **14**, **16** provides improved strength, improved modulus and improved acoustical properties to the acoustic composite material **10**. In addition, the composite material **10** has substantially uniform weight consistency, which results in uniform properties such as flexural and impact strength in the acoustic composite material.

[0073] The physical properties of the acoustic composite material **10** such as strength, stiffness, and load distribution may be altered or tailored to meet specific requirements by altering the weight, K-value, thickness and/or type of foam or by the specific type of other core material used (such as balsa weight) in the core layer **12**.

[0074] It is now possible to optimize the physical properties of the acoustic composite material **10** (strength, stiffness, and load deflection) by altering the amount and/or type of the chopped strands **310** and/or binder material **320** used in the outer strengthening layers **14**, **16**.

[0075] In addition, the strength, stiffness, and load deflection of the acoustic composite material **10** may be optimized by altering the weight of the reinforcing and/or organic fibers, by changing the reinforcing fiber content and/or length or diameter of the reinforcing fibers, or by altering the fiber length and/or denier of the organic fibers used in the acoustic core layer **12**. Thus, the strength, stiffness, load deflection, and acoustic requirements (if any) of the acoustic composite material **10** may be altered or improved by the specific combination of fibers present in the acoustic composite material **10**, and the acoustic composite material can therefore be tailored to meet the needs of a particular application.

[0076] The acoustic composite materials **10** may then be laminated, such as by using a laminator or other type of moving belt press. The acoustic composite material **10** may be compression molded or thermoformed into various shapes. The acoustic composite material **10** may be molded or die-cut to form a desired acoustical, semi-structural final part in a one step process. The process of manufacturing acoustic composite materials may be conducted either in-line (in a continuous manner), or in individual steps. In certain embodiments, the process is conducted in-line. Moreover, any additional process steps such as adding specialty films, scrims, and/or other fabrics are considered to be within the scope of the invention.

[0077] The multilayer acoustic composite material **10** is especially useful in a number of both structural and non-structural acoustical applications. Examples of non-structural applications include, for example, appliances, office screens and partitions, ceiling tiles, and building panels. Examples of structural applications include, for example, automobiles (e.g., headliners, hood liners, floor liners, trim panels, parcel shelves, sunshades, instrument panel structures, door inners, and the like), basement finishing systems, and wall panels and roof panels of recreational vehicles (RV's).

[0078] The thickness of the formed composite product, porosity of the formed composite product (void content), and the air flow path may be controlled by changing the basis weight of the organic fibers and/or glass content of the acoustic core layer **12**. Additionally, the use of wet chopped strand glass in the dry-laid process as described above with respect to FIGS. **1** and **2** contributes to the improved sound absorption of the acoustic composite material **10** because the composite material formed by the dry-laid process has a higher loft (increased porosity). In addition, composite materials formed by the processes described herein have a uniform or substantially uniform distribution of reinforcing and organic fibers, thereby providing improved strength as well as improved acoustical and thermal properties, stiffness, and impact resistance.

[0079] It is another advantage that when wet use chopped strand glass fibers are used as the reinforcing fibers, the glass fibers may be easily opened and fiberized with little generation of static electricity due to the moisture present in the glass fibers. In addition, wet use chopped strand glass fibers are less expensive to manufacture than dry chopped fibers because dry fibers are typically dried and packaged in separate steps before being chopped. Therefore, the use of wet use chopped strand glass fibers allows the composite product (and acoustic composite material) to be manufactured with lower costs.

[0080] The acoustic composite material **10** reduces the cycle time, materials, and labor cost needed to provide acoustic products having desired acoustic and strength properties. For example, when automotive interior panels or load floors are conventionally manufactured, additional layers of materials are added to the panels/floors to increase the flexural strength of the panels/floors.

[0081] Because of the high strength and high flexural modulus of the acoustic composite material **10**, there is no need to add a secondary material to the final acoustic product to achieve the desired strength. The elimination of these secondary materials reduces the amount of materials needed to form such interior acoustic and structural panels for automobiles and RVs and eliminates a manufacturing step (i.e., installing the secondary materials), thereby increasing overall productivity and decreasing cycle time.

[0082] In addition, the properties of the acoustic composite material **10** can be optimized for specific end-use applications by altering the amount and/or weight of the fibers in the different layers, by changing the glass content and/or length or diameter of the glass fiber, by altering the polymeric fiber length or denier, or by changing the formulations of the fibers in each of the layers during the manufacturing of the formed composite product.

[0083] In certain embodiments, for example, decreasing the weight and content of the organic fibers **210** in the acoustic core layer **12**, allows for a decrease in the thickness of the acoustic core layer **12** without sacrificing the desired strength and flexural modulus of the acoustic composite material **10**. The increased flexural strength of the composite material **10** allows the composite material to better resist deformation under load.

[0084] The use of the outer strengthening layer(s) **14**, **16** reduces the amount of organic fibers **210** needed in the acoustic core layer **12**. The acoustic material **10** has desirable properties that allow it to compete favorably with higher basis weight materials, but still be produced at faster rates, using fewer materials. In certain embodiments, the acoustic core layer **12** can have a weight distribution with basis weights ranging from about 400 to abut 2500 g/m^2, and in certain embodiments, can have a weight distribution of from about 600 to about 1000 g/m^2. The outer strengthening layer(s) **14**, **16** can have a basis weight distribution ranging from about 100 to about 200 g/m^2.

EXAMPLES

[0085] In one example, an acoustic composite material **10** can have an acoustic core layer **12** with a basis weight of about 800 g/m^2 and first and second outer strengthening layers **14**,

16 each having a basis weight of about 100 g/m^2, thus providing the acoustic composite material **10** with an overall basis weight of about 1000 g/m^2.

[0086] In another example, an acoustic composite material **10** can have an acoustic core layer **12** with a basis weight of about 1400 g/m^2 and first and second outer strengthening layers **14**, **16**, each having a basis weight of about 200 g/m^2, thus providing the acoustic composite material **10** with an overall basis weight of about 1800 g/m^2.

[0087] In still another example, an acoustic composite material **10** can have an acoustic core layer **12** with a basis weight of about 1000 g/m^2 and first and second outer strengthening layers **14**, **16** having basis weights of about 100 g/m^2 and 200 g/m^2, respectively, thus providing the acoustic composite material **10** with an overall basis weight of about 1300 g/m^2.

[0088] The data in the Table 1, shown in FIG. **4**, shows a comparison between multilayer acoustic composite materials and acoustic core layers. In the examples shown in Table 1, the multilayer acoustic composite materials (AMax+GMat) are formed of different basis weight acoustic core layers (AMax) having different basis weight outer strengthening layers (GMat). In the examples shown in Table 1, the "AMax" acoustic core layers (Compar. #1, #2, #3) had basis weights of 1000 g/m^2, 1200 g/m^2 or 1400 g/m^2. The "AMax+GMat" multilayer acoustic composite materials had opposing outer strengthening layers having basis weights of 100 g/m^2 or 200 g/m^2.

[0089] The data in Table 1 show the stiffness (N/mm) molded @ 5 mm) in both the machine direction (MD) and the transverse direction (TD) for various examples. The acoustic composite materials have desirably high strength and high flexural modulus properties.

[0090] The composite materials A and B, having a 1400 g/m^2 core layer, had increases in stiffness of about 42% and 55%, respectively, over the 1400 g/m^2 core layer alone Compar. # 3.

[0091] The composite materials C and D, having a 1200 g/m^2 core layer, had increases in stiffness of about 42% and 52%, respectively, increases in stiffness over the 1200 g/m^2 core layer alone Compar. # 2.

[0092] The composite materials E and F, having a 1000 g/m^2 core layer, had increases in stiffness of about 17% and 42%, respectively, over the 1000 g/m^2 core layer alone Compar. # 1.

[0093] The composite material **10** forms a final product that demonstrates improved structural and acoustical properties. Although not wishing to be bound by theory, the improved structural properties (e.g., strength and modulus properties) of the final composite material product are believed to be attributed to the various combinations of polymeric fibers and glass fibers of different physical properties (e.g., lengths and diameters) in the acoustical composite layer **12**. It is also believed that the improved strength properties of the final part may be attributed glass fibers in the outer strengthening layers **14** and **16**.

[0094] The high strength, high modulus acoustic composite material may be molded (e.g., thermo-formed or thermo-stamped) or die-cut to form a desired acoustical, semi-structural final product in a one step process.

[0095] The high strength, high modulus acoustic composite material optimizes the properties needed for specific applications by altering the weight of the fibers in the different layers or by changing the formulations of the fibers in each of the layers during the manufacturing of the product. The thickness of the formed composite product, porosity of the formed composite part (e.g., void content), and the air flow path may be controlled by changing the basis weight of the polymer fibers and/or glass content of the acoustical composite material.

[0096] While the compositions and methods of this invention have been described in terms of the foregoing illustrative embodiments, it will be apparent to those skilled in the art that variations, changes, modifications, and alterations may be applied to the compositions and/or methods described herein, without departing from the true concept, spirit, and scope of the invention.

[0097] The above descriptions of the preferred and alternative embodiments of the present invention are intended to be illustrative and are not intended to be limiting upon the scope and content of the following claims.

1-10. (canceled)

11. An acoustic composite material comprising at least one outer strengthening layer and an acoustic core layer next to a major surface of the at least one outer strengthening layer, the acoustic core layer comprising dehydrated reinforcing fibers and organic fibers.

12. The acoustic composite material of claim **11**, wherein the acoustic core layer comprises a substantially homogenous mixture of the dehydrated reinforcing fibers and the organic fibers.

13. The acoustic composite material of claim **11**, wherein at least some of the dehydrated reinforcing fibers and the organic fibers in the acoustic core layer are bonded to the outer strengthening layer.

14. The acoustic composite material of claim **11**, wherein the dehydrated reinforcing fibers are formed from wet reinforcing fibers.

15. The acoustic composite material of claim **14**, wherein the wet reinforcing fibers in the acoustic core layer are wet use chopped strand glass fibers.

16. The acoustic composite material of claim **11**, further includes a facing layer on at least one exposed major surface of the outer strengthening layer.

17. The acoustic composite material of claim **11**, wherein the acoustic core layer is thermally bonded to the outer strengthening layer.

18. The acoustic composite material of claim **11**, wherein the first and second outer strengthening layers are on opposing major surfaces of the acoustic core layer.

19. The acoustic composite material of claim **11**, wherein the outer strengthening layer comprises a chopped strand mat.

20. The acoustic composite material of claim **19**, wherein the first and second outer strengthening layer comprises a chopped strand mat.

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