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United States Patent [19]

Tailor et al.

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[54] **FABRIC-FACED THERMOPLASTIC COMPOSITE PANEL**

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[21] Appl. No.: **196,925**

[22] Filed: **Feb. 15, 1994**

[51] **Int. Cl.**^{6} **B32B 5/04**; B32B 5/12; B32B 5/28

[52] **U.S. Cl.** .... **428/110**; 12/142 N; 12/146 D; 12/146 M; 12/146 S; 36/71; 36/145; 36/154; 36/DIG. 2; 156/176; 428/35.7; 428/36.1; 428/36.2; 428/111; 428/195; 428/196; 428/226; 428/230; 428/231; 428/232; 428/236; 428/238; 428/239; 428/246; 428/294; 428/542.8

[58] **Field of Search** 428/231, 232, 428/236, 238, 196, 36.1, 542.8, 110, 111, 226, 230, 239, 246, 294; 156/176

[56] **References Cited**

U.S. PATENT DOCUMENTS

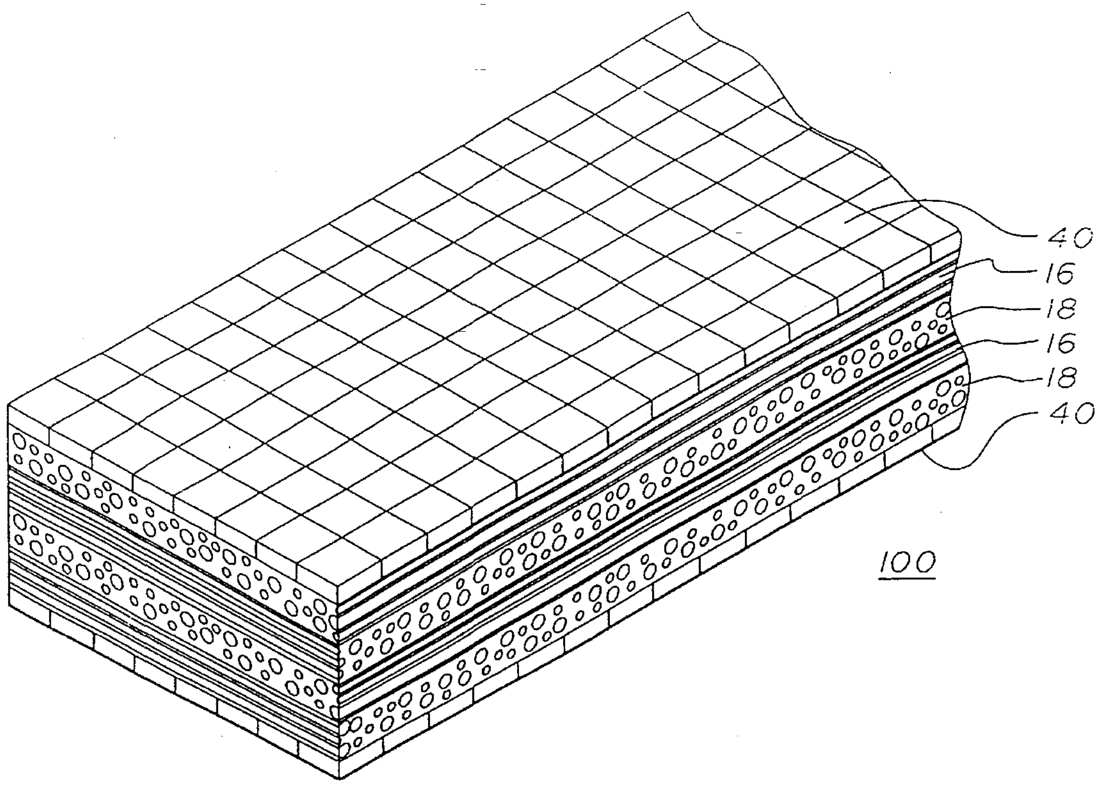
4,651,445	3/1987	Hannibal .
4,778,717	10/1988	Fitchmun .
5,082,701	1/1992	Craven et al. .

Primary Examiner—James C. Cannon
Attorney, Agent, or Firm—Duane, Morris, & Heckscher

[57] **ABSTRACT**

Polymer matrix composite materials containing a thermoplastic composite core bonded integrally with a fabric layer are provided. The fabric layer has a greater elasticity than the core, so that the fabric layer can conform smoothly to the core during thermoforming. This improvement has been demonstrated to improve aesthetic appearance and nearly eliminate wrinkling and distortion of the fabric layer when compared to conventional composite materials.

23 Claims, 3 Drawing Sheets



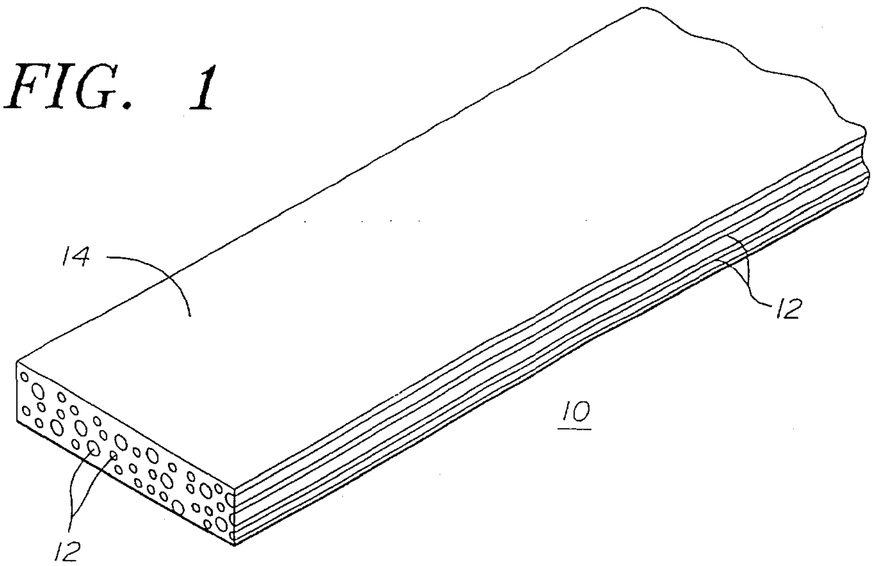


FIG. 1

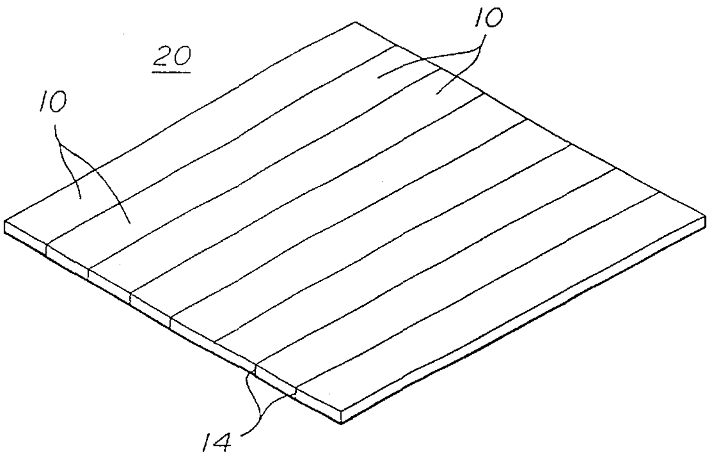


FIG. 2

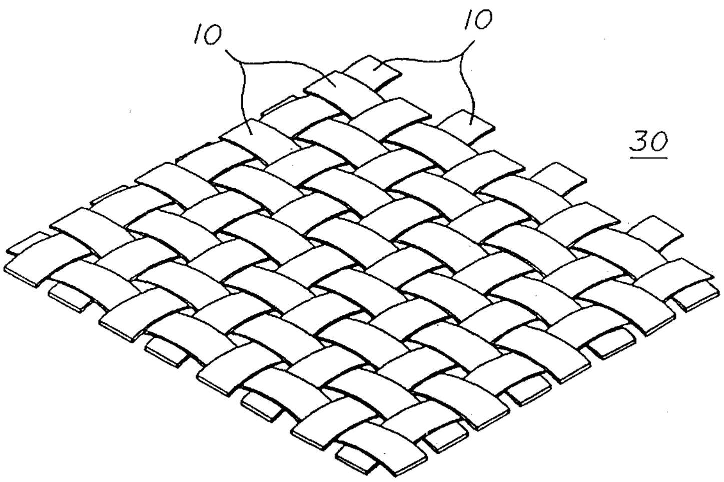


FIG. 3

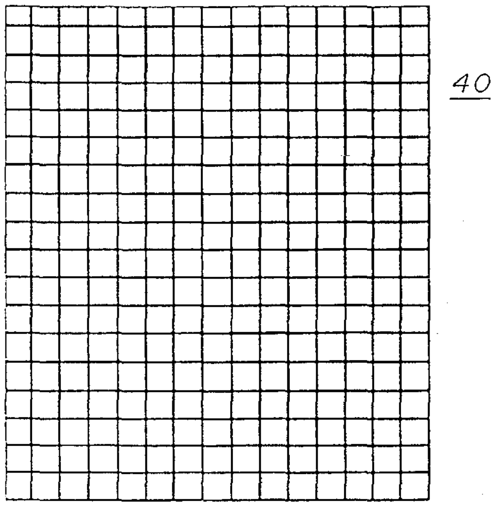


FIG. 4

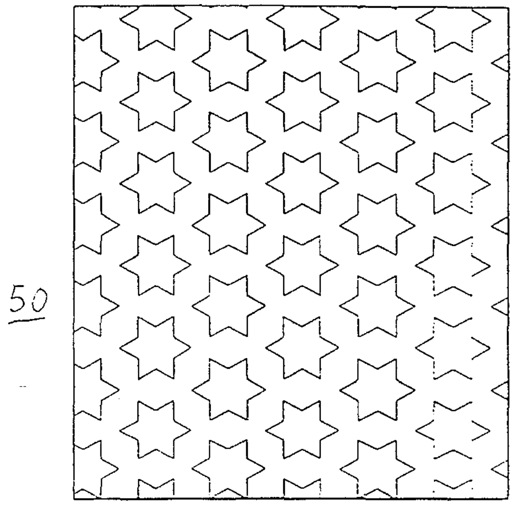


FIG. 5

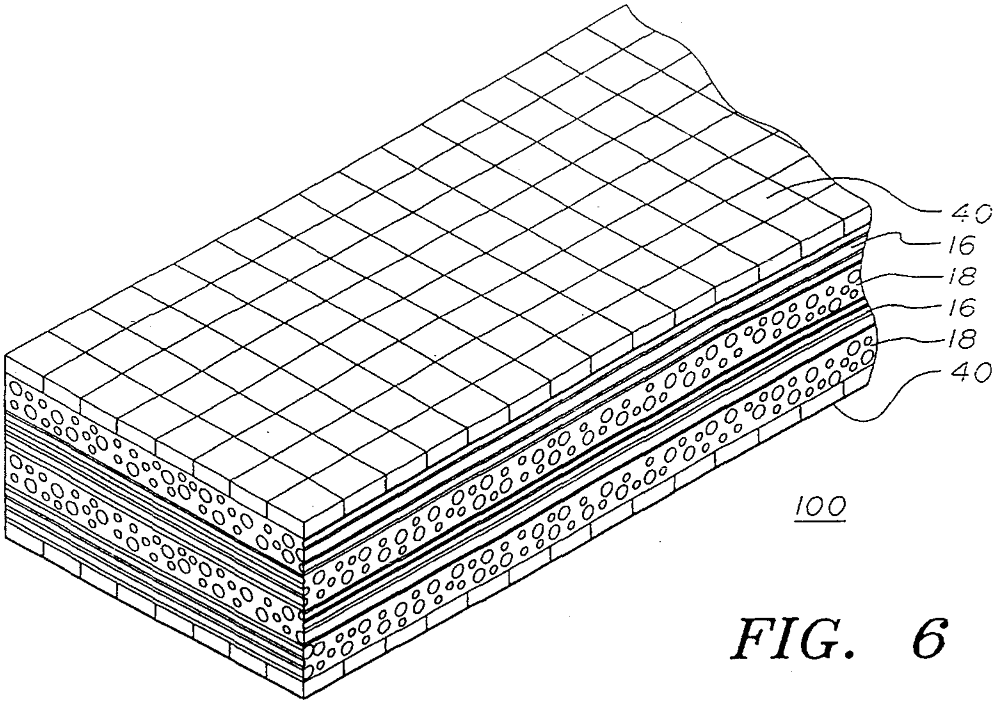


FIG. 6

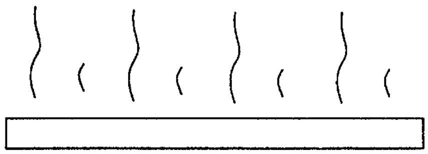


FIG. 7a

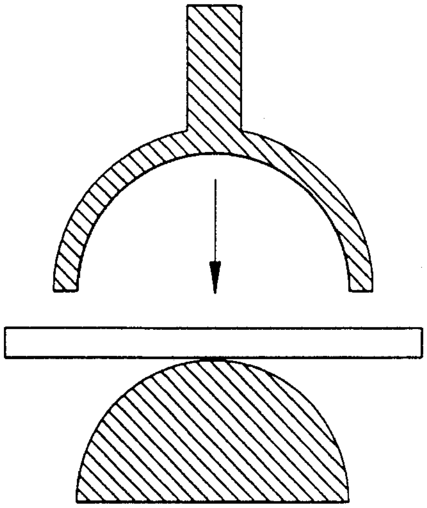


FIG. 7b

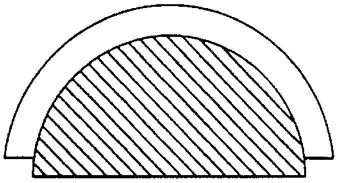


FIG. 7c

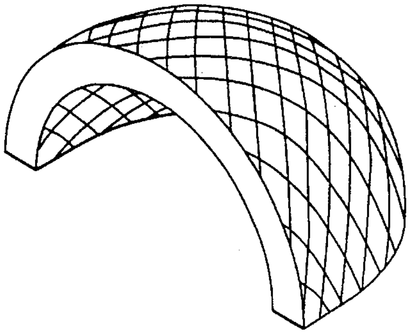


FIG. 7d

FABRIC-FACED THERMOPLASTIC COMPOSITE PANEL

FIELD OF THE INVENTION

This invention relates to polymer matrix composites, and more particularly, to thermoplastic composite materials that include a fabric facing for improving aesthetics and properties.

BACKGROUND OF THE INVENTION

Unreinforced engineering thermoplastics typically have tensile strengths that range from 8,000 to 15,000 psi. One popular engineering plastic, nylon 6/6, has a tensile strength of 12,000 psi and a tensile modulus of 500,000 psi. However, to compete with metals in applications ranging from automobiles to tennis rackets, plastics typically need to be reinforced to improve their mechanical properties.

Reinforcing thermoplastics and thermosets dramatically increases their strength. For example, short glass fibers at 30 wt. % loading can boost the tensile strength of engineering plastics by a factor of about two. Some advanced polymer-matrix composites (PMCs) have higher specific strength and stiffness than metals. Advanced composites reinforced with high modulus carbon fiber, for example, are known to have a tensile modulus of about 12.0 million psi and a tensile strength of 165,000 psi, but are much lighter than aluminum.

Polymer matrix composites are available in fiber-reinforced thermoset matrixes or fiber-reinforced thermoplastic matrixes. The thermoset matrixes typically include epoxy or polyester resins which harden through a catalytic process. The primary disadvantage of these systems has been that the resins include a hardener/catalyst to cure them, and this results in a limited shelf-life which may require refrigeration. This irreversible catalytic process requires a long curing cycle prior to hardening, and when these resins have finally set, they cannot later be thermoformed into a different configuration. Thermosets are also known to exhibit low ductility.

Because of their inherently faster processing time—no time-consuming curing or autoclaving—thermoplastic matrix composites are beginning to replace conventional thermoset composites. In the aircraft and aerospace sectors, current development work in thermoplastics is showing promising results for typical laminated structures, filament winding, and pultrusion. Several thermoplastic composite components have flown on United States Naval and Air Force jets in demonstration programs, and initial applications have included various access doors and outer wing panels on the Navy's F-18 fighter.

In order to obtain the maximum performance of thermoplastic composites in a given direction, continuous oriented fibers are lined in that direction in the composite. To improve the overall strength of the composite in all directions, these fibers can be alternated in succeeding layers to obtain multi-axial orientation and performance. The maximum performance of a thermoplastic composite is realized when each of the fiber filaments is wetted out by the resin, and when these wetted filaments are uniformly dispersed in the composite's cross-section.

The wetting of fiber filaments with thermoset resins is very efficient, since these resins tend to be low viscosity liquids. Thermoplastic resins usually require heat to melt them, and even then, they form a highly viscous melt, which does not readily flow to wet out the fiber filaments. Accordingly, special methods have been developed to produce unidirectional thermoplastic composites with good wet-out and uniform fiber dispersion.

One of these methods involves passing continuous fibers through a fluidized bed of thermoplastic resin powder. The powder penetrates into the web of the fibers, and the coated fibers are then heated and formed into a tape configuration. Alternatively, the fibers can be extruded through a melt of thermoplastic polymer, followed by shaping the coated fiber bundle. Still other methods of impregnating these fibers are to pass them through a solution in which a thermoplastic polymer powder is suspended, or sandwiching them between films of polymer. Other methods included passing the fiber through solvated resins, or through liquid partially polymerized or unpolymerized resins. The unidirectional tape can also be made using fibers of resin commingled with reinforcing fibers.

The end result of these impregnation methods is basically the same. A tape is produced in which there are continuous fibers in the axial or longitudinal direction, and these fibers are encapsulated within a given thermoplastic resin.

Fabrication of finished parts from fiber-reinforced thermoplastic composite unidirectional tapes has followed the especially labor-intensive process developed for fiber-reinforced thermoset composite unidirectional tapes. That is, these tapes are typically laid in successive laminated layers at predetermined angles to obtain the desired structural properties in a finished format of greater dimensions than the individual tapes. The tapes can be processed by hand, or with complicated, and often expensive, automatic tape laying machinery. Unlike fiber-reinforced thermoset tapes, which are more suitable for fabrication by these methods because they remain tacky until cured and can be held in a set position, lay-up fiber-reinforced thermoplastic tapes usually require that each tape be tacked, welded, or stitched in position before laying the next tape. These thermoplastic composite tapes can be difficult to mold since they are also known to be "stiff and boardy".

In order to produce a panel from these thermoplastic unidirectional tapes, techniques have been developed to hold them together prior to molding. One method disclosed in U.S. Pat. No. 5,082,701 suggests that the unidirectional fiber-reinforced thermoplastic tapes can be interlaced in an over-and-under relationship in a 0°/90° configuration. The interlaced material is then subjected to heat and pressure in single or multiple layers to form an integral panel. Alternatively, the tapes can be placed adjacently and seamed side-to-side, to produce a wide unidirectional sheet. In another method, the commingled resin/reinforcement fibers are woven into a fabric, and layers of this fabric are consolidated into a laminate by pressing or thermoforming. Laminates can also be produced by placing films of resin between layers of reinforcement fabric (woven or unwoven) and impregnating the fabric with the film by heat and pressure.

Preferably, the resulting sheets are placed on top of one another and then laminated together in a compression molding press. Additional polymeric films can be placed on top of the initial assembly, particularly over the woven sheets, to fill up the voids due to undulations of the woven pattern.

While such panels have successfully tackled the wet-out and uniform dispersion problems associated with impregnating fiber bundles with thermoplastic resin, there have been several drawbacks to these fabrication methods.

When the panels are thermoformed to extreme contours, as in deep drawing, there is a tendency for the panels to

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