# United States Patent [19]

**Hilton**

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[54] **RIGID LAMINATE OF CREPED SECONDARY FIBER SHEETS**


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[51] **Int. Cl.** .................... **B32b 5/12**

[58] **Field of Search** .................... 161/128, 129, 132, 161/133, 135, 136, 156, 56; 162/111, 112; 264/282, 283; 156/183



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,992,215 | 2/1935 | Kellett | 161/129 |
| 2,143,911 | 1/1939 | Fourness | 161/129 |
| 3,424,643 | 1/1969 | Lewis et al. | 161/136 |
| 3,014,832 | 12/1961 | Donnelly | 264/283 |
| 2,996,424 | 8/1961 | Voigtman et al. | 162/112 |
| 1,969,938 | 8/1934 | Mosher | 162/112 |
| 3,668,054 | 6/1972 | Stumpf | 161/128 |
| 2,754,236 | 7/1956 | Hermanson | 161/129 |
| 2,314,876 | 3/1943 | Greene | 161/129 |
| 3,477,084 | 11/1969 | Thomas | 161/129 |
| 2,042,586 | 6/1936 | Campbell et al. | 161/136 |



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[57] **ABSTRACT**

Sheets of primarily wood fiber laminated to form panels, boards and beams with mechanical and aesthetic properties similar to those of natural wood. The heavily ribbed sheets can be formed from pulp containing very low quality fibers, such as those recoverable from the paper and paperboard portions of municipal waste. A creping process imparts the ribbed structure to the lamina giving the material directional strength characteristics analogous to natural wood. Properties measured parallel to the ribs, like wood properties measured along the grain, are different than those measured in the opposite direction in the material.

**1 Claim, 3 Drawing Figures**


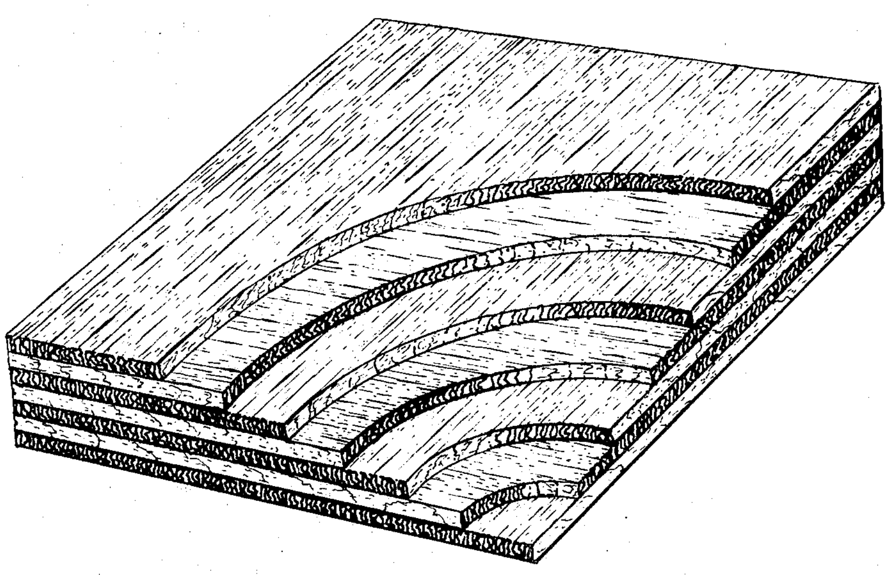

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FIG. 1

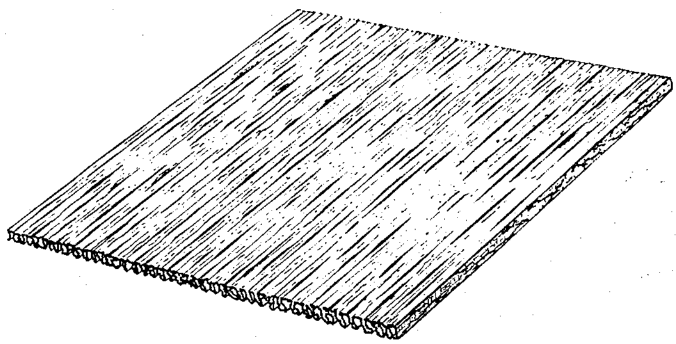


FIG. 2

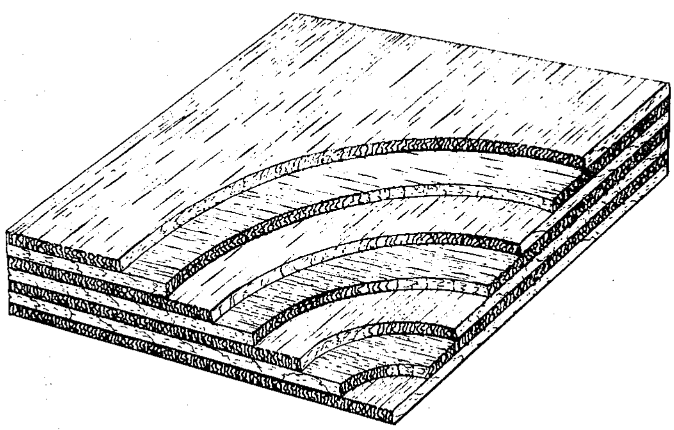
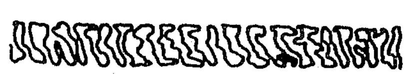


FIG. 3



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# RIGID LAMINATE OF CREPED SECONDARY FIBER SHEETS

A nonexclusive, irrevocable, royalty-free license in the invention herein described, throughout the world for all purposes of the United States Government, with the power to grant sublicenses for such purposes, is hereby granted to the Government of the United States of America.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

Rigid construction material laminated from creped sheets of wood fibers, or other vegetable, mineral or synthetic fibers.

2. Description of the Prior Art

Three categories of manufactured wood-based products are in wide use as construction materials: veneer laminates, including plywood, made from thin sheets of wood bonded together; particleboards formed from wood chips combined with resin; and fiber-based products consisting of individual wood fibers, generally in an aqueous suspension or pulp, reassembled to form the final material.

Within the field of wood fiber-based construction materials there are essentially four product types in two broad classes. Insulating board and hardboard are both classified as fiberboards, they are manufactured directly from the wood fibers. Laminated paperboard and PAPREG use sheets of paper formed from the fibers as an intermediate step in manufacture and are classified as laminated paper products.

Most insulating board is manufactured by a simple process: the pulp is deposited on a forming medium where the water drains from the fibers creating a wet lap which is then pressed between one or more pairs of press rolls and dried by hot air. This single operation forming dictates the use of relatively fast draining (high freeness) pulps for all but the thinnest boards. At one time insulating boards were often formed from pulps containing large amounts of refuse vegetable fibers but requirements for increased product uniformity have led to the predominant use of pulpwood. Recycled fibers such as newsprint are utilized in limited quantities and only where the source quality and uniformity can be well controlled. Insulating board is a low density material, generally below 32 lbs./cu. ft. The physical properties of this board limit it to predominantly interior non-load-bearing applications; low in both strength and resistance to water absorption, untreated boards are not suitable for exterior use.

Hardboard, e.g. Masonite (a registered trademark), is also formed directly from a pulp, but the process is more complex, requiring consolidation under heat and pressure. The pulp is made from wood chips either exploded against a target at high pressure or steamed and disc refined. The web is formed directly on a screen between the heated platens of a hydraulic press or on a fourdrinier machine with subsequent consolidation in a multiple-opening hot press. This high density (specific gravity of 0.5 to 1.5) product is harder than most natural wood and has approximately the same strength but is commercially available only in relatively thin panels. The need for uniformity and close tolerances have dictated the use of pulpwood rather than recycled fibers in hardboard manufacture.

Laminated paperboard consists of sheets of high quality paper adhesively bonded at relatively low pressure and temperature. The physical properties of the board directly correlate with the strenth of the paper. Panels one-eighth to three-eighths inch thick are used for wall and ceiling construction with water resistant grades available for exterior applications. The low density, approximately 32 lbs./cu. ft., material is not strong and is generally not specified for structural load-bearing applications.



PAPREG is a high strength product formed when sheets of high quality paper are impregnated with resin and laminated at high pressure and temperature. The high resin content, 30 to 40 percent by weight, products are often described as paper-base plastic laminates. The properties of PAPREG are directly inherited from the strength and quality of the paper utilized. The combination of high quality paper, large quantities of resin, and high pressure presses made PAPREG an expensive product which is, however, extremely strong, hard, and water resistant.

All of these products—insulating board, hardboard, laminated paperboard, and PAPREG—display physical properties which directly depend on the characteristics of their most basic constituent, the wood fiber. Factors such as fiber length and quality (measured indirectly as pulp freeness), the bonding between fibers, and the nature of the resin interaction with the fibers each contribute directly to the quality of the finished product.

Product dependence on fiber characteristics acts as a barrier to producing these types of boards using pulps obtainable from recycled waste. Three factors are present:

a. Quality. The pulp quality obtainable from mixed papers separated from municipal solid waste is low, typical refined (to obtain uniform fiber content) freeness is below 200 ml. C.S. (Canadian Standard). The use of such pulps would have a deleterious effect on the quality of most of these boards.

b. Uniformity. The changing nature of the constituents of mixed waste results in pulps of varying quality. This increases the difficulty of maintaining tight production tolerances on board specifications.

c. Impurities. These include clay and other fillers which may be part of the paper being recycled as well as nonpaper items such as plastics, dirt, wood, and cloth fibers which are unavoidable with present solid waste separation means. These pulp impurities affect both the quality and, to the extent they are localized, the uniformity of these boards.

At least one wood fiber-based material has partially overcome this tight relationship between fiber quality and product strength. Corrugated paper laminates are a reasonably stiff material suitable for a wide variety of packaging requirements. This strength is derived at least in part from the structure; the corrugating medium from which the material is formed is not a high quality pulp compared to those used in other papermaking processes. Each layer contains a series of even, open ridges which contribute to the laminate's strength as well as making it relatively crushable. As a sandwich-type construction, this strength is, however, limited by the inherent tensile strength of the skin of the material, a factor which is not independent of fiber quality. A low density material with little water resistance, corrugated paper also does not have the hardness or strength characteristics required in a structural material.

## SUMMARY OF THE INVENTION

The invention disclosed is a rigid structural material made from wood fibers, a laminate of heavily creped paper sheets. Less expensive and simpler to manufacture than hardboard or PAPREG and stronger than most insulating board, laminated paperboard or corrugated paper, this material can be produced from much lower quality pulps than are generally used to manufacture any of these other products.

The geometric configuration of each lamina seems to contribute much to the strength of the laminate. Tight flutes formed in the creping process are retained in each sheet giving it sharply directional strength characteristics. Sheets are extremely pliable when bent along the folds introduced by creping, but in the opposite direction their same tubelike structure stiffens the lamina. Because of this directionality, the strength characteristics of the final laminate can be varied by assembling the lamina in different orientations. Upon lamination these assemblies are compacted into formations of high density tubes or cells adjacent to one another throughout the formed product.

The paper lamina can be made from a wide range of pulps. Low quality, slow draining pulps with freeness of 100 to 150 ml. C.S. (Canadian Standard) made of recycled paper and paperboard products separated from municipal solid wastes have been successfully used. Higher quality pulps from part or all pulpwood can also be employed. In this respect groundwood or high yield semi-chemical pulps, which can be efficiently produced with little pollution but now have limited markets, are especially suitable. Pulp impurities, a common problem in secondary fiber pulps produced from machine separated municipal solid waste, seem to have little effect on the physical quality of the laminate. Deinking, a process required in most secondary fiber operations, is not needed.

Conventional papermaking equipment and processes can be used to form and crepe the lamina. In creping the length compression, called "creping ratio," is typically between 3 to 1 and 10 to 1 and can be even higher. Unlike many other creped paper products this crepe is retained in the paper.

Lamination of the creped sheets is also accomplished by conventional means. A variety of adhesives has been successfully employed, selection is on the basis of the environment of the laminate, desired physical characteristics, and cost. Single or multiple-opening hot presses are used to bond the sheets. Because of the tubular structure of the lamina the material is self venting, expelling the gases and steam generated during press drying, and the usual venting during lamination is eliminated. This structure also allows the density of the laminate to be controlled, lamination at higher pressure crushes the flutes together, increasing the density. The material has been produced in this manner with densities from 20 to 70 pounds per cubic foot.

The primary object of this invention is to provide a rigid structural material which can be easily manufactured from low quality, recycled fibers. Another object of this invention is to provide a utility for secondary fibers from mixed papers obtainable by even inefficient separation methods from municipal solid waste. Another object is to divert the lowest quality recovered fibers or low quality fibers from other sources into this relatively long-term utilization leaving higher quality fibers to be recycled into more transient products. This promotes the efficiency of the entire secondary fiber recycling operation by removing the lowest quality fibers from the "loop," leaving the better, more reusable fibers for the products most rapidly disposed of.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of a single creped sheet.
FIG. 2 is a cut-away view of a cross-ply laminate.
FIG. 3 is a cross section view of a single creped sheet.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

The following example is illustrative of the preferred utilization of the lowest quality secondary fibers in my invention. The use of better pulps, while not promoting the environmental goals of the inventor, will provide an equally satisfactory laminate. The basic processes and equipment described are conventional, a variety of alternatives will be apparent to persons of ordinary skill in the papermaking art.

Pulp Preparation

An acceptable pulp was obtained entirely from separated household wastepaper normally discarded with other refuse. Samples disclosed the average contents to be 47 percent newspapers, 13 percent magazines, 12 percent strong papers (including brown paper and bags, dark-colored bags, corrugated cartons, and milk cartons), and 28 percent all other papers and non-paper impurities mixed.

The wastepapers are pulped in a modified commercial pulper. Hot water at 190° F. separates the polyethylene plastic coating from milk cartons improving the ability of the pulper to break down the paper. The high temperature also improves the pulping of wet-strengthened papers. Approximately 120 pounds (ovendry weight) of mixed wastepaper is pulped in each 30 minute batch. A pump draws the pulp through an extraction plate surrounding the rotor. This pulp is passed through a centrifugal cleaner and returned to the pulper tub. At the end of each batch the pulp is routed from the cleaner to a holding chest.

Besides forming a pulp, the pulper serves as a wet separation means to remove some impurities. Large heavy particles which cannot pass through the extraction plate are removed from the junk trap near the bottom of the tub. These rejects include pieces of metal, rags, glass, wood, and plastic. Other, less dense, large pieces of material remain as residue on the bottom of the pulper tub. Pieces of plastic, cloth, and wood as well as lumps of pulp are removed after each batch. Finally the centrifugal cleaner removes staples and other bits of metal, small pieces of glass and hard plastic, and similar small, high-density materials.

It should be noted that none of these separation methods is particularly suited to removing small low density impurities such as dirt and small bits of plastic: they remain in the plup. The materials which are rejected and hand sorted: glass, metal and hard plastic are discarded; soft materials including pulp, soft plastic, rags, and wood are fed through a disc refiner to break them into small particles which are added to the pulp in the holding chest.

At this stage the pulp still is not uniform; it contains fiber bundles and plastic particles. To achieve uniform particle size the pulp is disc refined at zero setting of the refiner. As a result of this process the pulp freeness is reduced from 350 to 400 ml. C.S. (Canadian Standard) to 125 to 175 ml. Although the particle size is thus made more uniform the nature of the ingredients is not; the solids content of the pulp is approximately 90 percent fiber (nearly all wood) and 10 percent non-fibrous material. Before the pulp is conveyed to the paper machine 0.75 percent rosin size is added.

Sheet Formation

As pulp flows onto the wire of a Fourdrinier paper-making machine a wet web is formed. Most of the water is removed in the wet press section of the machine, the sheet has 45 to 50 percent solids content at this point. A typical sheet is 0.011 inches thick with a basis weight of 50 grams per square meter.

The characteristic fluting of the sheets is accomplished by creping. The wet web is couched onto a rotatng drum and the crepe is introduced as it is removed by a doctor blade. The flat-nosed, 0.050 inch thick, blade is held against the drum at an angle of 60° from tangent. As the drum rotates the blade exerts pressure against the web which buckles, forming a plurality of ridges across its entire width as it is pushed off the drum. This compresses the sheet in length, the amount of compression is measured by the "creping ratio" between the original and fluted lengths.

The creped sheet is dried, typically in the dryer section of the papermaking machine, to 55 to 95 percent solids content. The tight flutes give the material its desirable strength qualities, to prevent pulling out these folds the dryer end of the papermaking machine must be carefully adjusted, the ratio between the machine speeds at the wet and dryer ends should be the same as the creping ratio. To improve the handling characteristics of the sheets and prevent pulling the crepe out two sheets can be adhesively bonded together as they leave the dryer. The two-ply material resists elongation and yet remains reasonably pliable.

Sheet Characteristics

As can be seen in FIG. **1**, a striking characteristic of a sheet is the large number of substantially parallel ridges running across it. The number of these ridges per unit length depends on the thickness of the sheet and the process used to impart the flutes. Thin sheets will have a finer crepe, i.e., more flutes per inch, than thick sheets creped under the same conditions. The process used to impart the flutes determines not only their average density but also the variation in fluting across a single sheet. Creping by the process described above produces irregular fluting, measurements made at various locations on a single sheet may show from 15 to 30 flutes per inch. Alternative creping/fluting processes generally are more uniform. These methods include forming ridges by passing the wet web or a dry sheet between fine gear teeth or by forming the pulp initially in the fluted rather than flat configuration. Because the fluting rate may vary widely, it is not the most precise measurement to define and characterize this material.

Another distinguishing feature of these sheets is the compacted nature of the flutes. As can be seen in a typical cross-section in FIG. **3**, the material is tightly packed in contrast to the more even, open structure of corrugated board or the like. The folds are so tight that a substantial portion of the flutes are closed, the fabric forming one side of the flute touches the fabric forming the other side. This forms tubular voids within the lamina. The sheet is unique in the amount of fabric which is contained in a unit volume of the fluted sheet. The dimensional relationships between the fluted sheet and the fabric of which it is formed are the best means of quantifying this compacted structure.

The creping ratio or, more broadly for any method of fluting, the length compression ratio, compares the length of the fluted sheet to the length of the basic fabric used, as if the flutes were pulled out. A length compression ratio of at least 3:1 is needed to begin to impart the desired strength characteristics. The creping process described gives that material an average creping ratio of 7:1. Length compression ratios of 10:1 or higher may be used.

A second dimensional quantity with which to describe the compacted flute structure is the ratio between the thickness of the basic fabric and the fluted sheet. In the process described above this ratio is approximately 8:1, the 0.011 inch fabric is formed into a plurality of convolutes measuring 0.090 inch from top to bottom. The typical range for this is between 8:1 and 10:1 and an upper limit is a 15:1 ratio. These measurements apply to the individual sheets after creping; during lamination the flutes are compressed in thickness.

Another important lamina characteristic can be expressed using a conventional papermaking measurement: basis weight. This is the weight of a unit area of the paper at zero moisture content. The basis weight of the paper made from the low freeness pulp described above is approximately 50 grams per square meter before creping and becomes about 500 grams per square meter creped.

Laminate Fabrication

Lamination is the final step in the manufacturing process. Here again the methods, equipment, and material used are conventional. Dried sheets of the creped base material are cut to the desired size, coated with adhesive, laid up in a press, and hot pressed. The resulting laminate is oven-cured. Alternatively, continuous laminates can be produced by applying pressure through heated rollers or the like.

Phenolformaldehyde applied to one side of each sheet gives good bonding. Other alcohol-soluble, as well as water-soluble, phenolic resin adhesives may be used. Minimum tested resin content has been 3 percent (of laminate weight) with excellent results at 12 percent and above. Clay or diatomaceous earth fillers up to 50 percent of the resin weight can be used. I have also successfully laminated the creped base material with starches, latices, sodium silicate, and similar conventional adhesives. The adhesives can be applied to the surface of the creped sheets or they can be applied to the fabric before it is creped or even mixed with the pulp before the paper is formed.

In the lamination press the laid up sheets are compressed to a fixed thickness. The pressure developed is a function of the number of creped sheets, their thickness, and the setting of the press stops. These stops are adjusted to create a laminate with firm contact between layers without completely closing the fluted structure. Although conditions can vary widely to accomplish this, nominal operating parameters to produce a one-fourth inch thick medium density, 35 lbs./cu. ft., laminate are: a 1 inch laid up thickness, press stops at one-fourth inch, and a temperature of 190° C. for approximately 20 minutes. The time factor will vary proportionally with the thickness of the laminate. The creped sheets are self venting; the normal pressure relief cycles to vent steam are not required. Overlayment materials such as high quality paper or wood veneers may be laid up with the creped sheets and bonded to the laminate as it is formed. Following lamination, the boards are oven-cured at 160° C. for 30 minutes per one-eighth inch thickness.

Configuration Control

The final configuration of this product can be varied in a number of ways during lamination. The arrangement of lamina, the shape of the product, its density, and its external appearance may all be controlled to some degree independently.

The density of the material is primarily a function of the lamination pressure and depends on the extent to which the tubular voids left in the creped sheet strucure are crushed in the press. Other factors such as resin content also affect density. Laminates have been produced within the range of 20 to 70 pounds per cubic foot at pressures ranging from 0.5 to 500 pounds per square inch. This density control allows a wide variety of products with different strength and handling capabilities.

Lamina arrangement also affects product physical characteristics. One variation is the crepe or grain orientation of successive layers. The lamina are pliable in the machine direction and can be bent along the creped folds but the same tubular structures stiffen the lamina in the opposite axis. This is analagous to the characteristics of natural wood veneers which also have directional strength characteristics relative to the wood grain. Similar to wood, this laminate can be assembled in either a parallel ply or cross-ply configuration (as shown in FIG. 2), each possessing different physical characteristics. The strength properties of this laminate are generally in the same range as those of natural wood and particleboard.

Another lamina arrangement is the sandwich configuration with layers of different densities. For example, thin high density plies bonded to a medium or low density core produce a hard-su:faced relatively light-



weight panel.

Various facing materials can be bonded to a core of this laminate. Paper provides a good surface for painting and helps moisture seal the laminate. A wood veneer-surfaced laminate can be used in furniture.

The natural tubular crepe structure of the surface, when stained and sealed with a clear finish, provides an attractive three dimensional simulated grain surface which is suitable for use in interior panels or other decorative applications.

The laminate can be molded into a variety of product shapes. Because the individual lamina are pliable, extremely so in the machine direction but not inflexible in the other axis, they do not have to be laid up flat but can be formed into curved or angular shapes to form a variety of final products such as boat hulls.

Having thus disclosed my invention I claim:

**1.** A structural laminate having grain direction similar to natural wood with strength properties in the same range as natural wood, said laminate consisting of paper sheets 0.011 inch thick, each of said sheets creped to a length-compression ratio of 7:1 and to a thickness 8 to 15 times that of the uncreped sheet, each creped sheet having a basis weight of 500 grams per square meter and containing a plurality of substantially parallel furrows and ridges, a substantial portion of said furrows and ridges being closed to form both tubular voids within and exposed grooves at each surface imparting directional strength to each of said sheets, resin adhesive applied to one side of each creped sheet in such amount that the final laminate contains 12 percent resin by weight, a plurality of said creped sheets, assembled in parallel or cross-ply configuration, being laminated together to a controlled density of from 20 to 70 pounds per cubic foot dependent upon the extent to which said tubular voids in each creped sheet are crushed during lamination.

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