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Title: EXTRUDED WOOD POLYMER COMPOSITE AND METHOD OF MANUFACTURE

Abstract: An extruded composite artificial lumber product is manufactured from wood fibers, a polyethylene matrix and a foaming agent. A mixture is extruded through a molding die which forms the profile of the desired product. The endothermic foaming agent causes greater expansion in the center of the extruded profile and increased density at the outer edges of the extruded profile.
TITLE

EXTRUDED WOOD POLYMER COMPOSITE
AND METHOD OF MANUFACTURE

SPECIFICATION

Be it known that we, Michael E. Dahl, Robert G.
Rottinghaus, and Andrew H. Stephens, have invented
certain new and useful improvements in an Extruded Wood
Polymer Composite and Method of Manufacture, of which
the following is a specification.

FIELD OF THE INVENTION

This invention relates to an extruded composite
artificial lumber product manufactured from wood fiber
and polyethylene, including recycled polyethylene, and
its method of manufacture.

DESCRIPTION OF THE PRIOR ART

The prior art reflects many attempts to make an
acceptable artificial lumber out of wood fiber and
thermoplastics, particularly using recycled materials.
Some, such as the product and process disclosed in Laver
U.S. Pat. No. 5,516,472 Extruded Synthetic Wood
Composition and Method for Making Same, have enjoyed
some commercial utility as being a relatively cost-
efficient means of re-using materials, which might
otherwise be wasted, in the manufacture of lumber-like
products which are relatively strong, dimensionally
stable and moisture-resistant. Laver teaches that a
cellulosic wood fiber material may be mixed with a
thermoplastic material and a cross-linking material, all
of which are subject to heat (about 180 °C) and
pressure in a twin-screw extruder until they become
plastic. The plastic mixture is then extruded through a
series of dies including a "stranding" die having
multiple orifices in a honeycomb pattern to orient the
fibers in the plastic material in a longitudinal
direction. The die also includes gas evacuation
passages to relieve unwanted process gas, such as from
volatile cross-linking agents. As a result, according
to Laver, a product is created which may be formed into
intricate shapes with no expansion after leaving the
molding die. A water spray system cools the product
after it leaves the extrusion die, leaving a hardened
gloss or glaze on the surface of the product.

Brandt, et al. US 5,827,462 (10/27/98) discloses an
extruded synthetic wood product using a twin screw
extruder discharging a plasticized material which is 50-
70% cellulosic and 20-40% thermoplastic, containing
cross-linking agents into a transition die and then a
stranding die, and then cooling the extruded product
with water spray.

Deaner, et al. US 5,827,607 (10/27/98) discloses a
method of using a twin screw extruder to form composite
thermoplastic pellets having 45-70% polyvinyl chloride
and 30-50% wood fiber (not wood flour), and being at
least 0.1 mm long with an aspect ratio of 1.8. After
being pelletized, the material is used as feedstock for
a three stage extruder in which the pellets are mixed,
melted, and then formed at 195-200° C using a wax
lubricant, into structural shapes for doors, windows and
the like.

Brooks, et al. US 5,082,605 (1/21/92) discloses a
method for extruding a composite synthetic wood product
containing encapsulated cellulosic fibers. The feed
mixture contains polyethylene and up to 10-15%
polypropylene, in ratios in a general range of 40/60 to
60/40 fiber/polymer. The desirable fiber particles are
no more than 1.5 inches, and the polymeric materials are
ground to particles of no more than 0.25 inches. The
fiber particles are encapsulated in a jacketed
compounder at 300-600° F. Clumps of encapsulated
material no more than 1.5 inches in length are
introduced into a jacketed extruder, at temperatures
less than 450° F, and extruded through a fiber alignment
plate and then a heated forming die.
Brooks, et al. US 5,088,910 (2/18/92) discloses a
system for making synthetic wood products. Wood fiber
is mixed with thermoplastic material, including both
LDPE and HDPE, in plastic/fiber ratios of 40/60 to
60/40, and then heated and kneaded before being formed
into golf-ball sized chunks. A fiber alignment plate is
positioned ahead of the final extrusion die. The
product is cut to desired length using a flying cutoff
knife mounted on a table which tracks the movement of
the formed material as it leaves the extruder.
extruded fiber/polymer composite material in ratios of
40/60 to 60/40. The feed material is heated to a
working temperature between 190° and 350° F in a
jacketed mixer, until it reaches a clumpy, doughy
consistency, after which it goes to a size reduction
unit, and finally to a compounding extruder using a
fiber alignment plate ahead of the final extrusion die.
The disclosure teaches that the feedstock should contain
no foaming agent, and all but one of the claims reflects
that limitation by being limited to "unfoamed" polymeric
material. (The one claim not having that limitation is
limited to a process which achieves plasticization in a separate "jacketed mixer" prior to extrusion, which makes the process entirely different from the present invention.)

SUMMARY OF THE INVENTION

It is a primary general object of the present invention to provide a superior extruded wood polymer composite and method of manufacture which is easier, cheaper and quicker to manufacture, and requires less complex manufacturing steps and equipment.

A related general object of the invention is to provide a method which will produce a product which has physical properties as good or better than exhibited by prior art products of a similar kind.

A specific object of the invention is to provide a method for manufacturing a superior product which has a lower overall density and specific gravity compared to the prior art, while maintaining all or substantially all of its surface strength, hardness and finish, and moisture resistance. In particular, it is an object to provide an extruded artificial lumber product with similar surface qualities of density, hardness and strength, as the prior art, but having selectively reduced density at its central core. By this means the
product of the invention is substantially just as strong
as the prior art, but is significantly less dense and
more economical to manufacture, and is equal to or
superior to the prior art in terms of workability in
sawing, drilling, nailing, stapling, and the like.

By the method of the present invention, a high-
quality wood-like extruded artificial lumber product is
produced by finely dividing wood fiber and polyethylene
into particles, and then mechanically mixing them
together with a measured amount of a powdered
endothermic foaming or blowing agent. The resulting
feed mix is directly introduced, without pre-
pelletization, into a conventional twin-screw extruder
where it is compressed and heated into a homogenous
plastic state, and then extruded through a molding die
to form the structural profile of the desired product.
Gases, consisting of vaporized moisture from the
feedstock and excess process gas from the foaming agent,
is removed by vacuum through passages in the extruder
ahead of the molding die. In the process, the carefully
controlled amount of foaming agent ingredient has the
desirable effect of reducing the density at the center
of the extruded profile, while allowing the outer
surfaces to remain dense, hard and strong. This has the
overall desirable effect of producing a product which is relatively stronger with respect to its density, while continuing to present a smooth, hard well-finished external appearance.

It is believed that the controlled amount of foaming agent causes a greater degree of expansion in the center of the extruded profile than at its perimeter, thereby compressing a greater proportion of plastic material against the sides of the extrusion die. This has the effect of increasing the density and strength on the outside of the extrusion, while reducing the density (with no significant loss of overall strength) on the inside. The resulting extruded artificial lumber product can be selectively made with a specific gravity of 1.0, plus or minus 20%, with no significant variation in external dimensions after cooling.

THE DRAWINGS

FIG. 1 is a perspective view of four extruded artificial products, of which one represents a typical prior art product for comparison purposes, and three have been manufactured according to the present invention;
FIG. 2 is a schematic diagram of a process embodying the method of the present invention;

FIG. 3 is an enlarged horizontal cross-section of the forming die and stabilizing die which receives the molten exudate from the extruder; and

FIG. 4 is an enlarged vertical cross-section of the forming die and stabilizing die of Fig. 3.

DETAILED DESCRIPTION OF THE INVENTION

Turning to the drawings, there is shown in Fig. 1 a typical prior art extruded lumber product 10, such as might be manufactured using the process taught in the Laver U.S. Pat. No. 5,516,472. The product 10 might typically be produced in ten foot lengths, with dimensions of 6 inches by 5/4 inches (nominal) and 10, 12 or 16 feet in length. This product finds great utility in outdoor benches, tables, and railings, and as deck planking for exterior porches exposed to the weather year-round. Such a prior art product might typically be composed of about two parts finely divided wood fiber and one part finely divided recycled thermoplastic material, along with a lesser amount of thermosetting plastic material. The finely divided ingredients can be mixed directly prior to introduction
into an extruder, or they can be pre-pelletized, in the
Typically, a multiple-stage molding die having a fiber
alignment plate or stranding die is used, which aligns
the wood fibers, but also cause a high level of back
pressure in the extruder.

Such prior art artificial lumber planking, while
not generally as strong as natural wood, exhibits other
favorable qualities. It is generally maintenance free,
and can be exposed to the elements indefinitely without
significant degradation of either appearance or
strength. As for ease of fabrication, it is quite
similar to wood in that it can be drilled, sawed, and
nailed, and can receive screw and other fasteners, with
results very similar to natural wood.

However, despite the advantages set forth above,
prior art artificial lumber products such as the
illustrated example 10 often exhibit deficiencies which
can seriously and adversely affect their utility and
longevity in certain applications. For example, it has
been found that extruded composite products manufactured
using the stranding die technology taught in the Laver
U.S. Pat. No. 5,516,472 will sometimes suffer from
moisture absorption, possibly as a result of having a
lower thermoplastic content together with the presence
microscopic longitudinal channels created by the forced
alignment of the wood fibers during the extrusion
process. As a result, the product has, in effect, an
"end grain" through which moisture can enter, causing
eventually swelling, warping and distortion which can
upset the dimensional stability of any structure
manufactured with these materials.

In addition, while the prior art extruded
artificial lumber products 10 generally have a superior
surface in terms of strength, hardness and appearance,
they are generally quite dense, with some having
specific gravities substantially higher than 1.0,
meaning that they consume more raw materials per board
foot of product, and have a poorer strength-to-weight
ratio in comparison to natural wood. They will not
float at all.

Finally, the manufacture of prior art artificial
lumber products 10 by the prior art methods described
above is relatively costly and time-consuming because of
the need for either pre-pelletization or a pre-melt step
in some cases, and for multiple-part extrusion dies
(including stranding dies) in others.
Referring again to the drawings, there are also shown in Fig. 1 three additional extruded artificial lumber sections 12, 14 and 16, in the form of deck planks, manufactured according to the present invention. Improved plank 12 exhibits the same hard, strong, smooth surface as prior art plank 10, but has at its center a region 13 of reduced density which lowers the overall density and weight of the plank without significantly affecting its strength. Even though the density reduction may reduce the tensile strength and modulus of the product at its center, the fact that the outer surfaces are effectively unaffected causes the overall strength and modulus of the product to be substantially unchanged.

The density reduction of plank 12 at its center 13 is achieved by the addition of a controlled quantity of foaming agent, preferably up to 1% of an endothermic foaming agent such as bicarbonate of soda. This agent is added and mixed into the wood fiber and thermoplastic polymer components which, together with small quantities of certain other components, comprise the feedstock of the extruder. It has been found that it is possible to control the expansion of the foaming agent in a way which substantially confines it to the center of the
extruded product, thereby achieving additional lightness
without any sacrifice in surface characteristics or
overall strength.

The amount of endothermic foaming agent in the
feedstock mix has been found to be relatively critical.
Referring again to Fig. 1, plank 14 exhibits bowed outer
surfaces because of excessive expansion at its center
15. Similarly, the center 17 of plank 16 has not
expanded sufficiently, or has even shrunk after leaving
the extruder, giving the cross-section a "dog bone"
shape which is also unacceptable. It is therefore
important to adjust and balance the concentration of
endothermic foaming agent against the wood fiber and
thermoplastic polymer components of the feedstock
mixture so that a plank 12 with dimensionally stable
surfaces is achieved, and not a bowed plank 14 or sunken
plank 16 which may possess a reduced density at its
center, but which may be dimensionally unacceptable.

Turning to Fig. 2, there is shown in schematic form
a production line for producing the improved,
dimensionally stable plank 12 of the present invention.
A supply of wood fiber or other fibrous cellulosic
material 18 is introduced into a pulverizer or shredder
where it is finely divided into particles having a
maximum length dimension generally no smaller than 80
mesh (about 0.007 inches), and no larger than about 0.5
inches, with the preferred range being 10-40 mesh.
Another supply of thermoplastic material 20, which is
preferably scrap polyethylene such as may be reclaimed
from a materials recycling program, is similarly finely
divided in a pulverizer or shredder 21 into particles
generally no smaller than 80 mesh, with the preferred
range being 10-60 mesh.

After pulverization, the finely divided wood fiber
and thermoplastic particles are conveyed, such as by air
conveyor, to a mixer 22. To the mixer 22 is also added
a quantity of powdered endothermic foaming agent 23 such
as bicarbonate of soda, and (if desired) up to about 1%
of a wax lubricant 24.

In practice, the following ranges (parts by weight)
of components have been found most desirable in
achieving the objects of the invention:

<table>
<thead>
<tr>
<th>Composition</th>
<th>Wood Fiber</th>
<th>Polymer</th>
<th>Foaming Agent</th>
<th>Lubricant</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50</td>
<td>50</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>60</td>
<td>40</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>40</td>
<td>60</td>
<td>0.7</td>
<td>0.6</td>
</tr>
</tbody>
</table>
If desired, up to 5 parts of a thermoplastic olefin can also be added for optimizing melt flow characteristics.

According to the invention, the wood fiber, thermoplastic and foaming agent ingredients are thoroughly mixed in the mixer 22 and then conveyed, by means such as an air conveyor, to the input hopper 25 of a screw-type extruder 26. Excellent results have been achieved using the commercially available Cincinnati Milacron CM-80-BP twin screw extruder driven by motor 27. As is well known in the art, the twin screw extruder uses meshed counter-rotating flights (not shown) which have a larger pitch at the inlet end and a smaller pitch at the output end. The flights are heated internally, and the extruder barrel is also heated.

In combination, the heat imparted to the feedstock mixture by the heated extruder flights and barrel, plus the mechanical shearing and compression caused by the differential pitch of the flights, cause the feedstock mixture temperature to be raised to a point where it becomes plastic and homogenous, with the wood fibers being intimately mixed, coated and bound in the melted thermoplastic. In addition, any residual moisture in the feedstock components is vaporized, and as the
mixture heats further, its temperature is desirably in
the range of 320° F to 400° F, which causes the
endothermic foaming agent to become activated, absorbing
some of the heat energy and releasing carbon dioxide
gas.

As the heated and compressed feedstock approaches
the extruder die 29 at the exit end of the extruder,
excess volatiles including vaporized moisture and excess
foaming agent gas (principally carbon dioxide) are
removed from the extruder ahead of the molding die by a
vacuum pump 28. In practice, it has been found that the
best results are obtained at vacuum levels of at least
25 inches of mercury, with the best operating range
being between 27 and 30 inches of mercury. With less
vacuum, the resulting product is more sensitive to
moisture, possibly because the remaining volatiles
(water and carbon dioxide) permeating the melt and
create fissures in the final product, into which water
may penetrate. On the other hand, vacuum levels of 30
inches of mercury and more tend to negate the effect of
the foaming agent, leading to insufficient density
reduction, insufficient dimensional stability on leaving
the extruder, and poor workability in the finished
product.
With the process of the present invention, no special multiple die sets, and no fiber alignment or stranding die, are needed to produce a strong, stable, moisture-resistant product. As shown in Figs. 3 and 4, the extrusion die 29 has a converging entrance 33 leading to a throat 34 sized to produce the desired degree of pressure drop leaving the extruder, and a diverging exit 35 passage allowing for expansion of the melt in cross-section to form the desired profile of the extruded product.

From the exit passage the extruded product passes through a stabilization die 36 where it cools sufficiently to retain its shape upon entering the spray chamber 30. In practice, the extruded material leaving the throat of the die expands just sufficiently to take the fill the exit passage and thereby take its final shape, without undue pulling or dragging across its surface which might cause fissures known as "melt fractures".

From the extruder 26 and die 29, the formed ribbon of extruded product passes into a spray chamber 30 where it is cooled by spray jets of water from a reservoir 31 as is well understood in the art. Once cooled, it passes by conventional means to a cutoff station 32
where a traveling table or "flying" cutoff knife or saw
cuts the product to any length desired.

A typical product manufactured by the method of the
invention has been found to exhibit the following
characteristics (typical values):

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>ASTM Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of elasticity</td>
<td>285,758 psi</td>
<td>D4761</td>
</tr>
<tr>
<td>Modulus of rupture</td>
<td>1676 psi</td>
<td>D4761</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>786 psi</td>
<td>D198</td>
</tr>
<tr>
<td>Shear strength</td>
<td>706 psi</td>
<td>D143</td>
</tr>
<tr>
<td>Screw withdrawal force</td>
<td>650 lb/in</td>
<td>D1761</td>
</tr>
<tr>
<td>Nail withdrawal force</td>
<td>177 lb/in</td>
<td>D1761</td>
</tr>
<tr>
<td>Coefficient of thermal expansion</td>
<td>4.5 x 10^-5</td>
<td>E228</td>
</tr>
<tr>
<td>Water absorption</td>
<td>1.66%</td>
<td>D1037</td>
</tr>
<tr>
<td>Density (S.G.)</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>
I CLAIM AS MY INVENTION:

1. A process for manufacturing a composite extruded structural product having a desired profile from thermoplastic material and wood fiber comprising the steps of:

   finely dividing the thermoplastic material and wood fiber each into particles no smaller than about 0.007 inches and no larger than about 0.5 inches in length;

   mechanically mixing together the thermoplastic particles and the wood fiber particles in a ratio of between 60%-40% and 40%-60% by weight, together with an effective amount of a foaming agent, to form a feedstock mixture;

   introducing the feedstock mixture, without pre-pelletization, into a screw-type extruder;

   mechanically mixing, compressing and heating said feedstock mixture in said extruder until it becomes plastic and homogenous;

   extruding said heated, plastic, homogenous mixture through a molding die into the structural profile of a desired product;

   cooling said extruded product upon emerging from said molding die; and

SUBSTITUTE SHEET (RULE 26)
cutting the cooled extruded product into desired lengths.

2. The process of claim 1 in which an effective amount of foaming agent ingredient is selected to create an extruded product having a specific gravity of between about 0.8 and about 1.2 with no significant dimensional variation after cooling.

3. The process of claim 1 in which the effective amount of foaming agent ingredient is up to about 1% by weight.

4. The process of claim 1 in which the foaming agent ingredient is an endothermic foaming agent.

5. The process of claim 1 in which the foaming agent ingredient is bicarbonate of soda.

6. The process of claim 1 including the additional step of extracting excess volatiles under vacuum from said extruder, thereby producing an extruded product having a surface which is relatively dense, tight-grained and strong, and a center which is relatively more porous and less dense.

7. The process of claim 6 in which the vacuum extraction step is performed using a vacuum of at least 25 inches of mercury.
8. The process of claim 1 in which up to 1% by weight of wax lubricant is mixed into the feedstock mixture prior to introduction into the extruder.

9. The process of claim 1 in which up to 5% by weight of thermoplastic olefin is mixed into the feedstock mixture prior to introduction into the extruder.

10. The process of claim 1 in which the molding die has a converging entrance, a throat, and a diverging exit terminating in the profile of the desired structural product.

11. The process of claim 1 in which the extruded product upon emerging from said molding die is cooled with a direct water spray, and said cooled extruded product is cut into desired lengths with a traveling saw.

12. A process for manufacturing a composite extruded structural product having a desired profile from recycled polyethylene and wood fiber comprising the steps of:

   finely dividing recycled polyethylene and wood fiber each into particles of a size between 10 mesh and 40 mesh;
mechanically mixing together the polyethylene
particles and the wood fiber particles in a ratio of
between 60%-40% and 40%-60% by weight, and an effective
amount of a powdered endothermic foaming agent, to form
a feedstock mixture;
introducing the feedstock mixture, without pre-
pelletization, into a heated screw-type extruder
discharging into a molding die, said molding die having
an entrance, a throat, and an exit having the shape of a
desired product;
mechanically mixing, compressing and heating said
feedstock mixture in said extruder until it becomes
plastic and homogenous;
extracting excess volatiles and foaming agent
process gas under vacuum from said feedstock mixture
prior to entering said molding die;
forcing said heated, plastic, homogenous mixture
through said molding die to produce an extruded product
having a surface which is relatively dense, tight-
grained and strong, and a center which is relatively
more porous and less dense;
cooling said extruded product upon emerging from
said molding die; and
cutting the cooled extruded product into desired lengths.

13. A composite extruded artificial lumber product having a surface which is relatively dense, tight-grained and strong, and a center which is relatively more porous and less dense, manufactured by the process of claim 1.

14. A composite extruded artificial lumber product having a surface which is relatively dense, tight-grained and strong, and a center which is relatively more porous and less dense, manufactured by the process of claim 12.

15. The composite extruded artificial lumber product of claim 13 having a specific gravity between about 0.8 and about 1.2 with no significant dimensional variation after cooling.

16. The composite extruded artificial lumber product of claim 14 having a specific gravity between about 0.8 and about 1.2 with no significant dimensional variation after cooling.
FIG. 1

10

PRIOR ART

12

REGION OF REDUCED DENSITY
CORRECT FORMULATION

13

14

EXCESS EXPANSION

15

16

INSUFFICIENT EXPANSION

17

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