

[72] Inventor **Nathan D. Field**
Allentown, Pa.
[21] Appl. No. **830,533**
[22] Filed **June 4, 1969**
[45] Patented **Sept. 21, 1971**
[73] Assignee **E. I. du Pont de Nemours and Company**
Wilmington, Del.

[54] **A MOLDING FIBROUS WEBS**
11 Claims, No Drawings
[52] **U.S. Cl.**..... **264/119,**
264/120, 264/234, 264/257
[51] **Int. Cl.**..... **D04h 1/60**
[50] **Field of Search**..... **264/119,**
120, 257, 322, 234

[56] **References Cited**
UNITED STATES PATENTS
3,291,677 12/1966 Coates et al. 161/170
3,435,103 3/1969 Medhurst 264/320
Primary Examiner—Robert F. White
Assistant Examiner—J. R. Hall
Attorney—W. M. Moser

ABSTRACT: Expanded, nonwoven fibrous articles are formed by heating in a shaped mold compressed fibrous webs impregnated with a thermoplastic resin binder. The compressed webs may be economically shipped and the shaped articles generated at the point of destination.

A MOLDING FIBROUS WEBS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns bulky, nonwoven fibrous structures and, more particularly, the production of molded three-dimensional, lightweight, shaped articles of nonwoven fibers.

2. Description of the Prior Art

Three-dimensional nonwoven structures of fibers such as nylon and polyester are currently used as filling materials in such articles of commerce as furniture cushions, pillows, sleeping bags, and the like. Among the many advantages of using synthetic fibers are that they are lightweight and nonallergenic. Although the qualities of bulkiness and low density, which are inherent in these articles, are desirable in the eyes of the consumer, they cause economic problems in shipping. The situation is somewhat analogous to the problems of a balloon manufacturer having to ship gas-filled balloons instead of deflated ones and finding his trucking costs prohibitive. A solution to the problem of shipping bulky, nonwoven fibrous webs, batts, and the like, was proposed by Coates et al. in U.S. Pat. No. 3,291,677, issued Dec. 13, 1966. His contribution was to physically compress the nonwoven structure, apply heat, and cool it while under compressive restraint. The result was a wafer-thin fibrous article capable of being rejuvenated or restored to its original dimensions merely by the application of heat. Thus, in accord with these teachings, the manufacturer of nonwoven structure could make his fibrous structure, compress it to a wafer, ship the wafer at low cost, and the customer could rejuvenate the wafer at the desired time in his own mill. Thus, because only thin wafers would be shipped, space would be economized and, consequently, trucking costs would be relatively low.

Oftentimes, as in the manufacture of auto seat cushions, it is desirable to have a fibrous filling product molded in some desirable three-dimensional shape. Molding techniques related to fibrous webs are well known in the art. In the normal course of events consistent with the technology described above, the customers would rejuvenate the wafer, then subject the rejuvenated web to compressive molding techniques to obtain the desired three-dimensional shape. It has now been found, however, that if the compressed, wafer-thin, fibrous sheet produced by the above technology is placed in a mold and rejuvenated in the mold, as by heating, the expanding wafer assumes the inside shape of the mold and this shape can be made permanent.

SUMMARY OF THE INVENTION

This invention provides a process for producing a lightweight, three-dimensional, shaped nonwoven article of thermoplastic fibers comprising the steps of:

a. compressing a low-density assembly of crimped thermoplastic fibers bonded at their crossover points with thermoplastic resin, with the application of heat to raise the temperature of the assembly to T_2 ;

b. cooling the assembly to T_1 and then removing exterior compressive force;

c. placing the expansible fibrous assembly in a shaped mold;

d. heating the assembly to T_3 thus expanding it to the inside shape of the mold so as to form an expanded, shaped, fibrous article; and

e. removing said article from the mold, preferably preceded by cooling below T_m , wherein:

$T_3 > T_2 > T_0 > T_1$, and $T_m > T_2$, wherein T followed by the various subscripts indicates various temperatures, T_m being the melting temperature of the thermoplastic resin binder and T_0 being the glass-transition temperature of thermoplastic fibers. The symbol ">" indicates "is greater than."

DETAILED DESCRIPTION

T_0 , the classical "glass-transition" temperature, also called the "second-order" transition temperature of the fiber, is the

temperature at which the thermoplastic material changes from the rubbery state to the glassy state and also the temperature at which a discontinuity occurs in a graph showing temperature as a function of a thermodynamic variable such as heat capacity. The T_0 of poly(ethylene terephthalate) is about 67° C.

By T_m , the melting temperature of the thermoplastic resin binder, is meant the temperature at which the particular binder is sufficiently softened to be readily deformable to a new shape and retain its new shape. For many binders, this is the typical sticking point which is defined as temperature at which binder leaves a molten trail upon being rubbed across a heated metal block. For some highly cross-linked resins that have no true melting point, this is the temperature at which a marked softening of the binder is noted.

For convenience in understanding the present invention, reference will be made to three structures:

A. The Starting Web

B. The Compressed Web

C. The Molded Web

A. The Starting Web

The starting material for the new process is an array, such as a web, of crimped thermoplastic fibers bonded at their crossover points by means of a thermoplastic resin. The web may be prepared from a wide variety of forms of fibers and filaments, such as continuous monofilaments, continuous multifilaments, carded webs, warp sliver, top, roping, roving, tow, bulked tow, bulked continuous filament yarn, spun yarn, batts, and the like. The fiber orientation in the web may be random, partly oriented (as in a carded web) or oriented, i.e., running almost exclusively in one direction, as in a structure such as described by Koller, U.S. Pat. No. 3,085,922, issued Apr. 16, 1963. A suitable method for preparing the latter involves carding staple fibers into a web of substantially parallel fibers or a sliver of parallel fibers, stacking the web or the sliver in a perforated mold of the desired size, keeping all fibers parallel during the operation, impregnating the block of parallel fibers with latex or a solution of the desired binder, removing excess binder from the fiber block, preferably by suction, and forcing hot air through the block from end to end to dry and/or cure the binder matrix. The bonded fiber block is then removed from the mold and wafers or sheets of the parallel fibers-on-end are cut from the block by slicing across the end of the block perpendicular to the axis of the fibers. The desired angle of the filamentary structures may be achieved by varying the angle of the cut or by placing the strips in the mold at an angle and then making the cut on a plane parallel to the face of the block, transversely to the filamentary structures. The resulting bonded parallel fibers in the form of a self-supporting web may be cemented to one or more suitable backing materials depending on the particular end use desired.

Typical fibers useful in the present invention are of a thermoplastic nature and comprise, for instance, polyethylene terephthalate and nylon. Other polyesters that may be used are described in "Supplement to Book of ASTM Standards" part 10 (1960), p. 53. Deniers may range from about 1.0 to about 45 and the fibers may have from about 3 to about 20 crimps per inch (1.2-7.9 per cm.) which may be of the sawtooth variety (as produced by the stuffer-box crimper of Hitt, U.S. Pat. No. 2,311,174, issued Feb. 16, 1943) or the spiral variety (such as produced by Kilian, U.S. Pat. No. 3,050,821, issued Aug. 28, 1962) or even the type of crimp produced when the fiber passes in frictional contact with a sharp edge.

A typical starting material is a carded batt or garnetted web of the above-described fibers. A thermoplastic resin is applied to the web by spraying, dipping, or other convenient means and the resin is cured as by heating. Useful thermoplastic resins for nonwovens are common in the art and may comprise polyacrylates, polyesters, and the like, including copolymers.

B. The Compressed Web

The compressed web is an expansible, flat, waferlike sheet resulting from compressing the starting material with the application of heat. A useful process is to place the starting web

between the platens of a press and compress it to wafer thinness. Heat is applied to raise the temperature of the fiber structure to a temperature less than T_m of the binder resin but greater than T_g of the fiber. The structure is then cooled to a temperature below T_g of the fibers and the compressive force removed. The result is a thin waferlike web which has the potential to be rejuvenated to original thickness by the application of heat. C. The Molded Web

The compressed web is placed in a shaped mold such as the shape of an automobile seat cushion. The wafer is then heated to a temperature greater than T_g of the fibers and preferably, if a heat-stable structure is desired, greater than T_m of the binder resin. During this heating step, the wafer expands and assumes the inside shape of the mold. The structure is then cooled to at least a temperature below T_m of the binder resin.

The invention will be further illustrated by the following examples of preferred embodiments which are not intended to delimit the invention. Example I

This example shows the expansion of a wafer-thin expansible resin-impregnated fibrous material to the shape of a container.

Commercial poly(ethylene terephthalate) fibers of about 5 denier per filament and having about 8 crimps per inch (per 2.54 cm.) of the sawtooth variety is cut to staple of about 2-inch length. The staple is carded to a web which is cut transverse to the fiber orientation to 10-inch (25.4 cm.) lengths which are stacked on top of each other to fill a mold 10 inches by 16 inches by 24 inches (25.4 cm. by 40.6 cm. by 61 cm.). The fibers are substantially all oriented in the same direction.

The mold is impregnated with a 10 percent methylene chloride solution of a polyurethane resin having a T_m of about 165° C. to a pickup of 22 percent solids resin based on the weight of the resin-impregnated structure. The structure is cured at 140° C. for 1 hour to cross-link the resin. The density of the resin-impregnated web is about 1.33 pounds/foot³ (0.0213 gm./cc.) and it is sliced to pieces each being about 2.75 in. (6.99 cm.) high. A piece is placed between wooden boards and compressed therebetween to a height of about 0.25 in. (0.64 cm.) while heating at 110° C. for 1 hour. On cooling to about room temperature and release of the compressive force imposed by the boards, the cushion is only 0.75 in. (1.90 cm.) thick. A section of the compressed wafer-thin web is cut into chips approximately 0.25 to 0.50 in. (0.635 to 1.27 cm.) wide. The chips are placed in the bottom of a 400 ml. beaker, and the beaker containing them is heated to a temperature of about 130° C. Upon heating, the fibrous material expands to fill the beaker and surprisingly, upon removal of the fibrous web from the beaker, the inside contour of the beaker is retained in the web.

EXAMPLE II

This example illustrates the process of the present invention as applied to a fibrous structure the fibers of which are oriented in a single direction.

Poly(ethylene terephthalate) containing 0.3 percent by weight TiO_2 is spun to fibers in general accordance with procedures described in Kilian (reference above) to produce asymmetric birefringence across their cross sections. The yarn is heated and assumes a crimp of helical configuration and its T_g is about 70° C. The fibers are cut to 2.5-inch (6.35 cm.) staple. A blend is made comprising 30 percent by weight of this fiber with 70 percent by weight of 2.5 inch (6.35 cm.) commercially available stuffer-box crimp (sawtooth type) poly(ethylene terephthalate) having a T_g of about 70° C. The staple blend is garnetted to a batt and cut transverse to its length in slices 10 in. (25.4 cm.) thick. The slices are compressed in a mold and impregnated as in Example I with a binder resin comprising a copolyester of poly(ethylene terephthalate/azelate). The resin is cured and has a T_m of approximately 170° C. The process is similar to the process described in Koller, supra. The density of the fibrous structure upon release of the mold is 0.61 lb./ft.³ (0.0098 gm./cc.). The

4 1/8 inch (10.48 cm.) thick fibrous structure is compressed to 1 1/2 inch (3.81 cm.) between the platens of the press. The structure is heated while compressing to a temperature of 125° C. and cooled in an ice chest. The wafer-thin expansible structure is then placed in a cake mold of the form of a rabbit and expanded in the mold by heating to a temperature 185° C. for 10 minutes. It is then cooled to room temperature and removed from the mold. The fibrous structure is of the shape of a rabbit.

This example also describes the utility of the present invention in making such articles of commerce as stuffed toys.

Example III

Poly(ethylene terephthalate) is spun to filaments in accordance with the procedure Kilian, referenced above, to produce an asymmetric birefringence across their diameters. The fibers are heated and assume a spiral crimp configuration of about 9.5 crimp per inch (3.7/cm.). The T_g of the fibers is about 70° C. The fibers are cut to 2.5 in. (6.35 cm.) staple and garnetted and crosslapped to a 5 oz./46 in. yard weight (110 gm./m.²) web while spraying the top with a 16 percent by weight aqueous dispersion of a self-cross-linking acrylic resin made from acrylates, methacrylates, N-methylolmethacrylamide and a cross-linking agent, which has a T_m of 185° C. to give 8 percent by weight dry pickup. The resin is cured at 135° C. for 2 minutes and then the opposite side of the web is sprayed in the same manner to give a total (both sides) of 16 percent by weight, solids resin based on the weight of the resin-impregnated web. The spray is at high pressure on the thin batting and excellent penetration of the resin into the center of the batting is effected so that a great majority of the fiber crossover points are coated with resin. The thin batting is pretreated at approximately 191° C. for 5 minutes in a forced-draft oven, laminated in a stack of 10 layers by spraying a small amount of the above resin on one surface stacking and curing the entire structure at approximately 137° C. for 30 minutes. The resin-impregnated fibrous structure is then compressed to one-tenth of its original height by compressing between thin aluminum plates for 30 minutes at approximately 137° C. The wafer-thin expansible structure is then cooled, the plates removed, and it is cut to the dimensions of a housewife's eight-section aluminum muffin mold. The sample is then placed on the mold and clamped with a screen. The structure is heated in an oven at approximately 181° C. for 5 minutes. On cooling and removal, the fibrous batting is found to have expanded permanently to the shape of the depression in the mold. The expanded molded web is cut into four sections, one section is compressed flat at approximately 149° C. for 5 minutes and upon removal of the compressive force and heating to approximately 163° C. for 5 minutes, it expands, but not into the previously molded shape. Another section is heated in the original mold at approximately 199° C. for 5 minutes and then compressed flat at approximately 149° C. and then cooled. It is 0.5 in. (1.27 cm.) thick. It is heated at approximately 163° C. for 5 minutes and surprisingly it expands into the previously molded shape. This latter phenomenon illustrates the fact that the new molded structures themselves can be reheated above T_m in the molded shape, cooled below T_m to temperature T_5 , compressed to wafer thinness, cooled to T_4 followed by removal of compression, and reheated to temperature T_6 causing them to resume their molded shape, wherein

$T_6 > T_5 > T_g > T_4$, and $T_m > T_5$. This latter procedure is a preferred embodiment of the process of this invention; it enables articles to be molded according to the process of claim 1, compressed to wafer thinness convenient for shipping, and restored to the molded shape by heating in an ordinary oven without need for a shaping mold for the final heating.

I claim:

1. A process for producing a shaped nonwoven article of thermoplastic fibers comprising

5

heating a compressed plurality of crimped, thermoplastic fibers bonded with a thermoplastic resin binder at their crossover points, to a temperature T_2 ,
cooling the compressed fibers to temperature T_1 ,
removing the compressive force,
heating the fibers in a shaped mold to a temperature T_3 so as to form an expanded, fibrous article having the shape of the interior of said mold, and
removing said article from said mold,
wherein

$T_3 > T_2 > T_1$, and $T_m > T_2$, T_g being the glass-transition temperature of said thermoplastic fibers, T_m being the melting temperature of said thermoplastic resin binder.

2. The process of claim 1 wherein $T_3 > T_m$.

3. The process of claim 2 wherein said article is cooled below temperature T_m before removal from said mold.

4. The process of claim 1 wherein said thermoplastic fibers consist essentially of a material selected from the group consisting of poly(ethylene terephthalate) and nylon.

5. The process of claim 1 wherein said thermoplastic resin binder consists essentially of a material selected from the group consisting of polyacrylates, polymethacrylates, polyesters and polyurethanes.

6. The process of claim 5 wherein said thermoplastic resin binder consists essentially of the copolyester poly(ethylene terephthalate/azelate).

7. The process of claim 1 wherein said plurality of crimped, thermoplastic fibers bonded with a thermoplastic resin binder at their crossover points comprises a web of crimped thermoplastic fibers impregnated with said binder.

8. The process of claim 7 wherein said fibers have about 9 crimps per inch and are about 2 inches in length.

9. The process of claim 1 including the further steps of

6

heating said expanded, fibrous article above temperature T_m ,
cooling said article below temperature T_m ,
compressing said article at temperature T_5 ,
cooling said article to temperature T_4 ,
removing the compressive force, and
heating said article to temperature T_6 so as to cause said article to assume substantially the same shape it had before said further steps, wherein

$T_6 > T_5 > T_g > T_4$, and $T_m > T_5$.

10. The process of claim 2 including the further steps of cooling said article below temperature T_m , compressing said article at temperature T_5 , Cooling said article to temperature T_4 , Removing the compressive force, and heating said article to temperature T_6 so as to cause said article to assume substantially the same shape it had before said further steps, wherein $T_6 > T_5 > T_g > T_4$, and $T_m > T_5$.

11. The process of claim 3 including the further steps of compressing said article at temperature T_5 , cooling said article to temperature T_4 , removing the compressive force, and heating said article to temperature T_6 so as to cause said article to assume substantially the same shape it had before said further steps, wherein

$T_6 > T_5 > T_g > T_4$, and $T_m > T_5$.

35

40

45

50

55

60

65

70

75