NONWOVEN BONDING METHOD

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5 Claims

ABSTRACT OF THE DISCLOSURE

A self-bonded nonwoven fibrous sheet is made by (1) disposing an at least partially thermoplastic, oriented fibrous material upon a surface in random, multi-directional, overlapping and intersecting arrangement to form a batt or web and (2) imposing a source of sonic energy upon the batt or web to selectively heat and bond the fibrous elements at their points of contact or crossover.

The present invention relates to fibrous sheets and laminates incorporating same and, more particularly, to a method of making coherent, self-bonded, nonwoven sheets made from thermoplastic fibrous elements.

Nonwoven sheets are generally less costly than woven sheets of similar material, but to the extent that the weaving operation has been eliminated. To achieve adequate structural coherence and stability, nonwoven structures ordinarily must be treated in some manner to cause a consolidation of the fibrous network to provide a coherent sheet having improved properties. The use of adhesive binders, solvents, or heat or fiber entanglement operations to achieve an adequate degree of coherence is costly and offsets the economic advantage attending the elimination of the weaving operation. In an effort to avoid the complications attending the use of adhesive binders or the added processing steps involved in such as interleafing, there is the present practice of effecting a self-bonding of nonwoven fibrous networks by heating the entire network, such as by the use of a pair of heated platens or nip rolls, to a temperature sufficient to effect a fused bond of the fibrous elements at their crossover points. However, where the network is composed of oriented fibrous elements, such a fusion-bonding operation precipitates what is oftentimes undesired shrinkage and loss in orientation, with a consequent reduction in valuable mechanical properties, particularly as regards tensile strength.

Accordingly, it becomes an object of the present invention to provide a method for effecting the self-bonding of nonwoven fibrous sheet-like networks and laminated constructions containing same while substantially preserving the orientation level of the fibrous elements along their interbond portions. Other objects and advantages will become apparent from the discussion which follows.

In general, the novel process constituting the present invention comprises the formation of a contiguous fibrous network wherein the fibrous elements overlap one another, preferably in a multi-directional, uniformly random fashion, thence imposing a source of sonic energy upon said network to preferentially heat the points of fiber contact within said network to thereby effect a self-bonding of the network without a substantial reduction in the interbond orientation level of the fibrous constituents. The result is a bonded, nonwoven structure wherein the bond points are weaker than the interbond portions. One practical aspect of this feature lies in the use of such nonwovens as carpet backing in the present practice of carpeting, wherein a needle penetrates the carpeted surface during carpet formation, a fastener, rather than fiber breakage, resulting in a backing member of greater structural integrity than would otherwise be obtained. The process may also be utilized to form laminated constructions, one or more layers of which are in the form of a nonwoven fibrous network, other layers being in the form of, for example, a film or netting.

As employed herein, the term "fusion bonding" normally denotes a bonding by actual melting of the workpiece at the point of sonic excitation, but it is to be recognized that suitable bonding under the instant practice may as well be wrought by heating to the point of softening or the fibrous components being joined short of actual fusion, accompanied or immediately followed by a plastic deformation to effect a bond more in the nature of a mechanical interlock. It follows that the bond may take the form of and be enhanced by both fusion and mechanical interlock through deformation, wherein that portion of the bond receiving the most intense sonic excitation is in fact fused and the lesser excited bond portions are partially softened and plastically deformed. Where the two fibrous components being joined exhibit more than a small difference in melting point, the bonding operation is easily controlled to accomplish a mechanically interlocked, partially fused bond wherein a melted portion of the lower melting component is interlocked with a deformed portion of the higher melting component. It is, however, preferred to effect a mutual interfusion of the contiguous fibrous elements in order to promote maximum strength.

Most existing ultrasonic heating devices generally comprise an alternating current generator productive of a frequency in the ultrasonic range (usually 20,000 c.p.s. or greater), a transducer assembly or sonic converter, preferably of the piezoelectric type, wherein the electrical output of the generator is converted into high frequency longitudinal mechanical vibrations or compression waves due to the dimensional response of the piezoelectric crystal to the varying voltage placed across it, an acoustic coupling or booster bar connected to the output of the transducer and being operative to amplify the magnitude of the vibrations transmitted longitudinally through the bar, and a resonant section or horn secured to the output end of the acoustic coupling or booster bar for vibration therewith in the direction of the longitudinal axis of the coupling bar and, finally, a rigidly supported surface or anvil positioned in a plane substantially perpendicular to the longitudinal axis of the horn and against which the horn acts through the medium of a workpiece placed therebetween.

In the fusion-bonding of thermoplastic elements by the use of an ultrasonic device of the type above described, the horn or tool is vibrated perpendicularly to the anvil surface and against the thermoplastic material interposed therebetween to effect a r.p.m. and rapid compression of the thermoplastic material at the indicated ultrasonic frequency to thereby generate heat, both internally within the thermoplastic constituents and by inter-element surface friction, resulting in such a rapid build-up to the temperature of fusion that adjacent areas of the medium remain substantially at their original temperature. In order to focus and intensify the vibratory energy in the desired areas, the working head or horn employed will generally be provided with an active surface or surfaces of small area. As will readily be recognized by those conversant in the art of heating and forming by ultrasonic energy, the rapidity of temperature build-up in the workpiece is primarily a function of the mass of the workpiece or pieces, their thermal conductivity, modulus of elasticity, coefficient of friction, impact resistance and heat of condensation, the horn-tip geometry, sonic intensity (as measured by the force and velocity at which the horn tip is driven), and the pressure at which the horn is brought to bear upon the workpiece.

In a preferred mode of practice, a metallic screen is placed over the anvil surface upon which the nonwoven to be bonded is placed. It has been found that the use of a screen overlay minimizes any tendency towards over-
bonding of the fibrous cross-over points and tends to localize the sonic energy more precisely with a minimized risk of over-heating or melting. By suitable interrelations of the screen mesh and wire gauge to the fibrous network being bonded, particularly as regards density and fiber diameter, interesting variations in bond spacing and size may be accomplished with good reproducibility and uniformity.

The use of the term "thermoplastic" in characterizing the fibrous components utilized in the present invention is to be understood as including such blends of fibrous elements, a portion of which may be non-thermoplastic to the extent that they are not subject to charring during the bonding operation. The only criterion is that the fibrous network contain one or more thermoplastic constituents, preferably in a major proportion, which constituents preferably exhibit a close identity in their melting points where maximum bond strength is desired.

The structure and mode of formation of the nonwoven network or web may vary extensively, although, where isotropic constructions are sought, the filaments in the web should have a high degree of random positioning. One of the more preferred backing structures takes the form of an air-laid, random, continuous filament, uncrimped filamentary network. It is preferred for most applications that the filaments should be separate and independent from each other, except at their crossover points. A further form of random filamentary web amenable to the present practice may be obtained by depositing a staple fiber batt utilizing a Rando Weber. Still other suitable webs may be formed by cross-lapping or laminating unidirectional filamentary webs. Also, a carded staple fiber web, preferably of cross-lapped laminations, is ideally suited to processing according to the precepts of the present invention. Further, it is as well contemplated that laminated constructions containing one or more such webs with other layers, such as films, may also be formed according to the instant techniques.

For optimum uniformity in bond spacing and size, it is necessary that the nonwoven network be of a uniform thickness or density when in a fully compressed state and that the filamentary elements be uniformly disposed throughout, whether in a random or regular fashion. This follows from the fact that irregular agglomerations of filamentary elements within the network will provoke a more intense sonic excitation than adjacent areas resulting in indiscriminate fused masses.

For a more detailed understanding of the practice of the present invention, reference is now made to the accompanying drawing in which:

FIG. 1 is a simplified, partially sectionalized illustration of one possible implementation of the process of the present invention, and

FIG. 2 is an enlarged schematic representation of a portion of a bonded sheet product according to the invention, the sample illustrated being a thin layer of such a sheet. In the figure, sheet 1 is made up of randomly disposed, indefinite length filaments 2 bonded together at self-bonded crossover points through sonically formed bonds 3.

Referring now to FIG. 1, there is shown a relatively simplified arrangement which may serve to implement the practice of the present invention though it is, of course, contemplated that a more sophisticated and automated implementation would likely be utilized in commercial practice. As there shows, such an arrangement may comprise an ultrasonic tool, generally indicated by arrow reference numeral 10, which tool includes a housing 12 enclosing a suitable ultrasonic mechanical transducer, preferably in the form of a piezoelectric crystal, and an amplifying section 14 with the transducer. Since the details of the ultrasonic transducer are well known and form no part of the present invention, they will not be further described herein.

A mounting bracket 16 serves to rigidly interconnect the sonic tool to reciprocating bar 18, the latter being actuated in reciprocating fashion by hydraulic, pneumatic, or other suitable cyclic means, not shown. Any timed, tool-actuating mechanism employed should provide for a variable dwell time at a given stroke. For example, it will normally be desired to actuate the sonic tool into engagement with the workpiece, thence energize the horn for a brief interval to effect bonding, followed by a brief dwell period to allow partial cooling of the bond. In most instances, however, the dwell period pending partial cooling may be omitted.

The horn configuration is, again, a matter of art outside the contribution of the present invention. For the purposes here involved, it has generally been found desirable to provide a horn crown or working face 20 ranging from the planar, rectangular face illustrated in FIG. 1 to various knurled-like or multigrooved configurations. For example, where it is desired to vary the incidence of bonded crossover points within the network, a horn having a face area of corrugated configuration to define a series of working edges which are brought to bear upon the workpiece will be found highly effective. Similarly, a grid pattern may be formed in the face of the horn, the raised portions of which bear upon the fibrous network to bond same at these crossover points contacted by such raised portions. Generally, it has been found that the use of a high-low configuration for the horn face 20 helps minimize any tendency for overall bonding or indiscriminate sonic energization of the interbond network portions. This has been found especially true where the bonding operation is carried out against a mesh-like surface, as previously alluded to.

Disposed below horn 14 is drive drum 22 which propels endless belt 24, the latter preferably being in the form of a metallic screen. It is upon this belt that the nonwoven to be bonded is travelled to the bonding station under horn 14. Disposed directly under horn 14 is a relatively massive, rigid anvil 15 over which endless screen 24 passes in closely spaced or sliding contact therewith. On departing the bonding station, the bonded nonwoven is conveyed about a suitably disposed idler roll 34 onward to a point of take-up. From the foregoing, it will be appreciated that the screen belt 24, in conjunction with the anvil 15, functions as a mesh-patterned anvil surface upon which horn 14 works against the interwoven workpiece.

The principle of operation briefly follows. Beginning with the horn 14 in the solid line position A indicated in FIG. 1, the ultrasonic horn is lowered to bonding position B. An electronic timer, not shown, triggers the ultrasonic circuit to the horn for the desired pulse length, dictated by the particular nonwoven network being bonded, and, optionally, momentarily retains the horn in this position pending partial solidification of the workpiece. The horn is then returned to position A preparatory to being cycled through another bonding stroke. As will be apparent, the workpiece is indexed through the bonding station by increments chosen according to whether it is desired to effect a uniform bonding action throughout the entire surface of the nonwoven, or instead an open pattern of bonding, wherein the horn would contact spaced areas of the nonwoven surface.

The following examples will serve to further illustrate the practice of the present invention, but are not to be taken as a measure of its limitations. The ultrasonic transducer employed was one commercially available from Branson Instruments, Inc., designed for an input frequency of 20 kilocycles per second, the transducer assembly taking the form of a lead-zirconate-titanate piezoelectric element. As supplied, this instrument contains a timing circuit by which the duration of the energizing cycle may be readily controlled. The horns utilized are generally characterized by a half-wave resonance section made of a titanium alloy, selected for its strength-to-weight ratio to withstand the intense internal stresses
generated within the horn element, as well as its excellent
sonic conductivity. Though not essential, a conventional
time-delay mechanism was employed to control the dwell
time of the horn against the workpiece for a pre-set
length of time after the sonic excitation period to allow
at least a partial solidification of the bond points. A
source of variable pneumatic pressure (in the form of a
pair of double-acting air cylinders having a ¾-inch
diameter) was employed to control the force with which
the horn was brought to bear upon the workpiece. In
the tabulated results set forth in the examples, the air
cylinder pressure is reported as a measure of the horn
pressure upon the workpiece.

EXAMPLES 1–8

A web of continuous, uncrimped filaments was air-laid
in random fashion and collected on a moving, endless
screen conveyor belt. The yarn used consisted of 6 d.p.f.
oriented isotactic polypropylene continuous
multifilaments. The yarn was not bulked and had a denier and
filament count of 210/35 with zero twist. The melting
point of the yarn was 333° F., with a tendency to stick at 305–315° F. and the initial shrinkage temperature was 265° F. when in a relaxed state. The yarn was further
characterized by a breaking tenacity of 3.0–7.0 g/d. and
a tensile strength of 35,000–80,000 p.s.i.

The test results of the above ultraspinally bonded nonwovens are set forth in Table II. Testing of the material
was conducted at both room temperature (72° F.) and at
an elevated temperature of 250° F. In determining this
strain-strength data, the procedure of ASTM
D–1107 was followed. The crosshead speed of the Instron
tester was 5 inches per minute, and the span was 5 inches.

Table II

<table>
<thead>
<tr>
<th>Test sample</th>
<th>Test temp.</th>
<th>Basic weight</th>
<th>Load strain, %</th>
<th>Breaking load</th>
<th>Elongation, %</th>
<th>Tensile strength, lbs./in. 2</th>
<th>Tensile breaking, lbs./in. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>18 x 20 x</td>
<td>6.29</td>
<td>9.3</td>
<td>13.7</td>
<td>22.2</td>
<td>1.6</td>
<td>2.86</td>
</tr>
<tr>
<td></td>
<td>25 x 20 x</td>
<td>10.4</td>
<td>10.1</td>
<td>14.1</td>
<td>18.3</td>
<td>2.28</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>25 x 20 x</td>
<td>18.8</td>
<td>18.9</td>
<td>26.8</td>
<td>22.3</td>
<td>3.00</td>
<td>4.39</td>
</tr>
<tr>
<td></td>
<td>25 x 20 x</td>
<td>22.7</td>
<td>22.8</td>
<td>29.2</td>
<td>24.7</td>
<td>3.29</td>
<td>4.69</td>
</tr>
<tr>
<td></td>
<td>25 x 20 x</td>
<td>26.7</td>
<td>26.8</td>
<td>31.4</td>
<td>28.7</td>
<td>3.59</td>
<td>4.99</td>
</tr>
<tr>
<td></td>
<td>25 x 20 x</td>
<td>30.7</td>
<td>30.8</td>
<td>34.5</td>
<td>31.3</td>
<td>3.93</td>
<td>5.30</td>
</tr>
</tbody>
</table>

From the foregoing discussion and examples it will be
recognized that there has been heretofore disclosed a novel
and most beneficial method of manufacturing bonded
nonwovens, the bonding operation being accomplished in
a rapid, efficient manner without loss of inter-bond orient-
ation level. Numerous obvious variations from the dis-
closed details of nonwoven formation and manipulation
may be wrought without departing from the spirit of the
invention, as set forth in the appended claims.

1. A method for producing a coherent nonwoven fib-
rous sheet of improved tensile strength which comprises
in combination:

(a) subjecting oriented thermoplastic filaments to a
turbulent air stream to obtain a random arrangement
of the filaments on a movable collecting screen
therby forming a sheet of thermoplastic material
having a multiplicity of cross-over points;

(b) subjecting the sheet of thermoplastic material to
bonding at preferential cross-over points by indexing
an ultrasonic horn with the movable collecting screen
and ultrasonically bonding the sheet at said preferen-
tial cross-over points, and

(c) removing the sheet from the movable collecting
screen whereby the coherent nonwoven fibrous sheet
afioresaid obtained has an interbond orientation level
substantially equivalent to that of the original orient-
ed thermoplastic filaments.

2. The method of claim 1 wherein the preferential
cross-over points are bonded substantially throughout
the entire surface of the sheet with orientation of the inter-
bond portions thereof substantially preserved.

3. The method of claim 1 wherein the sheet of thermo-
plastic material comprises oriented filaments of indefinite
length.

4. The method of claim 1 wherein the sheet of thermo-

plastic material comprises oriented filaments of staple length.
5. The method of claim 1 wherein the thermoplastic material is isotactic polypropylene.

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