NONWOVEN FIBROUS FELT
BALLISTIC ARMOR MATERIAL

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Continuation-in-part of Ser. No. 773,336, Nov. 4, 1968, abandoned.

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ABSTRACT
A method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance comprising forming a batt of staple fibers, layering a plurality of the batts to form a laminar sheet, needling the laminar sheet once only in a substantially nonrepeating pattern by barbed needles penetrating the sheet in a direction substantially normal to the plane of the sheet to form a nonwoven fibrous felt, pressing the nonwoven fibrous felt to reduce its thickness, and layering a plurality of the nonwoven fibrous felts to form the nonwoven fibrous felt ballistic armor material.

5 Claims, No Drawings
NONWOVEN FIBROUS FELT BALLISTIC ARMOR MATERIAL

This application is a continuation-in-part of my U.S. Pat. appl. Ser. No. 773,336, filed 4 Nov. 1968, now abandoned for "Improved Ballistic Felt".

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates to a method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance.

The manufacture of body armor entails establishment of a reasonable compromise between ballistic resistance and stiffness of the material of which the armor is made. In recent times, body armor has come to be made of woven nylon fabric in an effort to obtain flexibility greater than that which is obtainable with metal plates or laminated plastic materials. The nylon yarn of this fabric is drawn to orient and strengthen it. The nylon fabric is assembled with a plurality of layers thereof superimposed one upon another to obtain a structure having approximately twelve layers of heavy nylon fabric spotwelded at intermittent points by means of adhesive materials in an effort to provide for shifting of the layers of fabric without causing too great a reduction in flexibility of the approximately one-half inch thick armor. Such armor is designed primarily to stop shrapnel or to so reduce the energy thereof that marked reductions in the severity of wounds resulting from shrapnel will be experienced by the military forces. More recently, nonwoven fibrous felt, particularly felts prepared from nylon staple fibers, have been found to be approximately equally effective in stopping shrapnel on a weight comparison basis as the above-described armor prepared from woven nylon fabric.

In the production of felt a needle punching operation is often employed using barbed needles to entangle the staple fibers after they have been carded to form a fleece, the needle-punching serving to bind several thicknesses of fleece together at a sufficient number of points of contact to obtain a felt product which can subsequently be handled like woven fabric despite its nonwoven nature. The needle-punching operation also improves tensile strengths of nonwoven fibrous felts prepared from nylon staple fibers. However, it has been found that the conventional needle-punching practices followed in the textile trade tend to prevent the attainment of as high ballistic resistance in nonwoven fibrous felt structures built up by needle punching and layering the needle-punched felt structures to thicknesses of approximately one-half inch as one would desire for use as body armor, particularly for stopping or effectively resisting missiles fired from small arms.

It is, therefore, an object of the present invention to provide a method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance over the ballistic resistance of nonwoven fibrous felt ballistic armor material produced from a plurality of batts of staple fibers which have been layered and needle punched in accordance with conventional needle punching practices employed in the nonwoven fibrous felt art.

It is a further object of the invention to provide nonwoven fibrous felt products having improved ballistic resistance over that of conventional felts prepared from the same type of fibers in substantially equivalent thicknesses and areal densities.

Other objects and advantages of the invention will become apparent from the following description of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

In the conventional production of nonwoven fibrous felts in the trade, it is customary to put the staple fibers taken from a bale thereof through an opener to separate the fibers more or less. They are then carded to produce a fleece or web, which may be formed into a batt by a lapping operation on a moving apron. Such batts may have areal densities from about 1 to about 5 ounces per square yard. Then two of these batts are superimposed and run through a needle-punching machine, such as a Hunter fiber-locker and needled at a selected needle penetration rate or number of penetrations per square inch. If it is desired to build up a felt of more than two batts, another batt is superimposed on the needled felt comprising the two batts previously needled together and the combination is passed through the needle-punching machine and needle punched with the selected number of needle penetrations again. This operation may be repeated as many times as desired to build up felts of four, five, six or more batts, the first batt being held in place indicated by another needle punching each time another batt is added. Thus the batts which are combined early in the process are repeatedly needle punched and the fibers therein are locked in place to a progressively greater extent as the building up of the felt progresses.

I have discovered that by layering the desired number of felts and thereafter needle punching the layered felts once only in a predetermined manner, a felt of greatly increased ballistic resistance can be obtained.

While I do not wish to be bound by a particular theory as to the cause of this phenomenon, it is my belief that the loss of ballistic resistance caused by needle punching in the conventional manner is mainly due to excessive binding of the fibers, resulting in their inability or greatly reduced ability to slip over one another when impacted by a fragment of shrapnel or a bullet. In order for the energy of a fragment or bullet to be absorbed most effectively, I believe that there must be a certain amount of freedom of the fibers to slip over each other, to elongate without immediately capturing upon impact by the missile. Nevertheless, there must also be a certain amount of coherence of the fibers; otherwise they will part very easily and the missile will pass through the felt with hardly any reduction in its velocity or its energy content. The basis of this invention accordingly lies in the discovery that in layering a plurality of felts of staple fibers to build up a felt of sufficient thickness to obtain the areal density deemed necessary to gain ballistic resistance when used as ballistic armor material, the plurality of felts in the form of a laminar sheet should be needle-punched once only in a substantially nonrepeating pattern to from about 150 to about 280 penetrations per square inch by barbed needles penetrating the laminar sheet in a direction substantially normal to the plane of the laminar sheet to form the nonwoven fibrous felt. In the process of the present invention, the felts are not repeatedly needle-punched in the building up of the nonwoven fibrous felts; they are accordingly not locked in place to an excessive extent; and they are reasonably free to slip over or by one another when the felt produced is in accordance with the invention is impacted by a missile, yet will hold together during handling in the manufacture of clothing or other ballistic armor-containing articles and will offer improved resistance to penetration by missiles.

In carrying out the present invention, I take a fleece or web of staple fibers, either crimped or uncrimped, and form a batt thereof having an areal density of from about 2 to about 4.5 ounces per square yard. I then layer a plurality of these batts to form a laminar sheet of superimposed batts having an areal density of from about 10 to about 20 ounces per square yard, and then needle punch the laminar sheet of superimposed batts once only in a substantially nonrepeating pattern to from about 150 to about 280 penetrations per square inch by means of barbed needles penetrating the laminar sheet in a direction substantially normal to the plane of the laminar sheet, that is, normal to the plane of either the top surface or the bottom surface of the stack of superimposed batts. I prefer to employ nylon staple fiber, which may be crimped or may be left uncrimped. A mixture of crimped and uncrimped fibers may also be used. Generally speaking, the staple fibers will be from about 2¼ inches to about 4 inches long, though still longer fibers may be employed. The practicality of handling the longer fibers in the carding operation are the only real limitations in this regard.

I also prefer to prepare batts of from about 3 to about 4.5 ounces per square yard areal density and to superimpose three
to five of these batts to form a laminar sheet and then to needle punch this laminar sheet once only to produce a nonwoven fibrous felt having an areal density of from about 10 to about 15 ounces per square yard, especially when prepared from nylon staple fibers. Each of these felt will usually be from about 0.12 to about 0.20 inch thick. It is then pressed to about 0.09 to about 0.11 inch thickness on either a rotary press or a flat bed press at a temperature not over about 300°F to condense the felt. Then about four to about six of these six felts are layered to form ballistic armor material for use in an armored vest or other armored clothing, the felts being usually stitched together at intermittent points by means of a button-stitching operation to prevent shifting or other distortion of the felts within the armored garment. Thus a ballistic body armor structure is obtained having a thickness of from about 0.4 inch to about 0.6 inch which is reasonably flexible and readily fabricated into armored clothing having greatly improved ballistic resistance over that of armored clothing made with woven fabric armor of the same thickness but appreciably greater weight and of armored clothing made with nonwoven nylon felt of the same areal density but needle punched in the conventional manner of the art of making nonwoven needle-punched fibrous felt structures.

Having described my invention in general terms, I will now proceed to describe several specific examples of the practice of the invention.

EXAMPLE I

A blend of staple nylon 6,6 fibers was prepared comprising 67 percent of 6 denier per filament, 3-inch uncrimped staple nylon and 33 percent of 3 denier per filament, 2¾-inch crimped staple nylon. This blend was fed into a card which converted it into a web of approximately 1.5 ounces per square yard. The web was converted into a batt weighing approximately 4.0 ounces per square yard, employing a total apex angle of 20°. Four of these batts were layered to form a laminar sheet and the laminar sheet was needle-punched by a single pass through a Hunter fiber-locker in a substantially nonrepeating pattern with 277 penetrations per square inch by "no pick up" barbed needles having nine barbs thereon, the needles penetrating the laminar sheet in a direction substantially normal to the plane of the laminar sheet. The resulting needle-punched felt had a weight of approximately 13.0 ounces per square yard and was approximately 0.12 inch thick. It was pressed on a rotary press at approximately 300°F. to a thickness of 0.09 inch. Four thicknesses of this felt were layered by superposition thereof and button stitched in intervals of about 2 inches to produce a ballistic armor material which had an areal density of approximately 5.8 ounces per square foot. The \( V_{50} \) ballistic limit of this material was 1,084 feet per second, \( V_{50} \) being the impact velocity at which there is a 50-percent probability of penetration by a 17-grain, caliber 0.22 fragment simulator. The ballistic armor material was incorporated in armored vests to be worn as body armor by soldiers in the field.

A nonwoven nylon felt was prepared in the conventional manner in accordance with well-known procedures in the felt-making art using the above-described blend of nylon 6,6 fibers and the batt prepared therefrom for comparative purposes. In this case, the needle punching was carried out in a different manner from that described above. A batt was passed through the Hunter fiber-locker and needle punched in a substantially nonrepeating pattern with 277 penetrations per square inch. The 12 more batts were needlecast onto alternating sides of the first-needled batt, the composite needle laminate being passed through the Hunter fiber-locker and needle alone with 277 penetrations per square inch each time an additional batt was laid on, the net result being a felt having a weight of approximately 55 ounces per square yard and a thickness of 0½ inch, the felt having been needled a total of 13 times at 277 penetrations per square inch each time. The felt was then pressed in a flat bed press at a temperature of approximately 300°F. to reduce the thickness of the composite needle punched felt to approximately 0.33 inches and to an areal density of 6.0 ounces per square foot. The \( V_{50} \) ballistic limit of this material was 1,040 feet per second, which is 44 feet per second lower than the above-described ballistic armor material produced in accordance with the present invention, even though the ballistic armor material of the invention had an areal density of 0.2 ounce per square foot less than the ballistic armor material made in accordance with the prior art needle-punching method. Since the energy absorption qualities of a ballistic material are a function of the square of the velocity of the projectile mass, comparison of the ability of two ballistic materials to stop a projectile must be made by comparing the squares of the \( V_{50} \) values of the two materials. Such a comparison shows that the above-described ballistic armor material made in accordance with the invention affords a ballistic protection approximately 10 percent better than that of the ballistic armor material made in accordance with the prior art needle-punching method.

EXAMPLE II

Crimped nylon 6,6 staple fiber of 6 denier per filament and 3-inch length was made into a batt weighing approximately 4.0 ounces per square yard in the same manner as that used in Example I. Three of these batts were layered to form a laminar sheet and the laminar sheet was needle-punched by a single pass through a Hunter fiber-locker at 223 penetrations per square inch using the same type of needles as in Example I. The nonwoven felt material thus formed was calendared or pressed twice at a pressure of 1,500 p.s.i. at a temperature of 280°F. to condense the felt to a thickness of 0.101 inches. Five layers of the felt so formed were layered to form a nonwoven fibrous felt ballistic armor material having an areal density of 5.4 ounces per square foot and a thickness of about 0.56 inches. The \( V_{50} \) ballistic limit of the resulting ballistic armor material, determined as described in Example I, was found to be 1,195 feet per second, which represented an improvement in ballistic protection of approximately 32 percent over that of the ballistic armor material made in accordance with the prior art needle-punching procedure as described in Example I even though the areal density of the ballistic armor material made in accordance with the method of the invention was approximately 10 percent less than the areal density of the prior art material.

While the invention is mainly concerned with the making of nonwoven fibrous felt ballistic armor materials by needle punching the laminar sheet formed of superimposed batts of staple fibers to a very limited extent, as described above, it is permissible to tack the individual batts prior to their superimposition to form the laminar sheet thereof by stapling the individual batts without detracting from the ballistic properties of the final nonwoven needle punched felt. Tacking may be generally considered to involve needle punching at from about 8 to 10 percent of the needle penetrations per square inch to be used in needling the felt. It is believed that this lack of interference of tacking with the ballistic characteristics of the ultimate felt material is because the staple fibers in the individual batts are so loose and the batts are usually so thin that the tacking thereof does not bind the fibers so tightly that they cannot slip over one another in the subsequently formed felt material. However, tacking generally facilitates handling of the batts in mill operations. Very few, if any, of the fibers would be ruptured during the tacking of the individual batts. However, multiple or repeated passes of the compounded mass of fibers in the superimposed batts thru the needle-punching machine, which has become standard practice in the art of making nonwoven fibrous felts, is definitely detrimental to ballistic resistance in the felt product. It is, therefore, to be understood that needle punching or needling, insofar as the claims are concerned, is intended to cover the joining of two or more batts together by means of a needle-punching operation and not to cover tacking of the individual batts prior to joining them together in a felt.
It is to be understood that the invention is applicable to the making of nonwoven fibrous felts from other fibers than nylon, for example, polyester fibers, such as "Dacron"; or acrylic type fibers, such as "Orlon"; or other fibers adaptable to the manufacture of ballistically resistant felts.

The temperature at which the felt is pressed is dependent on the type of fiber used in making the felt, the temperature in general approaching but not exceeding the softening or melting temperature of the fiber.

The method of my invention has a number of advantages over the prior art method of making nonwoven fibrous felt ballistic armor materials. The greatest advantage, of course, is the saving in weight of staple fibers required to produce a given amount of ballistic resistance. This is advantageous not only from a cost standpoint, but also from the standpoint of the lesser weight a soldier is required to carry on his person to provide him with a given amount of protection against shrapnel and bullets. Every ounce saved in this respect makes possible the carrying of that much more ammunition or food or other items which may increase the probability of survival or may make it easier for the soldier to move and to maneuver over rugged or otherwise difficult terrain, which may provide an additional survival factor. Further, the elimination of the repeated passes of the batts through the needle-punching machine reduces the overall cost of the manufacture of the nonwoven fibrous felt ballistic materials for armor purposes.

It will be understood, of course, that various changes in the details and materials which have been herein described in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention.

I claim:

1. Method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance comprising the steps of
   a. forming a batt of staple fibers, said batt having an areal density of from about 2 to about 4.5 ounces per square yard,
   b. layering a plurality of said batts to form a laminar sheet having an areal density of from about 10 to about 20 ounces per square yard,
   c. needling said laminar sheet once only in a substantially nonrepeating pattern to form from about 150 to about 280 penetrations per square inch by barbed needles penetrating said sheet in a direction substantially normal to the plane of said sheet to join said plurality of batts and thereby form a nonwoven fibrous felt,
   d. pressing said nonwoven fibrous felt at a temperature not over about 300° F. to reduce the thickness thereof to from about 0.09 to about 0.11 inch, and
   e. layering a plurality of said nonwoven fibrous felts to form said nonwoven fibrous felt ballistic armor material having a thickness of from about 0.4 to about 0.6 inch.

2. Method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance in accordance with claim 1, wherein said staple fibers substantially consist of nylon fibers.

3. Method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance in accordance with claim 1, wherein at least some of said staple fibers are crimped prior to the forming of said batt.

4. Method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance in accordance with claim 1, wherein said staple fibers are nylon fibers at least some of which are crimped prior to the forming of said batt.

5. Method of making a nonwoven fibrous felt ballistic armor material having improved ballistic resistance in accordance with claim 2, wherein said laminar sheet is formed by superimposing from three to five of said batts to form a laminar sheet or from about 10 to about 15 ounces per square yard.