A needle punching process is provided for producing a needle felted fabric that is useful for producing artificial leather. In the needled fabric some of the fibers are displaced by needles and caused to penetrate through others of the fibers; at least 60 percent of the fibers which penetrate do so either individually or as a group of two or three fibers.
NEEDLE FELTING METHOD

This is a division, of application Ser. No. 116,146, filed Feb. 17, 1971, now U.S. Pat. No. 3,774,273, granted Nov. 27, 1973.

BACKGROUND OF THE INVENTION

The present invention relates to a method for making a needle felted fabric having a homogeneous internal structure. In the needle felted fabric at least 60 percent of the fibers which penetrate the other fibers do so either individually or as a group and are composed of from two to three fibers. The needle felted fabric produced by the method of the present invention can be used advantageously as a base for artificial leather and has other uses described in further detail hereinafter.

In the production of conventional artificial leather, needle punched felted fabric has hitherto been used as a base material. It is usually produced by punching a random web or cross lapped web of fibers by using a needle punching machine wherein needles having a great number of barbs or having a great depth of barbs are fixed on a needle board, and are reciprocated back and forth through a mass or web of fibers to punch certain of the fibers through others. In such conventional needle punched fabric great numbers of fibers are caused to penetrate by means of one needle, therefore the final condition of the internal fibers is very random and not homogeneous. Accordingly, conventional needle felted fabric can be used only as a base material for textiles where great uniformity is not required, such as in carpets or rugs, for example. Conventional needle felted fabric is not at all satisfactory as a base material for high grade artificial leather, for example.

As a specific example, when a polyurethane film is applied to the surface of conventional needle felted fabric, in order to produce artificial leather having a grainy surface, the concave and convex curvatures attributable to the non-uniformity of the base material are apparent on the grainy surface whenever a tensile or bending force is applied to the artificial leather. This is because large groups of fibers have been picked up by the barb of a single needle and all such fibers cause to penetrate through the other fibers as a large group. The large masses of such large groups cause the formation of surface irregularities on the felted product. Therefore, conventional artificial leather is not adapted for use in high quality shoes.

Tensile and bending loads and forces are applied to the raw material in many ways when shoes are made, and it has been a technical requirement that there be a substantially complete elimination of the concave and convex curvatures normally produced on the surface of the artificial leather in carrying out the lasting and other operations in the manufacture of shoes.

One of many ineffective proposed counter measures has involved coating thick porous polyurethane on the base material made of needle felted fabric. However, the thickness of the rubber film is excessive and results in a rubber-like touch; also it is difficult to produce a high-grade product. When compared with natural leather which is almost entirely composed of fibrous material, the structure and touch of the substitute are remarkably poor. Also, in view of the high cost of production, the proposed process is disadvantageous and the yield is quite poor.

In accordance with another proposed method, textile material is adhered to a base material made of needle felted fabric, and porous polyurethane is coated thereon. However, in addition to the above mentioned drawbacks, the product is an artificial leather of high directional anisotropy, excessive hardness, and insufficient elongation, and the resulting artificial leather cannot be used easily for making shoes. Also, the resulting shoes do not conform well to the shape of the feet, but cause localized rubbing and aggravation.

On the other hand, concrete examples of suede artificial leather are referred to on pages 141 to 143 in "Science of New Industrial Materials" (Felt and non-woven fabric) published by Kanehara Publishing Co., Ltd.). There the respective penetrating fiber groups are composed of a remarkably great number of fibers per group, and the resulting needle felted fabric as a whole is composed of punched or penetrating fibers in the form of local groups. This needle felted fabric is treated with a binder, and the surface of the treated needle felted fabric is subjected to a buffing treatment, such that the resulting nap is formed in thick, individual bundles of fibers which are spaced apart from each other, and which do not have the appearance or quality of good suede leather.

SUMMARY OF THE INVENTION

The present invention relates to a method which provides needle felted fibrous sheets which are advantageous for producing artificial leathers having a velour finish, or a suede like finish, and/or a finish of a nubecula type having a uniform matted surface, or for producing artificial leather having a grainy surface of excellent surface smoothness. An object of the present invention is to produce a needle felted fabric having a uniform penetrating fiber structure which overcomes the drawbacks inherent in conventional needleled fabric used as a base material for artificial leather.

According to the present invention, the needle felted fabric produced by the method has the characteristic that at least 60 percent of the penetrating fiber groups are composed of from one to three fibers, in other words, either individual fibers or pairs of groups of three.

The invention further relates to a method of applying a felting needle having a fiber hooking coefficient which is below 3, and the diameter of the lateral cross-section of the blade is from 0.30 to 0.54 mm, (preferably from 0.38 to 0.51 mm).

The invention further relates to a method of applying felting needle wherein the catching modulus of the fiber is below 3, and the lateral cross-section of the blade is substantially a regular triangle, and the height thereof is from 0.28 to 0.61 mm, preferably from 0.35 to 0.56 mm.

Further, the present invention relates to a method of applying a conjugated needle wherein at least two felting needles, each of which has preferably less than three barbs, are united in such a manner that the interval between the points of the needles is from 300 to 5,000 microns, preferably from 900 to 3,500 microns.

Further, the present invention relates to a needle punching method which moves from 2 to 20 felting needles as a single bundled needle through the respective corresponding needle holes provided in the stripper plates and in the bed-plates, the distance between the outermost surface of said bundled needles and the
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wall surface of the corresponding needle hole is from 0.5 to 9 mm, preferably from 2 to 5 mm.

The felting needle used in the method of the present invention, as described above, can be used advantageously in forming such a conjugated needle, and this conjugated needle can be used advantageously in the needle punching machine.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an outline of the side view of part of a conventional needle loom;

FIG. 2 is a side view of a conventional needle;

FIG. 3 is an enlarged view of the barb portion of the needle of FIG. 2;

FIG. 4 is a vertical cross-sectional view of conventional needle felted fabric, taken as indicated by the lines and arrows IV—IV which appear in FIG. 1;

FIG. 5 is a cross-sectional view of the needle felted fabric, taken as indicated by the lines and arrows V—V which appear in FIG. 4;

FIGS. 6 (A through D) are diagrams showing various conditions of the needle punched fibers in conventional needle felted fabric;

FIG. 7 is a diagram showing the surface condition attained when conventional needle felted fabric is processed as a base material for artificial leather;

FIG. 8 is a lateral cross-sectional diagram showing needle felted fabric produced by a method according to the present invention;

FIG. 9 is a lateral view of the fabric of FIG. 8;

FIGS. 10 (A through C) are diagrams showing various conditions of the needle punched fibers in fabric according to the present invention;

FIG. 11 is a diagram showing the surface configuration attained when needle fabric produced according to the present invention is processed as the base material for artificial leather;

FIG. 12 is a lateral cross-section of a typical “islands-in-a-sea” type filament which is preferably present in needle fabric produced according to the present invention;

FIG. 13 is a longitudinal cross-section of the filament shown in FIG. 12;

FIGS. 14 and 15 are lateral cross-sections of other embodiments of “islands-in-a-sea” type filaments;

FIG. 16 is a diagram showing the barb portion of a needle for illustrating the fiber hooking coefficient of a needle;

FIGS. 17 through 21 are the diagrams showing side views of various modifications of the composite needle used in the method of the present invention;

FIGS. 22A through J are diagrams showing lateral cross-sections of the shank portions of various modifications of the composite needle used in the method of the present invention;

FIG. 23 is a diagram showing, in side elevation, a portion of a needle loom provided with composite needles used in the method according to this invention;

FIGS. 24—29 are sectional views taken internally in needle punching looms having conjugated needles of various types;

FIGS. 30A through H are diagrams showing the ground plans of various shapes of needle holes provided on the stripper plate and bed plate of the needle loom when a composite needle of this invention is used;

FIG. 31 is a diagram showing, in side view, a part of a needle loom according to the present invention;

FIG. 32 is a ground plan showing the arrangement of the cranks of the needles provided on a needle board of a single needle loom;

FIGS. 33 and 34 are ground plans showing arrangements of the cranks of needles provided on a needle board of a needle loom practicing a method according to the present invention;

FIGS. 35A through F are ground plans showing various arrangements of needles and needle holes of a needle board in a needle loom practicing a method according to the present invention;

FIGS. 36A and B are diagrams showing how two arrangements of needles in a needle loom in a method according to the present invention are carried out;

FIG. 37A and B are diagrams showing positional relations of the cranks and barbs of the respective needles, FIG. 37A showing a conventional needle and FIG. 37B showing a needle according to the present invention;

FIG. 37C is a diagram showing side view of FIG. 37B;

FIGS. 38A through C are diagrams showing side views of various modifications of a blind needle used in a needle loom for use in a method according to the present invention;

FIG. 39 is a graph showing the relationship between the number of needles calculated as needle board holes per square centimeter and apparent density;

FIGS. 40—45 are views in perspective showing various forms of adaptors for conjugated needles useful in a method according to this invention; and

FIGS. 46A—46C are cross-sectional views of needle shanks arranged in conjugated needles.

PRIOR ART

In accordance with the conventional method for producing a needle-punched fibrous sheet, a needle punching machine has been used, but it has been found to be not well adapted for producing needled fabrics economically at high yield.

FIG. 1 is a diagram showing part of a conventional needle punching machine; felting needles 2 are planted on the needle board 1 and a board 3 is provided on the upper surface of needle board 1.

The needle board 1 and the bord 3 are united, and move up and down together under the influence of the drive of the machine (not shown). The heads of the needles are held between the boards 1 and 3 as the boards reciprocate in the directions indicated by the arrows a in FIG. 1.

A stripper plate 5 and a bed plate 6 having needle holes 4 at positions corresponding to the respective needles 2, and the fibrous web 7 is transferred from left to right (in the direction shown by arrows b in FIG. 1) between the stripper plate 5 and the bed plate 6, and while being transferred between said stripper plate 5 and the bed plate 6, the fibrous web 7 is subjected to needle punching by the needles 2 which are moving up and down.

The felting needle 8 of FIG. 2 is composed of a crank 9, shank 10, intermediate blade 11, blade 12 and point 13. Barbs 14 are provided on the blade 12. The lateral cross-section of the blade 12 is a regular (equilateral) triangle. Three barbs are usually formed on each side of the triangle between the respective corners of said triangle; therefore nine barbs 14 are provided on each needle.

FIG. 3 is an enlarged view of a typical barb.
When the needle moves into and through the mass of fibers, some of the fibers 15 are hooked by the barbs 14 when the needles are transferred, and the fibers 15 are displaced in the direction of the thickness of the fibrous web 7, and are caused to penetrate through the spaces between the other fibers of the fibrous web 7.

The fibers carried with said needles are called penetrating fibers.

The conventional barbs, which may be of the kick-up type or of the non-kick-up type, have deep and large throats 16, and as is shown in FIG. 3 the throat depth D, the throat length L and undercut angle (alpha) are designed in such a manner that a large number of fibers 15 can be hooked at once with only one barb with one punch of the needle. Generally speaking, about five to ten fibers 15 are hooked with one barb 14.

FIG. 4 shows the vertical cross-section of a typical needle punched fabric produced by using a conventional needle punching machine as just described.

As is apparent from FIGS. 4 and 5, the respective penetrating fiber groups 18 formed in the fibrous web 17 with one needle, is composed of extremely large numbers of fibers, and when the whole needle fabric is observed, the local concentration of the penetrating fibers is apparent.

This is further explained in detail by taking as an example, one tangled fiber group, i.e., a group of the fibers penetrating with one needle, as is shown in FIGS. 6A through D, and FIG. 7 shows the napped condition of a product resulting from the condition shown in FIGS. 4 and 5 in a product which was doped with an elastic high polymer solution, and the surface of which was subsequently buffed.

In FIG. 6, the upper and lower dotted lines 19 and 20 represent the upper and lower surfaces of the needled fabric respectively. FIG. 6A shows how a great number of fibers 21 are all together hooked, curved and bound by the penetration of the needle through the thickness of the felt.

FIG. 6B shows the condition where, after the step of FIG. 6A has been completed, the fiber bundle which has been curved by reason of the mechanism of the needle, is cut at the curved end of the bundle or the neighborhood thereof.

FIG. 6C shows the condition in which a great number of fibers 21 are bound at various depths, each in the form of a local fiber group, across the thickness of the felt, by the operation of a needle having multiple barbs.

FIG. 6D shows the condition in which after the state shown in FIG. 6A has been formed, a typical bundled fiber group 18 is projected through and beyond the surface of the felt by the movement of the needle. This is an example of remarkably poor needle punching attained in accordance with the prior art.

FIG. 7 shows the conventional needled fabric processed as a base for artificial leather. Great numbers of penetrating fibers 21 are concentrated locally as heretofore described.

As described before, when film is provided on the surface of the base material of artificial leather to produce artificial leather having a grain surface, concave and convex curvatures attributable to the non-uniformity of the base material are produced on the surface of the grain, as heretofore discussed; conventional artificial leather is not at all adapted for artificial leather to be used in high grade shoes.

DETAILED DESCRIPTION OF THE INVENTION

On the other hand, the needled fabric produced by the method of the present invention has no such drawback and adapts excellently for artificial leather of high grade.

The following descriptions relate to specific forms of the needled fabric of this invention in accordance with the attached drawings, and are not intended to limit the scope of the invention as defined in the claims.

In FIGS. 8 and 9, the fibers 31 are the filaments which are associated substantially all in the same direction before they are subjected to needle punching. The fibers 32 are hooked with a needle moving substantially perpendicular to the web and penetrate substantially in the perpendicular direction into the web which is formed of a great number of fibers 31. Preferably, from one to three monofilaments are caught by each individual needle and accordingly penetrate as a group of from one to three monofilaments.

FIG. 9 is a diagram showing the lateral cross-section of the embodiment of FIG. 8, and shows that the penetrating fibers 32 actuated by a single needle can be observed predominantly as small groups of one, two or three filaments injected as groups between the great numbers of penetrating fibers 31.

The number of the fibers which are inserted and penetrated with a single needle are counted in accordance with the following method.

In FIGS. 10A, 10B and 10C, the upper and lower dotted lines 36 and 37 show the upper and lower surfaces of the needled fabric.

The cases in which monofilaments are considered to have been hooked and caused to penetrate with a needle are as follows:

The case in which both ends of one fiber 33 are almost horizontal on the surface of the sheet or in the neighborhood thereof, as is shown in FIG. 10A, and the fiber extends crosswise and is bent upon itself inside the sheet,

The case in which one end of one fiber 34 of FIG. 10B is positioned in the same manner as in FIG. 10A, but one end of said fiber 34 terminates in the sheet after having been bent upon itself,

The case in which one end of one fiber 35 of FIG. 10C is situated in somewhat the same manner as in FIG. 10A, but one of its ends terminates in the sheet without being bent back upon itself,

The case in which any two of the conditions shown in FIG. 10A, B and C are simultaneously present;

The case in which all conditions shown in FIG. 10A, B and C are present.

In the case of FIGS. 10A, B and C, the number of penetrating fibers is counted as one; the number of fibers in the penetrating fiber group formed by one needle is one.

When the conditions shown in FIGS. 10A and 10B are simultaneously present, or when the conditions of FIGS. 10A and 10C are simultaneously present, or when the conditions of FIGS. 10B and 10C are simultaneously present, and when two conditions shown by FIG. 10A are simultaneously present, or when two conditions of FIG. 10B are simultaneously present, or when two conditions of FIG. 10C are simultaneously present, the number of penetrating fibers is counted to be two.
In addition, when the conditions of FIGS. 10A, 10B and 10C are simultaneously present, the number of penetrating fibers is counted to be three.

In other combinations, counting is carried out in accordance with the method described above.

It will be recalled that FIG. 9 is a diagram showing a needled fabric according to this invention as is shown in FIGS. 8 and 9, which has been processed into a base material for artificial leather, and the number of penetrating fibers formed by one needle is from one to three, and therefore the nap of the needled fabric of this invention is remarkably uniform without presenting the locally concentrated nap condition as in the conventional products such as the one appearing in FIG. 7.

The denier of the fiber to be used in the present invention is preferably from about 0.5 to 30, more preferably about 0.8 to 10.

The staple length of the fiber to be used in the present invention is preferably about 15 - 120 mm, more preferably about 25 - 84 mm.

As the raw material of the fiber of this invention, natural filaments or artificial filaments can be used, but more in particular, the advantageous features of the present invention can be attained with use of artificial fibers whose felting effect is generally inferior to natural fibers. More in particular, filaments of the "islands-in-a-sea" type are especially preferable.

An "islands-in-a-sea" type filament is a filament formed from two types of high molecular weight polymers; when the lateral cross-section of such a filament is observed, there is a portion which forms the sea which is composed of one of these high polymers, and the islands are composed of the other polymer. The respective islands are dispersed in the sea, and this lateral cross-sectional condition is continuously present along the length of the filament. An islands-in-a-sea type filament in which the number of islands is more than 10 is especially preferred.

Typical high molecular weight polymers for forming said island include polyamides, polyesters, polylefins, polyacrylonitriles or polyurethanes and such polymers. Also copolymers are preferably used. The high polymers for forming the sea include polystyrene and copolymers thereof, polymethylmethacrylate and copolymers thereof, polyvinyl alcohol and the like.

FIG. 12 shows the lateral cross-section of one form of islands-in-a-sea type filament, FIG. 13 shows its longitudinal cross-section. In FIGS. 12 and 13, the islands-in-a-sea type filament 41 is composed of a sea forming portion 42 and islands forming portions comprising a greater number of islands 43 dispersed in said sea forming portion 42. The above mentioned condition substantially continues along the length of the filament as is shown in FIG. 13, and in this respect, the islands-in-a-sea type filament of this invention is different from the filament obtained by spinning a blend of two kinds of polymers as is generally known to those skilled in the art.

On the other hand, FIG. 14 is a diagram showing an enlarged view of the lateral cross-section of an embodiment of another islands-in-a-sea type filament. It differs from that of FIG. 12 in that the islands 43 are relatively more thickly dispersed in the sea forming portion 42 inside the filament 41.

In FIG. 15 the central portion 44 of the filament 41 is hollow. The reference numeral 42 shows the sea forming portion, and 43 shows the islands.

The islands-in-a-sea type filament of FIG. 15 is especially adapted for remarkably reducing the surface non-uniformity similar to an "orange peel" which appears in making shoes when it is used as a base material for artificial leather.

In addition to the above, it is possible to utilize islands-in-a-sea type filaments wherein the arrangement of the islands is changed in various ways, or the forms of the islands are changed in various ways, or the forms of the lateral cross-sections of the filaments are changed in various ways.

The islands-in-a-sea type filaments can be produced in accordance with the method described in the specification of British Pat. No. 1,171,843, or of U.S. Pat. No. 3,531,368, or modifications.

The islands-in-a-sea type filaments according to this invention are hooked on a needle as one filament when they are subjected to the needle punching process, and are caused to penetrate but the island forming portions are caused to remain as separate fine fibers by removing the sea forming portion of the filament after having been incorporated into the needled fabric, and the island forming portion takes on a structure very similar to the collagen of natural leather.

In an islands-in-a-sea type filament great numbers of fine filaments are present in one filament, but in counting the number of fibers present as the penetrating fibers which are tangled according to this invention, the total number of islands-in-a-sea type filaments is counted as the number of the penetrating fibers.

In producing a needled fabric according to this invention, needle punching is effected by using a felting needle having a diameter from about 0.30 to 0.54 mm, preferably from about 0.38 to 0.51 mm, when the lateral cross-section of the blade portion is circular, and the fiber hooking coefficient is below 3, or by using a felting needle of equilateral triangle cross-section wherein the height or altitude of the triangle (the distance from any apex along a line perpendicular to the opposite base) is from about 0.28 to 0.61 mm, preferably from about 0.35 to 0.56 mm.

The expression fiber hooking coefficient as used in this specification refers to the number of fibers hooked with all the bars whose undercut ends are positioned on the blade portion within 8 mm from the undercut end of the bar closest to the needle point of one needle, as the starting point.

This is further explained in detail in accordance with the drawings.

FIG. 16 is an enlarged view of the blade portion of a needle preferably used in practicing the method of this invention. When a line 54 is drawn from the end 52 of the undercut portion of the barb 51 to the center line 53, the number of fibers within the region 55 within the space defined by said line 54 and the internal wall of the barb 51 represents the fiber hooking coefficient of one barb 51.

Therefore, if three bars are provided, each having a hooking coefficient of 1, on the blade portion of the needle within 8 mm from the barb closest to the needle point as the starting point, the fiber hooking coefficient of that needle is 3.

In the foregoing definition of "fiber hooking coefficient," the angle 45° is selected for good reason. In car-
The distance of 8 mm from the starting point has been selected because when fibers are hooked on a barb close to the needle point, it becomes difficult for a barb located farther from the needle point to hook fibers, and it has been found from many experiments that the barbs beyond 8 mm from the starting point, hardly take part in the needling operation at all.

Therefore, in the actual measurement of the fiber hooking coefficient of the needle, a barb whose undercut end is placed within a distance of 8 mm from the undercut end of the barb closest to the needle point, is left as it is, while all the other barbs are filled in with molten metal or the like, the fibrous fabric is needle punched, and the number of fibers in the resulting needled fabric (needled with one needle) is counted in accordance with the method for counting the tangled fibers already explained with reference to FIG. 10.

As a result of many experiments we have established that substantially the same result can be obtained by measuring the fiber hooking coefficient of a needle by carrying out the needle punching operation without filling in the other barbs with molten metal, and the latter method can be used in the interest of simplicity.

In regard to the needle density to be adopted when needle punching is carried out by using the above described needle, a needle density ranging from 200 to 12,000 is preferable.

When a needled fabric according to the present invention is used as the base material for artificial leather, the needled fabric is dipped into an elastic high polymer solution and coagulated and solidified.

As examples of suitable elastic high molecular weight polymers, the following are listed:

- polyurethane
- natural rubber
- styrene-butadiene copolymer
- acrylonitrile-butadiene copolymer
- neoprene rubber, etc.

Among those given above, polyurethane is preferable.

The elastic high polymer is used in solution form by dissolving the elastic high polymer in an organic solvent, for example N, N-dimethyl formamide, dimethyl sulfoxide, N, N-dimethyl acetamide, N-methyl pyrrolidone, tetrahydrofuran and trimethyl phosphate, or by dispersing the elastic high polymer in water.

The preferable amount is from about 15 to 140 percent by weight of solid portion based on the amount of fibrous fabric. The primary Young's modulus of the elastic high polymer, as measured in the form of film in accordance with the dry or wet process, is preferably from about 0.09 to 3.0 kg/mm², and more preferably from about 0.09 to 1.7 kg/mm².

When polyurethane is used, after doping it is preferably coagulated in accordance with the wet process.

In particular, it is preferable to carry out the coagulation at a temperature ranging from about 0° to 40°C, and more preferably from about 10° to 35°C. When coagulation is almost finished, the coagulation should be terminated, and the solvent should be removed at a temperature from about 75° to 98°C.

When the above mentioned islands-in-a-sea type filament is used, after having formed the needled fabric, the sea forming portion can be removed before or after the doping of the elastic high polymer solution.

On the other hand, when the needled fabric of this invention is used, a base material for artificial leather having a very smooth surface is prepared when the needled fabric, doped with elastic high polymer solution in a pseudo-set state, is subjected to a buffing treatment.

The resulting base material for artificial leather is very useful as an artificial leather having a grain surface, or napped surface.

In particular, when the islands-in-a-sea type filament is used, the surface of the base material is very similar to the structure of natural leather; this makes it possible to produce a suede type artificial leather of high quality by buffing.

In a needle punching machine the durability of the needle is prolonged by using a needle of the type heretofore described because the load applied to the needle is reduced. The needle bends only very slightly, and it is accordingly possible to carry out very regular punching process. It is possible to make the size of the needle punching machine larger as the load applied to the needle punching machine is reduced. Since the load is reduced, it is possible to plant needles on the needle board at a high density in terms of needles per unit of area.

In carrying out punching, the cutting of fibers is reduced. It is not necessary to increase the depth of barbs, and therefore the needles can be produced easily.

As heretofore stated, the conjugated needle is advantageously used in producing the needled fibers of the present invention. The term “conjugated needle” means that at least two felting needles, each of which preferably has less than three barbs, are united in such a manner that the interval between the needle points is about 300 to 5,000 microns, preferably from about 900 to 3,500 microns.

In the conventional needle punching machine as is shown in FIG. 1, in order to obtain punching efficiency, the density of the needles 2 of the needle board 1 is required to be increased, and it is necessary to increase the number of needle holes 4 of the bed plate 6 and the stripper plate 5 in correspondence with the respective needles 2.

However, generally speaking, the needles are bent when punching is carried out, and therefore the diameter of the needle holes is adjusted to be much larger than the diameter of the needles; therefore there is a restriction with respect to the hole density of the needle holes 4 that may be attained on the stripper plate 5 and the bed plate 6; when the hole density is increased beyond the applicable limitation, the bending of the plates 5 and 6 becomes pronounced.

On the other hand, when the needle density of the needle board 1 is increased, the adjustment of needles becomes very difficult, which is considered to be a drawback.

In addition, in the conventional needle punching machine, great numbers of barbs are provided on one needle, and therefore great numbers of fibers are concentrated and caused to penetrate at one place in one punching operation.
The number of felting needles forming a conjugated needle used in the method according to the present invention is preferably from about two to seven, and in particular, from two to four.

However, when the depth of the barbs is selected within the range about which it is described hereinafter, more than eight felting needles can be used.

When the internal space between needle points goes beyond 5,000 microns, a marked deterioration of needle punching efficiency is noted. When such space goes below 300 microns, the effect attained by conjugating a plural number of needles is reduced, and undesirable needle marks are left on the needle fabric, and the breakdown of needles becomes pronounced.

FIG. 17 shows conjugated felting needle; the elements 61 are blades and 62 are the barbs.

In the conjugated felting needle of FIG. 17, three needles are united into one shank 63 at the upper portions of these needles; a “conjugated” needle as referred to in the specification of this invention is a needle having at least two blades 61 on one shank 63.

FIG. 22B is a diagram showing the cross-section across the line XXII—XXII in FIG. 17. 64 is the root of each needle and 63 is the shank formed with synthetic resin or welded metal for holding the needles and fixing them in position.

It is, of course, possible to fix the needles directly into one by means of welding, in the case of needles whose shank is quite thick.

Barbs 62 are provided on the blade portion, and the ends of the needles are sharpened in the form of a ball point, round point or heavy point.

In the conjugated felting needle of the present invention, the throat depth of the barbs is from about 20 to 100μ, preferably from about 20 to 65μ, and in regard to the unification of needles, it is not necessary to unite the needles in parallel; a predetermined angle may be used such as the relative angle of ±10°.

When the needles are united at a predetermined angle, the needle felted condition of the fibers formed by punching becomes random, and in view of the desire for uniformity of the felt, preferable results are obtained.

On the other hand, it is also preferable that the needles be united at a predetermined angle, from the viewpoint of the production rate of the felting needles.

On the other hand, the unification of the needles is not restricted in sufficient durability and strength should be built into the conjugated felting needle so that it can be used without fear of being broken in the needle punching operation.

FIGS. 18 to 20 are diagrams showing various embodiments wherein two needles 65 are united with synthetic resin or molten metal (inclusive of welding) to form a shank, and FIG. 21 is a diagram showing an embodiment in which three needles 65 are united similarly to form a shank 63.

The respective conjugated felting needles shown in FIGS. 17 through 21 have different forms of cranks 66, and in the diagrams FIG. 18 and FIG. 20, the latter conjugated felting needles have intermediate blades 67 which is a difference from the former embodiments.

FIGS. 22A through J are the lateral cross-sections of shank 63 of various form of conjugated felting needles and the arrangement of needles 64 is explained by taking examples in which from two or seven needles are provided.

FIG. 23 is a diagram showing how conjugated felting needles are provided on a needle punching machine. In FIG. 23, 71 is the portion where needle board is fixed which moves up and down, 72 is the needle board, and 73 is a conjugated needle. 74 is the stripper plate, and 75 is the bed plate.

In other words, one conjugated needle is provided on one hole in the needle board 72, i.e., the hole of one conventional needle, and no special change is required, except that the diameter of the holes of the conventional needle board or plate is more or less increased.

It is an important characteristic that a great number of needle points pass through one hole of the stripper plate and the bed plate.

FIG. 30 shows many embodiments of the form of the holes 76 and 77 provided on the stripper plate 74 and the bed plate 75. Most commonly, the form of the holes is circular.

Most preferably one barb is provided per needle. In addition, barbs which do not hook too many fibers, in particular barbs of small depth, are preferable.

In regard to the thickness of the blade portion, the height of the cross-section should be preferably from about 0.28 to about 0.66 mm, preferably from about 0.28 to about 0.61 mm because the cross-section is generally a regular or equilateral triangle.

When the thickness of the blade is within the above specified range, it is most preferable to use a fiber which has preferably from about 0.5 to about 30 denier, more preferably from about 0.8 to about 10 denier with a conjugated felting needle.

For this purpose, as mentioned above, the throat depth of the barbs should be preferably below 100 microns, or more preferably below 65 microns, so that uniform needling can be attained.

Preferably, the direction of the barbs of the needle should be perpendicular to the direction in which the fibers of the web are arranged. Also, it is preferable to locate the barbs to the outside when there are many needles closely spaced, in view of the close relationship between the needles.

Even if we use the same total number of barbs (assuming that the forms of the barbs are the same) on one conjugated felting needle of this invention as compared to the use of conventional needles, the features and effects are remarkably different.

For example, when conventional felting needles are used, each of the fibers forming the felt, i.e., each of the fibers forming the web, is at one displaced in the longitudinal direction by the barbs, since the fibers hooked by the respective barbs are concentrated into one needle, while when the conjugated felting needle of the present invention is used, the fibers are dispersed because the needle is conjugated, and therefore there is almost no danger of the fibers being concentrated into one pin hole; because n number of needle points are respectively injected into n number of different places. Therefore, uniform and excellently needed felt can be obtained.

When a conventional felting needle is used, the stress given to each barb when punching is carried out, one blade must receive the stress, but when the conjugated felting needle used in the method of the present invention is used, the given stress is dispersed as the barbs are dispersed in the respective blades, and therefore the frequency of binding or breakage of needles can be reduced by that much.
Conjugated needles are also advantageous because the whole needle is thick, and therefore the removal of the needle can be easily carried out.

One conjugated needle is unified with plastic, and therefore the production of the needle is simplified.

When punching is carried out by using a conjugated felting needle of the present invention, the needle punching efficiency is high because the number of needle points is great (or because the needle is injected in such a state that the web is being pressed).

The needle used in the method of the present invention is effective especially for needle punching of the islands-in-a-sea type filament, and in particular, when the sea component is a vinyl type polymer such as poly-styrene, a copolymer of styrene and acrylonitrile, or a copolymer of styrene and methylmethacrylate.

The depth and the position of the barb at the needle in the method of the present invention have no relation to the needle, and the thickness of blade can be different.

When a conjugated needle used in the method according to the present invention is adapted for the first punch wherein the handling of a web sheet is difficult, the felt can be bound together to a considerable degree by one punch, and the punching efficiency from the second punching on can be improved.

When the second punch is carried out after having wound up the felt having been subjected to the first punch, or when a felt having been subjected to the first punch is used along with other felt by overlapping the same, the effect of the present invention is remarkably presented.

Therefore, the random state of felt can be reduced, and the quality of the felt can be improved, and the punching machine can be effectively used according to this invention.

FIG. 24 shows a needle punching loom having two needle boards 71, 71 each carrying conjugated needles 73, 73 having three needles. The stripper plate 74 and the bed plate 75 retain the fibers as they move between them and both sets of needle boards and needles are caused to reciprocate into and out of the felted fibers; when one set of needles is in, the other set is out. The opposed needles move through opposed holes in the boards 74, 75.

In FIG. 25, the conjugated needles are staggered so the needles of one board pass through holes that are spaced between the holes penetrated by the needles of the other needle board 71.

FIG. 26 is the same as FIG. 25 except that a single shafted needle opposes each conjugated needle, as shown.

In FIG. 27 the upper needle board 71 has conjugated needles composed of three shafts of varying lengths; the opposed needle board 71 has conjugated needles composed of two shafts of varying lengths, the shorter length shafts arranged in opposition to the longer length shafts of the opposing conjugated needle.

In FIG. 28 the arrangement is similar to FIG. 25 except that the staggered needles are single-shaft needles instead of conjugated and the needle boards do not reciprocate; the fiber retaining plates 74, 75 are instead reciprocated toward and away from the needle boards.

In FIG. 29 the arrangement is essentially the same as FIG. 27 except that the lengths of the needle shafts is uniform and the needle boards do not reciprocate; the fiber retaining plates 74, 75 are instead reciprocated toward and away from the needle boards.

In the needle punching machine used in the method of this invention, the distance between the outermost side of the bundled needle and wall surface of the needle holes is from about 2 to 5 mm in transferring from two to 20 felting needles as one bundled needle through the respective needle holes provided in correspondence to the stripper plate and bed plate.

As one of the drawbacks of the conventional needle punching machine, the cycle of the needle punch is 500 punches/min as a normal running condition, and at the fastest it is 1,200 punches/min, which is considered to be the upper limit.

Therefore, even if the density of punching should be desired to be increased, there is a natural restriction.

After one attempt made in the prior art to increase density of punching, the clear traces of the needles were left on the needle fabric. As results of the second and third attempt, a great number of fibers were concentrated to be penetrated at one place by one penetration of the needles, and therefore the needle fabric assumed a remarkably non-uniform structure.

As a result of the fourth attempt, the strength of stripper plate and bed plate was deteriorated, and there was a limitation to the increase of the density of needles. Also, it was very difficult to repair the needles, and other like drawbacks were encountered.

Therefore, it has been desired to develop a needle punching method capable of accurately producing a needle fabric having a uniform structure at high efficiency.

The needle punching method desirably utilizes a machine which is described in the following paragraphs, and overcomes the above mentioned problems.

The fiber needleling loom of FIG. 31 is a completely new one which cannot be arrived at from the prior art, and is a needle punching machine having a great number of sets of holes each of which is made of three holes 84, 85 and 86 respectively through the needle board 81, the stripper plate 82 and the bed plate 83. From 2 to 20 felting needles 87 are provided for each hole 84 of the needle board. The cross-sectional area of the shank portion of the conjugate needle is larger than the cross-sectional area of the blade portion. The holes 84 fit close to the shank portion in such a manner that a space is provided between the peripheries of the holes 85 and 86 and the needles.

In FIG. 31, three felting needles 87 are provided for each hole 84 of the needle board 81.

The hole 85 provided on the stripper plate as is shown by 82 in FIG. 31, is not composed of three holes but is one hole, and it is noteworthy that said hole is a little larger than the hole of prior art.

In other words, the diameter of the hole 85 is not \( n \) times larger than the diameter of the hole of the prior art, but the diameter of the hole 85 is very slightly larger than the diameter of the hole of the prior art, and it is a remarkable characteristic of the embodiment of FIG. 31 that it is not necessary to provide a hole whose diameter is \( n \) times larger than the diameter of the hole of the prior art.

In accordance with the prior art, it is a general practice to provide a needle hole with sufficient allowance of space between the needle hole and the needle. This allowance is necessary to provide for lack processing precision and for insertion operability, and to provide
for allowance for needle bending. If there is no such allowance in the diameter of the needle hole, there is no practical value in the device from the industrial point of view. However, according to the method of the present invention it has been found that when more than \( n \) needles are bundled in one hole, almost \( n \) times more industrial value can be obtained only by increasing the diameter of the hole slightly more than the diameter of the conventional hole.

On the other hand, it is not necessary to provide the same number of holes as the number of needles, but the production of stripper plate and bed plate can be easily carried out; as a remarkable advantage, sufficient strength remains in the plate and bed in spite of the danger predicted because of the radical increase of the number of needles.

It has been found that when a plural number of needles are closely planted on shank, the practical value thereof can be remarkably improved contrary to the predicted danger that fibers would become clogged between blades particularly during and after the primary stage of needle punching on a fiber web.

The felting needle to be used in the present invention has a shank portion whose cross-sectional area is larger than the cross-sectional area of the blade portion.

In other words, it is preferable that the thickness of the shank portion be greater than that of the blade portion.

It is preferable that the value of

\[
\begin{align*}
\text{Thickness of Shank} \\
\text{Thickness of Blade}
\end{align*}
\]

should be greater than one, and more in particular, it is preferable that the number of needles to be planted in one hole should be greater than one.

The reason for this is that the formation of tangled fiber flux in the form of local bundles can be prevented thereby, and the uniformity of the needles structure can be attained thereby.

It is also preferable that the throat depth of the barbs of the felting needle should be from about 20 to 70 \( \mu \) and more in particular it should be from about 20 to 55 \( \mu \) when the number of needles to be bundled is more than three.

When the throat depth is too large, the needles bend easily, and tangled fiber flux can be formed as bundles, and the surface smoothness of the felt is decreased. Also, the needle traces and punching irregularity become pronounced; therefore it is not preferable that the throat depth should be too large. On the other hand, when the throat depth is too small, the needle punching effect becomes poor.

In regard to the thickness of the needles, the needles whose JIS numbers range from No. 28 to No. 46, are more preferably used, and more in particular No. 34 – No. 44.

When the number of needles to be planted in one hole of the needle board is more than 20, the web is pressed with too much concentration, and therefore fiber flux can be formed as bundles and a felt whose interlayer structure becomes non-uniform is apt to be produced. At the same time, the needle traces become too prominent. At the same time, when a great number of needles are inserted into one hole, the fixation of the needles becomes insufficient. Therefore, it is not preferable to provide more than 20 needles in one hole of the needle board.

It is preferable that the distance between the needles and the outer periphery of the hole when the needle is inserted most deeply, i.e., the interval between the outermost needles bundled with shanks contacted against each other and the stripper plate as well as the bed plate, should be from about 0.5 to about 9 mm, preferably from about 2 to about 5 mm, and more preferably from about 2.5 to 4 mm.

In the above mentioned case, when the distance is less than 0.5 mm, the operation for attaching needles onto the needle board becomes difficult, and when the needles are bent slightly, they break easily. When the distance is more than 9 mm, the needle density is hard to increase and the strength of the respective plates is lowered; at the same time, the fibers tend to accumulate between needles during the primary stage of needle punching, making it difficult to produce a beautiful smooth felt surface. At the same time punching efficiency is likely to be lowered. Therefore it is not preferable to make the distance more than 9 mm.

In accordance with the method of the present invention, the manner of planting or arranging the felting needles onto the needle board is important.

In FIG. 32 the arrangement of the needles 92 of the prior art is such that the needles are planted on the needle board 93 of the conventional fiber needling loom. The crank portions 91 of the needles are observed from the needle ends.

On the other hand, FIGS. 33 and 34 show the arrangement of the crank portion 95 of the needle board 94 in the needle loom of the present invention. In FIG. 33 an embodiment having three needles is shown. In FIG. 34 an embodiment in which seven needles are planted in a common shank is shown.

In FIG. 34 the crank portion of the central needle only is not shown, and the reason for this is explained hereinafter.

The configuration of needles on the needle board in the needle punching machine of the present invention is explained in the following paragraphs in accordance with FIG. 35.

FIG. 35 is a diagram showing the relation between the needle hole 84 viewed across the line XXXV—XXXV of FIG. 31 and the needle 87, i.e., the manner in which the needles are planted on the needle board.

FIG. 35A shows the arrangement of three needles, and FIG. 35B shows an arrangement of seven needles in a common shank.

The arrangements of three needles and seven needles are the most preferable embodiments of the method of the present invention.

In addition to the above, the arrangements of four needles, six needles, two needles, and 11 needles are shown by FIGS. 35C, 35D, 35E and 35F; these are also preferred embodiments of the method of the present invention.

In FIG. 35A three needles 87, 88 and 89 are planted at the maximum density. FIGS. 35B through 35F show similar embodiments, but the embodiments of FIGS. 35A and 35B are the most preferable because the needles are excellently fixed.

In the cases such as FIG. 35D and FIG. 35F, it is necessary to provide needles of different thickness.

It is a matter of course that in accordance with the present invention it is possible to provide needles of different thickness or length, and that it is possible to
plant different numbers of needles for the respective needle holes.

The hole 84 of the needle board is not required to be circular by any means, but it can have rectangular, slit-like, oval, or petal form.

In addition, in accordance with the present invention, it is possible to plant needles by using blind needles along with the needles as is explained hereinafter.

In the cases shown by FIGS. 35B, 35D and 35F, the blind needle plays an important role, and in particular, it has an important relation to the crank.

Next, the felting needle and the arrangement of said felting needle on the needle board in the needle punching machine of the present invention, are explained in further detail in the following paragraphs.

For the sake of convenience, reference is made to a barb, but the same thing can be said about a needle having a plural number of barbs.

When three needles are planted, as is shown in FIG. 35A, the arrangement of needles having a crank portion is not always the same.

FIGS. 36A and B show different arrangements of the needle board in which the relation between the crank portions of the needles and the direction of the barbs is shown as is observed from the crank ends.

The reference numeral 95 in the diagrams FIGS. 36A and B shows the crank, and the dotted circle 84 shows the hole in the needle board. The circle 97 shows the shank and 98 shows the blade.

FIGS. 36A and B show embodiments in which three needles are planted but the directions of the cranks are different.

This can be determined by the direction in which the barbs are placed.

In accordance with the results obtained by the inventors of the present invention, when a plural number of needles each of which has one barb are planted by bundling the same, the punching efficiency is high when all the barbs face toward the outside and this has a tendency toward production of uniform felt.

Almost all the felting needles which are commercially distributed on the market are those of the standard type as is shown in FIG. 37A in which the directions of the respective tops of the triangular cross-section of the blade which is called the standard type as is shown in FIG. 37A. The embodiment of FIG. 37B has no such a relation.

When the end of the needle is directed toward the eye, and when the needle is observed right from the above, it appears as is shown in FIG. 37A.

When the center line of the needle is made the fulcrum, and the direction of the crank is made 0°, the directions of the respective corners of the triangular cross-section of the blade are 60°, 300° and 180°, and generally they are called the first row, the second row and the third row.

In the conventional needle, when only one barb is provided, said barb is present on the first row or the second row, but in most cases the barb is present on the third row.

When the needle is planted by turning the crank as is shown in FIG. 33 or FIG. 34, the bars are all turned inside.

Therefore, in order to turn the barb outside, it is necessary to plant the needle in such a manner that the needle with the barb on the second row is slightly twisted as is shown in FIG. 36A, and this has been found out for the first time as a result of the researches of the inventors of the present invention.

From the above mentioned standpoint, the needle composed of the crank portion as is shown in FIG. 37B, and the blade portion is important.

Namely, when the direction of the barb is turned in the same direction as the crank, i.e., at 0°, the barb can be turned outside in all the cases as is shown in FIGS. 33, 34 and 35.

When the barb is turned in the direction of 0° in FIG. 36B as mentioned above, it is not necessary to plant the needle at the twisted position as is shown in FIG. 36A.

In this sense, the needle of the type of FIG. 37B is the most appropriate felting needle for carrying out the method of the present invention, and in addition, it is quite a new needle which cannot be compared with conventional needles.

The felting needle of low throat depth which has a low fiber hooking coefficient, is very effective in view of the fact that the needed felt produced has uniformity of fiber needleling; the reason for this is that the fibers are not hooked in the form of large bundles.

When a felting needle having a plurality of barbs is used, or when it has large barbs, large numbers of fibers are collected in the needle hole in the form of a bundle; therefore it is impossible to produce a uniform and excellent needle structure in the felt.

From this standpoint, it is preferable that the distance between barbs of the needle be as large as possible, as in the present invention.

When comparison is made between a first case in which the needle has a barb on the third row, as is shown in FIG. 33, and a second case when the needle has a barb at the 0° position and is provided as in FIG. 33, the distance between barbs is greater in the second case. The arrangement of the second case if effective and no local bundle formations are produced; punching efficiency is higher in the second case as mentioned before.

FIG. 38 is a side view of a blind needle 99 which is useful in the method of the present invention. A blind needle, as the term is used in connection with this invention, is a conventional felting needle having no blade portion and no intermediate blade portion. In other words, in the conventional felting needle as is shown in FIG. 2, the intermediate blade 11 and the blade 12 are not provided in a blind needle.

FIG. 38A shows a blind needle produced from a conventional needle. FIG. 38B shows a pin type blind needle, or T-type blind needle, while FIG. 38C shows a pin-type needle whose shank 99 is unusually thick.

The characteristic of the blind needle of FIG. 38A is that a defective needle whose blade portion is broken can be effectively used.

The blind needle of FIG. 38B is effective as a center needle as in the case of FIG. 35B.

Of course, in the case of FIG. 35B, if the same needle is used, it is not necessary to use such a blind needle as is shown in FIG. 38B when the plate with holes is placed on six needles on the outer periphery, and by planting the central needle.

The blind needle has no blade portion with barb, and therefore it does not take part in the punching directly.

However, as is shown in FIG. 35, when a plural number of needles are bundled and provided in one hole, the fixation of needles can be made stable by placing a blind needle in the center thereof, and at the same
time as the secondary effect, the blind needle can perform the role of preventing the formation of fiber flux needed in the form of a bundle, when needle punching is carried out.

It is preferable that the felting needle should be provided perpendicularly and uniformly in relation to the direction in which felt proceeds.

Therefore, it is preferred to provide the felting needle in a slit form, one-row arrangement, or a rectangular arrangement perpendicularly against the direction in which felt proceeds, rather than a circular arrangement.

It is preferable to bundle the needles in such a manner that the needles can be arranged in the lateral direction as uniformly as possible by utilizing the blind needle as effectively as possible even in the case of a circular needle hole.

As fibers to be used in practicing the present invention, conventional ordinary or highly shrinkable polyesters, polyamides, polypropylene, and such synthetic fibers, or natural fibers such as cotton, wool, or rayon, can be used in the present invention. In addition to those given above, the aforementioned islands-in-a-sea type filament is preferably used in practicing this invention.

The fibers mentioned above are formed into a fiber web by means of a typical carding machine or crosslapper and the fiber web is subjected to the needle punching operation by using a needle punching machine of the present invention.

In carrying out the needle punching by using the needle punching machine of the present invention, when the number of needles to be planted on the punching board is great, or when the punch number is small, the felt takes on a non-uniform structure, but when the punch number is increased, the felt structure becomes uniform.

Therefore, as conditions for needle punching, the needle density is 1,500/cm² or above, or more preferably above 3,000/cm².

On the other hand, needle punching should be carried out with a large number of needles after having carried out needle punching with a lesser number of needles, and a uniformly needled structure can be thus obtained.

And needle punching may be carried out with a conjugated felting needle having a lesser number of needles after having carried out needle punching with a conjugated felting needle having a large number of needles.

In the present invention, after needle punching has been carried out with the conjugated felting needle, subsequently needle punching may also be carried out with a needle having one to nine barbs, preferably one to three barbs.

On the other hand, when finishing punching is carried out with a lesser number of needles, the same effect can be obtained.

The surface of a needled fabric obtained by using a needle punching loom of the present invention is excellently uniform, and therefore it is preferable in providing slices for subsequent fabrication.

The effects and features of the needles arranged in a plural number of bundles to be provided on one hole of the needle board in the needle punching machine, and the conventional needles each of which has one barb, are remarkably different even if the total number of barbs should be the same.

For example, (a) in accordance with the present invention, a plural number of needle ends are injected at respectively different places of the fiber web, and therefore a felt of more uniform needled structure than the prior art can be obtained, (b) in accordance with the prior art, the stress applied at the time of punching is applied to one blade, but in accordance with the present invention, the stress is dispersed through a plurality of blades, and the breakage of needles and the bending of needles may be reduced significantly, (c) it is possible to change the broken needle alone if the needle should be broken, and if the blade portion should be broken it can be used as a blind needle, (d) needle punching efficiency is high because the number of needle ends at the time of punching is great, and (e) the needle punching machine of the present invention is especially effective for needle punching of a web made of the above mentioned island-in-a-sea type filament, and in particular, the needle punching machine is effective when the sea portion thereof is composed of a vinyl type polymer such as polystyrene a copolymer of styrene and acrylonitrile, or a copolymer of styrene and methylmethacrylate.

The following are examples to illustrate the present invention further.

**EXAMPLE 1**

A crimp of 15 to 10 crimps per inch was applied to an islands-in-a-sea type filament of 4.5 denier wherein the island portion thereof was composed of polyethylene terephthalate (the number of islands was 16), and the sea portion thereof was composed of polystyrene (prepared by adding polyethylene glycol), and the ratio of sea portion to island portion was 50:50, and the filament was cut into 49 mm staple. The staple thus obtained was subjected to opening, and the opened staple was passed to a carding machine, and then made into web of sheet-like formation by using a cross lapper.

The sheet form web thus obtained was subjected to a needle punching machine, and then finished into a needled felt or mat.

The needle which was used in this example was provided with one barb, and the barb of the needle having a blade whose cross-sectional height (altitude) was from 0.4826 ± 0.0254 mm, was processed with a dead-smooth cut file so that the needle had the ability to hook one fiber on the average, and the needled felt obtained had a structure composed of one needled fiber or fiber flux on the average.

The confirmation of the fiber hooking coefficient of the needle was carried out by pressing the web with a coarse metal net, and the needle was injected deeply twenty times into the different net-eyes in the punching state.

For the sake of comparison, three kinds of needles were used, and needle punching was carried out on a web made of the same island-in-a-sea type filaments as above, and felt A, felt B and felt C were produced.

A: The needle having nine barbs, and the cross-sectional height or altitude of the triangle was the same as in this example: the needle had the ability to hook more than 15 fibers per single injection (the needle corresponds to the commercially distributed No. 40 needle).
B: Needle having one barb with a blade whose cross-sectional height was 0.65 ± 0.01 mm, the needle had the ability to hook from eight to 14 fibers of the same kind at once.

C: The needle of B was processed so that only from one to three fibers could be hooked upon one single injection into the web.

The fiber web was punched sufficiently to make the apparent density of the felt above 0.15 g/cm²; the product of the present invention required at least 5,000 needle punches per square centimeter (punching number).

In the case of felt A, a punching number of at least 800/cm² was required, and in the case of felt B, at least 1,200/cm² of punching number, was required.

When the resulting felts were compared, in the case of felt B and felt C, needle traces were very noticeable, and it has been found that when the needle is too thick it is impossible to produce an excellent felt even if only one barb is provided on the needle and the fiber hooking coefficient is low.

In the case of felt A, the needle traces were less than felt C, but since the number of fibers to be injected was greater, and therefore more than three needed fibers, or the fiber group composed of fiber flux are noticeable on the surface of felt, and therefore felt A was not an excellent product.

The respective felts were dipped into 98° C boiling water in advance to stabilize the size, and thereafter 15 percent of carboxymethyl cellulose (based on the weight percentage of fiber) was added thereto, and sizing was thus carried out.

After having dried the treated felts, the sea portions of the islands-in-a-sea type filaments forming the felts were removed by using perchloroethylene, and then the felts were dried again, and then 75 percent by weight of a polyurethane solution (having a primary Young's modulus of 0.213 kg/cm² when the solution is made into a film by wet forming) was saturated into the felts based on 100 parts by weight of the island portion, and then it was coagulated (at 20°C), and when the coagulation was almost finished in 30 minutes, the felts were put into hot water, and squeezing and the treatment with hot water were carried out again.

Thereafter, both sides of the felts were buffed with sandpaper, and then each of the felts was sliced into two, and the surfaces were compared.

In the case of control felt A, the nap close to that of the base skin, i.e., velour type artificial leather had such a structure that the naps of fiber flux were in groups. In the case of control felt B, lines and the concave and convex curvatures corresponding to the needle traces were noticeable on the surface in addition to the nap groups of felt A, and control felt B was worse.

In the case of control felt C, grouping of the fiber flux naps was less, and fairly good, but noticeable lines and the concave and convex curvatures corresponding to the needle traces were produced.

When compared with the above given controls, the felt produced in accordance with the conditions of the present invention, had a smooth surface with only very few grouped fiber fluxes, and the felt was a suede type artificial leather close to the nebeuclle type; when compared with the control products, the surface state was excellent even when strongly stretched.

EXAMPLE 2

The same island-in-a-sea type filaments as in Example 1 was used, except that the fineness of the filaments was 2.1 denier, the island portion was composed of polyethylene terephthalate containing 4.5 mol percent of isophthalic acid and 5 mol percent of phthalic acid, and the sea portion was composed of polystyrene with polyethylene glycol added thereto, having about 35 percent of boiling water shrinkability. The felts were worked on an opener, and then passed through a carding machine, and were made into a web by a cross lapper.

The web thus obtained was worked on a needle punching machine provided with a needle which was processed so as to hook from one to two fibers (fiber hooking coefficient C = 1.3), and made into a needle felt needled with less than two tangled fibers and fiber flux.

On the other hand, a control felt was prepared by using a needle whose barb had the ability to hook more than three fibers on the average.

The felts thus obtained were treated in the same manner as in Example 1, and the final products were produced.

The principal difference between the products of Example 1 and the products of Example 2 was that all the products of Example 2 were greatly shrunk and solidified in the form-stabilizing treatment by means of the boiling water treatment.

The fibers of the felt were fixed as they were formed into such a special structure that the fibers could not be moved and therefore they were as hard as boards.

As a result, the fiber density and other factors were improved as a whole, but when the products of the present invention were compared with the control products, a great difference was apparent between the product of the present invention in Example 1 and the controls of Example 1.

EXAMPLE 3

Islands-in-a-sea type filaments were used, the fineness thereof being 3.5 denier; the fiber length being 51 mm; the number of crimps being from 10 to 15 crimps per inch. These filaments had not been subjected to any thermal treatment. The island portion was composed of 30 parts of polyethylene terephthalate (the number of islands being 18), the sea portion was composed of 70 parts of polystyrene (with polyethylene glycol added thereto). The filaments were worked on a carding machine, and a cross lapped web was obtained.

Thereafter, in the same manner as in Example 1, the barb was processed so that the fiber hooking coefficient C was between 1 and 2, and the average was 1.4. 5,600/cm² of needle punches were carried out, and a needle felt having less than two needle fibers per group was produced.

After having shrunk the felt with boiling water, the felt was dried (in this case almost the same shrinkability around 35 – 45 percent could be observed even after a dry thermal shrinking treatment) and then it was treated with 1.2 percent partially saponified polyvinyl alcohol solution, and then the treated felt was squeezed, and then the felt was dried as a 10 percent felt.

After having been dried, the felt was treated with trichloroethylene to remove the sea portion, and the felt was passed through a machine to squeeze and wash the felt over again, and thereafter it was dried.
Next, the treated felt was saturated with polyurethane solution and then it was coagulated at 20°C in accordance with the wet process, and then treated with hot water at a temperature ranging from 80°C to 95°C, and squeezed.

Said polyurethane solution was coated on polyethylene terephthalate film, and then it was coagulated at 20°C and the product thus obtained was subjected to a hot water treatment, and then it was dried. Thereafter, the primary stage Young's modulus of the polyurethane film obtained in accordance with the wet process and the primary stage Young's modulus of the polyurethane film obtained in accordance with the dry process were more or less different (respectively 0.196 kg/cm² and 1.40 kg/cm²) but both of them adhered onto the polyethylene terephthalate film, and when they were positively pulled out, they peeled off. It is undesirable that only the polyurethane film coagulated in accordance with the wet process could be peeled off.

The base material obtained was dried, and its surface was buffed at a high speed, and the surface was made smooth, and thereafter polyurethane films having thicknesses respectively of 150μm, 100μm, 50μm, and 30μm were adhered on the base material.

For the sake of comparison, a control product was prepared by using two kinds of needles with fiber hooking coefficients of C = 15 and C = 8 in the same manner as before, and the coarseness and the smoothness of the surfaces were evaluated, and the product of the present invention had remarkably improved coarseness and surface smoothness, when compared with the control product.

On the other hand, another control product was prepared by using a polyester fiber having the same shrinkability as before without using islands-in-a-sea type filaments, at a fiber hooking coefficient C of respectively C = 15, C = 8, and C = 1.5 to produce felt, and thereafter the resulting felt was treated in the same manner as before. The felt thus obtained was compared with the product of the present invention, and it was found that the coarseness and the smoothness of the surface of the product of the present invention were remarkably improved when compared with the three control products.

Among all the control products, the control obtained at the fiber hooking coefficient of 1.5 was better than the other two control products. It should be noted that the coarseness and smoothness of the surface of conventional artificial leather are very poor unless the surface film is made as thick as from 300 to 700μm, and the commercial value of such conventional artificial leather is very low, while in accordance with the present invention, it is possible to produce an artificial leather of high commercial value even if the thickness of the surface film was as thin as that of natural leather.

On the other hand, the touch, feel of thickness, softness, and the state of wrinkles of the product of this invention were all excellent.

**EXAMPLE 4**

In a procedure similar to Example 3, a composite felted fabric was made wherein the front portion of the thickness (about 60 percent) was composed of island-s-in-a-sea filaments of Example 3, and the other 40 percent of the thickness representing the back side portion of the non-woven cloth was made of a different island-s-in-a-sea type filament as described below.

<table>
<thead>
<tr>
<th>ISLANDS COMPONENT</th>
<th>4.9 mol% of naphthalic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEA COMPONENT</td>
<td>Polyethylene glycol</td>
</tr>
<tr>
<td>RATIO OF ISLAND:SEA</td>
<td>53:47</td>
</tr>
</tbody>
</table>

In regard to the fiber hooking coefficient which is important in carrying out punching, the same consideration was observed as in Example 3. In addition, when punching was carried out from below, caution was used so that bars could not go beyond the middle of the upper layer fiber web in the direction of the thickness thereof, and when punching was carried out from above, caution was used so that bars could reach to the lower surface of the lower layer thereof.

As a result, excellent coarseness and surface smoothness could be obtained, and more excellent wrinkles, thick feeling, and more excellent resistance against the size change attributable to the improvement of fiber density, could be attained.

**EXAMPLE 5**

The same experiment was carried out as in Example 4 by using the needle, the height of the cross-section of its blade being respectively from 0.65±0.01 mm, from 0.69±0.02 mm, and from 0.74±0.03 mm, and the concave and convex curvatures of the surface of the product were remarkable and it was found that there is a restriction on the thickness of the blade separately from the fiber hooking coefficient C.

**EXAMPLE 6**

A web composed of the fibers described below was subjected to needle punching by using the conjugated needle described.

For the sake of comparison, a control is also described.

**FIBER:**

<table>
<thead>
<tr>
<th>Component of islands:</th>
<th>polyethylene terephthalate...50 parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component of sea:</td>
<td>polystyrene (containing 3% PEG)...50</td>
</tr>
<tr>
<td>Number of islands:</td>
<td>16 (a type)</td>
</tr>
<tr>
<td>Cut length:</td>
<td>51 mm</td>
</tr>
<tr>
<td>Denier:</td>
<td>from 3 to 5</td>
</tr>
<tr>
<td>Number of crimps:</td>
<td>from 10 to 13 crimps/in.</td>
</tr>
<tr>
<td>Web weight:</td>
<td>750 g/m²</td>
</tr>
<tr>
<td>Method employed for</td>
<td>carding plus cross lapper machine</td>
</tr>
<tr>
<td>making sheet:</td>
<td></td>
</tr>
</tbody>
</table>

**CONJUGATED FELTING NEEDLE:**

| Number of needle ends: | 3                                      |
| Number of barbs:       | three in all (one barb per one needle) |
| Throat depth of each barb: | 50μm                             |
Position of barbs: all three barbs were 3.5 mm away from the needle end
Arrangement and method for application: substantially the same as FIG. 17 and FIG. 22, at the blade portion cross-sectional height: 490μm
Thickness of needle: 1850μm
Distance between needle ends: 100μm

The above prescribed fiber and conjugated felting needle were used to carry out punching at a density of 1,500/cm² as a conjugated needle (three needle ends), and excellent needle felt whose thickness was 8.2 mm (as measured by using the commercially distributed dial thickness gauge) was obtained.

On the other hand, punching was carried out by using conventional felting needles having the same structure as the above mentioned needles (11 needles) by using the same punching machine and 5,050 needles/cm² were required to attain the same thickness.

Thus, it was found that the frequency for passing a wet sheet through the punching machine was remarkably poor.

It was confirmed that the present invention was remarkably effective when compared by calculating the number of needle ends.

The felt obtained was excellent as a base material for artificial leather.

EXAMPLE 7
In a procedure like Example 6, conjugated felting needles were arranged as in FIG. 22E.
In other words, the process was carried out in the same manner as in Example 6 except that the number of needle ends per shank was changed to seven.
In spite of the fact that the efficiency of the punching machine was the same and the punching machine had the same strokes, in accordance with the present invention 100 needles/cm² (with seven needle ends), i.e., 700 needles/cm² (as calculated in the conventional product) while the conventional needle could punch 100 needles/cm² only, and the needle felt of the present invention had the same fixation as a conventional needle felt of 800 needles/cm².

The rest of the punching was carried out with a conventional needle and a punching of 2,000 needles/cm² was carried out, and an excellent felt well adapted for artificial leather was obtained.

EXAMPLE 8
The cross lapped web prepared from islands-in-a-sea type filaments (the polymer comprising the island portion being polyethylene terephthalate; the polymer comprising the sea portion being polystyrene) was subjected to needle punching under the conditions given in the column of Example 8 of Table 1 given below.

The expression direction means the side of each needle upon which the barb is placed with the center of the bundles of needles as the fulcrum.

Outwardly planted means that when the barb location is 60°, needles are planted as shown in FIG. 36A.
The result is shown at line 101 in FIG. 39.
In FIG. 39, the apparent density represented by the ordinate shows the value obtained by measuring the thickness of the felted product under a load of 40 g/cm² and computing the density; the density value shows exactly the condition of penetration of the needle fabric; the more the punching is carried out the more the density is improved. (The load of 40 g/cm² is lighter than the load applied when the thickness is measured with an ordinary thickness meter; the ordinary dial gauge type thickness meter is not appropriate for this purpose because the load is changed along with the thickness to be measured).

As a comparative value we determined the result of needle punching carried out by providing one felting needle per hole on a needle board in accordance with the conventional method.

Therefore the abscissa of FIG. 39 shows the number of needles calculated in the number of holes of the needle board in the same device. One conjugated needle is counter as one needle. This means that the needle density was measured on the basis of holes, either the needle punching carried out with one needle or with a plural number of needles bundled together in one hole of the needle board.

The conditions as Control 8 given in Table 1 show the comparative test, and the results of the test are shown by the line 102 in FIG. 39.
When the two curves 101 and 102 are compared, it will be understood that the punching effect of the present invention is very excellent.
Namely, the same punching effect as is attained by working the punching machine 9 times in accordance with the conventional method can be attained by working the punching machine for only three times in accordance with the present invention.

EXAMPLE 9
Needle punching was carried out by using the same web of islands-in-a-sea type filaments under the same conditions as in Example 9, Control 9 given in Table 1.
The results obtained are shown by the lines 103 and 104 of FIG. 39.
Thus, it is apparent that the productivity of the present invention is very excellent.
Example 9 and Example 8 are almost the same in so far as needle planting operability and industrial value are concerned, and it has been sufficiently confirmed that the industrial value of the present invention is high.
The manner of planting needles in this example is the same as is shown in FIG. 33. Therefore, the barbs are turned inside.

EXAMPLE 10
Needle punching was carried out on a fiber web made of the same islands-in-a-sea type filaments as in Example 8, under the conditions of Example 10 given in Table 1, and a control was carried out under the conditions of Control 10, and the results obtained are shown respectively by the line 105, Example 10, and by the line 106, Control 10 of FIG. 39.
A felt of excellent needle structured was obtained in accordance with the present invention, and it was confirmed that the punching effect thereof was very high.
Namely, in regard to the barb, one barb per needle was used, and the fiber hooking coefficient was small,
and therefore the needled state was uniform, and the surface of the felt was smooth.

In regard to the manner in which the needles were planted in this example, it was of the arrangement shown in FIG. 35B, and a blind needle with a broken blade was used for one central needle. The blind needle was produced from a broken needle.

The pressing board was of two stages, and it was contrived that the central needle and the peripheral needles could be sufficiently pressed to be fixed.

TABLE 1

<table>
<thead>
<tr>
<th>Conditions for experiments</th>
<th>Example 8</th>
<th>Control 8</th>
<th>Example 9</th>
<th>Control 9</th>
<th>Example 10</th>
<th>Control 10</th>
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<tbody>
<tr>
<td>(unit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total length of needle</td>
<td>88.9</td>
<td>88.9</td>
<td>88.9</td>
<td>88.9</td>
<td>76.2</td>
<td>76.2</td>
</tr>
<tr>
<td>Length of needle shank</td>
<td>67.8</td>
<td>67.8</td>
<td>28.1</td>
<td>28.1</td>
<td>53.2</td>
<td>53.2</td>
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<tr>
<td>Length of needle blade</td>
<td>21.1</td>
<td>21.1</td>
<td>30.0</td>
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<td>23.0</td>
<td>23.0</td>
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<tr>
<td>Length of intermediate blade</td>
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<td>-</td>
<td>31.0</td>
<td>31.0</td>
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<td>-</td>
</tr>
<tr>
<td>Thickness of needle crank</td>
<td>0.91</td>
<td>0.91</td>
<td>1.84</td>
<td>1.84</td>
<td>1.21</td>
<td>1.21</td>
</tr>
<tr>
<td>Thickness of blade (one side)</td>
<td>0.47</td>
<td>0.47</td>
<td>0.50</td>
<td>0.50</td>
<td>0.42</td>
<td>0.42</td>
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<tr>
<td>Thickness of shank</td>
<td>0.91</td>
<td>0.91</td>
<td>1.84</td>
<td>1.84</td>
<td>1.21</td>
<td>1.21</td>
</tr>
<tr>
<td>Thickness of intermediate blade</td>
<td>-</td>
<td>-</td>
<td>1.23</td>
<td>1.23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of bars</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Position of bars (from the end)</td>
<td>-</td>
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<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bar length location</td>
<td>60°</td>
<td>60°</td>
<td>180°</td>
<td>180°</td>
<td>180°</td>
<td>180°</td>
</tr>
<tr>
<td>Length of crack</td>
<td>4.0</td>
<td>4.0</td>
<td>5.2</td>
<td>5.2</td>
<td>5.5</td>
<td>5.5</td>
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<tr>
<td>Throat length</td>
<td>0.65</td>
<td>0.65</td>
<td>0.6</td>
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<td>0.75</td>
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<td>0.07</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
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<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Direction of bar (End opening direction is positive)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Direction of bar</td>
<td>Outward</td>
<td>Inward</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of blind needles</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Position of blind needle</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Center</td>
<td>-</td>
</tr>
<tr>
<td>Diameter of needle board hole</td>
<td>4.0</td>
<td>0.92</td>
<td>4.0</td>
<td>0.92</td>
<td>4.0</td>
<td>0.92</td>
</tr>
<tr>
<td>Diameter of stripper plate hole</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Diameter of bed plate hole</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Stroke width</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Stroke frequency (CPm)</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Web speed mm/min</td>
<td>480</td>
<td>480</td>
<td>480</td>
<td>480</td>
<td>480</td>
<td>480</td>
</tr>
<tr>
<td>Web weight g/m²</td>
<td>650</td>
<td>650</td>
<td>650</td>
<td>650</td>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td>Density of needle board holes (hole/cm²)</td>
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<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
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<tr>
<td>Characteristics of raw material: fineness (d)</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Number of cimps</td>
<td>13.1</td>
<td>13.1</td>
<td>13.1</td>
<td>13.1</td>
<td>13.1</td>
<td>13.1</td>
</tr>
<tr>
<td>(Islands-in-a-sea type filaments)</td>
<td>16.9</td>
<td>16.9</td>
<td>16.9</td>
<td>16.9</td>
<td>16.9</td>
<td>16.9</td>
</tr>
<tr>
<td>Degree of cimps</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Cut length</td>
<td>50/50</td>
<td>50/50</td>
<td>50/50</td>
<td>50/50</td>
<td>50/50</td>
<td>50/50</td>
</tr>
<tr>
<td>Ratio of islands against sea (PET/PSt)</td>
<td>38.9</td>
<td>38.9</td>
<td>38.9</td>
<td>38.9</td>
<td>38.9</td>
<td>38.9</td>
</tr>
</tbody>
</table>

* PET stands for polyethylene terephthalate
** PSt stands for poly styrene

EXAMPLE 11

Polyester staple (3d x 76 mm) and nylon staple (5d x 51 mm) were made into a sheet-like web by use of a random webber and then needle punching was carried out on the fiber web obtained under the same conditions as in Examples 8, 9 and 10.

As a result, when three needles were bundled, they were 3 times more effective than when only one needle was used, and when seven needles were bundled (one of said seven needles being a blind needle), they were 6 times more effective than the case in which only one needle was used.

the resulting needle punched fabric was well adapted.
FIGS. 40 and 41 show needle adapter 112 for conjugate felting needles according to this invention. The needle adapter is made of a resin and has holes 115 into which needles are inserted and has ribs 113 on its periphery. The adapter is fixed in the needle fixing hole of a needle board. The adapter is tapered from top to bottom. FIG. 42 shows another adapter provided with holes 115 in a row and each hole is connected to its neighbor(s) lengthwise.

FIG. 43 shows an adapter similar to that shown in FIG. 42, except that the top portion of the adapter is cut off for setting the cranks of the needles. FIGS. 44 and 45 show other adapters also preferably made of resin.

<table>
<thead>
<tr>
<th>Conditions for experiments</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length of needle Shank</td>
<td>(mm)</td>
<td>88.9</td>
<td>88.9</td>
<td>76.2</td>
<td>76.2</td>
<td>76.2</td>
<td>76.2</td>
</tr>
<tr>
<td>Length of needle Shank</td>
<td>(mm)</td>
<td>28.6</td>
<td>28.6</td>
<td>28.6</td>
<td>28.6</td>
<td>28.6</td>
<td>28.6</td>
</tr>
<tr>
<td>Length of needle blade</td>
<td>(mm)</td>
<td>31.9</td>
<td>31.9</td>
<td>31.9</td>
<td>31.9</td>
<td>31.9</td>
<td>31.9</td>
</tr>
<tr>
<td>Length of intermediate blade</td>
<td>(mm)</td>
<td>28.4</td>
<td>28.4</td>
<td>28.4</td>
<td>28.4</td>
<td>28.4</td>
<td>28.4</td>
</tr>
<tr>
<td>Thickness of needle Shank</td>
<td>(mm)</td>
<td>0.91</td>
<td>1.84</td>
<td>1.21</td>
<td>0.91</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Thickness of blade (one side)</td>
<td>(mm)</td>
<td>0.47</td>
<td>0.50</td>
<td>0.42</td>
<td>0.47</td>
<td>1.42</td>
<td>0.47</td>
</tr>
<tr>
<td>Thickness of Shank</td>
<td>(mm)</td>
<td>0.91</td>
<td>1.84</td>
<td>1.21</td>
<td>0.91</td>
<td>1.21</td>
<td>0.91</td>
</tr>
<tr>
<td>Thickness of intermediate blade</td>
<td>(mm)</td>
<td>—</td>
<td>1.23</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Number of bars</td>
<td>—</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Bar spacing row to row</td>
<td>(mm)</td>
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<td>2.11</td>
<td>2.11</td>
<td>2.11</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Position of bars (from end to end)</td>
<td>(mm)</td>
<td>6.35</td>
<td>6.35</td>
<td>6.35</td>
<td>6.35</td>
<td>6.35</td>
<td>6.35</td>
</tr>
<tr>
<td>Barb location</td>
<td>(*)</td>
<td>60°, 180°, 60°, 180°, 60°, 180°, 60°, 180°, 60°, 180°, 60°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Length of crank</td>
<td>(mm)</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
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<tr>
<td>Throat length</td>
<td>(mm)</td>
<td>—</td>
<td>—</td>
<td>0.75</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Throat depth</td>
<td>(mm)</td>
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<td>0.096</td>
<td>0.096</td>
<td>0.096</td>
<td>0.096</td>
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<tr>
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<td>(mm)</td>
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<td>6.0</td>
<td>1.83</td>
<td>6.0</td>
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<tr>
<td>Diameter of stripper plate hole</td>
<td>(mm)</td>
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<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>7.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Diameter of head plate hole</td>
<td>(mm)</td>
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<td>8.0</td>
<td>7.0</td>
<td>8.0</td>
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<tr>
<td>Stroke width</td>
<td>(mm)</td>
<td>75.0</td>
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<td>75.0</td>
<td>75.0</td>
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</tr>
<tr>
<td>Stroke frequency</td>
<td>(CPM)</td>
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<td>500</td>
<td>500</td>
<td>500</td>
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<tr>
<td>Web speed</td>
<td>(mm/min)</td>
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<td>Diameter of needle board hole</td>
<td>(holes/cm²)</td>
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<td>0.66</td>
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</tr>
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<td>Fineness (d)</td>
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<tr>
<td>Fiber</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Degree of crimps</td>
<td>—</td>
<td>16.9</td>
<td>—</td>
<td>16.9</td>
<td>—</td>
<td>16.9</td>
<td>—</td>
</tr>
<tr>
<td>Cut length</td>
<td>(mm)</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Ratio of lands against sea (PET/PSC)</td>
<td></td>
<td>50/50</td>
<td>—</td>
<td>50/50</td>
<td>—</td>
<td>50/50</td>
<td>—</td>
</tr>
<tr>
<td>Needle density (number/cm²)</td>
<td></td>
<td>380</td>
<td>390</td>
<td>1200</td>
<td>780</td>
<td>300</td>
<td>2000</td>
</tr>
<tr>
<td>Felt density (g/cm²)</td>
<td></td>
<td>0.15</td>
<td>0.165</td>
<td>0.14</td>
<td>0.165</td>
<td>0.10</td>
<td>0.115</td>
</tr>
<tr>
<td>Needle density (number/cm²)</td>
<td></td>
<td>—</td>
<td>2000</td>
<td>1000</td>
<td>—</td>
<td>2000</td>
<td>—</td>
</tr>
<tr>
<td>Felt density (g/cm²)</td>
<td></td>
<td>0.175</td>
<td>0.116</td>
<td>—</td>
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</table>

FIGS. 44 and 45 show needle adapter 112 for conjugate felting needles according to this invention. The needle adapter is made of a resin and has holes 115 into which needles are inserted and has ribs 113 on its periphery. The adapter is fixed in the needle fixing hole of a needle board. The adapter is tapered from top to bottom. FIG. 42 shows another adapter provided with holes 115 in a row and each hole is connected to its neighbor(s) lengthwise.

FIG. 43 shows an adapter similar to that shown in FIG. 42, except that the top portion of the adapter is cut off for setting the cranks of the needles. FIGS. 44 and 45 show other adapters also preferably made of resin.

These adapter 112 have needle inserting holes 115 and each hole opens on the periphery of the adapter and forms a slot 116. The adapter shown in FIG. 45 has a cut-off portion on its top for setting the crank of the needle.

The aforementioned adapters are very useful for fixing a conjugate felting needle on the needle board which is normally made of metal, for example, aluminum plate.

FIG. 46 shows a conjugate felting needle which has a non-circular cross-sectional shank 87. Each flat face of the shanks is contacted face to face and is set into
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We claim:

1. A method for producing a felted fabric from a web of loosely matted fibers which comprises the steps of providing a fibrous web in which a plurality of fibers is in a generally uni-directional arrangement, subjecting the fibrous web to repeated penetrations of conjugated needles while restraining the web to hold it in position during penetration and withdrawal of said needles, at least some of said conjugated needles having capacity to catch some of said loosely matted fibers to displace them across said direction of said uni-directional arrangement, to produce a felted fabric, each of said conjugated needles being mounted separately from each other with a predetermined space therebetween, each of the conjugated needles being a bundle of plural individual needles, with an interval provided between the points of the individual needles in a range from about 300 to 5,000 microns, and relatively reciprocating the conjugated needles through the openings and penetrating into and withdrawing from the web, with the distance between the outermost portion of the needles and the surface of the corresponding opening being restricted in the range from about 0.5 to 9 millimeters, whereby needle punching is carried out wherein a multiplicity of fibers penetrate substantially perpendicularly into said web.

2. A method for producing felted fabric according to claim 1, wherein the needle punching step is carried out at a needle density per square centimeter ranging from about 200 to 12,000.

3. A method for producing a felted fabric according to claim 1, wherein the needle punching step is carried out by needles having a blade and barbs, the fiber hooking coefficient of all the barbs provided on the blade being below 3, and the distance across the lateral cross-section of the blade being from about 0.03 to 0.54 millimeter, whereby from one to three fibers are caught by each individual needle and accordingly penetrate as a group of from one to three fibers.

4. A method for producing a felted fabric from a web of loosely matted fibers which comprises the steps of providing a fibrous web in which a plurality of fibers is in a generally uni-directional arrangement, subjecting the fibrous web to repeated penetrations of conjugated needles while restraining the web to hold it in position during penetration and withdrawal of said needles, at least some of said conjugated needles having capacity to catch some of said loosely matted fibers to displace them across said direction of said uni-directional arrangement to produce a felted fabric, the conjugated needles being arranged with predetermined spaces, each of said conjugated needles being mounted separately from each other with a predetermined space therebetween, each of the plurality of conjugated needles being formed by a plurality of individual needles with the interval between the needle points being restricted in a range from about 300 to 5,000 microns, and relatively reciprocating the conjugated needles to cause penetration of the conjugated needles into the web, with the distance between the outermost portion of the needles and the restraining means being restricted in the range from about 0.5 to 9 millimeters, whereby needle punching is carried out wherein a multiplicity of fibers penetrate substantially perpendicularly into said web.

5. A method for producing a felted fabric according to claim 4, wherein the needle punching is carried out at a needle density per square centimeter ranging from about 200 to 12,000.

6. A method for producing a felted fabric according to claim 4, wherein the needle punching is carried out by using a needle, composing of the conjugated needles, comprising a blade and barbs, the fiber hooking coefficient of all the barbs provided on the blade being below 3, and the distance across the lateral cross-section of the blade being from about 0.03 to 0.54 millimeter, whereby from one to three fibers are caught by each individual needle and accordingly penetrate as a group of from one to three fibers.

* * * * *
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,859,698  Dated January 14, 1975

Inventor(s)  Miyoshi Okamoto et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the Cover Sheet, in item [75] the name of the second inventor "Toyoniko Hikota" should read
-- Toyohiko Hikota --.

Signed and sealed this 13th day of May 1975.

(SEAL)
Attest:  
RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks