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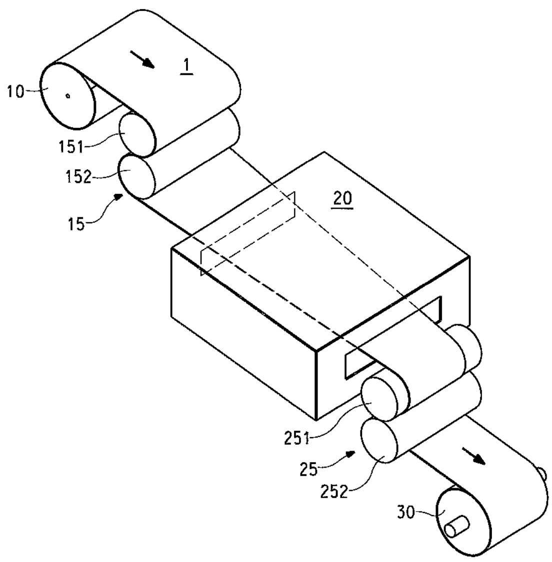
(54) Title: PROCESS FOR PREPARING AN ELASTIC NONWOVEN WEB



(57) **Abstract:** A process of preparing an elastic thermally bonded nonwoven web, whereby the process is characterized by the following steps: (i) providing a thermally bonded nonwoven precursor web containing thermoplastic fibers, (ii) subjecting the precursor web of step (i) to a drawing treatment in a machine direction at a drawing rate of from 45 to 70 %, and a strain rate within a range of from 1000 to 2400 %/min at a temperature between the softening point and the melting point of the fibers for preparing the elastic thermally bonded nonwoven web. The elastic thermally bonded nonwoven web preferably has an elasticity in the cross direction of at least 70% recovery from a 100% elongation, and at least 60% recovery from a 150% elongation.

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PROCESS FOR PREPARING AN ELASTIC NONWOVEN WEB

FIELD OF THE INVENTION

The present invention relates to a process for preparing an elastic thermally bonded nonwoven web or fiber mat and an elastic thermally bonded nonwoven web or fiber mat prepared by the process according to the invention. The present invention also relates to the use of the elastic thermally bonded nonwoven web or fiber mat prepared according to the invention in the manufacture of a disposable sanitary protection product, a medical product, a protective work wear or a personal use item. Finally, the present invention relates to a product containing the elastic nonwoven web or fiber mat of the invention.

BACKGROUND OF THE INVENTION

US 5,113,997 relates to a continuous process for the thermo-mechanical treatment of a nonwoven web by heating a precursor web with a specific gas stream followed by a mechanical treatment. GB 2 096 048 relates to nonwoven fabrics made from a bicomponent fiber resisting thermal shrinkage during thermal bonding. US 5,582,903 relates to process for the preparation of barrier fabric having stretch and recovery function. The precursors used are meltblown fiber containing webs and the necking is no more than 50%. The method does not apply heat to the precursor web in the stretching section whereby the web may not be stretched at the maximum temperature.

Thermally bonded nonwoven webs are well known in the art (Wendt, Industrial and Engineering Chemistry Volume 48, No. 8 (1965) pages 1342; US 3,978,185, US 3,795,571; 3,811,957). Stretching of nonwoven webs is described in US 3,772,417, US 4,048,364, US 4,223,059, 3,949,127, US 4,276,336, US 5,296,289, US 4,443,513 and EP 0 882 147. However, none of these disclosures relates to the causal connection of stretching of a nonwoven web and imparting elastic properties.

Thermally bonded nonwoven webs are conventionally used for the mass production of disposable sanitary protection products such as adult and infant diapers or sanitary napkins, medical products such as masks, operating gowns, head covers or operating drapes; protective workwear such as coveralls, head covers and masks; and personal use items such as underwear. A major deficiency of nonwoven webs is their lack of elasticity or stretch and conformability. Since conventional thermally bonded nonwoven webs do not have sufficient elastic properties, products containing such nonwoven webs that require elastic properties conventionally further contain latex bands for fastening and fitting. However, proper adjustment of latex straps is difficult to achieve whereby a fit is usually observed which is either too loose or too tight. Moreover, latex straps are allergenic and irritating to the skin to some degree. Additionally, the use of latex and rubber components in huge volume for disposable products has raised serious environmental concerns in view of toxic waste generation such as dioxins and other harmful emissions in the waste incineration process.

Attempts were made in the prior art to provide nonwoven webs having elastic properties. In one approach, elastomers are incorporated into nonwoven webs as films, bands, or threads of natural or synthetic rubber whereby full-web elasticity in two directions is achieved. However, nonwoven webs based on elastomers lack dimensional stability in at least one direction whereby it is difficult to handle such webs in automated manufacturing processes. Moreover, nonwoven webs based on elastomeric fibers are expensive. Therefore, the use of elastomeric fibers poses inherent problems, which render them unsuitable for the mass production of disposable products.

An alternative approach for imparting elasticity to a nonwoven web relates to the so-called thermo-mechanical treatments. US 4,965,122 discloses a sequential thermal-mechanical method by slow stretching the precursor in the ambient temperature before subjecting in the heat setting process. The fiber binding and tensile strength of resultant webs can be significant reduced by the room temperature stretching, or some webs can even be broken at draw rate described as high as 60%. US 5,492,753 describes an opposite sequential thermo-mechanical method for treating easy-to-break meltblown fibers containing web by slowly heating the precursor before transferring to the stretch at ambient temperature. Both US 4,965,122 and US 5,492,753 methods make resultant webs with elasticity of under 100%, and the web require 1-5 minutes of process time to go through the multiple-set rolls or drums of the heating device, either after a stretch or before. US 4,048,364 describe drawing thermoplastic meltblown precursor at elevated temperature to improve web properties. The draw rate is from 100% to 900%. However, no elasticity is noted.

Methods using a drawing step at elevated temperature for imparting elasticity to a nonwoven web are described in US 5,244,482 and US 6,051,177 (EP 0 844 323). US 5,599,366 relates to the method of US 5,244,482 applied on selected laminates as precursors, Accordingly, a thermally bonded nonwoven precursor web is subjected to a stretching treatment at an elevated temperature in one direction (machine direction) whereby the width of the precursor web shrinks in perpendicular direction (cross direction) resulting in a certain elasticity in cross direction while maintaining non-elastic properties in machine direction. The anisotropic elasticity combining dimensional stability in machine direction and elastic properties in the cross direction facilitates the use of such webs in automated manufacturing processes.

US 5,244,482 and US 5,599,366 disclose a method requiring selected nonwoven webs for the preparation of a filter material, wherein a draw rate of from 10% to 100% and a strain rate of from 2000 to 20000%/min, preferably of from 3000-6000%lmin, are used to laterally consolidate the precursor web. The precursor web is required to have a high crystalline content of more than 30% or a room temperature elongation to break under 40%. These high strain rate methods of US 5,244,482 and US 5,599,366 were shown to significantly change the morphology of this high crystalline content nonwoven web, to reduce its pore size and to narrow the pore size distribution. A degree of elasticity is created, but the elastic modulus is low (70% recovery at 50% elongation, 40% recovery at 100% elongation). If a continuous process is desired, the high strain rate methods of US 5,244,482 and US 5,599,366 require that heating and stretching of the web are carried out in a very short distance, or whereby the precursor web travels through the processing apparatus in very high speed and very short time, e.g. in less than one second, preferably less than 0.5 seconds. Although to some degree dependent on the capacity of the heating apparatus, a sufficient processing time is still needed for the precursor web to pick up temperature in order to avoid breaking of the web by the stretching treatment. Furthermore, the high strain rate methods of US 5,244,482 and US 5,599,366 are limited with regard to the possible processing speeds that are within a range of from 3-122 m/min (10-400 feet/min), preferably 7.5-60 m/min (25-200 feet/min).

US 6,051,177 (EP 0 844 323) discloses a method wherein a nonwoven web is stretched at elevated temperature, but at lower speed through carefully controlled multi-sets of stretching rolls with draw rate under 35% to make accumulated strain rates from 350 to 950 %/min. The low stretch and slow speed process described in both US 5,492,753 and US 6,051,177 (EP 0 844 323) is mainly developed for treating fragile and easy-to-break material typically meltblown nonwoven webs. The degree of elasticity (85% recovery at 50% elongation) in resultant webs of US 6,051,177 (EP 0 844 323) is similar to that of US 5,492,753 (70% recovery at 60% elongation). However, these degrees of elasticity of the resultant webs turned out to be still insufficient for meeting the standards required for commercially successful applications. Moreover, although the process may be carried out in a continuous mode, the process speed of US 6,051,177 (EP 0 844 323) attainable through the multi-sets of stretching device is around 60 m/min or below whereby mass production cannot be considered economical.

DISCLOSURE OF THE INVENTION

It is the problem of the present invention to overcome the drawbacks of the prior art and to provide a cost effective process of mass producing an elastic thermally bonded nonwoven web having elastic properties in cross direction with high stretchability and recovery, whereby preferably, the elasticity of the resultant webs is characterized by a recovery of at least 70% from 100% elongation or at least 60% from 150% elongation.

It is a further problem of the invention to provide a process wherein the processing speed (i.e. feeding speed) is at least 100 m/min, typically at least 150 m/min, and preferably in a range of from 200 to 400 m/min.

It is a further problem of the invention to provide a novel elastic nonwoven web having high stretchability in cross direction of over 100% with recovery of more than 70%. Moreover, it is a further problem of the invention to provide a novel elastic nonwoven web having high stretchability in cross direction of over 150% with recovery of more than 60%.

It is a further problem of the invention to provide a elastic nonwoven web which is characterized by an increase or less than 20% decrease of the maximum pore size of the a elastic nonwoven web compared to the precursor web, and by a significant reduction of the mean flow pore size of more than 5%.

It is a further problem of the present invention to provide novel products containing the elastic nonwoven web of the present invention.

These problems are solved according to the claims. Accordingly, the present invention provides a process of preparing an elastic thermally bonded nonwoven web, whereby the process is characterized by the following steps:

(i) providing a thermally bonded nonwoven precursor web containing thermoplastic fibers,

(ii) subjecting the precursor web of step (i) to a drawing treatment in a machine direction at a drawing rate of from 45 to 70 %, and
a strain rate within a range of from 1000 to 2400 %/min
at a temperature between the softening point and the melting point of the fibers
for preparing the elastic thermally bonded nonwoven web.

For the drawing treatment, the web is heated to a temperature above the softening point where a thermoplastic fiber looses its room temperature modulus and becomes soft, viscous and transformable. The processing speed of the precursor web in step (ii) is preferably at least 100 m/min, typically at least 150 m/min, and preferably in a range of from 200 to 400 m/min.

The present invention is based on the recognition that control of the strain rate alone is insufficient for imparting superior elastic properties to a thermally bonded nonwoven precursor web in a thermomechanical treatment. The present invention is further based on the recognition that control of a further measure is essential for obtaining superior elastic properties. The present invention identifies the control of the drawing ratio (i.e. drawing rate) in combination with the control of the strain rate as essential measures for imparting superior elastic properties. The drawing ratio was found to be causal for shrinking the web width and for creating the stretchability and elasticity. A low drawing rate insufficiently reduces the width of the precursor web and imparts less stretchability and elasticity to the finished web. Finally, the present invention is based on the recognition that the control of a combination of the drawing rate of from 45 to 70 %, and a strain rate within a range of from 1000 to 2400 %/min, preferably at most 1950 %/min provides superior elastic properties, notably with nonwoven precursor webs containing polypropylene. Accordingly, elastic properties imparted by a thermo-mechanical treatment to a thermally bonded nonwoven precursor web may be dramatically improved whereby the nonwoven webs show an elasticity in the cross direction of at least 70% recovery from a 100% elongation, and at least 60% recovery from a 150% elongation. Moreover, the nonwoven webs provide unidirectional elasticity wherein the ratio of elongation at break in cross direction to the elongation at break in machine direction is at least 800%. Thermally bonded nonwoven web having such elastic properties were unknown prior to the present invention.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows schematically an apparatus for carrying out the process of the invention.

Figure 2 shows a schematic side view of an apparatus for carrying out the process of the invention.

Figure 3 illustrates shows a schematic side view of a further embodiment of an apparatus for carrying out the process of the present invention.

Figure 4 is a graph showing the relationship of the present invention to US 5,244,482 and US 6,051,177 (EP 0 844 323) with regard to the parameters of the best mode strain rates (X-axis) vs. the draw rates (Y-axis).

Figure 5 shows schematic representations of typical temperature profiles of prior art processes known from US 4,965,122 (Fig. 5a), US 5,492,573 (Fig. 5b) and the present invention (Fig. 5c).

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows schematically an apparatus for carrying out the process of the invention. The apparatus comprises an unwinding roll (10) and a winding roll (30) provided essentially in parallel orientation for allowing transfer of a web (1) from the unwinding roll (10) to the winding roll (30). The winding roll (10) preferably has a width corresponding to the width (a) of the precursor web prior to the stretching treatment. The winding roll preferably has a width corresponding to the width (b) of the web after the drawing treatment. Since the width of the web (1) decreases during the drawing treatment, the unwinding roll (10) has a greater width than the winding roll (30). The unwinding roll (10) and the winding roll (30) may be rotated around their longitudinal axis. The rotation may be controlled independently for the unwinding roll (10) and the winding roll (30). The unwinding roll supports a nonwoven web (1). The nonwoven web extends from the unwinding roll (10) to the winding roll (30) through a heating means (20) such as an oven. Preferably, a first S-wrap (15) comprising guiding roll (151) and guiding roll (152) is provided between the unwinding roll (10) and the heating means (20). Moreover, a second S-wrap (25) comprising guiding roll (251) and guiding roll (252) is provided between the heating means (20) and the winding roll (30). The nonwoven web supported by the unwinding roll (10) corresponds to a precursor web. The precursor web extends from the unwinding roll (10) in machine direction optionally passing S-wrap (15) towards the entrance of the heating means (20). The nonwoven web enters the heating means (20) and extends through the heating means towards the exit of the heating means. The method of heating the precursor web is not particularly limited as long as the heat transfer may be accomplished in as short a time as necessary to avoid damage of the web. Heating may be accomplished by radiation or convection. Radiation heating may be carried out by using infrared or microwave radiation. Convection heating may be carried out by a suitable heating fluid, preferably a gas such as air. Heating by infrared radiation is preferred. Downstream from the heating means, the nonwoven web extends optionally via S-wrap (25) to the winding roll (30). The heating means (20) is provided for heating the nonwoven web to a temperature between the softening point of the thermoplastic fibers of the web and the melting point of the thermoplastic fibers. The S-wraps (15) and (25) are provided for better controlling the movement of the nonwoven web.

Now, the process of the invention will be illustrated based on the apparatus shown in Figure 1. Accordingly, an elastic thermally bonded nonwoven web is prepared by providing a thermally bonded nonwoven precursor web containing thermoplastic fibers whereby said precursor web is supported by unwinding roll (10). Unwinding roll (10) is rotated around its longitudinal axis whereby the precursor web leaves unwinding roll (10) in machine direction along arrow (MD) at a speed A. The precursor web travels via S-wrap (15) into the heating means (20), through the heating means and from the exit of the heating means via S-wrap (25) to the winding roll (30). Winding roll (30) is driven at a speed higher than the unwinding speed A by a factor of (1+X%). The factor (1+X%) determines the drawing rate of the nonwoven web in the process of the present invention. According to the invention, the precursor web is subjected to a drawing treatment in a machine direction at a drawing rate of from 45 to 70 %, and a strain rate with a range of from 1000 to 2400 %/min, preferably at most 1950 %/min, at a temperature between the softening point and the melting point of the fibers in order to allow a consolidation of the fiber structure and a decrease of the width of the nonwoven web.

As a result of the drawing treatment, the width of the web decreases in the cross direction (CD). Preferably, the machinery for carrying out the process of the invention is constructed for commercial capacity with an unwinder roll and a winding roll(s) installed in a distance of from 4 to 12 m, preferably about 6 to 10 m, specifically 8 m, and a heating device installed in between. The unwinder advantageously runs at commercial speed of more than 100 m/min and up to 400 m/min, preferably at least 150 m/min and up to 250 m/min, and a draw ratio of 45% to 70 % is created by increasing the speed of the winding roll. The strain rate is adjusted to 1000 to 2400 %/min, preferably 1200 to 2200 %/min. In a preferred embodiment, the strain rate is at most 1950 %/min. The draw rate relates to the degree of width reduction of the precursor web. The strain rate relates to the speed of the treatment: it was found that in case the strain rate is below the claimed range, the web tends to be overheated whereby it becomes stiff. On the other hand, if the strain rate is above the claimed range, the precursor web is not sufficiently heated whereby the web either breaks during the drawing treatment or in that the width reduction is not maintained after the web is released from the draw tension. Preferably, the drawing treatment in step (i) comprises introducing the thermally bonded nonwoven web into a heating means for heating the web to a temperature between the softening point and the melting point of the fibers. The drawn web is preferably cooled after the drawing treatment and prior to winding on storage roll. The time for the heating and drawing treatment, i.e. the time between the unwinding of the precursor web and the winding of the resultant web is preferably in the range of from 1 to 3 seconds, more preferably in the range of from 1.1 to 2.8 seconds.

Preferably, the elastic nonwoven web is characterized by an increase or by a decrease of less than 20% of the maximum pore size of the elastic nonwoven compared to the precursor web. Preferably, the mean and minimal pore size of the resultant elastic or non-woven web are significantly reduced. Preferably, the elastic nonwoven web is further characterized by a significant reduction of the mean flow pore size of more than 5%.

The web used in the process of the invention preferably contains polypropylene fibers. The amount of the polypropylene fibers in the web is preferably at least 30 % by weight. The web may contain further fibers, such as thermoplastic fibers or cellulosic fibers. In a specific embodiment, the web consists of polypropylene fibers. The resultant nonwoven web of the present invention has anisotropic elasticity properties, preferably a ratio of elongation at break in cross direction to the elongation at break in machine direction of at least 800 %. The nonwoven web may be a spunbonded web, a melt blown web or a carded thermally bonded nonwoven web, or the nonwoven web may be a laminate containing two or more of the above mentioned nonwoven webs or the web may be a laminates of the above mentioned nonwoven webs and a thermoplastic film. Several kinds of thermally bonded nonwoven webs including carded, spunbond, SMS and SMMS from different producers have been processed and the resultant webs exhibit high stretchability with high recovery in the cross-direction. The cross-direction-only elasticity of these webs truly frees the nonwoven product converting from the need of sewing latex straps in their conventional methods, and the converted products provide sensational easy-fit and stressless comfort to wearer. A spunbonded web and a carded thermally bonded web are preferred.

The webs of this invention may be a multilayer laminate. An example of a multilayer laminate is an embodiment wherein some of the layers are spunbond and some meltblown such as a spunbond-meltblown-spunbond (SMS) laminate as disclosed in US 5,169,706. SMMS is the laminate of spunbond-meltblown-meltblown-spunbond. Such a laminate may be made by sequentially depositing onto a moving forming belt first a spunbond fabric layer, then a meltblown fabric layer and last another spunbond layer and then bonding the laminate in a spot bonding device. Alternatively, one or more of the fabric layers may be made individually, collected in rolls, and combined in a separate bonding step.

The carded or thermally bonded web described in this invention is obtainable by mixing and carding staple fibers to form a mat, which is then bonded with a spotbonding method.

Preferably, the process of the invention is carried out continuously. The drawing treatment in step (i) of the continuous process according to the invention may comprise unwinding the thermally bonded nonwoven web into a first variable tension means which feeds said web into a web heating means for heating the web to a temperature between the softening point and the melting point of the fibers, followed by continuously stretching the heated web lengthwise in the machine direction, cooling the web and collecting the cooled web. The heating and stretching treatment is preferably carried out simultaneously so as to allow spontaneous stretching at the highest possible temperature between the softening point and the melting point of the fibers.

The nonwoven web containing thermoplastic fibers can be softened in the range of temperature prior to melting. In the softened states, a mechanical force can be applied to the web to change its morphology and properties. After the drawing treatment and the cooling below the softening temperature, the finished web exhibits different characteristics from its precursor.

Figure 2 shows a schematic side view of an alternative apparatus lacking S-wraps. The apparatus comprises one unwinder and a winder and an oven in between to apply constant heat to a fabric that runs through. The transformation of the nonwoven web is carried out within the distance between the unwinder and winder (D). The strain rate (%/t) is generally described as a piece of fabric being drawn and extended certain (X) percentage in a period of time. The extension percentage can be achieved by the speed ratio of winder to unwinder, and the time period of fabric run through can be calculated by dividing D over the average of unwinder speed (A) and winder speed [(1+X%) A]. Speed A is generally expressed in m/min as

$$X\%/\{D/[A+(1+X\%)A]12\}=X\%/\{2D1[A+(1+X\%)\ A]\}=$$
$$\{X\%x[A+(1+X\%)\ A]\}\ /\ 2D$$

Figure 3 illustrates a schematic view of a further embodiment of an apparatus for carrying out the process of the present invention. The apparatus includes one S-wrap (15) after unwinder and one S-wrap (25) before winder for stabilizing the fabric feeding through. The transformation of the nonwoven web is carried out within the distance (D) between these two S wraps. The extension percentage can be achieved by the speed ratio of S-wrap 25 to S-wrap 15, and the time period of fabric run through can be calculated by dividing D over the average of S-wrap 15 speed (A) and S-wrap 25 speed [(1 +X%) A].

Figure 4 is a graph showing the relationship of the present invention to US 5,244,482 and US 6,051,177 (EP 0 844 323) with regard to the parameters of the best mode strain rates (X axis) vs. the draw rates (Y axis). US 5,244,482 discloses a strain rate range of 2000-20000 %/min with a preferred best range of 3000-6000 %/min and with a draw rate range of 10-100% and a preferred best range of 20-80%. US 6,051,177 discloses a strain rate range of 350-950 %/min and a draw rate range of 7-35%. In one embodiment, the current invention has a strain rate range of 1000-1950 %/min and a draw rate range of 45-70%. US 5,244,482 and US 6,051,177 describe methods with feeding speeds below 120 m/min, typically about 60 m/min. The feeding speed in the process of the present invention is at least 100 m/min, typically at least 150 m/min and preferably in the range of 200 to 400 m/min. The present invention provides a window of opportunity for increasing the process speed and improving the elastic properties, which only exists in the claimed area as shown by the examples.

Figure 5 shows schematically the conceptional differences between the methods of prior art processes known from US 4,965, 122 (Fig. 5a), and US 5,492,573 (Fig. 5b) and the method of the present invention (Fig. 5c) based on typical temperature profiles of a web portion traveling through the processing apparatus.

According to the method of US 4,965,122 shown in Fig 5a, a precursor web is transferred from an unwinding roll (U) at ambient temperature to a stretch section (S) wherein the portion of the web is subjected to a stretching treatment at ambient temperature below the softening point of the web. Subsequently, the stretched web is heated to a maximum temperature above the softening point and below the melting point of the fibers of the web in a heating section (H) and immediately cooled down to ambient temperature (C) and wound on a winding roll (W). The heating and cooling according to this method is intended to retain the memory of its stretched condition, which would cause the recovery after non-destructive stretching in the reduced direction. Stretching of nonwoven fabrics for more than 10% at room temperature is found to pull fibers loose from binding points and or to break fibers. Thereby the tensile strength both in machine direction and in cross direction is significantly reduced.

According to the method of US 5,492,573 shown in Fig 5b, a precursor web is transferred from an unwinding roll at ambient temperature (U) to a heating section (H) wherein the portion of the precursor web is subjected to a heating treatment (H) to a maximum temperature above the softening point of the fibers of the web. Subsequently the heated web is transferred to a stretching section while the temperature of the web inevitably decreases. Therefore, the precursor web cannot be stretched at the highest possible temperature, i.e. just below the melting temperature of the fibers. In the stretching section, the partially cooled precursor web is subjected to a stretching treatment (S) while the web further cools down. The web is then cooled (C) and wound (W) on a winding roll. Accordingly, the precursor web must be heated to a temperature higher than available for the stretching treatment so as to account for the temperature loss during transfer from the heating section to the stretch section.

According to the preferred process of the present invention shown in Fig. 5c, a precursor web is transferred from an unwinding roll (U) to a section wherein the a combined heating and stretching treatment is performed. The precursor web is held under a predetermined tension while the temperature of the portion of the web traveling between the unwinding roll and the winding roll is increased to a level permitting spontaneous stretching of the web. The stretching occurs in a very short period of time at the maximum temperature attained in the course of the process and avoids any undesired overheating. Due to the continued heating during stretching, the temperature profile may be adjusted so that the web temperature is kept constant at the optimum temperature during the entire stretching necessary to impart the desired elasticity properties to the web. Accordingly, in the method of the present invention, fibers are mainly gathered closer in the stretched direction whereby the web typically has a higher tensile strength in machine direction and a lower tensile strength in cross direction as compared to the precursor web.

The present invention also provides an elastic thermally bonded nonwoven web containing polypropylene fibers, which is obtained or obtainable by the process of the present invention. The web elasticity is defined by measuring the variations of a 5-cm wide and 10 cm long strip along the longitudinal axis as follows:

(stretched length - recovered length) / (stretched length - original length).

The elastic thermally bonded nonwoven web preferably has an elasticity in the cross direction of at least 70% recovery from a 100% elongation, and at least 60% recovery from a 150% elongation. In a specific embodiment, the elastic thermally bonded nonwoven web is laminated on an elastomeric film.

The present invention also provides a use of the elastic nonwoven web for the preparation of a disposable sanitary protection product, a medical product, a protective work-wear or a personal use item. The present invention also provides a product containing an elastic nonwoven web of the invention. The product may be a disposable sanitary protection product, a medical product, a protective work-wear, or a personal use item. The disposable product may be an adult or infant diaper, or a sanitary napkin. The medical product may be a mask, an operating gown, a head cover, or an operating drape. The protective work-wear may be a coverall, a head cover, or mask. The personal use item may be underwear.

The process of the invention does not use expensive, allergenic, and environmentally unsafe elastomeric fibers for imparting elasticity.

EXAMPLES

Terminology:

The basis weight of nonwoven webs is usually expressed in gram of material per square meter (gsm).

The softening point is the temperature where a thermoplastic fiber loses its room temperature modulus and becomes soft, viscous, and transformable to applied force.

As used herein the term "spunbond" refers to the webs formed by small diameter fibers which are formed by extruding molten thermoplastic material as filaments from a plurality of fine, usually circular capillaries of a spinneret with the diameter of the extruded filaments then being rapidly reduced as by, for example, in US 4,340,563, US 3,692,618, US 3,802,817, US 3,338,992, US 3,341,394, US 3,502,763, US 3,502,538, and US 3,542,615. Spunbond fibers are generally not tacky when they are deposited onto a collecting surface. Spunbond fibers are generally continuous and have average diameters (from a sample of at least ten fibers) larger than 7 microns, more particularly, between about 10 and 30 microns.

Tensile test:

The tensile test is a measure of breaking strength and elongation or strain of a fabric when subjected to unidirectional stress. This test is known in the art and conforms to the specifications of ASTM Method D5034. The results are expressed in kilograms to break and percent stretch before breakage. Higher numbers indicate a stronger, more stretchable fabric. The term "elongation" means the increase in length of a specimen during a tensile test. Values for grab tensile strength and grab elongation are obtained using a specified width of fabric, usually 3 cm, clamp width and a constant rate of extension. The sample is wider than the clamp to give results representative of effective strength of fibers in the clamped width combined with additional strength contributed by adjacent fibers in the fabric.

Example 1

17gsm SMS nonwoven fabrics were processed over 8-meters distance for simultaneous heating and stretching treatments to show the width reduction under different strain rates and conditions further specified in Table 1. As shown by Table 1, a draw rate over 45% was required to reduce the width by 50%. Upon increase of the speed by 10 m/min, it was required to increase the draw ratio by about 1.5% to maintain the width reduction.

Table 1

Unwinding Speed	Draw Ratio	Winding Speed	Strain Rate	Width Reducing
m/min		m/mm	% / min	
150	40	210	900	45.4
	45	218	1035	52.3
	50	225	1172	57.7
	55	233	1317	61.5
	60	240	1463	62.2
	65	250	1625	63.1
200	40	280	1200	43.4
	45	290	1378	51.8
	50	300	1563	55.7
	55	310	1753	58.5
	60	320	1950	60.6
	65	330	2153	61.8
250	40	350	1500	41.4
	45	363	1724	50.7
	50	375	1953	53.6
	55	388	2193	56.3
	60	400	2438	57.9
	65	413	NA	Broke webs

Example 2

Different basic weights of SMS precursor webs were processed at unwinding speed of 200 m/min and with 50 % draw rate. The results shown in Table 2 demonstrate that the draw ratio made similar width reductions to precursor webs with different basic weights.

Table 2.

Precursor Basic Weight	Draw Ratio	Strain Rate	Width Reduction	Finished Basic weight
g/m^2	%	%/min	%	g/cm^2
16.7	50	1563	56.8	26.4
26.6	50	1563	55.3	39.8
35.4	50	1563	57.1	51.3
52.3	50	1563	55.4	68.6

Example 3

Nonwoven webs of Spunbond (S), Carded (C) SMS and SMMS were treated at 200 m/min unwinding speed with 30 to 60% draw ratios. It was shown in Table 3 that the draw ratio made the length extension and the width reduction in similar pattern of 30-60% with different thermally bonded nonwoven webs and at least 45% draw ratio was required to reduce 50% of the precursor width.

Table 3

Precursor	Basis Weight	Draw Ratio	Strain Rates	Finished Basis weight	Length Extension	Width Reducing
	g/m^2	%	%/min	g/m^2		
S	12.7	30	750	15.5	1.26	34.6
	12.7	40	1000	17.4	1.34	45.0
	12.7	45	1125	18.1	1.37	50.6
	12.7	50	1250	19.2	1.40	52.4
	12.7	60	1500	21.7	1.53	59.8
S	25.6	30	750	28.3	1.28	32.3
	25.6	40	1000	33.6	1.37	43.8
	25.6	45	1125	34.7	1.40	50.1
	25.6	50	1250	36.5	1.44	50.6
	25.6	60	1500	40.8	1.56	58.1
C	22.6	30	750	31.4	1.20	38.1
	22.6	40	1000	33.9	1.29	49.6
	22.6	45	1125	35.2	1.32	52.2
	22.6	50	1250	36.7	1.36	55.8
	22.6	60	1500	41.3	1.45	61.8
C	44.3	30	750	56.9	1.21	37.0
	44.3	40	1000	67.6	1.26	49.1
	44.3	45	1125	69.2	1.30	52.7
	44.3	50	1250	70.3	1.34	54.2
	44.3	60	1500	74.9	1.44	60.9
SMS	15.2	30	750	20.9	1.18	37.7
	15.2	40	1000	22.6	1.24	48.3
	15.2	45	1125	23.4	1.31	51.5
	15.2	50	1250	24.1	1.36	53.4
	15.2	60	1500	26.3	1.46	57.8
SMS	41.7	30	750	54.4	1.15	35.5
	41.7	40	1000	62.5	1.20	46.1
	41.7	45	1125	65.2	1.31	52.2
	41.7	50	1250	67.2	1.42	56.4
	41.7	60	1500	72.6	1.51	62.3
SMMS	17.1	30	750	20.5	1.17	
	17.1	40	1000	23.8	125	42.5
	17.1	45	1125	24.4	1.31	50.3
	17.1	50	1250	25.6	1.37	52.2
	17.1	60	1500	29.1	1 48	59.4
SMMS	50.6	30	750	58.7		32.9
	50.6	40	1000	68.8	1.34	46.2
	50.6	45	1125	70.4	1.38	50.1
	50.6	50	1250	72.8	1.41	51.6
	50.6	60	1500	78.3	1.52	58.3

Example 4

Spunbond 35 gsm, Carded 45 gsm and SMMS 25 gsm were used as precursor webs for processing under different draw ratio to obtain the width reduction from 30% to 60%. The results are shown in Table 4. The elasticities were measured from 50%, 100%, and 150% elongation respectively. The resultant webs with width reduction less than 40% are most unlikely be extended for more than 100% and obtained good recovery for over 50%. In contrast, the resultant webs with width reduction over 50% showed recovery of more than 70% at 100% elongation and more than 60% at 150% elongation.

Table 4

	Width Reduction	Strain Rate	Elongation at Break	Recovery from 50% elongation	Recovery from 100% elongation	Recovery from 150% elongation
	%	% /min	%	%	%	%
Spunbond	30	720	89	72	NA	NA
Spunbond	40	1050	104	88	NA	NA
Spunbond	50	1380	184	>95	78	63
	60	1710	237	>95	86	73
Carded 54gsm	30	690	104	75	NA	NA
Carded 60gsm	40	1020			24	NA
Carded 67gsm	50	1350			73	65
Carded 78gsm	60	1680	248	>95	80	74
SMMS 28gsm	30	780	93		NA	NA
SMMS 31gsm	40	1080	115	85	NA	NA
SMMS 36 gsm	50	1410	197	>95	77	66
SMMS 40 gsm	60	1790	226	>95	86	77

Example 5

The results shown in Table 5 further confirmed the high elastic recovery rates of the webs over five stretches for 100% (A) and 150% (B) elongations. The unique high ratio (1000-1400%) of CD/MD elongation at break is also shown.

Table 5.

Finished Webs		Spunbond 38gsm		Carded 40gsm				SMMS 70gsm	
Strain Rate Applied	%/min	1410		1410		1410		1410	
Width Reduction	%	52		54		53		50	
Elongation at Break (+%)	MD	14.6		15		15.3		16.3	
	CD	178		210		190		188	
CD/MD Elongation Ratio	%	1220		1400		1240		1150	
Recovery Ratio for 5 repeated stretches with 100% (A) and 150% (B) elongation	Elongations	A	B	A	B	A	B	A	B
		83	68	80	66	78	66	76	63
		75	62	74	61	73	57	71	55
		73	60	71	58	70	54	67	50
		71	57	69	55	68	52	66	47
		70	55	67	52	66	51	63	45

Example 6

The stretchability and recovery were tested with 5-cm strips of treated SMS webs with the claimed high and low limits of strain rates. The results are shown in Table 6. The unique characteristics of cross direction (CD) width reduction, elongation at break, CD/MD elongation ratio and recovery at 100% elongation were measured.

Table 6.

Precursor Basic Weight	(g/m²)	16.4	16.4	25.6	25.6	34.7	34.7	51.3	
Unwinding Speed	m/min	150	250	150	250	150	250	150	250
Strain Rate Applied	%/min	1035	2438	1035	2438	1035	2438	1035	2438
Finished Basic Weight	(g/m²)	23.7	28.3	35.7	42.8	47.6	56.4	64.4	76.9
Width reduction	%	50.7	58.8	52.1	60.6	50.4	61.2	53.2	62.4
Elongation (+%)	MD	19.4	16.7	18.7	15.3	21.4	16.9	20.8	16.3
	CD	162	214	167	223	176	231	184	243
CD/MD Elongation	%	835	1280	1 890	1458	822	1367	885	1490
Recovery % for 10 stretches at 100% elongation	%	76	83	76	82	73	80	72	77
		72	78	72	76	68	74	68	71
		70	76	70	74	66	73	65	68
		70	74	70	73	63	73	62	67
		69	73	68	72	62	71	60	66
		69	73	67	71	59	70	58	65
		68	72	65	70	59	69	59	64
		68	72	65	68	59	67	55	64
		67	72	64	68	58	65	55	63
		67	70	64	68	57	65	55	63

The strain rate is calculated by the percentage of increasing length within the time period of time that makes such increase. The percentage of increasing length is the draw ratio, which is carried out by increasing the winding speed over the unwinder. The time period of making such length increasing is calculated by dividing the distance between the unwinder and the winding roll with the speed of the web passing through, and that speed is an average of unwinder speed and winding speed.

For example, the present invention requires at least 45% draw ratio in a distance of 8 meters between unwinder and winding roll and with a minimal speed of 150 m/min for unwinder, to reduce the width of the precursor web by 50% and become the elastic nonwoven web of the invention. The strain rate in the low limit of the present invention is calculated as: 45% / {8m/ [1 50m/min + (150m/min x 1.45)] *12)* = 1034% / min wherein

(1) 45% is the draw ratio;

(2) 8 m is the distance between unwinder and winding roll or wherein the drawing being created;

(3) 150m/min is the unwinding speed;

(4) 150m/min x 1.45 = 217.5m/min is the winding roll speed;

(5) [150m/min + (150m/min x 1.45)]/ 2 = 183.75 m/min is the averaged traveling speed of the web through the drawing;

(6) 8m1 [150m/min + (1 50m/min x 1.45)] / 2 = 0.04354 minute is the time that the drawing happened.

The 0.04354 minutes (2.61 second) processing time is essential also for the web to pick up the heat and raise its temperature from 25ºC to 125°C for softening.

The higher strain rates can be obtained by processing at high speed and high draw ratio. However, tests in the 8-meter processing distance had revealed that it would be impractical and break the commonly available nonwoven web that containing thermally bonded polypropylene fibers at a draw ratio of over 70% and a winding speed over 500 m/min. In the case, the strain rate was 3500 %/min and less than 1.2 second for web to run through 8 meter distance and pick up heat for increasing temperature by 100°C.

Any higher draw ratio or higher speed for higher strain rates as the previous US 5,244,482 inventions described is considered incredible and impossible to be achieved especially for a continuous processing with the current commercial apparatus and on polypropylene nonwoven web. A temperature very close to the melting point was probably used in combination with a very high strain; however, such a fabric would be of little commercial value due to the stiffness and low degree of elasticity or very narrow width. Mainly, US 5,244,482 places many limitations on selecting the precursor webs by the physical properties such as to crystallinity over 30%, thermoplastic fiber content, fiber diameter, random fiber deposition, and isotropic tensile properties and tensile elongation to break to be less than 40%.

The best result is obtained according to the present invention at 50% draw rate with feeding speed (unwinding speed) of 200m/min to make the strain rate at 1600%/min. The average strain rate of the best mode claimed by US 5,244,482 was 4750%/min, and to attain it with an apparatus as shown in figure 1 and a 50% drawing rate, the feeding speed would have to be as high as 608m/min, i.e. three (3) time higher than the present invention. As tested in an apparatus according to figure 1 with the 50% draw rate and with commercially available nonwoven webs, the feeding speed cannot be increased over 400 m/min without breaking the web. As a matter of fact, the maximal finishing speed stated in the experiment of US 5,244,482 was below 122m/min (400f/min), then for reaching its best strain rate, the draw rate has to be as high as 250% as it is described in content, or processed through a very narrow heating device. The inventors of the present invention experienced that no higher than 80% draw rate can be made.

Developed for treating fragile and easy-to-break material, US 6,051,177 (EP 0 844 323) described the low speed and multiple-sets drawing device. US 6,051,177 (EP 0 844 323) describe a method of using low 30% draw rate and low strain rate that between 350% and 950% per min. It describes the width reduction of the precursor web was between 30-40% through the multi-sets of drawing device and the finished web has an elasticity for 85% recovery from 50% elongation. According to the width reduction on precursor, the draw ratio would be less than 35% and that theoretically it should not be possible to stretch the finished web more than 66.7% (100/60) to over the width of its precursor. Further, US 6,051,177 (EP 0 844 323) describes the treatment with multiple sets of drawing rolls to make the accumulated strain rate typically below 950% but above 350 % per minute. Assuming with a minimal two (2) sets of drawing rolls over 8 meters distance and 35% drawing ratio equally made in two sets to make the claimed highest 950%/min strain rate, the maximal feeding (unwinding) speed (x) can be no higher than 92m/min as calculated on the following:

17.5% / [4m/(x + 1.175x)/2] + 17.5% / {4ml[1.175x + 1.175 (1.175x)]/2} <_ 950%/min

Equal: [17.5% (2.175x) 18m] + [17.5% (2.556x) /8m] = 950%/min 17.5% (4.731x) = 7600 % m /min x = 91.8 m /min

In fact, the more sections of drawing rolls are present, the lower the processing speed has to be adjusted to meet the claimed low strain rate range. The process speed is certainly below 100m/min to around 60m/min. Processing under such low speed would raise the cost and has little commercial value to meet the applications of mass quantity and low-cost disposable nonwoven products, but any higher processing speed would make the strain rate over its claimed limit. More sets of drawing rolls or lower strain rates would further lower the processing speed. Additionally, the low draw ratio would not consolidate the web enough to make the high elasticity as the web resulted from the present invention.

Most importantly, the strain rate is not appropriate to be used alone to describe a process without specifying the two variables, the draw ratio, and the rate of the processing (the processing distance over the processing speed), since the same strain rates can be obtained with different combinations of parameters in the equation. Both US 5,244,482 and EP 0 844 323 use either the strain rate or the draw rate alone as the only parameter for defining their methods but without clarifying the rate of the processing and so there is no way of knowing how to come up the numbers of their strain rates. Still, there is no conflict of those previous descriptions with the present invention in the strain rates. US 5,244,482 claims a method using a strain rate of at least 2000% per min, and US 6,051,177 (EP 0 844 323) claims the range between 350 %/min to 950 %/min. The present invention operates in the range of 1000% to 2400%/ min, preferably at most 1950 %/min, as shown by figure 4. While US 5,244,482 and US 6,051,177 are operated at a speed well below 120 m/min, typically around 60 m/min, whereas the feeding speed according to the present invention is typically at least 150 m/min. Consequently, the resultant web in present invention has been produced at a speed around 250 m/min and show stretchability over 150% that was not found in any previous methods.

Example 7:

Web pore size distributions were measured by ASTM F 316-86. Max Pore Size is the standardized measure of the diameter of the largest pore channels in the distribution of pore sizes supporting flow through the web. Mean Pore Size is the measure of the median pore channel diameter for the pores supporting the total flow. Min Pore Size is the minimum pore size measured for the web.

Table 7:

Carded, Spunbond, and SMMS precursors and resultant webs were measured for the changes of pore sizes. The present resultant webs showed either an increase or no major decrease in Max Pore Size with significantly reduced Mean Pore Size and Min Pore Size.

Table 7

Strain Rate 1650%/min	Max. Pore Size (.t)			Mean Pore Size (μ)			Min. Pore Size (.t)		
Carded	Precursor	Resultant	Change	Precursor	Resultant	Change	Precursor	Resultant	Change
Precursor 22 gsm Resultant 32 gsm	61.4	83.1	+ 35.3%	28.6	24.0	- 16.2%	20.4	16.5	-19.3%
Precursor 35 gsm Resultant 48 gsm	50.1	61.3	+ 22.4%	22.5	18.1	- 19.6%	14.8	10.0	-32.4%
Precursor 55 gsm Resultant 67 gsm	41.8	40.8	-2.4%	14.8	10.6	-28.7%	10.9	6.7	-38.2%
Spunbond	Precursor	Resultant	Change	Precursor	Resultant	Change	Precursor	Resultant	Change
Precursor 15 gsm G Resultant 22 gsm G	65.1	97.4	+49.6%	33.6	27.1	-19.3%	24.4	21.3	-12.7%
Precursor 35 gsm P Resultant 52 gsm P	55.7	71.3	+28.0%	28.2	21.1	-25.2%	20.7	14.4	-30.6%
Precursor 65 gsm Resultant 92 gsm	38.7	34.3	-11.4%	17.5	11.4	-34.7%	12.2	7.2	-41.2%
SMMS	Precursor	Resultant	Change	Precursor	Resultant	Change	Precursor	Resultant	Change
Precursor 17 gsm Resultant 25 gsm	51.3	73.6	+43.5%	17.5	16.3	-6.9%	15.4	12.8	-16.9%
Precursor 35 gsm Resultant 50 gsm	45.7	53.7	+17.6%	15.2	10.2	-32.9%	13.6	8.1	-40.4%
Precursor 50 gsm Resultant 67 gsm	33.2	33.3	+0%	12.1	6.1	-49.6%	8.2	4.0	-51.2%

The pore size change of the present resultant webs are obviously different from those characterized by US 5,244,482 for reducing more than 20% in maximum pore size, and by US 5,492,753 for no change in mean pore size. The different results in pore size changes further indicated the method of present invention is different from previous methods.

Claims

1. A process of preparing an elastic thermally bonded nonwoven web having an elasticity of at least 70% recovery from a 100% elongation, or 60% recovery from a 150% elongation, in the cross direction, whereby the process is characterized by the following steps:
   (i) providing a thermally bonded nonwoven precursor web containing thermoplastic fibers,
   (ii) subjecting the precursor web of step (i) to a drawing treatment in a machine direction at a drawing rate of from 45 to 70 %, and a strain rate within a range of from 1000 to 2400 %/min at a temperature between the softening point and the melting point of the fibers for preparing the elastic thermally bonded nonwoven web.

2. The process according to claim 1, wherein the processing speed is at least 100 m/min, typically at least 150 m/min, and preferably in a range of from 200 to 400 m/min.

3. The process according to claim 1, wherein the drawing treatment in step (i) comprises introducing the thermally bonded nonwoven precursor web into a heating means for heating the web to a temperature between the softening point and the melting point of the fibers.

4. The process according to claim 1, which further comprises the step of cooling the web after the drawing treatment.

5. The process according to claim 1, wherein the precursor web contains polypropylene fibers.

6. The process according to claim 5, wherein the polypropylene fibers are contained in an amount of at least 30% by weight.

7. The process according to claim 1, wherein the precursor web contains cellulosic fibers.

8. The process according to claim 1, wherein the precursor web consists of polypropylene fibers.

9. The process according to claim 1, wherein the elastic nonwoven web has anisotropic elasticity properties.

10. The process of claim 9, wherein the ratio of elongation at break in machine cross direction to the elongation at break in machine direction is at least 800%.

11. The process according to claim 1, wherein said nonwoven precursor web is a spun bonded web.

12. The process according to claim 1, wherein nonwoven precursor web is a melt blown web.

13. The process according to claim 1, wherein said nonwoven precursor web is a carded thermally bonded nonwoven web.

14. The process according to claim 1, wherein said nonwoven web is a laminate containing two or more of the nonwoven webs according to any one of claims 11 to 13, or a laminate of the nonwoven webs according to any one of claims 11 to 13 and a thermoplastic film.

15. The process according to claim 1, wherein said thermally bonded nonwoven web is a blend of thermoplastic fibers and cellulosic fibers wherein said web contains at least 30% thermoplastic fibers.

16. The process according to claim 1, wherein the process is carried out continuously.

17. The continuous process according to claim 16, wherein the drawing treatment in step
    (i) comprises unwinding the thermally bonded nonwoven web into a first variable tension means which feeds said web into a web heating means for heating the web to a temperature between the softening point and the melting point of the fibers, followed by continuously stretching the heated web lengthwise in the machine direction, cooling the web and collecting the cooled web.

18. A thermo-mechanical method for treating a nonwoven web, in particular according to any one of the previous claims which comprises:
    (a) providing a thermally bonded polypropylene nonwoven web of carded, spunbond, SMS and SMMS as precursor web;
    (b) provide an unwinder roll and the winding roll in a distance of 6-10 meters.
    (c) continuously feeding the precursor web from the unwinder roll to the winding roll at a speed in a range of from 150m/min to 400m/min;
    (d) heating the precursor web at a temperature between the softening temperature and melting temperature of the thermoplastic polypropylene;
    (e) drawing the heated web by increasing the speed of winding roll over the unwinder at least 45% and to 70%, to thereby reduce the-width of the web by 50% to 65 % whereby the
    (f) strain rates are within the range of 1000% to 2400% /min.

19. The process according to claim 18, wherein the unwinding roll is a pair of pin-rolls to make a S-wrap for creating the draw ratio and release the finished web to the winder.

20. The process according to claim 18, wherein the precursor web is a single layer or multiple layers construction that are thermally bonded or laminated.

21. A elastic thermally bonded nonwoven web containing polypropylene fibers, obtained or obtainable by the process of any one of claims 1 to 20.

22. An elastic thermally bonded nonwoven web which has an elasticity in the cross direction of at least 70% recovery from a 100% elongation, and at least 60% recovery from a 150% elongation.

23. An elastic nonwoven web in particular according to claim 21, made from a nonwoven precursor of carded, spunbond, SMS, and SMMS comprising polypropylene thermoplastic fibers and being heated and drawn in longitudinal direction over a 6-10 meters distance at speed range of 150m/min to 400m/min to reduce 50% to 65 % the width of its precursor, wherein the drawing is made by feeding the web through a heating device installed between the unwinding and winding rolls to heat up the web in the temperature between the softening temperature and melting temperature of the thermoplastic fibers and by spontaneously increasing the speed of winding roll over unwinder at least 45% to maintain the strain rate in the range of 1000% to 2400% per minute, whereby the elastic nonwoven web is characterized by the elasticity of at least 70% recovery from a 100% elongation, or 60% recovery from a 150% elongation, in the cross direction.

24. The elastic nonwoven web of claim 23 wherein the precursor web is composed of co-filament fibers, or the mix of mono and co-filaments.

25. The elastic nonwoven web of claim 23 wherein the core of the co-filaments is composed of different thermoplastics of sheath.

26. An elastic laminate comprising:
(a) the elastic nonwoven web of claim 21; and
(b) a stretchable substrate bonded to the elastic nonwoven web.

27. The elastic nonwoven laminate of claim 26 wherein the substrate is an elastomeric layer.

28. The elastic nonwoven web of claim 26 or 27 wherein the substrate is a film.

29. Use of the elastic nonwoven web according to any one of claims 21 to 28 for the preparation of a disposable sanitary protection product, a medical product, a protective work-wear or a personal use item.

30. The use according to claim 29, wherein the disposable product is an adult or infant diaper, or a sanitary napkin.

31. The use according to claim 29, wherein the medical product is a mask, an operating gown, a head cover, or an operating drape.

32. The use according to claim 29, wherein the protective work-wear is a coverall, a head cover or mask.

33. The use according to claim 29, wherein the personal use item is underwear.

34. Product containing an elastic nonwoven web according to any one of claims 21 to 28.

35. The product according claim 34, which is a disposable sanitary protection product, a medical product, a protective work-wear or and a personal use item.

36. The product according claim 35, wherein the disposable product is an adult or infant diaper, or a sanitary napkin.

37. The product according claim 35, wherein the medical product is a mask, an operating gown, a head cover, or an operating drape.

38. The product according claim 35, wherein the protective work-wear is a coverall, a head cover or mask.

39. The product according claim 35, wherein the personal use item is underwear.

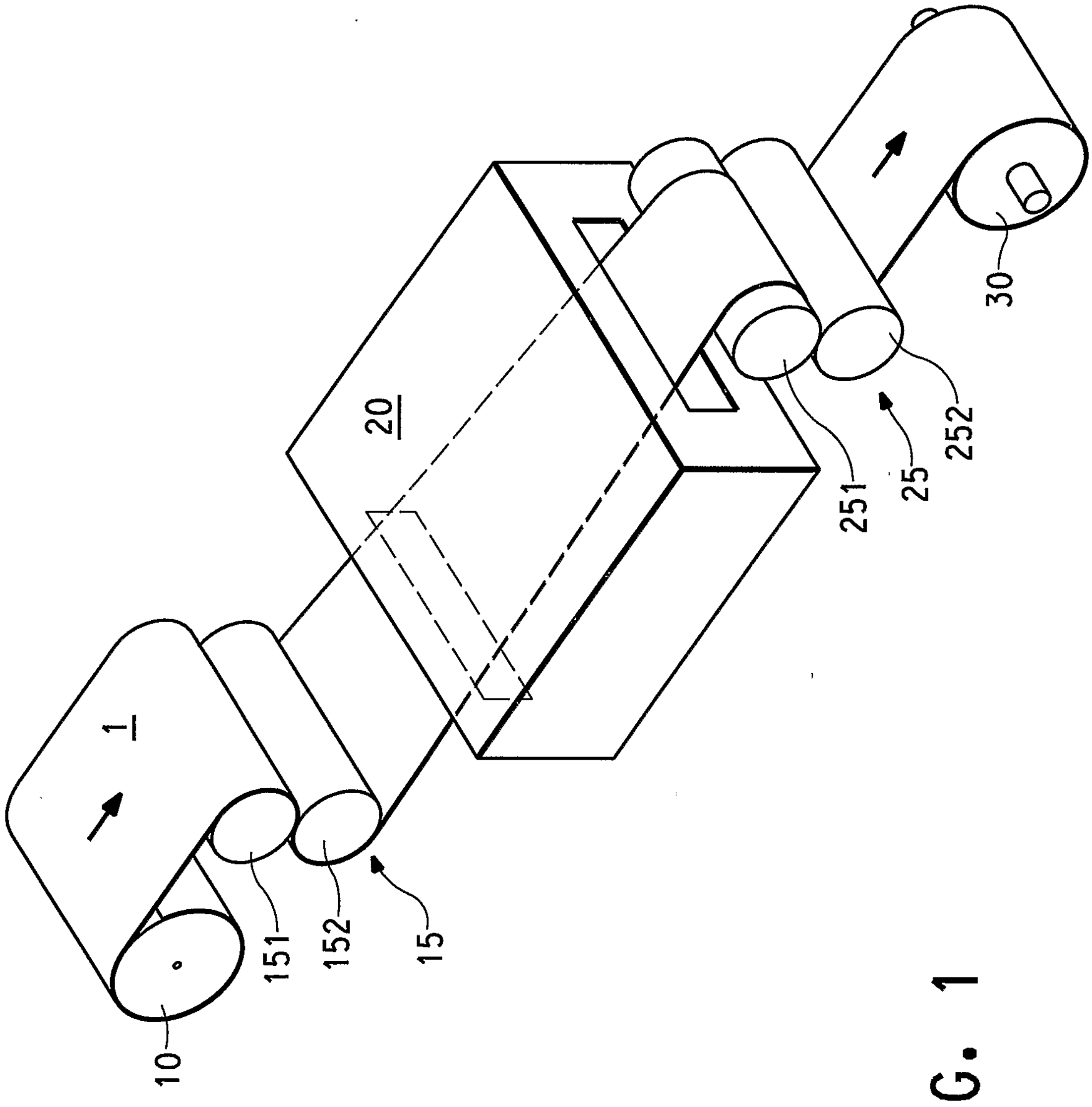


FIG. 1

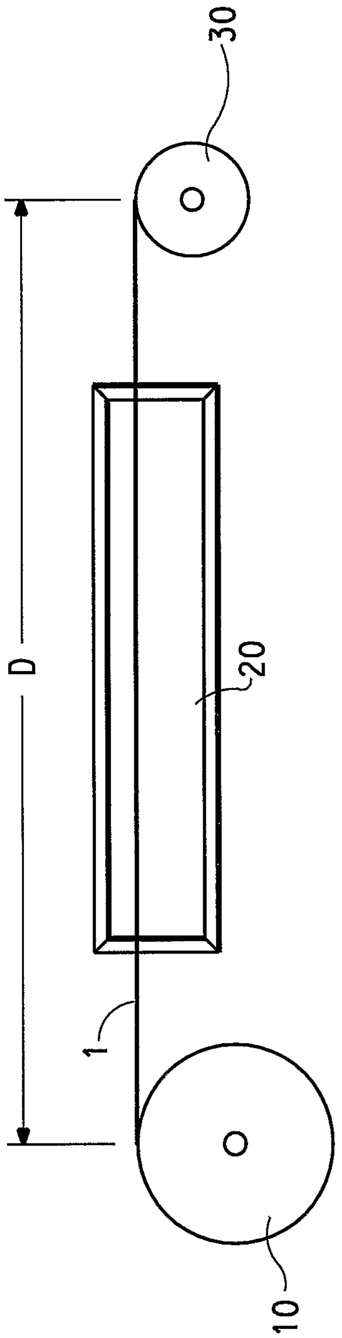


FIG. 2

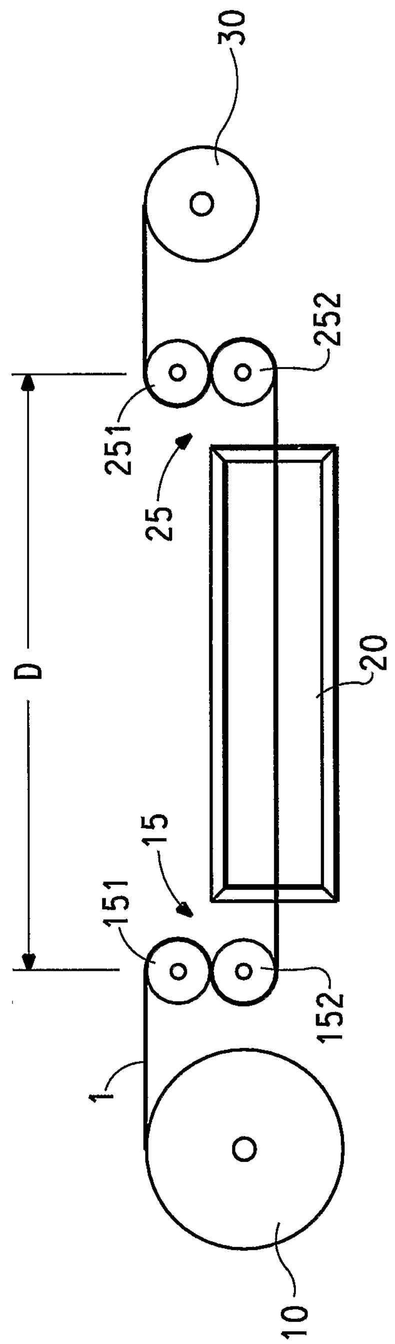


FIG. 3

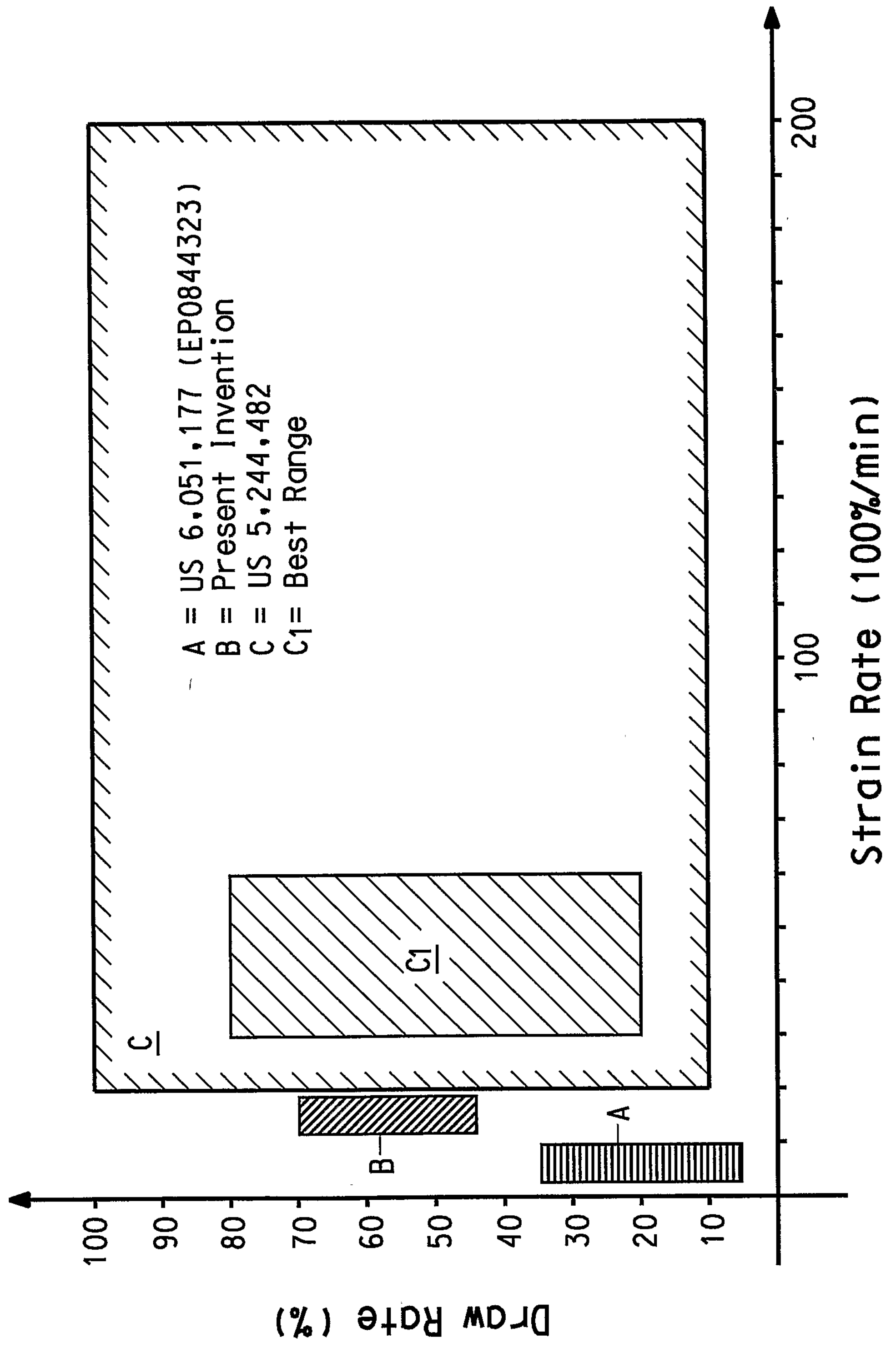

A = US 6.051.177 (EP0844323)
B = Present Invention
C = US 5.244.482
C1= Best Range
C
C1
A
B
Strain Rate (100%/min)
100
200
Draw Rate (%)
100
90
80
70
60
50
40
30
20
10

FIG. 4

FIG. 5A

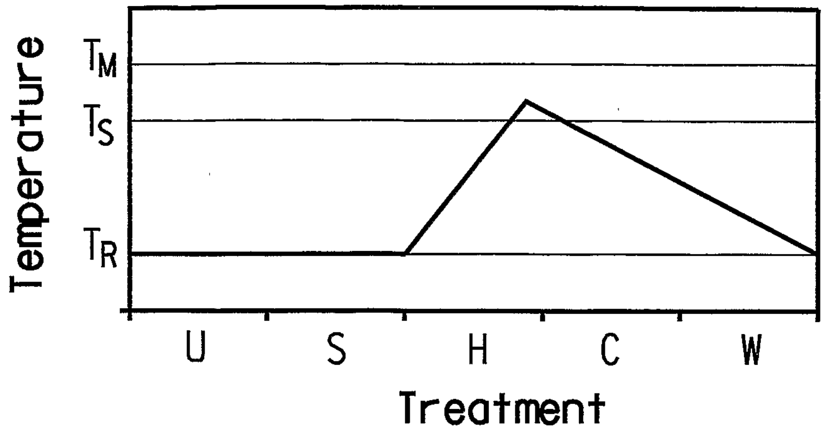


FIG. 5B

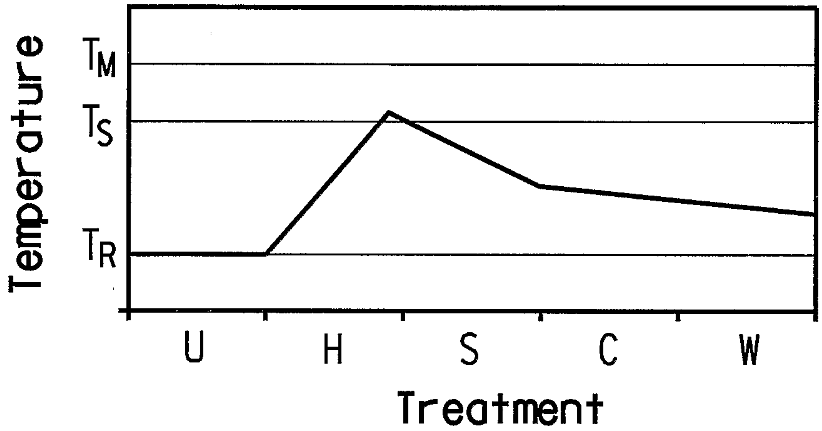
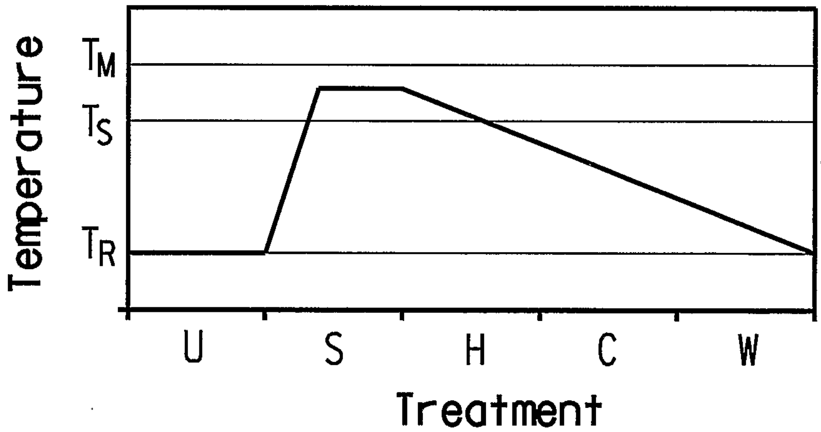


FIG. 5C



U = Unwinding
S = Stretching
H = Heating
C = Cooling
W = Winding

T_R = Room Temperature
T_S = Softening Temperature
T_M = Melting Temperature

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/040569

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D04H1/54 D04H3/16 D04H5/04 D04H13/00 D06C3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D04H D06C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 244 482 A (WADSWORTH LARRY C ET AL) 14 September 1993 (1993-09-14) cited in the application column 4, lines 28-56 - column 9, lines 43-60; claims 1,16	1
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-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2005	04/04/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lanniel, G

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	GB 2 096 048 A (AKZO NV) 13 October 1982 (1982-10-13) page 4, lines 50-58	1-39

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