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(54) **Title**: CUT RESISTANT ARTICLES

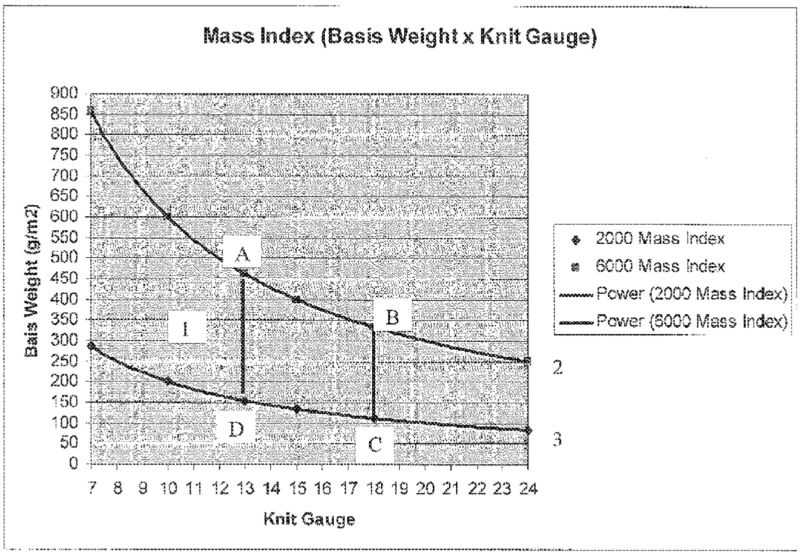

Fig. 1

(57) **Abstract**: A cut resistant article comprising a glove, sleeve, or apron comprising a knit fabric having yarns of fibers having essentially a round cross section and comprising linear polyethylene having a weight average molecular weight of at least 1 million, the yarns having a tensile modulus equal to 500 grams per denier (455 grams per dtex) or less and a yarn elongation at break of 4 percent or greater, the fabric further having a basis weight of 857 grams per square meter or less and having a mass index of 6000 or less.

WO 2014/093615 A1

TITLE OF THE INVENTION

Cut Resistant Articles

BACKGROUND OF THE INVENTION

1. Field of the Invention.

This invention relates to cut resistant articles, which include such items as gloves, sleeves, or aprons, and methods of making the same.

2. Description of Related Art.

Articles of apparel such as gloves, sleeves, and aprons made from fabrics containing ultra-high-molecular-weight (UHMW) polyethylene fibers having high yarn tenacities and tensile moduli can have excellent cut performance and command a premium price in the marketplace. However, it is believed the high fiber tensile modulus of the fiber translates into stiffer fabric which is undesirable, since this can mean the articles of apparel using such fabrics are less comfortable. Since workers are less likely to wear uncomfortable protective apparel, any improvement in the comfort of such cut resistant articles is desired.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to a cut resistant article comprising a glove, sleeve, or apron comprising a knit fabric having yarns of fibers having essentially a round cross section and comprising linear polyethylene having a weight average molecular weight of at least 1 million, the yarns having a tensile modulus equal to 500 grams per denier (455 grams per dtex) or less and a yarn elongation at break of 4 percent or greater, the fabric further having a basis weight of 857 grams per square meter or less and having a mass index of 6000 or less. In some embodiments the article is provided with a polymeric coating for gripping objects.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph illustrating knit fabric mass index.

Figure 2 is a representation of a substantially solid polymer fiber having essentially a round cross section with a nominal aspect ratio of 1.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to a cut resistant article comprising a glove, sleeve, or apron comprising a knit fabric having yarns of fibers having essentially a round cross section and comprising linear polyethylene having a weight average molecular weight of at least 1 million, the yarns having a tensile modulus equal to 500 grams per denier (455 grams per dtex) or less and a yarn elongation at break of 4 percent or greater, the fabric further having a basis weight of 857 grams per square meter or less and having a mass index of 6000 or less.

The “mass index” as used herein relates to knit fabrics and is the product of the fabric basis weight, in grams per square meter, times the knit fabric gauge. The knit gauge is the number of wales per inch (or defined in SI units the number of wales per 2.53 cm) in the fabric. The gauge of a knitting machine is the number of knitting needles per inch (or defined in SI units the number of wales per 2.53 cm) in the machine.

Further, it has been found that knit fabrics having a mass index of 6000 or less made with yarns comprising high molecular weight polyethylene fibers having a low tensile modulus and a round cross section provide cut resistant articles having improved comfort. Personal comfort is almost always cited as a desirable feature of protective apparel, in that apparel that is less comfortable is more likely to not be worn, resulting in more injuries to workers.

Surprisingly, it has been found that the cut resistance of low tensile modulus yarns is not sacrificed even if the lower tensile modulus is achieved by reducing the tensile strength of the high molecular weight polymer yarns. Instead, the inventors believe the presence of higher molecular weight polyethylene is a more important factor with regards to cut resistance of yarns and fabrics, and apparel made from those yarns and fabrics. In particular, the fabrics made with the low modulus yarns claimed herein can have cut resistance essentially equivalent to fabrics made with typical high strength (> 30 grams per denier (27 grams per dtex)) and high modulus (>500 grams per denier (455 grams per dtex)) polyethylene fibers.

The knit fabrics in the cut resistant article have a mass index of 6000 or less; in some embodiments a mass index of 2000 to 6000 is desired. In some other embodiments, a mass index of 3000 to 5000 is desired. **Fig. 1** illustrates an area **1** between line **2**, which represents the upper bound mass index of 6000, and line **3**, which represents one preferred lower bound mass index of 2000. Lines **2** and **3** have endpoints at knit gauges of 7 and 24 and basis weights of about 290 and 860 grams per square meter indicating what is believed to be the more practical ranges for gloves, sleeves, and aprons used by workers. Knit gauges lower than 7 and basis weights higher than about 860 grams per square are believed to provide gloves and other items that are too stiff, while knit gauges higher than 24 and lower than about 290 grams per square may not provide adequate cut protection. **Fig. 1** also illustrates a preferred mass index embodiment that is the area within the points designated by the letters **A-B-C-D**. This area represents fabrics having a mass index of 2000 to 6000 and a knit gauge of from 13 to 18.

The knit fabric utilizes yarns, and in some embodiments the fabric has a basis weight of 3 to 25.3 oz/yd^2 (100 to 857 g/m^2), preferably 4 to 21 oz/yd^2 (136 to 712 g/m^2), with the fabrics at the higher end of the basis weight range providing more cut protection.

By “yarn” is meant an assemblage of fibers or filaments spun, combined, or twisted together to form a continuous strand. As used herein, a yarn generally refers to what is known in the art as the simplest strand of textile material suitable for such operations as weaving and knitting. The yarn can be in the form of a continuous multifilament yarn formed with or without twist. The yarn can be in the form of a spun staple yarn made from staple fibers with more or less twist. When twist is present in a singles yarn, it is all in the same direction. Preferably, the yarn is a continuous multifilament yarn.

The term “yarn” also embraces “ply yarn” and “plied yarn”, which refers to two or more individual yarns twisted or plied together. It is understood the ply yarn can be made from two or more of the same type of staple or continuous filament singles yarns, or the ply yarn can be made from at least one of the singles yarn made from staple fibers and at least one continuous filament yarn. Ply yarns generally contain individual yarns having the same twist direction, plied together in the opposite twist direction to provide a “balanced” ply yarn. Preferably, plied yarns comprise two or more continuous multifilament yarns.

The term “yarn” also embraces a “covered yarn”, which refers to a yarn having a sheath-core structure. Covered yarns are also known as “wrap-covered yarns” and/or “air-covered yarns”. The sheath-core structure generally has one or more center core yarns of one type of fiber with a covering sheath made from one or more differing types of fiber. The center core can be can be made from one or more yarns with little or no twist. The outer sheath can be can be made from a wrap of staple fibers, as in a DREF process, or the outer sheath can be one or more yarns that serve as wrapper yarns that are mechanically wrapped or positioned around the core with “S” and/or “Z” twist. Any of these wrapper yarns can be made from staple fibers or continuous filament. Air-covered sheath-core yarns use air jets to wrap the yarns around the core, normally using continuous filament yarns as both the core and the wrapping.

In some embodiments, the yarn comprises a composite structure made from two or more individual yarns and contains a center core structure and outer sheath structure. At least one of these yarns comprises low modulus high molecular weight polyethylene fiber used in the center core structure with organic, inorganic and/or elastomeric fibers. In some preferred composite structures, the sheath structure contains organic fibers.

One example of the sheath/core yarn has a first core strand of a cut-resistant, continuous-filament, polymer fiber, such as an aramid fiber or a polyester fiber. The yarn also has a second core strand of a cut-resistant, continuous-filament, high molecular weight polyethylene fiber as described herein. The core strands are wrapped with first and second wraps of continuous filament nylon yarns, with the turns of each wrap substantially touching the previous turn, one to the next, to cover the core and/or preceding wrap. In some embodiments it is not critical that the turns of each wrap substantially touch the previous turn or entirely cover the core and/or preceding wrap. Alternatively, the core can be wrapped with other yarns such as polyester yarns. In another alternate embodiment, the core strand can include glass filament(s) or metal filament(s).

Still another example of the sheath/core yarn has a single core strand of a cut-resistant, continuous-filament, high molecular weight polyethylene fiber as described herein. The core strand is wrapped with first and second wraps of continuous filament nylon yarns, with the turns of each wrap substantially touching the previous turn, one to the next, to cover the core and preceding wrap.

Another example of the sheath/core yarn has a first core strand of elastomeric yarn under tension to impart stretch-recovery properties. The yarn can also have a second core strand of a cut-resistant, continuous-filament, high molecular weight polyethylene fiber as described herein. The core strands are wrapped with first and second wraps of continuous filament nylon yarns or polyester yarns as previously described.

In some embodiments, the yarn comprises an intimate blend of the high molecular weight polyethylene staple fibers with other fibers. By intimate blend it is meant the various different types of staple fibers are distributed homogeneously in the staple yarn bundle. For reliable processing, in some embodiments the maximum amount of polyethylene staple fibers used in the intimate blend are 60 weight percent or less; in some embodiments, the preferred amount of polyethylene staple fibers is 50 weight percent or less in the intimate blend. The staple fibers used in some embodiments can have a length of 2 to 20 centimeters. The staple fibers can be spun into yarns using short-staple or cotton-based yarn systems, long-staple or woolen-based yarn systems, or stretch-broken yarn systems. In some embodiments the staple fiber cut length is preferably 3.5 to 6 centimeters, especially for staple to be used in cotton based spinning systems. In some other embodiments the staple fiber cut length is preferably 3.5 to 16 centimeters, especially for staple to be used in long staple or woolen based spinning systems.

For purposes herein, the term "fiber" is defined as a relatively flexible, macroscopically homogeneous body having a high ratio of length to the width of the cross-sectional area perpendicular to that length. Also, such fibers preferably are generally solid polymers having a generally solid cross section for adequate strength in textile uses; that is, the fibers do not have a large quantity of objectionable voids or are essentially void-free. In many embodiments, the cut resistant article includes fibers having a filament linear density of from 0.5 to 3.5 denier (0.55 to 3.9 dtex). In some preferred embodiments, the fiber has a filament linear density of from 0.8 to 2.5 denier (0.88 to 2.75 dtex). The shape of the high molecular weight polyethylene fiber cross section is round or essentially round as represented in **Fig 2**. Further, the fibers have an essentially round cross section; that is, the cross section is essentially solid circular in shape, unlike a hollow fiber that has a circular shape but also an central annular void. Since the shape of the fiber cross section is round or essentially round, it necessarily has a nominal cross sectional aspect ratio (the maximum width divided by the minimum width measured for a particular cross section, generally measured in perpendicular directions) of 1 or essentially 1.

The high molecular weight polyethylene fiber has a yarn tensile modulus equal to 500 grams per denier (455 grams per dtex) or less. In some embodiments, the fiber has a yarn tensile modulus of 100 grams per denier (91 grams per dtex) to 500 grams per denier (455 grams per dtex). In some preferred embodiments the fiber has a maximum yarn tensile modulus is 400 grams per denier (364 grams per dtex) or less. In some preferred embodiments the fiber has a yarn tensile modulus of 100 grams per denier (91 grams per dtex) to 350 grams per denier (318 grams per dtex). In some other preferred embodiments, the fiber has a yarn tensile modulus of from 200 grams per denier (grams per dtex) to 400 grams per denier (364 grams per dtex).

The high molecular weight polyethylene fiber has a yarn tensile elongation at break of 4 percent or greater. In some embodiments, the fiber has a yarn elongation at break of 4 to 15 percent.

For high cut resistance, the fiber is made of linear polyethylene polymer having a weight average molecular weight of 1 million or greater. Polyethylene is made from polymers or copolymers of ethylene with at least 50 mole percent ethylene on the basis of 100 mole percent polymer. The ultra-high molecular weight polyethylene polymer can have an intrinsic viscosity measured in decalin at 135 C of 10 dl/g or greater. In some preferred embodiments the polyethylene has a weight average molecular weight of 2 million or greater, and in some other preferred embodiments the polyethylene has a weight average molecular weight of 2 million or greater. In some embodiments the average molecular weight of the polyethylene is 1.0 million to 3.5 million. In some other embodiments the average molecular weight of the polyethylene is 3.5 million to 6.0 million.

Since polyethylene polymer having a weight average molecular weight of 1 million or greater creates melts of very high viscosity, direct spinning of fibers from such melts is not practical. Instead, the high molecular weight polyethylene fiber is made by processes that spin fibers from a solution of polyethylene in a solvent, and then remove essentially all or the vast majority of the solvent from the spun fibers.

It has been found that surprisingly good cut resistance is found in fibers made from polyethylene polymer having a weight average molecular weight of 1 million or greater, even if the tenacity of these fibers is not considered exceptionally high. In some embodiments, the cut resistant article includes fiber that has a yarn tenacity of less than 25 grams per denier (22.7 grams per dtex) and in some embodiments the fiber has a yarn tenacity of less than 22 grams per denier (20 grams per dtex). Further, in some embodiments, the fiber has a yarn tenacity of less than 18 grams per denier (16 grams per dtex).

The knit fabric comprising linear polyethylene fibers is meant to include a structure producible by interlocking a series of loops of one or more yarns by means of needles or wires, such as warp knits (e.g., tricot, milanese, or raschel) and weft knits (e.g., circular or flat). The knitted fabric uses any appropriate knit pattern and conventional knitting machines. Knitted fabrics can be made on a range of different gauge knitting machines. As used herein, the unit of measure “gauge” used in the mass index is the number of wales per inch (or in SI units the number of wales per 2.53 cm) in a knitted fabric. A wale is the column of loops lying lengthwise in the knitted fabric.

The knitted fabric can be made by hand, mechanical, or modern electronic flat machines (Stoll, Shima-Seiki, Protti, etc.). Some knitting machines are said to be of a certain gauge, which means the knitting machine has that number of needles per inch (or per 2.53 cm) needed to achieve that gauge knitted fabric.

Gauge is a measure of the fineness of the knitted fabric and a lower numerical gauge fabric is a thicker fabric and a higher numerical gauge represents a thinner fabric. In some embodiments, the knit is 7 gauge or higher. In some embodiments the knit is 10 gauge or higher; in other embodiments the knit is 13 gauge or higher. In some specialized applications requiring very thin fabrics the knit is 18 gauge or higher. In some articles, the gauge for the knit is 24 gauge or lower. In some preferred embodiments, the knit is 10 to 18 gauge, with the most preferred embodiments being 13 to18 gauge knit or higher.

A wide variety of flat-bed and circular knitting machines can be employed. For example, Shima-Seiki knitting machines can be used to make the knitted fabrics. If desired, multiple ends or yarns can be supplied to the knitting machine. For example, two of any of the yarns previously described herein can be knitted two-ends-in, i.e., both yarns or ends are concurrently knitted by a common needle to directly produce a cut-resistant protective glove. Such machines can produce plated (also called plaited) fabrics and gloves where one of the yarns is distributed primarily to one side of the fabric or glove and the other yarn is distributed primarily on the opposite side of the fabric or glove. In so doing, a glove having distinct inner and outer sides can be produced. The tightness of the knit can be adjusted to meet any specific need. Very effective cut resistance has been found in, for example, single jersey knit, interwoven knit, mesh knit and terry knit patterns.

The cut resistant articles in the form of gloves, aprons, and sleeves can be directly knit on a knitting machine or parts of these articles can be knit separately and then attached together, typically by sewing. If articles are made by sewing parts together on a sewing machine, woven fabrics can also be combined with the knit fabric in the articles. The cut resistant article can further comprise a polymeric coating for gripping objects. In some instances the polymeric coating can be positioned in discrete areas on the article, such as beads of coating on the palm and/or fingers of a cut resistant glove.

The high molecular weight polyethylene fiber is preferably made by spinning a solution of polyethylene in a solvent, and then removing essentially all or the vast majority of the solvent from the fiber. The spinning process for forming filaments of such ultra-high molecular weight polyethylene or extended chain polyethylene fibers can include the principles taught, for example, in U.S. Patent No. 4,457,985.

Generally after spinning, in typical gel-spun fiber processes the fiber tensile properties are then increased by hot drawing the fiber at temperatures in excess of 125 C. The temperatures used during hot drawing are referred to herein as being “hot-draw” temperatures. This hot drawing can be achieved in one or multiple stages with each stage having a specified temperature and draw ratio. As used herein, draw ratio refers to the ratio of the speed of the fiber exiting the draw stage to the speed of the fiber entering the draw stage. If multiple stages are used, the total draw is calculated by multiplying the individual draws ratios from each stage together.

To achieve the desired low modulus high molecular weight polyethylene fiber, it has been found the fibers are preferably hot drawn in only one hot draw stage, and that the fibers are exposed to a draw ratio in the stage of preferably no more than 6, and more preferably a draw ratio of no more than 4. However, the fibers can be drawn in more than one stage. In that instance, the total draw is preferably no more than 6, and more preferably no more than 4. Typical hot draw temperatures used in the hot drawing step are from 135 to 150 C, preferably greater than 140 C.

This process differs from other processes that seek to attain fibers having their highest possible tenacity and which are drawn in as many as four different successive stages with increasing temperature (close to melting temperature of the fiber) and high draw ratios totaling 10 or greater.

Further, it has been found that after drawing, it is preferred to relax the fiber in a least one subsequent draw stage, wherein the amount of draw ratio is about 1.0 or less, preferably 1 or less, and most preferably less than one. If the relaxation is done in multiple stages, then the total draw is about 1.0 or less, preferably 1 or less, and most preferably less than one.

The temperatures used in the relaxation step are referred to herein as being “relaxation” temperatures. The relaxation temperature is chosen such that it is either within +/- 5 degrees C of the hot-draw temperature or it is higher than the hot-draw temperature. Typical temperatures used in the relaxation step are about 140 to 160 C. In some preferred embodiments the relaxation temperature is greater than the hot draw temperature. In some preferred embodiments the relaxation temperature is greater than 145 C.

While this combination of spinning and drawing techniques are known to provide the desired fiber, it is understood that the fiber can be made by any other spinning and drawing techniques as long as that fiber meets the claimed requirements.

TEST METHODS

Cut Resistance. The method used is the "Standard Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing", ASTM Standard F 1790-97. In performance of the test, a cutting edge, under specified force, is drawn one time across a sample mounted on a mandrel. At several different forces, the distance drawn from initial contact to cut through is recorded and a graph is constructed of force as a function of distance to cut through. From the graph, the force is determined for cut through at a distance of 25 millimeters and is normalized to validate the consistency of the blade supply. The normalized force is reported as the cut resistance force.

The cutting edge is a stainless steel knife blade having a sharp edge 70 millimeters long. The blade supply is calibrated by using a load of 400 g on a neoprene calibration material at the beginning and end of the test. A new cutting edge is used for each cut test.

The sample is a square piece of fabric cut 75 x 75 millimeters on the bias at 45 degrees from the warp and fills directions.

The mandrel is a rounded electrically conductive bar with a radius of 38 millimeters and the sample is mounted thereto using double-face tape. The cutting edge is drawn across the fabric on the mandrel at a right angle with the longitudinal axis of the mandrel. Cut through is recorded when the cutting edge makes electrical contact with the mandrel.

Tensile Properties. Tensile modulus, tenacity, and elongation-at-break are all determined for the polyethylene yarns by following the procedure disclosed in ASTM D7269 “Standard Test Methods for Tensile Testing for Aramid Yarns”, substituting the polyethylene yarns for the aramid yarns.

Example 1

A polyethylene fiber was made in the following manner. An oil jacketed double helical mixer is charged with 6 wt% UHMWPE powder (GUR 4120, Ticona), 0.6 wt% of antioxidants (tri(2,4-di-(tert)-butylphenyle)phosphate (Irgafos 168, Ciba) and tetrakis-(methylene-(3,5-di-(tert)-butyl-4-hydrocinnamate))methane (Irganox 1010, Ciba), and 94.4 wt% mineral oil (Hydrobrite 1000, Sonneborn). The mixture is heated to 170 C with agitation at 60 rpm under nitrogen until UHMWPE is fully dissolved to make a spin dope.

The spinning dope is then pumped through an 180-hole spinneret and each hole of the spinneret has 1 mm diameter and 6/1 L/D. The throughput is 16 g/min and the spin stretch was 13. The extruded thread line is quenched by a water bath located at a distance of 1 inch below the spinning die. The gel filament yarns are wound up onto a 4 1/8 inch diameter perforated plastic core.

The bobbin of gel fiber yarns is immersed in hexane to extract the mineral oil. This step is repeated several times until mineral oil is fully extracted from the fiber. During the extraction, the semi-extracted fiber yarns are unwound from the bobbin to prevent filaments sticking to each other. The fully extracted fiber yarns are dried in the air at room temperature overnight.

The dried yarn is then drawn in multiple steps using single zone pilot fiber convection oven from Litzler. The effective heated length per pass is 2.08 meters. The dry gel yarn is drawn three times at oven temperature of 125°C, 135°C, and 143°C with draw ratio of 4, 2 and 1.5 respectively. The yarn feeding speed is 2.5 m/min. The loosely wound yarn is then relaxed on the bobbin at 142 °C for couple of hours. The yarns are 400 denier (364 dtex) having round filaments with a nominal aspect ratio of 1 and a tenacity of less than 20 grams/denier and modulus less than 350 grams/denier.

Example 2

Five polyethylene continuous 400 denier (364 dtex) multifilament yarns are obtained. Representative yarn properties are shown in Table 2. Yarn 1 is the yarn obtained from Example 1. Comparative Yarns A, B, & C are representative of commercially available high tenacity and high modulus, solution-spun, high molecular weight polyethylene yarns. Comparative Yarn D is representative of low tenacity and low modulus, melt-spun, low molecular weight polyethylene yarns.

Table 2

Yarn Samples	Yarn Tensile Modulus, g/dtex (g/denier)	Yarn Linear Density, dtex (denier)	Filament Linear density, dtex (denier)	Polymer Molecular Weight (millions)
1	< 318 (< 350)	440 (400)	2.4 (2.2)	> 1.0
A	> 900 (> 1000)	440 (400)	2.2 (2.0)	> 1.0
B	> 900 (> 1000)	440 (400)	3.9 (3.5)	> 1.0
C	> 900 (> 1000)	440 (400)	1.1 (1.0)	> 1.0
D	<360 (<400)	440 (400)	1.3 (1.2)	< 0.5

Knit fabric samples are made from each of the five filament yarns. In particular, to facilitate acceptable knitting, two ends of all yarns are plied and are twisted with 1.5 turns per inch (tpi) using a Saurer Allma twisting machine. A Shima Seiki 13-gauge glove knitting machine is used to produce knit fabric material about two meters long, which is enough fabric to provide samples for subsequent cut testing and other evaluations. Glove samples are also knit from each ply twisted yarn for comparative comfort evaluation.

The fabrics are subjected to ASTM Standard F 1790-97 "Standard Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing". The relative cut test results are shown in Table 3, with a “+” in this column indicating good cut resistance and with a “-“ indicating less cut resistance. As shown in the table, the fabrics made with higher molecular weight polymer have better cut resistance.

Table 3

Fabric	Yarn Composition (1.5 Turns per Inch)	Fabric Areal Density, g/sq. meter (oz/sq. yd.)	Mass Index	Polymer Molecular Weight (millions)	Cut Resistance	Perceived Glove Fabric Comfort
1	2 Ends of Yarn 1	325 (9.6)	4225	> 1.0	+	+
A	2 Ends of Yarn A	329 (9.7)	4277	> 1.0	+	-
B	2 Ends of Yarn B	325 (9.6)	4225	> 1.0	+	-
C	2 Ends of Yarn C	329 (9.7)	4277	> 1.0	+	-
D	2 Ends of Yarn D	349 (10.3)	4537	< 0.5	-	+

In addition, the glove fabrics are evaluated in Table 3 for their perceived relative flexibility and comfort, with a “+” in this column indicating good relative flexibility and comfort and a “-“ indicating less relative flexibility comfort. Glove Fabric 1 has a subjectively more comfortable and flexible “hand” than Glove Fabrics A, B, or C, and has comfort equivalent to Glove Fabric D. This is believed to be due to the use of lower modulus yarns in Glove Fabric 1and Glove Fabric D. Therefore Glove Fabric 1 is superior to the Comparative Fabrics in that it has both good cut resistance and good perceived comfort.

Example 3

The general process of Example 1 is repeated, using suitable spinnerets and spinning conditions to create 200 and 1000-denier linear density polyethylene yarns of round cross section filaments having individual filament linear densities ranging from 1.1 to 3.9 dtex per filament (1.0 to 3.5 denier per filament). The properties of these yarns are shown in Table 4.

Table 4

Yarn Samples	Yarn Tensile Modulus grams/dtex (grams/denier)	Yarn Linear density dtex (denier)	Filament Linear density dtex (denier)
3-1	< 450 (< 500)	220 (200)	2.2 (2.0)
3-2	< 450 (< 500)	1100 (1000)	2.2 (2.0)

Example 4

Fabrics are made from the yarn samples of Example 3 were then prepared for knitting fabric samples. In particular, to facilitate acceptable knitting, one end of 200-denier Yarn 3-1 is twisted with 1.5 turns per inch (tpi) using a Saurer Allma twisting machine to make ply twisted 200-denier yarn designated Yarn 4-1. Then three ends of the 200-denier Yarn 3-1 are plied and twisted with 1.5 turns per inch (tpi) using a Saurer Allma twisting machine to make ply twisted 600-denier yarn designated 4-2. Then two ends of 1000-denier Yarn 3-2 are twisted with 1.5 turns per inch (tpi) using a Saurer Allma twisting machine to make ply twisted 2000-denier Yarn 4-3. Finally, three ends of the 1000-denier Yarn 3-2 are plied and twisted with 1.5 turns per inch (tpi) using a Saurer Allma twisting machine for make 3000-denier ply twisted Yarn 4-4. The resulting four single and ply twisted yarns ranged in linear density from 200 to 3000-denierShima Seiki glove knitting machines are used to make 18, 15, 10, & 7 gauge knit fabric sleeves from the Yarns 4-1, 4-2, 4-3, & 4-4, respectively, for cut testing and gloves for comparative comfort evaluation. The fabrics/gloves were in turn designated 4-1, 4-2, 4-3, & 4-4.

Properties of the fabrics/gloves are shown in Table 5. All of the fabric samples have good cut resistance, equivalent to high modulus, high tenacity polyethylene yarns. This is represented with a "=" in in this column of Table 5. Further, all of the glove samples had improved perceived relative flexibility and comfort when compared to gloves made from to high modulus, high tenacity polyethylene yarns. This is represented with a "+" in this column in Table 5. In addition, the higher knit gauge polyethylene gloves have more flexibility and comfort when compared to lower knit gauge gloves.

Table 5

Fabric / Gloves	Yarn Composition (1.5 Turns per Inch)	Knit Gauge	Fabric Areal Density g/sq. meter (oz/sq yd)	Mass Index	Cut Resistance	Perceived Glove Fabric Comfort
4-1	Yarn 4-1 (1 End of Yarn 3-1)	18	170 (5)	3060	=	+
4-2	Yarn 4-2 (3 Ends of Yarn 3-1)	15	271 (8)	4065	=	+
4-3	Yarn 4-3 (2 Ends of Yarn 3-2)	10	423 (12.5)	4230	=	+
4-4	Yarn 4-4 (3 Ends of Yarn 3-2)	7	644 (19)	4508	=	+

Claims

What is claimed is:

1. A cut resistant article comprising a glove, sleeve, or apron comprising a knit fabric having yarns of fibers having essentially a round cross section and comprising linear polyethylene having a weight average molecular weight of at least 1 million, the yarns having a tensile modulus equal to 500 grams per denier (455 grams per dtex) or less and a yarn elongation at break of 4 percent or greater, the fabric further having a basis weight of 857 grams per square meter or less and having a mass index of 6000 or less.

2. The cut resistant article of claim 1 having a mass index of 2000 to 6000.

3. The cut resistant article of claim 2 having a mass index of 3000 to 5000.

4. The cut resistant article of any one of claims 1 to 3 wherein the fiber has a yarn tensile modulus of 400 grams per denier (275 grams per dtex) or less.

5. The cut resistant article of any one of claims 1 to 4 wherein the fiber has a yarn tensile modulus of 100 grams per denier (91 grams per dtex) or greater.

6. The cut resistant article of any one of claims 1 to 5 wherein the fiber has a yarn elongation at break of 4 to 15 percent.

7. The cut resistant article of any one of claims 1 to 6 further comprising a polymeric coating for gripping objects.

8. The cut resistant article of claim 7 wherein the polymeric coating is positioned in discrete areas on the article.

9. The cut resistant article of claim 1 wherein the knit is 7 gauge or higher.

10. The cut resistant article of claim 9 wherein the knit is 10 gauge or higher.

11. The cut resistant article of claim 10 wherein the knit is 13 gauge or higher.

12. The cut resistant article of claim 11 wherein the knit is 15 gauge or higher.

13. The cut resistant article of claim 12 wherein the knit is 18 gauge or higher.

14. The cut resistant article of any one of claims 9-13 wherein the knit is 24 gauge or lower.

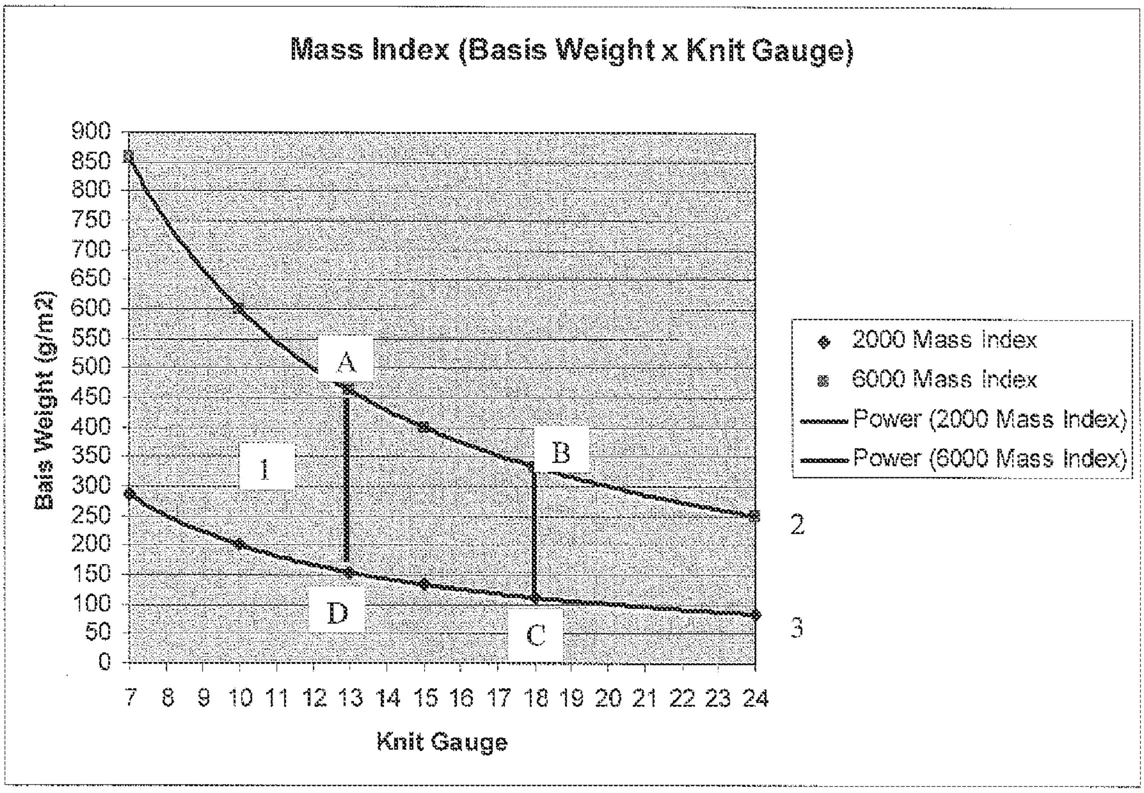
Mass Index (Basis Weight x Knit Gauge)
Basis Weight (g/m2)
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Knit Gauge
A
B
C
D
1
2
3
2000 Mass Index
6000 Mass Index
Power (2000 Mass Index)
Power (6000 Mass Index)

Fig. 1

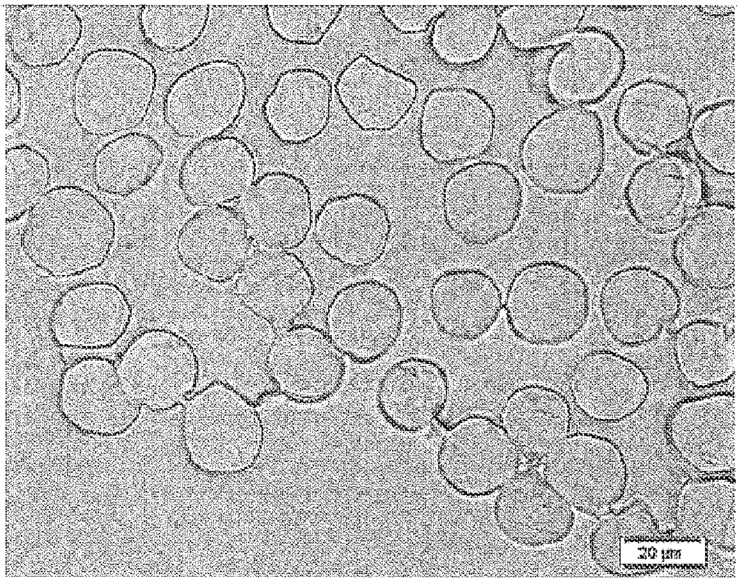

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/074657

A. CLASSIFICATION OF SUBJECT MATTER
INV. D04B1/28
ADD. D02G3/44

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)
D04B D02G

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2011/028746 A1 (KOLMES NATHANIEL H [US]; BRITTAIN DAN [US]; HERRING JAMES EDWARD [US]) 10 March 2011 (2011-03-10) page 8, line 10 - page 9, line 4; claims 1, 13, 18; figures 1-4 -----	1-6
A	US 5 119 512 A (DUNBAR JAMES J [US] ET AL) 9 June 1992 (1992-06-09) column 3, line 12 - column 4, line 59; claims 2, 4, 13; figure 1; examples A, C column 7, lines 24-27 -----	1-6,9,10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 March 2014	17/03/2014

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, Fax: (+31-70) 340-3016	Sterle, Dieter

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/074657

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2011028746 A1	10-03-2011	US 2010050699 A1	04-03-2010
		WO 2011028746 A1	10-03-2011
US 5119512 A	09-06-1992	NONE	