The present invention relates to a multi-directional stretch fabric that has excellent flash fire and flame resistant qualities.
MULTI-DIRECTIONAL-STRETCH, FLAME-RESISTANT FABRIC

FIELD OF THE INVENTION

[0001] The present invention relates to fabric manufacture, fabrics, and related articles. More particularly, the invention relates to methods and products having improved flash fire and flame resistance and flexibility for the wearer.

DESCRIPTION OF RELATED ART

[0002] It is known that various environments require specially crafted articles of clothing to protect the wearer. For example, military personnel, such as pilots, flight crews, tanker crews, special forces, aircraft carrier personnel, first responders, such as firemen, police and EMS workers, petrochemical workers, electrical linemen, etc. require clothing that protects them against flash fire and flame. Although certain protective clothing exists, this clothing is unacceptably rigid and, as such, fails to provide the wearer with the necessary flexibility or freedom of movement to allow the wearer to effectively perform necessary duties.

[0003] U.S. Pat. Nos. 5,527,597 and 5,694,981 disclose a fabric made of Kevlar® and poly-benzimidazole and an elastic material, such as rubber or spandex, to be used to construct garments such as a firefighters’ turn-out coat. Their disclosures state that the fabric did not melt, drip, separate, or ignite upon static exposure in a 500° F. oven for at least five minutes. However, what is truly needed is a multi-directional, stretchable garment that protects its wearer when subjected to flash fire or flame.

[0004] Other known products either fail to be sufficiently stretchable or fire resistant or both. Thus, although there have been attempts to produce a stretchable, flash fire and flame resistant fabric, to date all have substantial shortcomings.

SUMMARY OF THE INVENTION

[0005] The invention satisfies the need and avoids the drawbacks of the prior art by providing a light-weight, multi-directional stretch, flash fire and flame resistant fabric that provides both sufficient fire protection and sufficient flexibility for the wearer. In one aspect, a stretch-woven aramid fabric is disclosed that permits improved mobility and durability while at the same time exhibits superior resistance to flash fire and flame.

[0006] The fabric is produced from a system of stretchable warp yarns interlaced with a pattern of stretchable filling or weft yarns on a weaving loom. The warp yarns run lengthwise in the fabric and cross at right angles to the filling yarns to produce a woven fabric. The stretchable warp and filling yarns may be of the same size or count or they may be different depending on the desired stretch and weight of the fabric that the wearer desires.

[0007] The warp and filling yarns are constructed of flame resistant yarns or fibers, in one case N303 solution-dyed Nomex, and may be constructed of para-aramid or meta-aramid fibers. The amount of flame resistant yarn or fiber relative to the amount of elastomeric fiber core must be limited in order for the resultant fabric to provide adequate protection from flash fire or flame. On the other hand, the amount of elastomeric fiber core cannot be reduced to such an extent that the fabric has insufficient stretch and recovery. In one aspect, the flame resistant yarns or fibers are wrapped or spun around an elastomeric core. The yarns or fibers that are wrapped around the elastomeric core protect the core from melting or supporting a flame when the fabric is exposed to flash fire or flame.

[0008] In one aspect, after weaving, the fabric is secured and heatset to provide certain physical properties including desired stretches and recovery in both directions, weight, width and resistance to shrinkage in laundering. A topical finish to obtain moisture management or water repellency may be applied during the process to provide additional performance characteristics. In another aspect, finishes that detract from the flame resistance performance of the fabric are avoided.

[0009] A stretchable, fire resistant fabric including warp and filling fibers is provided. The warp and filling fibers are constructed with an elastic core yarn that is wrapped by a flash fire and flame resistant material such that the fabric is not flammable when subjected to an open flame for a variety of time frames including but not limited to 5, 10, and 12 seconds. In one aspect the elastic core yarn may be wrapped by two layers of a flash fire and flame resistant material. In another aspect the elastic core yarn of the invention may be limited to about 3%, 4%, and 5% (w/w). In yet another aspect of the invention, the flash fire and flame resistant material may be provided in amounts including but not limited to about 90 to about 98% (w/w). Of course, various combinations of amounts of elastic core yarn and flash fire and flame resistant material are contemplated by the invention. Spandex may be employed as an elastic core yarn and para-aramid and meta-aramid material, including but not limited to a blend of Nomex® material, may be utilized as a flash fire and flame resistant material. In another aspect the fabric of the invention may stretch and recover about 20% to about 60% in each direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a side elevation view of illustrating an elastic core yarn wrapped with a fire resistant yarn in one direction that is wrapped with another fire resistant yarn in the opposite direction.

[0011] FIG. 2 is a cross-section of a plain weave.

[0012] FIGS. 3A and 3B are top plan views of a fabric constructed according to the invention.

[0013] FIGS. 4A and 4B are top plan views of another fabric constructed according to the invention.

[0014] FIG. 5 is an elevation view of a garment constructed according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] As set forth above, military personnel, first responders, petrochemical workers, electrical linemen, etc. need garments that are extremely flexible and provide the requisite safety from flash fire and flame. Specifically, the invention provides a stretch-woven fabric that has good stretch and recovery, flame resistance, static dissipative properties and limited spectral reflectance in compliance
with MIL-C-83429. Additionally, the material is dimensionally stable, colorfast, and pill resistant in compliance with MIL-C-29567.

[0016] According to the invention, a flame resistant fiber may be wrapped around an elastomeric fiber core. Various flash fire and flame resistant materials may be employed including but not limited to aramids, polyamides with para-phenylene group linkages, polyamides with meta-phenylene group linkages, polybenzimidazole, Nomex® 450 (crystallized Nomex®, Nomex® 455 (95/5 blend of Nomex®/Kevlar®), Nomex® 460 (85/15 blend of Nomex®/Kevlar®), Nomex® 462 (93/5/2 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® N330 Military grade (92/5/3 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® E502 (93/5/2 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® E510 (crystallized Nomex®), Nomex® N301 (95/5 blend of Nomex®/Kevlar®), Nomex® N302 (93/5/2 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® N304 (77/5/3 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® N305 (75/23/2 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® N306 (84/10/6 blend of Nomex®/Kevlar®/P-140 antistat), Nomex® N308 (40/60 blend of Nomex®/Kevlar®), Nomex® N310 (50/50 blend of Nomex®/Kevlar®), Nomex® E50 (Nomex®), Nomex® E50ZT (Nomex®), Nomex® 430 (crystallized Nomex®), Nomex® N104 (uncrystallized Nomex®), Nomex® N102 (Nomex®), and any other materials that can be formed into fabric that meet the criteria of both stretch and recovery and flash fire and flame resistance. Antistat, such as that referred to above as P-140, may be added to a fabric material to eliminate the possibility of static discharge.

[0017] Elastic materials are employed to provide the products of the invention with flexibility. According to the invention, elastic means that the material may be stretched repeatedly in different directions and still recover to very near its original length and shape. Various elastic materials may be utilized including but not limited to spandex, Lycra®, rubber, long-chain synthetic polymers including polyurethane, and any other materials that have the quality of elasticity.

[0018] Nomex® N302 (Military grade), which is a 93% Nomex®, 5% Kevlar®, and 2% P-140 antistat, may be combined with spandex to form a stretchable, flash fire and flame resistant fabric. In another embodiment, Nomex® N303 (Military grade), which is 92% Nomex®, 5% Kevlar®, and 3% P-140 antistat, may be combined with spandex. Nomex® N302 and N303 may be solution-dyed materials.

[0019] In one aspect, a spandex material (5%) is combined with flash fire and flame resistant material (95%), such as Nomex® N303, to form a useful fabric according to the invention. In another aspect, 96% of a flash fire and flame resistant material, such as Nomex® N303, is combined with 4% spandex material, which, compared to the 5% spandex product, provides slightly improved flash fire and flame protection. In yet another aspect, 97% Nomex® N303 or another flash fire and flame resistant material may be combined with 3% spandex material to permit even greater flash fire and flame protection. In each of these examples, greater flash fire and flame resistance is achieved at the expense of stretchability and recovery of the fabric material. Thus, the 3% spandex material has better flash fire and flame protection than the product having 5% spandex. However, the 5% spandex material provides better stretch and recovery compared to the 3% spandex material.

[0020] According to the principles of the invention, the manufactured yarn is produced by encapsulating the elastic material within the flash fire and flame resistant material. As a result of the high rigidity of flame resistant material, the flame resistant yarn may encounter significant torquing or bending problems when it is employed as a single outer wrapping. One way to overcome torquing problems is to add starch or other sizing agents to yarn fibers before putting the fabric through a loom. This option is unsuitable because starch is flammable, which is a problem that the invention seeks to avoid or eliminate. Although starch removal compounds exist, these compounds are also flammable, which again runs counter to the aims of the invention. Thus, starch and starch removal compounds, which are flammable, do not present an effective solution to the bending/torque issue.

[0021] Wrapping the flame resistant material around the elastic core using two coverings or wrappings as shown in FIG. 1 is another alternative. Two distinct coverings having the same amount of flame resistant material as the single covering discussed above reduce the torquing problems. Because the torquing problems are minimized, flammable starch or other sizing agents and starch removal compounds are unnecessary.

[0022] Conventional equipment may be used to double wrap, in both the x-direction and the y-direction, the elastic core yarn with flame resistant fibers or yarns in a single pass. Certain torquing problems still exist with this method due to the properties of the flash fire and flame resistant materials. In another aspect, the double wrapping may be applied to the core in two sequential procedures. First, the core material may be wrapped by the flame resistant material. Then, a second wrapping may be applied to the previously wrapped core. This second wrapping may be wrapped in the opposite direction to help offset the torquing problems.

[0023] In one aspect of the invention, the double-wrapped, encapsulated elastic material is incorporated in the fabric in both the warp and fill directions to permit stretch and recovery in both directions. Special handling of the warps is necessary and tension-free warping is required to allow the yarn to be woven in the warp direction. In one aspect, precision tensioning devices may be employed on each end of each warp yarn in order to maintain tension of the yarn during the manufacture of the fabric. Otherwise, uneven bands may result in the finished product, which is unsatisfactory because a smooth woven appearance of the warps is typically desired. Additionally, in a preferred aspect, a consistent inlay is utilized on the filling yarn or weft during the weaving process to assure a smooth woven appearance in the fabric.

[0024] FIG. 1 depicts a warp yarn according to the principles of the invention. An elastic core yarn 10 may be wrapped or covered with a flame resistant material 20. For example, the core yarn 10 may be spandex and the flame resistant material 20 may be a 40/1 Nomex® spun yarn. According to the invention, a second flame resistant material 30 may be wrapped around flame resistant material 20 in a reverse ply with another 40/1 Nomex® spun yarn. Thus, the
construction illustrated in FIG. 1 includes a core yarn 10 that is covered with both flame resistant material 20 and flame resistant material 30. The coverings may be applied such that no openings or gaps are present. The double wrap approach provides a stronger yarn and one having greater stability. The flame resistant material may be employed in single or multiple plies and may have a cotton count from 50 to 15. In various aspects, the flame resistant material may be constructed with yarn ranging from 50 cotton count/2 ply to 15 cotton/2 ply. In one aspect, a 40/2 is employed. If a heavier fabric is desired, 30/2 or even 15/2 may be utilized. On the other hand, if a lighter weight fabric is needed, a 50/2 may be employed which provides about the same stretch and recovery as 40/2 and is less flammable. The number of wraps range from 10 to 24 turns per inch and, in one aspect, are about 16 turns per inch. The weight of the fabric may be up to about 12 ounces/yd² and generally is about 3 to about 8 ounces/yd². In one aspect, the fabric weighs about 5-6 ounces/yd².

[0025] FIG. 2 illustrates a cross-section of a plain weave constructed using yarns of the invention. Each strand is depicted as being made of an elastic core yarn 10 that is wrapped in two layers of flame resistant material 20, 30.

[0026] FIGS. 3A and 3B and FIGS. 4A and 4B illustrate two variations of twill weaves depicted by woven yarns and patterns. In the figures, arrow 40 indicates the warp direction and arrow 50 indicates the filling direction.

[0027] In one aspect of the invention, the fabric is finished or modified to certain physical specifications. The fabric may be manufactured as solution-dyed (fiber dyed prior to forming yarn), as yarn-dyed (yarn dyed prior to weaving), or prepared for print (securing the fabric so that it is white).

[0028] The woven fabric may be relaxed in a hot water bath at about 170°F. to about 200°F. for a dwell time of about 0.1 to about 2 seconds. In one aspect, the fabric is placed in an approximately 190°F. bath for approximately 0.5 second. If securing is desired, the fabric may be secured using an anionic wetting agent, such as (Lynxet SS) SL-62 nonionic detergent, in a bath at about 90°F. to about 110°F. for about 10-30 minutes, and in some cases the securing temperature is approximately 10°F. for a time period of approximately 20 minutes. In one aspect the pH is adjusted using soda ash to approximately 6-8. If desired, thereafter the temperature of the bath may be elevated to about 180°F. to about 215°F. for about 10 to about 30 minutes. In another aspect of the invention, the temperature of the bath may be raised to approximately 205°F. for about 20 minutes. Stretch and recovery of the fabric may be achieved by framing the fabric by width and picks using horizontal and vertical tension. The fabric may then be heat set at about 385°F. to about 400°F. for about 30 to about 90 seconds or, in one aspect, approximately 1 minute. Suitable time and temperature settings are dependent on the weight of the fabric.

[0029] After finishing, the fabric may be made into a garment or may be further processed. Examples of additional processing include but are not limited to laminating the fabric to a flame retardant fleece, waterproof breathable fire resistant film, or other flame retardant knitted or woven fabrics. The fabric of the invention may be placed next to the skin of the wearer, as an exterior layer, or within a multilayer article of clothing.

[0030] According to the principles of the invention, a wide variety of articles may be constructed with the novel fabric of the invention. Flight suits, shirts, pants, trousers, bib overalls, battle dress uniforms, jackets, thermal layer jackets, vests, face masks, socks, shoe uppers, hats, gloves, and the like may be produced with the disclosed fabric. Potential wearers include but are not limited to military personnel, such as pilots, flight crews, tanker crews, special forces, aircraft carrier personnel, first responders, such as firemen, police and EMS workers, petrochemical workers, electrical linemen, and other professionals that require stretchable clothing that protects against flash fire and flame.

[0031] FIG. 5 depicts a garment constructed according to the invention and indicates the four-way stretch of the novel fabric at arrows 60. For example, a fleece-backed fabric having the characteristics of flame resistance, multi-directional stretch and recovery, moisture management, warmth, breathability and comfort may be produced and constructed into a useful article. In another aspect, the fabric may be combined with a grid velour material using a flame resistant adhesive to maintain stretchability.

[0032] As described above, the invention provides a product with useful characteristics. The fabric of the invention passes the vertical flammability test, NFPA 1971, which introduces an open flame to a vertically mounted fabric. One method of applying this test is to clamp a strip of a fabric in a vertical position and place a flame emanating from a Bunsen burner in contact with the lower portion of the fabric. After the flame from the Bunsen burner is in contact with the fabric for a period of time, e.g., 5 seconds, 10 seconds, 12 seconds, 15 seconds, 20 seconds, the flame is removed and the After Flame, Glow, and Char are measured. After Flame is the time that the fabric remains ignited and Glow is the time the fabric glows both are calculated beginning when the Bunsen burner flame is removed. Char is the length of brittle residue on the fabric caused by the exposure to the flame. Visual evidence of melting and dripping of the fabric caused by the flame are also investigated. All of these tests and investigations are performed along the length and the width, or warp and fill directions, of the fabric.

[0033] Because a wide variety of processes and materials may be utilized and products constructed according to the invention, it is understood that the following examples are merely exemplary.

[0034] Two examples were prepared according to the principles of the invention as discussed below. Examples 1 and 2 were made of 96% Nomex® N330 Military grade flame resistant material and 4% spandex. Example 1 was constructed as a plain weave and Example 2 was constructed as a 2×1 Twill. A 12-second vertical flame test was performed on Examples 1 and 2. As displayed below, neither example exhibited any After Flame in either direction subsequent to the flame being removed from the fabric. The glow times were 4.5 and 5.1 seconds, respectively, in the length direction and 4.5 and 5.2 seconds, respectively, in the width direction. The char length was 3½ inches and 3 inches, respectively, in the length direction and 3 and 3⅛ inches, respectively, in the width direction. Neither of the examples showed signs of melt and drip in either direction.
In addition to protection from flash fire and flame, the fabric of the invention has exceptional stretch and recovery in the warp and fill directions. In one aspect, the fabric exhibits about 20% to about 60% stretch in both the warp and fill directions in accordance with ASTM 2594. Notably, a 60% stretch is more than a comfort stretch, which is typically about 20%, and provides for a body hugging stretch such that the garment is capable of stretch and recovery and compression with each movement of the wearer.

While the invention has been described in detail and with reference to specific examples thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope thereof.

What is claimed is:

1. A stretchable, fire resistant fabric, comprising:
   a plurality of warp fibers, said warp fibers having an elastic core yarn wrapped by a flash fire and flame resistant material; and
   a plurality of filling fibers, said filling fibers having an elastic core yarn wrapped by a flash fire and flame resistant material;
   wherein said plurality of warp fibers are interwoven with said plurality of filling fibers and said fabric is not flammable when subjected to an open flame for 5 seconds.

2. The fabric of claim 1, wherein said fabric is not flammable when subjected to an open flame for 10 seconds.

3. The fabric of claim 1, wherein said fabric is not flammable when subjected to an open flame for 12 seconds.

4. The fabric of claim 1, wherein said fabric comprises no more than about 5% (w/w) elastic core yarn.

5. The fabric of claim 1, wherein said fabric comprises no more than about 4% (w/w) elastic core yarn.

6. The fabric of claim 1, wherein said fabric comprises no more than about 3% (w/w) elastic core yarn.

7. The fabric of claim 1, wherein said fabric comprises at least about 92% (w/w) flash fire and flame resistant material.

8. The fabric of claim 1, wherein said fabric comprises at least about 95% (w/w) flash fire and flame resistant material.

9. The fabric of claim 1, wherein said fabric comprises at least about 97% (w/w) flash fire and flame resistant material.

10. The fabric of claim 1, wherein said elastic core yarn comprises spandex material.

11. The fabric of claim 1, wherein said flash fire and flame resistant material comprises para-aramid and meta-aramid material.

12. The fabric of claim 1, wherein said flash fire and flame resistant material comprises Nomex® material.

13. A stretchable, fire resistant fabric, comprising:
   a plurality of warp fibers, said warp fibers having an elastic core yarn wrapped by a flash fire and flame resistant material; and
   a plurality of filling fibers, said filling fibers having an elastic core yarn wrapped by a flash fire and flame resistant material;
   wherein said fabric comprises no more than about 5% (w/w) elastic core yarn.

14. The fabric of claim 13, wherein said fabric comprises no more than about 4% (w/w) elastic core yarn.

15. The fabric of claim 13, wherein said fabric comprises no more than about 3% (w/w) elastic core yarn.

16. The fabric of claim 14, wherein said fabric is not flammable when subjected to an open flame for 10 seconds.

17. The fabric of claim 14, wherein said fabric is not flammable when subjected to an open flame for 12 seconds.

18. The fabric of claim 14, wherein said elastic core yarn comprises spandex material.

19. The fabric of claim 14, wherein said flash fire and flame resistant material comprises para-aramid and meta-aramid material.

20. The fabric of claim 14, wherein said flash fire and flame resistant material comprises Nomex® material.

21. A stretchable, fire resistant fabric, comprising:
   a plurality of warp fibers, said warp fibers having an elastic core yarn wrapped by a flash fire and flame resistant material; and
   a plurality of filling fibers, said filling fibers having an elastic core yarn wrapped by a flash fire and flame resistant material;
   wherein said fabric comprises at least about 95% (w/w) flash fire and flame resistant material.

22. The fabric of claim 21, wherein said fabric comprises at least about 96% (w/w) flash fire and flame resistant material.

23. The fabric of claim 21, wherein said fabric comprises at least about 97% (w/w) flash fire and flame resistant material.

24. The fabric of claim 21, wherein said fabric is not flammable when subjected to an open flame for 10 seconds.

25. The fabric of claim 21, wherein said fabric is not flammable when subjected to an open flame for 12 seconds.

26. The fabric of claim 21, wherein said elastic core yarn comprises spandex material.

27. The fabric of claim 21, wherein said flash fire and flame resistant material comprises para-aramid and meta-aramid material.

28. The fabric of claim 21, wherein said flash fire and flame resistant material comprises Nomex® material.

29. A stretchable, fire resistant fabric, comprising:
   a plurality of warp fibers, said warp fibers having an elastic core yarn wrapped by two layers of a flash fire and flame resistant material;
a plurality of filling fibers, said filling fibers having an elastic core yarn wrapped by two layers of a flash fire and flame resistant material;

wherein said plurality of warp fibers are interwoven with said plurality of filling fibers and said warp and filling fibers stretch and recover about 20% in each direction.

30. The fabric of claim 29, wherein said warp and filling fibers stretch and recover about 40% in each direction.

31. The fabric of claim 29, wherein said warp and filling fibers stretch and recover about 60% in each direction.

32. The fabric of claim 29, wherein said fabric is not flammable when subjected to an open flame for 5 seconds.

33. The fabric of claim 29, wherein said fabric is not flammable when subjected to an open flame for 10 seconds.

34. The fabric of claim 29, wherein said fabric is not flammable when subjected to an open flame for 12 seconds.

35. The fabric of claim 29, wherein said fabric comprises no more than about 5% (w/w) elastic core yarn.

36. The fabric of claim 29, wherein said fabric comprises no more than about 4% (w/w) elastic core yarn.

37. The fabric of claim 29, wherein said fabric comprises no more than about 3% (w/w) elastic core yarn.

38. The fabric of claim 29, wherein said fabric comprises at least about 92% (w/w) flash fire and flame resistant material.

39. The fabric of claim 29, wherein said fabric comprises at least about 95% (w/w) flash fire and flame resistant material.

40. The fabric of claim 29, wherein said fabric comprises at least about 97% (w/w) flash fire and flame resistant material.

41. The fabric of claim 29, wherein said elastic core yarn comprises spandex material.

42. The fabric of claim 29, wherein said flash fire and flame resistant material comprises meta-aramid and meta-aramid material.

43. The fabric of claim 29, wherein said flash fire and flame resistant material comprises Nomex® material.

44. The fabric of claim 36, wherein said fabric comprises at least about 92% (w/w) flash fire and flame resistant material.

45. The fabric of claim 36, wherein said fabric comprises at least about 94% (w/w) flash fire and flame resistant material.

46. The fabric of claim 36, wherein said fabric comprises at least about 96% (w/w) flash fire and flame resistant material.

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