(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
06 September 2024 (06.09.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/178544 A1

(51) International Patent Classification:
D02G 3/04 (2006.01) *D02G 3/32* (2006.01)
D02G 3/28 (2006.01) *D02G 3/36* (2006.01)
D02G 3/18 (2006.01)

(21) International Application Number:
PCT/CN2023/078460

(22) International Filing Date:
27 February 2023 (27.02.2023)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

WO 2024/178544 A1

(54) Title: YARNS USEFUL IN ARC, CUT, HEAT & FLAME-RESISTANT FABRICS AND ARTICLES COMPRISING THE SAME

(57) Abstract: Disclosed herein is ply-twisted yarn for use in arc, cut, heat and flame protection articles, the ply-twisted yarn comprising: a) a first yarn having a sheath/core construction with a core of continuous glass filament and a sheath comprising cut, heat and flame resistant polymeric fibers, the glass filament accounting for at least 30%by weight of the total weight of the first yarn, b) a second yarn having a sheath/core construction with a core of continuous elastic filament and a sheath comprising cut, heat and flame resistant polymeric fibers, wherein the elastic filament being stretched, and accounting for at most 15%by weight of the total weight of the second yarn; and c) a third yarn comprising cut, heat and flame resistant polymeric fibers. Also disclosed herein is a woven or knitted fabric comprising the ply-twisted yarn, and An article comprising the woven or knitted fabric.

Yarns Useful in Arc, Cut, Heat & Flame-Resistant Fabrics and Articles Comprising the Same

Field of the Invention

This invention relates to yarns and fabrics suitable for use in articles of protective apparels that have arc-resistant, cut-resistant, heat-resistant and flame-resistant properties. Particularly, this invention relates to ply-twisted yarn for use in arc, cut, heat and flame protection articles.

Background of the Invention

Workers in multiple industries, e.g. utility, oil & gas, mining, electrical and etc. are facing not only cut injury but also heat & flame and arc hazards.

Gloves/sleeves made with DuPont Kevlar® fiber only can provide medium cut & heat /flame protection but very marginal arc protection.

Glove/sleeves made with generic aramid /glass/ modacrylic blends CANNOT provide either consistent high cut & arc rating performance or good dexterity /comfort.

Yarns comprising modacrylic fiber, p-aramid fiber, and m-aramid fiber that are useful for the production of fabrics which possess arc and flame protective properties are disclosed, for example, in U.S. Pat. Nos. 7,065,950 and 7,348,059. These yarns may further comprise, as an optional component, 2 to 15 weight percent of an abrasion – resistant fiber such as nylon and/or 1 to 5 weight percent of an antistatic component.

Yarns and fabrics having a combination of fire resistance and elastic recovery properties are described, for example, in U.S. Pat. Nos. 5,069,957; 5,527,597; and 5,694,981. These existing solutions utilize yarns made by covering elastic core yarns with a substantial protective fiber outer covering made from a fire - resistant fiber. In other words, these references describe protecting the elastic core by structurally shielding the elastic core from flame by use of another fiber that is in the same yarn.

A ply-twisted yarn suitable for used in a flame-retardant, cut-resistant fabric is disclosed, for example in US 2022/0325443 A1. The ply - twisted yarn comprises (a) at least one first yarn comprising at least 50 weight percent heat - resistant polymeric fiber, wherein at least 30 weight percent of the polymeric fiber present in the at least one first yarn is cut - resistant heat – resistant polymeric fiber having a cut resistance of 500 grams force or higher per ASTM F2992-15 ; and (b) at least one second yarn having a sheath/core construction with a sheath of halogenated self-extinguishing staple fibers and a core

comprising at least one continuous elastic filament.

However, the current references provide technical solution to some of the protective aspects; and it has always been highly desired to provide a yarn and/or fabric having overall protections of arc-resistant, cut-resistant, heat-resistant and flame-resistant properties.

Glove or sleeve or clothing made with innovated yarn could effectively protect workers from being harmed from the mentioned multiple hazards with an integrated technical solution.

Brief Summary of the Invention

This invention relates to yarns and fabrics suitable for use in articles of protective apparels that have arc-resistant, cut-resistant, heat-resistant and flame-resistant properties.

Surprisingly, the inventor finds that an innovated ply-twisted yarn can provide the mentioned overall protections against arc-, cut-, heat- and flame- hazards; in which this ply-twisted yarn comprises:

a) a first yarn having a sheath/core construction with a core of continuous glass filament and a sheath comprising cut, heat and flame resistant polymeric fibers, the glass filament accounting for at least 30% by weight of the total weight of the first yarn,

b) a second yarn having a sheath/core construction with a core of continuous elastic filament and a sheath comprising cut, heat and flame resistant polymeric fibers, wherein the elastic filament being stretched, and accounting for at most 15% by weight of the total weight of the second yarn; and

c) a third yarn comprising cut, heat and flame-resistant polymeric fibers.

This invention also relates to a woven or knitted fabric comprising the ply-twisted yarn of the invention.

This invention also relates to an article comprising the woven or knitted fabric of the invention.

Detailed Description of the Invention

This invention relates to yarns and fabrics, suitable for use in articles of protective apparels that have arc-resistant, heat-resistant and flame-resistant properties, and additionally provide cut protection. The unique combination is created by ply-twisted yarn comprising at least two yarns having sheath/core construction and a further yarn having non-sheath/core construction.

Specifically, this invention relates to a ply-twisted yarn suitable for use in arc, cut, heat and flame protection articles, the ply-twisted yarn comprising:

a) a first yarn having a sheath/core construction with a core of continuous glass filament and a sheath comprising cut, heat and flame resistant polymeric fibers, the glass filament accounting for at least 30% by weight of the total weight of the first yarn,

b) a second yarn having a sheath/core construction with a core of continuous elastic filament and a sheath comprising cut, heat and flame resistant polymeric fibers, wherein the elastic filament being stretched, and accounting for at most 15% by weight of the total weight of the second yarn; and

c) a third yarn comprising cut, heat and flame-resistant polymeric fibers.

"Ply-twisted yarn"

The ply-twisted yarn of this invention is made by twisting together individual single yarns. It is well known in the art to twist single yarns together to make ply-twisted yarns.

By the phrase "twisting together individual single yarns", it is meant the individual single yarns are twisted together without one yarn fully covering any of the others. This distinguishes ply-twisted yarns from covered or wrapped yarns where a single yarn is completely wrapped around another single yarn so that the surface of the resulting ply-twisted yarn only exposes the first single yarn.

The ply-twisted yarns of this invention are made up of at least three different single yarns. More preferably, the ply-twisted yarns of this invention are made up of three different single yarns.

According to the invention, the first yarn is a yarn having a sheath/core construction with a core of continuous glass filament and a sheath comprising cut, heat and flame resistant polymeric fibers.

In a preferred embodiment of the invention, the first yarn is a yarn having a sheath/core construction with a core of continuous glass filament and a sheath made from cut, heat and flame resistant polymeric fibers.

According to the invention, the second yarn is a yarn having a sheath/core construction with a core of continuous elastic filament and a sheath comprising cut, heat and flame resistant polymeric fibers.

In a preferred embodiment of the invention, the second yarn is a yarn having a sheath/core construction with a core of continuous glass filament and a sheath made from cut, heat and flame resistant polymeric fibers.

According to the invention, the third yarn is a yarn comprising cut, heat and flame resistant polymeric fibers.

In a preferred embodiment of the invention, the third yarn is a yarn made from cut, heat and flame resistant polymeric fibers.

"Sheath/core construction"

A sheath/core construction is used so that because the sheath fibers cover and shield the core filament from direct contact with other materials, which also may give fabrics containing the yarn improved performance.

The sheath fiber can be wrapped or spun around the core fiber. These can be achieved by known means, such as, conventional ring spinning including improvements to the conventional process such as those utilizing COTSON technology; core-spun spinning such as DREF spinning; air-jet spinning using so-called core insertion with Murata (now Muratec) jet-like spinning; open-end spinning, vortex spinning and the like. Preferably the sheath fiber is consolidated around the core filament at a density sufficient to cover the core filament. The degree of coverage depends on the process used to spin the yarn; for example, core-spun spinning such as DREF spinning (disclosed, for example, in U.S. Patent Nos. 4,107,909; 4,249,368; & 4,327,545) provides better coverage than ring spinning. Conventional ring spinning provides only partial coverage of the center core but even partial coverage is assumed a sheath/core structure for the purposes of this invention. The sheath can also include some fibers of other materials to the extent that decreased cut resistance, due to that other material, can be tolerated.

Glass Filament

According to the invention, continuous glass filament is used as the core of the first yarn; for example 240 dtex (220 denier) glass filament. Glass filament is an inorganic nonmetallic material with excellent performances, with the advantages of good insulation, strong heat resistance, good corrosion resistance and high mechanical strength. It is usually made from pyrophyllite, quartz sand, limestone, dolomite, boracite, and brucite as raw materials through high-temperature melting, drawing, and other processes. The diameter of glass filament is from several microns to more than 20 microns, and each bundle of fiber precursor is composed of hundreds or even thousands of monofilaments. Glass fiber can be used in fabrics or textile to improve its strength, flame retardance and, especially, cutting performance.

A number of commercially available glass filament can be used in the present invention without specific limitation; for example, those commercially available as SC8-24×1Z55 FE-5 from Sinoma.

According to the invention, the first yarn comprises, based on the weight of the first yarn, at least 30% by weight of glass filament; more specifically, from 30 to 50% by weight of glass filament; more preferably, from 35 to 45% by weight of glass filament.

Elastic Filament

According to the invention, continuous elastic glass filament is used as the core of the second yarn. Continuous elastic filament as used herein means a core formed from elastomer material, the core preferably having the ability to return to its original length rapidly after repeated stretching, even to at least twice its original length. Preferred elastic core include polyurethane based yarns such as Spandex or Elastane filament; Suitable well-known elastic yarns also include the products sold under the trade name of Lycra.

The preferred at least one continuous elastic filament is spandex fiber. As used herein, "spandex" has its usual definition, that is, a manufactured fiber in which the fiber-forming substance is a long chain synthetic polymer composed of at least 85 % by weight of a segmented polyurethane. Among the segmented polyurethanes of the spandex type are those described in, for example, U.S. Pat. Nos. 2,929,801; 2,929,802; 2,929,803; 2,929,804; 2,953,839; 2,957,852; 2,962,470; 2,999,839; and 3,009,901.

The elastic filament of the second yarn is stretched. Typical stretch ratios are 1.5 to 5.0 with 1.5 to 3.50 being preferred, and 3.2 being most preferred. Low stretch ratios yield less elastic recovery while very high stretch ratios make the single yarns difficult to process and the fabric too tight and uncomfortable.

According to the invention, the second yarn comprises, based on the weight of the second yarn, at most 15% by weight of elastic filament; preferably, from 10 to 15% by weight of elastic filament; more preferably, from 12 to 14% by weight of elastic filament.

Commercially available elastic filament, for example, comprises Spandex Creora® H350 from Kolon, Korea.

Cut, heat and flame resistant polymeric fibers

According to the invention, the cut, heat and flame resistant polymeric fibers used therein include para-aramid, meta-aramid, modacrylic, FR-treated rayon, FR-treat cotton, polybenzoxazole, polybenzimidazole, pre-oxidized fiber, or mixtures thereof.

According to the invention, the cut, heat and flame resistant polymeric fibers in the first, the second and the third yarn are at least two selected from para-aramid, meta-aramid, modacrylic, FR-treated rayon, FR-treat cotton, polybenzoxazole, polybenzimidazole and pre-oxidized fibers. More preferably, the cut, heat and flame resistant polymeric fibers in

the first, the second and the third yarn are at least two selected from para-aramid, meta-aramid and modacrylic fibers.

Modacrylic fiber

By "modacrylic fiber" it is meant acrylic synthetic fiber made from a polymer comprising primarily acrylonitrile. Preferably the polymer is a copolymer comprising 30 to 70 weight percent of a acrylonitrile and 70 to 30 weight percent of a halogen-containing vinyl monomer. The halogen-containing vinyl monomer is at least one monomer selected, for example, from vinyl chloride, vinylidene chloride, vinyl bromide, vinylidene bromide, etc. Examples of copolymerizable vinyl monomers are acrylic acid, methacrylic acid, salts or esters of such acids, acrylamide, methylacrylamide, vinyl acetate, etc.

The preferred modacrylic fibers of this invention are copolymers of acrylonitrile combined with vinylidene chloride, the copolymer having in addition an antimony oxide or antimony oxides for improved fire retardancy. Such useful modacrylic fibers include, but are not limited to, fibers disclosed in U.S. Pat. No. 3,193,602 having 2 weight percent antimony trioxide, fibers disclosed in U.S. Pat. No. 3,748, 302 made with various antimony oxides that are present in an amount of at least 2 weight percent and preferably not greater than 8 weight percent, and fibers disclosed in U.S. Pat. Nos. 5,208,105 & 5,506,042 having 8 to 40 weight percent of an antimony compound.

Commercially available modacrylic fiber includes, for example, Protex® A from Kaneka Corporation, Japan.

Aramid fibers

As used herein, "aramid" is meant a polyamide wherein at least 85% of the amide (-CONH-) linkages are attached directly to two aromatic rings. Additives can be used with the aramid and, in fact, it has been found that up to as much as 10 percent, by weight, of other polymeric material can be blended with the aramid or that copolymers can be used having as much as 10 percent of other diamine substituted for the diamine of the aramid or as much as 10 percent of other diacid chloride substituted for the diacid chloride of the aramid. Suitable aramid fibers are described in Man-Made Fibers-Science and Technology, Volume 2, Section titled Fiber-Forming Aromatic Polyamides, page 297, W. Black et al., Interscience Publishers, 1968. Aramid fibers are, also, disclosed in U.S. Pat. Nos. 4,172,938; 3,869,429; 3,819,587; 3,673,143; 3,354,127; and 3,094,511. M-aramids are those aramids where the amide linkages are in the meta-position relative to each other, and p-aramids are those aramids where the amide linkages are in the para-position relative to each other. In the practice of this invention the aramid as most often used are poly(para-phenylene terephthalamide), i.e., meta-aramid or p-aramid; and

poly(meta-phenylene isophthalamide), i.e., meta-aramid, or m-aramid.

M-aramid fiber provides additional tensile strength to the yarn and fabrics formed from the yam. Modacrylic and m-aramid fiber combinations are highly flame resistant but do not provide adequate tensile strength to a yarn or fabric made from the yam to offer the desired level of breakopen resistance when exposed to an electrical arc.

Within yams of this invention p-aramid fibers provide a high tensile strength fiber which when added in adequate amounts improves the breakopen resistance of fabrics formed from the yam. Large amounts of p-aramid fibers in the yams make garments comprising the yarns uncomfortable to the wearer.

Commercially available aramid fibers, for example, comprise Kevlar® K series from DuPont Corporation, the U.S.A. as p-aramid fibers, and Nomex® N series from DuPont Corporation, the U.S.A. as m-aramid fibers.

In an even more preferred embodiment of the invention, the cut, heat and flame resistant polymeric fibers in the first yarn are 20% to 40% by weight of para-aramid and 20% to 40% by weight of modacrylic, more preferably, 25% to 35% by weight of para-aramid and 25% to 35% by weight of Modacrylic, calculated based on the total weight of the first yarn; and the remaining of the first yarn is the core material of glass filament; which is, at least 30% by weight of the total weight of second yarn..

In a more preferred embodiment of the invention, the cut, heat and flame resistant polymeric fibers in the second and third yarns are para-aramid, meta-aramid and modacrylic.

In an even more preferred embodiment of the invention, the cut, heat and flame resistant polymeric fibers in the second yarn are 30% to 50% by weight of para-aramid, 0% to 35% by weight of meta-aramid, and 20% to 55% by weight modacrylic, more preferably, 33% to 40% by weight of para-aramid, 20% to 35% by weight of meta-aramid, and 25% to 55% by weight of modacrylic, calculated based on the total weight of sum of the cut, heat and flame resistant polymeric fibers in the second yarn; and the remaining of the second yarn is the core material of elastic filament; which is, at most 15% by weight of the total weight of second yarn.

In an even more preferred embodiment of the invention, the cut, heat and flame resistant polymeric fibers of the third yarn are 30% to 50% by weight of para-aramid, 0% to 40% by weight of meta-aramid, and 20% to 65% by weight modacrylic; more preferably, 35% to 45% by weight of para-aramid, 25% to 35% by weight of meta-aramid, and 30% to 60% by weight of modacrylic, calculated based on the total weight of the third yarn.

Woven or Knit Fabric & Articles

Woven and/or knit fabric can comprise the ply twisted yarns described herein.

The preferred fabric is a knit fabric, and any appropriate knit pattern is acceptable.

Articles can comprise the ply - twisted yarns described herein or articles can be made from the aforementioned fabrics comprising the ply-twisted yarns described herein. Especially useful articles include gloves, sleeves, and aprons.

The following examples are provided to illustrate the instant invention. However, the present invention is by no means limited by these examples.

Test Method

The test specimens are knit fabrics manufactured preferred by a 13G knitting machine.

Cut Resistance: Cut resistance performance is determined according to ANSI/ISEA 105-2016 "American National Standard For Hand Protection Classification", specifically the requirements outlined in section of 5.1.1. When tested in accordance with ASTM F2992-15, the glove's cut resistance shall be classified against the levels from A1 to A9.

ARC Rating: Arc Thermal Performance Value (ATPV) is measured by ASTM F2675 / F2675M-21 "Standard Test Method for Determining Arc Ratings of Hand Protective Products Developed and Used for Electrical Arc Flash Protection". The test specimen used for the testing are knitted glove liners with example yarns.

Flame Resistance: Flame Resistance is rated per EN407:2020 "Protective gloves and other hand protective equipment's against thermal risks (heat and/or fire)" , specific test procedures are outlined in clause of 6.2, herein, Test method is according to EN ISO 15025:2016, method B with modification for the complete glove.

Heat Resistance: The determination of contact heat is achieved by the use of EN ISO 12127-1:2015 "Clothing for protection against heat and flame - Determination of contact heat transmission through protective clothing or constituent materials - Part 1: Contact heat produced by heating cylinder".

Raw Materials used in the Examples

Table 1 below lists the raw materials used in all Examples.

Table 1

Category	Trade Name	Manufacturer	Note
Para-Aramid	Kevlar® K29	DuPont	In all Examples except Example 2
	Kevlar® K100	DuPont	In Example 2

Meta-Aramid	Nomex® N301	DuPont	In all Examples
Spandex	Creora® H350	Kolon	In all Examples
Modacrylic fiber	Protex® A	Kaneka	In all Examples
Glass Filament	SC8-24×1Z55 FE-5	Sinoma	In all Examples

Note: Kevlar® K29 differs from Kevlar® K100 mainly in color.

Examples

Ply-twisted yarns and knits made from the yarns are exemplified in Examples 1 and 2; Comparative Examples A and B, and summarized in Table 2, and performances thereof are summarized in Table 3.

Example 1

Ply-twisted yarn and knits made with the produced yarns were detailed below

A stretchable ply-twisted yarn was constructed by doubling and twisting a first yarn, a second and a third yarn.

The first yarn was a 10 cotton count sheath-core yarn have a para-aramid and modacrylic fiber blended sheath and a 220D multi-filament glass core yarn by vortex spinning. Both The para-aramid and modacrylic fiber were 1.5dpf with 38 mm length.

The second yarn was a 20 cotton count sheath spandex core yarn constructed by core-spinning on ring spinning frame. The sheath is a blend of para-aramid and modacrylic fiber and the core is a 105D spandex with multifilament. The spandex is stretched 3.0 X while spun into the core yarn.

The third yarn was a 20 cotton count none-core ring spun yarn with para aramid and modacrylic fiber blends.

The resulting ply-twisted stretchable yarn has a total cotton count 15/3 or 117 tex. The ingredients of each single yarn are shown in 1.

The resulting ply-twisted stretchable yarn was knitted into a 13G glove knitting machine. The resulting sleeve had superior comfort and dexterity. The glove liner was tested to ANSI/ISEA 105-2016, ASTM F2675 / F2675M-21, EN ISO 15025:2016 and EN ISO 12127-1:2015 and got consistent A4 cut level, arc rating of ATPV 9.3 cal/cm^2, excellent fire resistance, conductive and contact heat performance.

Examples 2

Example 1 was repeated, with the exception on the ingredients of the second yarn and the third yarn. The sheath of the second yarn was a blend of para-aramid, meta-aramid and modacrylic fiber; and the third yard was a none-core ring spun yarn with para aramid, meta-aramid and modacrylic fiber blends as well.

The finally obtained glove liner was tested to ANSI/ISEA 105-2016, ASTM F2675/ F2675M-21, EN ISO 15025:2016 and EN ISO 12127-1:2015 and got consistent excellent A5 cut level, arc rating of ATPV 11.9 Cal/cm^2, excellent fire resistance, conductive and contact heat performance.

Example A

Example A was comparative. Compared with Example 1 and 2, the first yarn was a sheath/core construction, but the second yarn was a none-core ring spun yarn without a Spandex core, and the third yarn was also a non-core ring spun yarn. Finally, the same tests were conducted, results were summarized.

Example B

Example B was comparative. Compared with Example 1 and 2, the first yarn was a sheath/core yarn with low glass filament content, the second yarn was a sheath/core yarn similar to examples 1 and 2; but the third yarn was a sheath/core yarn, the same as the first yarn; thus the whole glass contents in the finally obtained ply-twisted yarn was even higher than those in Example 1 and 2. The same tests were conducted, obtaining overall result inferior than that of Example 1, let alone the best results of Example 2; but better than Example A.

Table 2: Components of All Examples

Ply-twisted Yarn	Items	Example A	Example B	Example 1	Example 2
The First Yarn (a)	Linear Density (tex)	58	41.8	58	58
	Para-aramid	0.00%	35.51%	29.30%	29.30%
	Modacrylic	58.60%	35.51%	29.30%	29.30%
	Glass Filament	41.40%	28.97%	41.39%	41.40%
The Second Yarn (b)	Linear Density (tex)	24.4	29.2	29.2	29.2
	Para-aramid	60.00%	34.73%	34.73%	34.73%
	Meta-aramid	0.00%	52.10%	0.00%	26.05%
	Modacrylic	40.00%	0.00%	52.10%	26.05%
	Spandex	0.00%	13.17%	13.17%	13.17%
The Third Yarn (c)	Linear Density (tex)	24.4	41.8	29.2	29.2
	Para-aramid	60.00%	35.51%	40.00%	40.00%
	Meta-aramid	0.00%	0.00%	0.00%	30.00%
	Modacrylic	40.00%	35.51%	60.00%	30.00%
	Glass Filament	0.00%	28.97%	0.00%	0.00%

Table 3: Performances of All Examples

Ply-twisted Yarn	Items	Example A	Example B	Example 1	Example 2
Yarn Performance	Cut level	A4	A4	A4	A5
	ARC Rating (Cal/cm^2)	<8	8.6	9.3	11.9
	Contact Heat @ 100°C	NA	18.9	19	20.8
	Limited Flame Spread	NA	Level 4	Level 4	Level 4

From the results of Example A, it can be seen that a Spandex core for the second yarn is firsthand critical for overall performances; and from the results of Example B, it can be concluded that a glass filament core in the first yarn is secondhand critical for overall performances. Between inventive Examples 1 and 2, when para-aramid, meta-aramid and modacrylic are all combined together, the best overall performance could be obtained.

What is claimed is:

1. A ply-twisted yarn for use in arc, cut, heat and flame protection articles, the ply-twisted yarn comprising:

a) a first yarn having a sheath/core construction with a core of continuous glass filament and a sheath comprising cut, heat and flame resistant polymeric fibers, the glass filament accounting for at least 30% by weight of the total weight of the first yarn,

b) a second yarn having a sheath/core construction with a core of continuous elastic filament and a sheath comprising cut, heat and flame resistant polymeric fibers, wherein the elastic filament being stretched, and accounting for at most 15% by weight of the total weight of the second yarn; and

c) a third yarn comprising cut, heat and flame resistant polymeric fibers.

2. The ply-twisted yarn according to claim 1, wherein the cut, heat and flame resistant polymeric fibers in the first, the second and the third yarn are at least two selected from the group consisting of para-aramid, meta-aramid, modacrylic, FR-treated rayon, FR-treat cotton, polybenzoxazole, polybenzimidazole, pre-oxidized fibers, and mixture thereof.

3. The ply-twisted yarn according to any one of claims 1 to 2, wherein the cut, heat and flame resistant polymeric fibers in the first, the second and the third yarn are at least two selected from the group consisting of para-aramid, meta-aramid, modacrylic fibers, and mixture thereof.

4. The ply-twisted yarn according to any one of the preceding claims, wherein the cut, heat and flame resistant polymeric fibers in the first yarn are para-aramid and modacrylic fibers.

5. The ply-twisted yarn according to any one of the preceding claims, wherein the cut, heat and flame resistant polymeric fibers in the second yarn comprise para-aramid and modacrylic fibers.

6. The ply-twisted yarn according to any one of the preceding claims, wherein the cut, heat and flame resistant polymeric fibers in the second yarn and the third yarn are para-aramid and modacrylic fibers.

7. The ply-twisted yarn according to any one of the preceding claims, wherein the cut, heat and flame resistant polymeric fibers in the second yarn and the third yarn are para-aramid, meta-aramid and modacrylic fibers.

8. The ply-twisted yarn according to any one of the preceding claims, wherein the first yarn comprises at least 25% by weight of para-aramid fiber, more preferably, from 28%

to 45% by weigh, based on the total weight of the first yarn.

9. The ply-twisted yarn according to any one of the preceding claims, wherein the second and third yarns comprise at least 30% by weight of para aramid fiber, more preferably, from 32% to 50% by weight, most preferably, from 33% to 45% by weight, based on the total weight of the second and third yarns separately.

10. The ply-twisted yarn according to any one of the preceding claims, wherein the first, second and third yarns comprise 20% to 65% by weight of modacrylic fiber, more preferably, 25% to 60% by weight, based on the total weight of the first, second and third yarns separately.

11. The ply-twisted yarn according to any one of the preceding claims, wherein the second and third yarns comprise 0 to 40% by weight of meta-aramid fiber, more preferably, from 20% to 35% by weight, based on the total weight of the second and third yarns separately.

12. The ply-twisted yarn according to any one of the preceding claims, wherein the elastic filament is Spandex filament.

13. The ply-twisted yarn according to any one of the preceding claims, wherein the meta-aramid fiber is poly-m-phenylene isophthalamide.

14. The ply-twisted yarn according to any one of the preceding claims, wherein the para-aramid in each yarn is poly-p-phenylene terephthamide.

15. A woven or knitted fabric comprising the ply-twisted yarn of any one of claims 1 to 14.

16. The woven or knitted fabric according to claim 15, wherein the fabric has a minimum cut resistance force 15 N per ASTM F2992-15, a minimum ATPV 8 cal/cm^2 per ASTM F2675/F2675M-21, limited flame spread Level 4 and contact heat level 1 per EN407 : 2020.

17. An article comprising the woven or knitted fabric of any one of claims 15 to 16.

18. The article of claim 17 in the form of knitting glove, cutting & sewing glove, sleeve, apron or clothing.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/078460

A. CLASSIFICATION OF SUBJECT MATTER

D02G3/04(2006.01)i; D02G3/28(2006.01)i; D02G3/18(2006.01)i; D02G3/32(2006.01)i; D02G3/36(2006.01)i

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: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)

ENTXTC,VCN,WPABSC:ply,composit???,twist???,yarn,fiber,fibre,filament,sheath,core,cover???,glass,elastic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 112458582 A (DUPONT SAFETY & CONSTR INC.) 09 March 2021 (2021-03-09) paragraphs [33]-[56], figures 1-2	1-18
Y	CN 104894736 A (NATIONAL DONG HWA UNIVERSITY) 09 September 2015 (2015-09-09) paragraphs [3]-[16]	1-18
A	CN 1875135 A (DU PONT DE NEMOURS & CO., E. I.) 06 December 2006 (2006-12-06) the whole document	1-18
A	CN 102292481 A (DU PONT DE NEMOURS & CO., E. I.) 21 December 2011 (2011-12-21) the whole document	1-18
A	CN 1703545 A (DU PONT DE NEMOURS & CO., E. I.) 30 November 2005 (2005-11-30) the whole document	1-18
A	CN 211814776 U (CHANGZHOU KEXU TEXTILE CO., LTD.) 30 October 2020 (2020-10-30) the whole document	1-18
A	US 6581366 B1 (WORLD FIBERS INC.) 24 June 2003 (2003-06-24) the whole document	1-18

☐ 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
"D" document cited by the applicant in the international application
"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
24 October 2023	**31 October 2023**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/078460

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