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(54) **Cut-resistant knitted fabric**

(57) A cut-resistant knitted fabric comprising a para-aramid yarn knitted with a composite yarn to provide the fabric with a sandwich knit structure. The composite yarn is comprised of a reinforcing filament, a polyolefin filament and a polyester filament. The fabric preferably comprises 10 to 90 % of the para-aramid yarn, which is preferably poly-paraphenylene terephthalamide yarn. A

method for producing such a cut-resistant fabric is also described. This combination of yarns and sandwich knit structure provides a relatively light and flexible with a cut resistance and anti-slash performance equivalent to current protective garment fabrics produced using woven fabrics that are two to three times heavier.

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Description

[0001] The present invention relates to a cut-resistant knitted fabric for use in, for example, cut- or slash-resistant clothing.

[0002] Many different applications, such as military, security and industrial applications, require protective clothing exhibiting cut or slash resistance. By way of example, workers in the glass manufacturing industry must wear clothing to protect them from cuts whilst handling pieces of glass. Statutory requirements are in place to ensure that such clothing meets the required safety criteria. Annex II of PPE (Personal Protective Equipment) directive 98/868/EEC provides a classification system (EN388:2003 6.2) for protective fabrics according to their blade cut resistance having levels 0 (indicating a low cut resistance) to 5 (indicating a high cut resistance).

[0003] Knitted fabrics currently employed in protective clothing used in the glass industry typically exhibit an EN388:2003 6.2 blade cut resistance of around 2. It is desirable to provide fabrics having a much higher blade cut resistance, such as level 4 or more preferably level 5. Efforts to provide a fabric exhibiting increased blade cut resistance have so far resulted in fabrics which are significantly heavier, less flexible and thereby less comfortable to wear than current fabrics exhibiting level 2 cut resistance.

[0004] An object of the present invention is to obviate or mitigate the aforementioned problems and to provide a fabric exhibiting higher blade cut resistance than current protective fabrics but which is not significantly heavier or less flexible than current fabrics.

[0005] According to a first aspect of the present invention there is provided a cut-resistant knitted fabric comprising a para-aramid yarn knitted with a composite yarn comprised of a reinforcing filament, a polyolefin filament and a polyester filament to provide said fabric with a sandwich knit structure.

[0006] A second aspect of the present invention provides an item of clothing comprising a fabric according to the first aspect of the present invention.

[0007] According to a third aspect of the present invention there is provided a method for producing a cut-resistant knitted fabric comprising knitting a para-aramid yarn and a composite yarn comprised of a reinforcing filament, a polyolefin filament and a polyester filament to provide said fabric with a sandwich knit structure.

[0008] This combination of yarns and sandwich knit structure provides a relatively light and flexible fabric of a weight similar to that of a conventional non-protective garment fabric but with a cut resistance equivalent to current protective garment fabrics produced using woven fabrics that are two to three times heavier. This results in a much improved comfort level for users wearing garments made from the inventive fabric. It is envisaged that the composite yarn may comprise any desirable number of different reinforcing, polyolefin and/or polyester filaments. In particular, the composite yarn may comprise two or more different polyester filaments. The sandwich knit structure provides the fabric with opposite front and back surfaces in which the desired proportion of para-aramid yarn to composite yarns can be provided. Thus it is possible to provide the fabric with face and back surfaces in which the face surface is predominantly comprised of the composite yarn and the back surface is predominantly comprised of the para-aramid yarn. In this way, the fabric can be used to produce an item of clothing in which, for example, the back (predominantly para-aramid yarn containing) surface is provided on the inside of the item of clothing so as to be preferentially in contact with a wearer's skin and the face (predominantly composite yarn) surface is provided on the outside of the item of clothing to minimise skin contact.

[0009] Preferably the fabric comprises 10 to 90 % of the para-aramid yarn. More preferably the fabric comprises 25 to 75 % of the para-aramid yarn. Most preferably the fabric comprises approximately 60 % of the para-aramid yarn.

[0010] The fabric may comprise 10 to 60 % of the composite yarn, more preferably 20 to 50 % and most preferably approximately 40 % of the composite yarn.

[0011] Any appropriate percentage ratio of the para-aramid yarn to the composite yarn in the inventive fabric may be used, however, preferred percentage ratios lie in the range 90-10 (para-aramid yarn) : 10-90 (composite yarn). Further preferred percentage ratios of the para-aramid yarn to the composite yarn in the fabric lie in the range 75-25 : 25-75, with the most preferred percentage ratio of the para-aramid yarn to the composite yarn in the fabric being approximately 60 : 40.

[0012] Although any suitable para-aramid may be used, a preferred para-aramid is polyparaphenylene terephthalamide, which is marketed under the registered trademark Kevlar®. The para-aramid yarn may possess a yarn count of between 5 and 100 NM, more preferably in the range 20 to 70 NM and most preferably approximately 40NM. The para-aramid yarn comprises a fibre or filament possessing a fineness preferably in the range 0.5 to 15 decitex, more preferably in the range 1 to 3 dtex, and most preferably approximately 1.7 decitex. It will be appreciated that the para-aramid yarn typically comprises a plurality of such fibres or filaments.

[0013] Any appropriate arrangement of reinforcing filament and polyolefin filament may be employed in the composite yarn, however, it is particularly preferred that the composite yarn comprises the polyolefin filament wrapped around the reinforcing filament. Such an arrangement may be considered as the reinforcing filament forming a core with the polyolefin filament wrapped around the core in a substantially helical arrangement. Wrapping the polyolefin filament around the reinforcing filament core in this way can induce undesirable helical strain within the combined polyolefin/reinforcing

filament structure. It is therefore desirable to incorporate further filament or filaments arranged in an appropriate manner with respect to the polyolefin and reinforcing filaments to help reduce this induced strain. Thus, it is preferred that the composite yarn comprises the polyester filament(s) wrapped around the polyolefin and reinforcing filaments.

[0014] The composite yarn count can be selected depending upon the properties and intended applications for the final fabric incorporating the yarn. It is therefore preferred that the composite yarn possesses a resultant yarn count in the range 100 to 2000 decitex, more preferably in the range 200 to 1000 decitex and yet more preferably in the range 300 to 400 decitex. It is most preferred that the composite yarn possesses a resultant yarn count of approximately 365 decitex.

[0015] The percentage composition of the various filaments comprised in the composite yarn can also be chosen to suit a particular application. Thus the composite yarn may comprise up to approximately 50 % of the reinforcing filament, more preferably up to approximately 25 % and most preferably approximately 12.5 % of the reinforcing filament. Moreover, the composite yarn preferably comprises up to approximately 75 % of the polyolefin filament, more preferably up to approximately 60 % and most preferably approximately 52.5 % of the polyolefin filament. Furthermore, it is preferred that the composite yarn comprises up to approximately 50 % of polyester filament, more preferably up to approximately 40 % of polyester filament, yet more preferably approximately 35 % of polyester filament.

[0016] When the most preferred fabric composition is employed, i.e. a percentage ratio of the para-aramid yarn to the composite yarn in the fabric of approximately 60 : 40, it is preferred that the fabric comprises approximately 5 % of the reinforcing filament, approximately 14 % of the polyester filament and approximately 21 % of the polyolefin filament.

[0017] The reinforcing filament is preferably a fibreglass filament or a metal filament, which may be a stainless steel filament.

[0018] The fibreglass filament preferably possesses a Denier in the range 10 to 100, more preferably 25 to 75 or yet more preferably a Denier of approximately 50. Preferably the polyolefin filament possesses a Denier in the range 100 to 500, 200 to 250 or approximately 215. Particularly preferred polyolefin filaments for use in the composite yarn are marketed under the registered trademarks Spectra® and Dyneema®. It is preferred that the polyester filament possesses a Denier in the range 25 to 200, 50 to 100 or approximately 70. Whilst any one of a number of different polyester filaments may be used, a preferred polyester filament is a polyethyleneterephthalate filament.

[0019] Many different types of knitted sandwich structure are known and may be used in accordance with this aspect of the present invention, however, preferably the sandwich structure of the fabric is selected from a group consisting of a weft knitted sandwich structure, a warp knitted sandwich structure and a flat bed knitted sandwich structure.

[0020] The weight of the fabric can be selected to suit a particular application. Preferably the fabric preferably has a weight in the range 100 to 700 g / m², more preferably in the range 200 to 500 g / m², yet more preferably in the range 300 to 350 g / m², and most preferably in the range 320 to 330 g / m².

[0021] An important property of the inventive fabric is its resistance to being slashed or cut using an implement having a sharp edge such as a knife or a piece of glass. Annex II of PPE directive 98/868/EEC provides a set of classifications for materials according to their abrasion resistance, blade cut resistance, tear resistance and puncture resistance. A fabric according to the first aspect of the present invention was tested in accordance with the PPE directive and achieved an EN388 6.2 blade cut resistance index of 59, which is around three times greater than the index required to be awarded the top level 5 for blade cut resistance. It is preferred that the fabric exhibits a blade cut resistance of at least 4 and preferably level 5 on the EN388:2003 6.2 scale.

[0022] When the fabric of the present invention has been incorporated in to an item of clothing it is preferred that the fabric comprised in the item of clothing is arranged such that an inner surface of the item of clothing configured to be in contact with a wearer is predominantly comprised of the para-aramid yarn and an opposite outer surface of the item of clothing is predominantly comprised of the composite yarn.

[0023] Preferably the yarns are knitted employing a method selected from a group consisting of weft knitting, warp knitting and flat bed knitting. The yarns may be knitted in a single or double jersey style. It is preferred that at least one of the yarns is produced using a method selected from a group consisting of ring spinning, core spinning, wrapping and folding. The yarns and the fabric may be coloured any desirable colour using any appropriate method during the production of the fabric. For example, at least one of the yarns may be dyed prior to knitting. Finishing of the fabric preferably comprises the step of washing the fabric at a temperature of up to approximately 130 °C, more preferably at a temperature of approximately 100 °C. It is envisaged that an item of clothing, such as a sweatshirt, t-shirt, balaclava or piece of underwear, comprised of the inventive fabric should be washed as required after wearing at a temperature not exceeding around 40 °C. Moreover, such an item of clothing should not be bleached, dry cleaned or tumble dried and should be ironed using a low temperature iron.

[0024] An embodiment of the present invention will now be described with reference to the following non-limiting Example.

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EXAMPLE

Production Parameters

5 Yarns

[0025]

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1. 1/40 Nm, 100 % Kevlar® 1.7 dtex, 38 mm, short staple spun.

2. 365 dtex combination hollow spindle yarn - core 900 fibreglass filament (50 Den), bottom cover Spectra® 215 Den filament, middle and top covers 70 Den textured polyester filament.

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Knitting

[0026]

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Machine: Wildt Mellor Bromley model 9/MSJ749 30 ins diameter, 18 gg, 48 feeder, 1728 + 1728 needles
Speed: 10 rpm.
Production: at 3.5 kg / hr.

Machine Settings

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Feeders

[0027]

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Dial Feeder:	1	2	3	4	5	6
	B	B	miss	A	A	miss
Yarn:	1	1	2	1	1	2

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Cylinder Feeder:	1	2	3	4	5	6
	A	miss	B	B	miss	A
Yarn:	1	2	1	1	2	1

Knock Over Settings

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[0028]

Dial:	1	2	3	4	5	6
	30	40	15	30	40	15

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Cylinder:	1	2	3	4	5	6
	30	20	40	30	20	40

Tape Drive

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[0029]

Top row: 2 ins - 16, yarn 1. Tapes closed.
Bottom row: ½ ins - 41, yarn 2. Run with tapes open.

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Fabric Tension Medium tight.

Finishing

5 **[0030]** Slit, light scour, stenter at 100 °C to natural width and weight.

RESULTS

Fabric Properties

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[0031] The properties of fabric produced using the production parameters set out in the Example are as follows:

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Composition:	60 % para-aramid; 21 % polyolefin; 14 % polyester; 5 % fibreglass.
Weight:	320/330 g / m ² .
Width:	155/165 cm.

Fabric Performance

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[0032] The sample of fabric produced as described in the Example exhibited the following performance when tested in accordance with Annex II of PPE directive 98/868/EEC:

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EN388	6.1 Abrasion resistance level:	0
	6.2 Blade cut resistance level:	5
	6.3 Tear resistance level:	4
	6.4 Puncture resistance level:	2

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[0033] The fabric achieved a blade cut resistance index of 59, equating to a blade cut resistance of level 5, which is the highest level achievable under PPE directive 98/868/EEC.

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[0034] It will be understood that numerous modifications can be made to the embodiments of the invention described above without departing from the underlying inventive concept and that these modifications are intended to be included within the scope of the invention. For example, the percentage composition of the fabric and the composite yarn can each be chosen to suit any given application. The fabric can be used to produce any desirable item of clothing, although it is envisaged that the inventive fabric would be eminently suitable to produce anti-slash clothing for use in military, security and industrial applications (such as the glass manufacturing and automotive industries). For example, the fabric may be comprised in linings for anti-slash jackets, arm protectors, cuff protectors, aprons and trousers, or in anti-slash pullovers, sweatshirts, balaclavas and underwear.

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Claims

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1. A cut-resistant knitted fabric comprising a para-aramid yarn knitted with a composite yarn comprised of a reinforcing filament, a polyolefin filament and a polyester filament to provide said fabric with a sandwich knit structure.

2. A fabric according to claim 1, wherein the fabric comprises 10 to 90 % of the para-aramid yarn.

3. A fabric according to claim 1, wherein the fabric comprises approximately 60 % of the para-aramid yarn.

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4. A fabric according to claim 1, wherein the fabric comprises 10 to 60 % of the composite yarn.

5. A fabric according to claim 1 or 3, wherein the fabric comprises approximately 40 % of the composite yarn.

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6. A fabric according to any preceding claim, wherein the para-aramid is polyparaphenylene terephthalamide.

7. A fabric according to any preceding claim, wherein the para-aramid yarn possesses a yarn count of between 5 and 100 NM.

8. A fabric according to any preceding claim, wherein the para-aramid yarn comprises a fibre or filament possessing a fineness in the range 0.5 to 15 decitex.
- 5 9. A fabric according to any preceding claim, wherein the composite yarn comprises the polyolefin filament wrapped around the reinforcing filament.
- 10 10. A fabric according to any preceding claim, wherein the composite yarn comprises the polyester filament wrapped around the polyolefin filament and the reinforcing filament.
- 10 11. A fabric according to any preceding claim, wherein the composite yarn possesses a resultant yarn count in the range 100 to 2000 decitex.
- 15 12. A fabric according to any one of claims 1 to 10, wherein the composite yarn possesses a resultant yarn count of approximately 365 decitex.
- 15 13. A fabric according to any preceding claim, wherein the composite yarn comprises up to approximately 50 % of the reinforcing filament.
- 20 14. A fabric according to any one of claims 1 to 12, wherein the composite yarn comprises up to approximately 75 % of the polyolefin filament.
- 20 15. A fabric according to any one of claims 1 to 12, wherein the composite yarn comprises up to approximately 50 % of the polyester filament.
- 25 16. A fabric according to any one of claims 1 to 12, wherein the composite yarn comprises approximately 12.5 % of the reinforcing filament.
- 30 17. A fabric according to any one of claims 1 to 12 or 16, wherein the composite yarn comprises approximately 52.5 % of the polyolefin filament.
- 30 18. A fabric according to any one of claims 1 to 12, 16 or 17, wherein the composite yarn comprises approximately 35 % of the polyester filament.
- 35 19. A fabric according to any preceding claim, wherein the reinforcing filament is a fibreglass filament or a metal filament.
- 35 20. A fabric according to claim 19, wherein the metal filament is a stainless steel filament.
- 40 21. A fabric according to claim 19, wherein the fibreglass filament possesses a Denier in the range 25 to 75.
- 40 22. A fabric according to claim 19, wherein the fibreglass filament possess a Denier of approximately 50.
- 45 23. A fabric according to any preceding claim, wherein the polyolefin filament possesses a Denier in the range 200 to 250.
- 45 24. A fabric according to any one of claims 1 to 22, wherein the polyolefin filament possesses a Denier of approximately 215.
- 50 25. A fabric according to any preceding claim, wherein the polyester filament possesses a Denier in the range 50 to 100.
- 50 26. A fabric according to any one of claims 1 to 24, wherein the polyester filament possesses a Denier of approximately 70.
- 50 27. A fabric according to any preceding claim, wherein the sandwich structure of the fabric is selected from a group consisting of a weft knitted sandwich structure, a warp knitted sandwich structure and a flat bed knitted sandwich structure.
- 55 28. A fabric according to any preceding claim, wherein the fabric has a weight in the range 300 to 350 g / m².
29. A fabric according to any preceding claim, wherein the fabric exhibits a blade cut resistance of level 5 on the EN388: 2003 6.2 scale.

30. An item of clothing comprising a fabric according to any preceding claim.

5 31. An item of clothing according to claim 30, wherein the fabric comprised in the item of clothing is arranged such that an inner surface of the item of clothing configured to be in contact with a wearer is predominantly comprised of the para-aramid yarn and an opposite outer surface of the item of clothing is predominantly comprised of the composite yarn.

10 32. A method for producing a cut-resistant knitted fabric comprising knitting a para-aramid yarn and a composite yarn comprised of a reinforcing filament, a polyolefin filament and a polyester filament to provide said fabric with a sandwich knit structure.

33. A method according to claim 32, wherein the yarns are knitted employing a method selected from a group consisting of weft knitting, warp knitting and flat bed knitting.

15 34. A method according to claim 32 or 33, wherein the yarns are knitted in a single or double jersey style.

35. A method according to claim 32, 33 or 34, wherein at least one of the yarns is produced using a method selected from a group consisting of ring spinning, core spinning, wrapping and folding.

20 36. A method according to any one of claims 32 to 35, wherein at least one of the yarns is dyed prior to knitting.

37. A method according to any one of claims 32 to 36, wherein the method comprises the step of washing the fabric at a temperature of up to approximately 130 °C.

25 38. A method according to any one of claims 32 to 36, wherein the method comprises the step of washing the fabric at a temperature of approximately 100 °C.



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Place of search Munich		Date of completion of the search 27 December 2005	Examiner Sterle, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

**ANNEX TO THE EUROPEAN SEARCH REPORT
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