FLAME-RESISTANT YARN

Inventors: William C. STUCKEY, Hendersonville, NC (US); Yanda JIN, Etowah, NC (US); Frederick R. RIDEWOOD, Greensboro, NC (US)

Assignee: COATS AMERICAN INC., Charlotte, NC (US)

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ABSTRACT

A yarn having flame-resistant properties comprises a blend of: (a) between 20% and 50% by mass of p-aramid fibres; (b) between 0% and 40% by mass of fire-resistant rayon fibres; and (c) between 0% and 60% by mass of modacrylic fibres, the yarn having a coating of resin polymer and organic pigment.
Fig. 1

Fig. 12
OPENING

CARDING

DRAWING

VORTEX SPINNING

DOUBLING

TWISTING

END

Fig. 2
Fig. 6
Fig. 9

- CREELING
- APPLICATOR #1
- EVAPORATION 1
- APPLICATOR #2
- EVAPORATION 2
- FINISHING
- END
Fig. 11

THREAD & SOLUTION TO TOWER

SOLUTION

1106

1104

1102

1108

FOAM INSERT
FLAME-RESISTANT YARN

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to flame-resistant yarn, such as sewing thread, for example, and to its manufacture. The term “yarn” is the name given to any group of fibres which have been twisted together, typically by some spinning process of other, into a composite. Where fibres are twisted in an anti-clockwise direction, this is known as an S-twist and fibres spun in a clockwise direction are said to have a Z-twist. A yarn which is comprised of only a single group of fibres which have been spun together is said to have only one “ply”. Typically, however, yarns will be made of two, three or more plies. In order to produce a composite yarn which has what is known as a neutral torque, where the plies have an S-twist they will be plied together with a Z-twist, or visa versa.

[0003] Different kinds of yarns will serve different purposes and thus, yarn may be used for weaving fabric, or as sewing thread, which is then used to join different fabric panels together.

[0004] 2. Description of Related Art

[0005] It is known to make flame-resistant yarn out of aromatic polyamide fibres, also known as “aramid” fibres, which have good heat resistance properties. One particular genus of Aramid known as meta-aramid is widely used to create fabrics for fire-resistant garments due to its combination of heat-resistance and suppleness handling characteristics. One example of such meta-aramid fibre is produced by DuPont under the trade mark Nomex. However, the advantageous handling properties which make meta-aramid fibres suitable for weaving into fire-resistant fabric mean that yarn made of meta-aramid has relatively low strength.

[0006] A further kind of aramid, para-aramid (also known as p-aramid) has a much greater strength, to the extent that DuPont produced the “Kevlar” fabric from p-aramid in or around 1973. P-aramid fibres therefore have the advantageous properties of good fire-retardancy and strength required for the creation of a flame-resistant yarn. One disadvantage of p-aramid fibres, however, is a difficulty associated with dying them, meaning that a special dying process is required, thus increasing the cost.

SUMMARY OF THE INVENTION

[0007] The first aspect of the present invention provides a flame-resistant yarn comprising a blend of p-aramid, fire-resistant rayon, and modacrylic fibres, which are then dyed by applying a multipolymer resin to the yarn.

[0008] According to one embodiment of the invention the fibres are spun into a yarn using vortex spinning; a further embodiment provides for spinning of the fibres into a yarn using ring spinning. Other methods of spinning such as jet spinning may be used.

[0009] In one preferred embodiment of the invention, the spun yarn is imparted with colorant by immersing the yarn in a solution of nylon multipolymer resin dissolved in a suitable solvent mix, and which additionally contains a suitable colorant.

[0010] In a further preferred embodiment, two separate colouration steps are undertaken, whereby the first step applies colourant via a solvent which is then evaporated and the second step applies a bonding solution via a solvent which is also then evaporated.

BRIEF DESCRIPTION OF DRAWINGS

[0011] Embodiments of the invention will now be described, by way of example, and with reference to the accompanying drawings in which:

[0012] FIG. 1 is a flow chart showing the generic steps involved in a method according to an embodiment of the present invention;

[0013] FIG. 2 is a flow chart of a spinning process forming part of an embodiment of method according to the present invention;

[0014] FIG. 3 is a section through a simplified illustration of a blending feeder;

[0015] FIG. 4 is a section through a simplified illustration of an incline cleaner;

[0016] FIG. 5 is a section through a simplified illustration of a revolving flat card;

[0017] FIG. 6 is a perspective view of a drawing frame;

[0018] FIG. 7 is a flow chart of an embodiment of dying operation according to the present invention;

[0019] FIG. 8 is a schematic illustration of an apparatus for performing the process set out in the flow chart of FIG. 7;

[0020] FIG. 9 is a flow chart of a further embodiment of dying operation according to the present invention;

[0021] FIG. 10 is a schematic illustration of an apparatus for performing the process set out in the flow chart of FIG. 9;

[0022] FIG. 11 is a detail of FIG. 10; and

[0023] FIG. 12 is a cross section through a three ply yarn according to an embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0024] Referring now to FIG. 1, a first step in an embodiment of method according to the present invention is the spinning process 10, by which fibres of p-aramid, fire-resistant rayon, and modacrylic are spun into yarns having one or more plies. Once spinning has been completed, the spun yarn is then dyed at step 12 using, in the present embodiment, a process according to which a coloured pigment is effectively applied to the yarn by means of a polymer resin such as, for example, a nylon multipolymer resin. The dyed yarn is then subjected to one or more finishing processes at step 14 such as, for example, the application of an appropriate lubricant finish to enable the yarn to be used as sewing thread (in the case whether the yarn is to be used as sewing thread) or, a fluorochemical additive which imparts non-wetting or non-wicking properties to the yarn. Thereafter, at step 16 the thread is wound onto an appropriate bobbin to form a package for use by the end user.

[0025] Referring now to FIG. 2, the first step in a spinning operation is step 210, this being the opening step which involves blending of the p-aramid fibres with at least one of fire-resistant rayon and modacrylic fibres which blend will, eventually, form the spun yarn. Referring now to FIG. 3, a typical blending feeder is illustrated in section and includes a feed port 302 into which different kinds of fibre which are to be blended together are inserted. The inserted fibres 303 land on to a first conveyor belt 304 which delivers the fibres onto a second, upwardly inclined conveyor belt 306 whose belt has a series of teeth 307. The fibres on the conveyor belt 306 are
then engaged with a first, counter-rotating beat roller 308 before being delivered into the path of two further beat rollers 310 and 312, both of which rotate consistent with the direction of travel of fibres fed from the conveyor belt 306. Beat rollers 310, 312 act further to blend and straighten the fibres against a porous sleeve, 314, through which debris falls then. Blended fibres 316 are then passed to an incline cleaner illustrated in FIG. 8.

0026] The proportions of the various elements blended together may vary, together with the proportion of p-aramid fibres varying between a minimum of approximately 20% and a maximum of approximately 50% by mass; the proportion of fire-resistant rayon varying between a minimum of approximately 0% and a maximum of approximately 50% by mass; and the proportion of modacrylic varying between a minimum of approximately 0% and a maximum of approximately 60% by mass. Where all three fibres are to be included in the blend the proportions will vary between 20% and 50% of p-aramid; 20% and 40% of fire-resistant rayon; and 20% and 60% of modacrylic.

0027] Examples of advantageous blends are given below:

0028] 50% by mass of p-aramid fibres
0029] 50% by mass of modacrylic fibres
0030] 50% by mass of p-aramid fibres
0031] 50% by mass of fire-resistant rayon fibres
0032] 30% by mass of p-aramid fibres
0033] 30% by mass of fire-resistant rayon fibres
0034] 40% by mass of modacrylic fibres
0035] 50% by mass of p-aramid fibres
0036] 20% by mass of fire-resistant rayon fibres
0037] 30% by mass of modacrylic fibres

0038] The proportions of fibres used to produce the greige yarn (i.e. undyed and unfinished yarn) will vary depending upon desired characteristics of the yarn to be produced. P-aramid provides the composite yarn with excellent strength and flame-resistant properties but its handling properties are, for some practical applications, too ‘lively’ (i.e. overly resilient and apt to exhibit excessive spring-like properties); fire-resistant rayon has good flame-retardant properties, good moisture-transportation properties and is reasonably strong but has the disadvantage of being less expensive than p-aramid; and modacrylic has acceptable flame-resistant properties and has a relatively soft ‘hand’, that is to say that it has the characteristic of being soft to the touch and therefore imparts a degree of the corresponding characteristic to the yarn thus produced. Self-evidently, the greater proportion of a given constituent which is employed in the final yarn, the greater extent to which the final yarn will have those characteristics of that particular constituent.

0039] Because each of the constituent elements are staple fibres (i.e. fibres which are short cut lengths as opposed to a continuous filament strand) the diameter and length of fibre used is likely to be generally consistent. In preferred form of the present invention, fibres of approximately corresponding lengths will be used in order to facilitate a good level of uniformity for the resulting yarn though this is not essential.

0040] Subsequent to the initial blending step, the fibres are then passed to an incline roller for further opening. Referring now to FIG. 4, fibre from the blending feeder is fed into an entry port 402 and the fed fibres are then beaten up a sequence of inclined grids 404 by a correspondingly mounted sequence of toothed beat rollers 406 before being ejected at outlet port 408. Discarded elements 410 of textile passing through the grids 404 fall to the base of the feeder and are collected as garbage.

0041] Once the blending of the fibres has been completed during the opening step at 210, the process proceeds to 212, this being carding in which entanglements and unorganised clumps of fibres are tended to and aligned so that they are substantially parallel with each other. Referring now to FIG. 5, fibres which are to proceed through the carding step are entered into a hopper 502 and pass, by virtue of gravity through a sequence of processing the rollers 504 which produce a relatively even rate of distribution of fibres that eventually pass out through the hopper onto an inclined platform 506. As the fibres descend the inclined platform, they come into engagement with a licker-in roller 510 which sweeps fibres evenly onto the circumferential surface of a large cylinder 512. The transfer action between the licker-in roller 510 and the cylinder is illustrated in an exploded view of the point of transfer. A carding belt 516 which extends around approximately ⅓ of the cylinder 512 has fine teeth 517 which undertake a combing action on the fibres as the fibres are rotated around in conjunction with the cylinder. Upon coming into contact with a doffer roller 518, whose fine teeth further comb the fibres and transfer them from the cylinder onto the doffer 518, thereby to provide further carding action. The carded fibres are removed from the doffer 518 by a further comb 520, which points against the (anti-clockwise) rotation of the doffer 518 to remove the carded fibres.

0042] Referring once again to the flowchart of FIG. 2, once carding is complete, thereafter, the process proceeds to step 214 in which the fibres are drawn by rollers into longer, narrower lengths of groups of fibres, as ‘sliver’. Referring now to FIG. 6 carded fibres are collected in cans 602 from which they are drawn, via a sequence of draft rollers 606, 608, 610. The speed of each of the draft rollers is chosen such that the roller 610 most remote from the cans 602 rotates and therefore draws the fibres more rapidly than the adjacent roller 608, which in turn draws the fibres more rapidly than the roller which is immediately adjacent the cans, roller 606. This provides a sequential drawing out of the fibres into longer and narrower fibres. The drawn fibres which are produced pass through two calendar rolls 612, and thereafter, via a curling mechanism 614 into a sliver can 616.

0043] Thereafter, the fibres are spun together by a vortex spinning process at step 216. Subsequently, where a yarn of two or more plies is required they are wound together at the ‘doubling’ step 218 into a multi-PLY yarn. After the doubling step 218 the yarn is then twisted at step 220 and wound onto a package which will permit it to be dyed following which the spinning process ends at step 222. These processes, being well-known in the art will not be described further herein.

0044] In a modification of the embodiment described above, one or more further drawing steps are added following step 214 where this is thought to be desirable in order to increase overall fibre uniformity.

0045] In a further modification, jet spinning is employed and, in yet a further modification of the embodiment described above ring spinning is used rather than vortex spinning. According to this latter embodiment, step 216 is replaced by a combination of two further steps, the first of which is roving, this being a step in which the fibres are further drawn by draughting rollers whereupon the further step of ring spinning spins the threads together during winding about a rotating spindle.
Referring now to FIG. 7, the dying process starts at step 710 with the step of creeling which involves the arrangement of many packages of yarn wound on to suitable packages in an array. Thereafter, yarn is drawn off groups of packages simultaneously and passed through a specially-prepared tank containing a bond resin which, in the present example is a nylon resin of the class of terpolymers, dissolved in an solvent mix, such as ethanol. Alternatively, a urethane polymer may be used in place of a nylon polymer.

This resin bonding solution additionally contains colorants preferably in the form of aqueous organic pigments such as those often used in textile pigment printing applications, for example. Typically, the bond solution contains between 4 and 12% of resin; more preferably in the region of 9%. The thread is dipped into the bond solution and then wiped with felt to provide a uniform coating. Upon leaving the dying bath the yarn then passes through three steps of evaporation 714, 716, 718, in which they are heated in ovens ranging from 110 to 210 °C to 190 to 205 and 210 °C, respectively to evaporate all of the solvent. According to a further preferred embodiment, only a single evaporation step is employed, however, with only a single oven. Thereafter, at step 720 the thread a lubricant, such as, in the present example, a blend of silicone and wax is applied to the thread.

The actual operation of the process schematically referenced above is illustrated in FIG. 8, in which the creel containing a matrix of thread packages 810 is illustrated, with thread being pulled off the packages 810a in a given row R in the creel matrix simultaneously through a guide roller 811 and through the colorant tank 812. Thereafter, the threads pass through the ovens 814, 816, 818, and through a lubricant-applying roller 820. Thereafter, the thread passes through driver rollers which operates to provide the motive tension by means of which the thread is drawn off the creel and packed into the oven, and wound onto bonding take-up bobbins 822 (bearing in mind that several threads are being pulled through the process at one time. Subsequently, the thread is then wound on to a user bobbin to create a thread package for use by an end user.

The process of FIG. 7 and the apparatus of FIG. 8 which embodies that process use a horizontal oven and only a single application process. In an alternative embodiment, the coloration and bonding additions are made through two separate but coupled steps. In the first pass, formulated aqueous dye solution is applied through a specially designed applicator which can precisely control the amount of the dye solution added for colour match. The second pass applies bonding solution.

Referring now to FIG. 9, subsequent to creeling, at step 910, a ‘first pass’ dying operation is performed in which, at step 912, the formulated aqueous dye solution is applied through a specially designed applicator which can precisely control the amount of the dye solution added for colour match. This aqueous solution can be a low molecular weight polyester resin solution mixed with organic pigment. Thereafter, at step 914, the solvents are evaporated. A second dying operation is then performed in which the dyed thread then has a coating of bonding solution applied to it at step 916 (this solution is typically nylon resin of the class of terpolymers, dissolved in a solvent mix, such as isopropanol). The thread is then passed once again into an evaporation step at step 918. The oven temperature is typically ranged from 160 to 220 °C to evaporate the solvents. The dyed and bonded thread is then lubricated with a controlled amount of lubricant which can be a blend of silicone and wax and wound at finishing step 920.

The apparatus required to perform the steps in FIG. 9 will now be described with reference to FIG. 10. Yarn is drawn off a creel 1002 and then passes through a first applicator 1004, which is commonly referred to as a ‘slasher bath’. In one embodiment, this contains an aqueous solution of low-molecular weight polyester resin with an addition of malamine formaldehyde cross-linking resin. This serves to build up the weight of the polymer applied and improves the strength of the film applied to the yarn as well as its fastness properties. Typically, the resin concentration at this application is in the region of 9% by mass, though the quantity which is applied to the thread is typically in the region of 6%.

Thereafter, the yarn passes into a four-storey oven 1006 which applies heat to the yarn as it passed up through each of the stories, over pulleys 1008 and back down through the stories. Typically, the tensions which are used in the vertical oven range from 50 to 150 gramNewtons. This is one advantage of a vertical oven since it permits the use of lower tensions and, thereby, enables weakened yarns to be processed than in the case of a horizontal oven—where tensions typically range upwards from 150 gramNewtons.

Upon passing out of the oven 1006, the yarn passes through a second applicator 1010. This applicator 1010 uses a solvent blend of low grade alcohol such as isopropanol and water, typically 70% isopropanol and 30% water. Within this a further resin in the form of a terpolymide resin which is soluble in alcohols is dissolved (this is, essentially, the same or similar class of resin used in conjunction with the process of FIGS. 7 and 8. Alternatives to isopropanol include lower grade alcohols generally such as ethanol, n-propanol, and butanol. Typically the ratio will be between 65% isopropanol to 35% water to 80% isopropanol to 20% water, with 70%/30% being a preferred ratio.

Upon passing out of the oven 1006, the thread may then be lubricated by a further applicator (not shown) as desired, before being taken-up onto a stand 1020.

Referring now to FIG. 11, an applicator of the kind illustrated schematically in FIG. 10 includes a housing 1102 containing a foam insert 1104. Solution of the appropriate kind (i.e. whether being the solution for the first colouration step or the second bonding step, for example, or even the step of applying binder) is fed in via inlet 1106 which has the effect of soaking the insert 1104. The thread 1108 passes through the foam insert and, as a result of the solution retained in the foam insert, passes through that solution, which has the effect of coating the thread. The pressure within the housing 1102 can be controlled as desired since this may have the effect of increasing the amount of resin (or lubricant as the case may be) to the thread for a given speed of thread passage through the applicator.

An example of a three ply yarn produced by the present invention is illustrated in FIG. 12. Each ply 1210 is made up of, in this example, 30% p-aramid fibres, 35% fire-resistant rayon and 35% modacrylic fibres. Around the outside of the three ply yarn there is a resin coating 1212 (not illustrated to scale in FIG. 12) which contains pigment. The amount of the coating will vary in dependence upon, inter alia, the concentration of resin in the bonding tank. Typically, the quantity of resin present in the yarn after dyeing is in the region of between 3% and 9% by mass per unit length of the yarn.
The quantity of resin in the yarn will depend upon a number of factors, such as the amount of pigment the final yarn is required to carry, the uses to which it will be put and the desired handling characteristics of the final yarn.

As mentioned above, p-aramid has excellent strength characteristics though has a tendency to difficult handling characteristics due to being very lively. This characteristic is correspondingly present in the blended yarn of embodiments of the present invention and, as a result, yarn including p-aramid can be difficult to use. Difficult handling characteristics can be exacerbated to a degree in the case of preferred embodiments of method in which yarn is produced by vortex spinning, this being preferred because of the cost savings which result. Yarn spun by vortex spinning, however, tends to be yet more lively for a given amount of twist imparted to it than the corresponding yarn made by ring spinning. To compensate for this, yarn produced by vortex spinning typically has a lower level of twist imparted to it to produce a yarn of the same liveliness. A consequence of this is that yarn produced by vortex spinning can be more difficult to handle in manufacturing operations since it is more apt to unwind. These effects are, at least to a degree, ameliorated by the use of the resin bonding dyeing process, since this operates to ‘fix’ the yarn and prevent unwinding, while also reducing to a degree the liveliness of the thread.

In addition, and as mentioned previously, p-aramid requires a special dyeing process. That process can be apt to impart deleterious effects upon the other fibres in the blends of embodiments of the present invention and, therefore, in situations where that special process is to be used, the p-aramid fibres will need to be dyed in advance of the spinning process, followed by a further dyeing process for the other threads. Not only is this an expensive way to produce flame-resistant dyed thread but it also places a restrictive practical limit on the range of colours in which thread can be produced. By contrast, the resin bonded dyeing process of embodiments of the present invention enable blended thread containing p-aramid to be dyed to any colour desired.

1. A yarn having flame-resistant properties comprising a blend of:
   (a) between 20% and 50% by mass of p-aramid fibres
   (b) between 0% and 40% by mass of fire-resistant rayon fibres
   (c) between 0% and 60% by mass of modacrylic fibres

2. A yarn a blend of:
   (a) between 20% and 50% by mass of p-aramid fibres
   (b) between 20% and 40% by mass of fire-resistant rayon fibres
   (c) between 20% and 60% by mass of modacrylic fibres

3. A yarn according to claim 2 having a blend of:
   (a) 30% by mass of p-aramid fibres
   (b) 30% by mass of fire-resistant rayon fibres
   (c) 40% by mass of modacrylic fibres.

4. A yarn according to claim 2 having a blend of:
   (a) 50% by mass of p-aramid fibres
   (b) 20% by mass of fire-resistant rayon fibres
   (c) 40% by mass of modacrylic fibres.

5. A yarn according to claim 1 having a blend of:
   (a) 50% by mass of p-aramid fibres
   (b) 50% by mass of fire-resistant rayon fibres.

6. A yarn according to claim 1 having a blend of:
   (a) 50% by mass of p-aramid fibres
   (b) 50% by mass of modacrylic fibres.

7. A yarn according to claim 1 wherein the polymer is one of a nylon terpolymer and urethane polymer.

8. A yarn according to claim 1 wherein the pigment is derived from aqueous organic pigment.

9. A yarn according to claim 1 wherein the coating comprises between 3% to 9% of the mass of the yarn, per unit length.

10. A method of manufacturing a flame-resistant yarn comprising the steps of:
   (a) between 20% and 50% by mass of p-aramid fibres
   (b) between 0% and 50% by mass of fire-resistant rayon fibres
   (c) between 0% and 60% by mass of modacrylic fibres

11. A method according to claim 10 wherein the step of spinning to produce greige yarn comprises vortex spinning.

12. A method according to claim 11 wherein the step of spinning to produce greige yarn comprises one of ring spinning and jet spinning.

13. A method according to claim 10 wherein the evaporation step includes passing the thread through at least one oven.

14. A method according to claim 13 wherein the evaporation step comprises passing the thread through a plurality of ovens having sequentially higher temperatures.

15. A method according to claim 10 additionally comprising the step of applying lubricant to the thread subsequent to evaporation of the solvent.

16. A method according to claim 10 wherein the resin comprises between 4% and 12% by mass of the resin-solvent or aqueous-pigment mix.

17. A method according to claim 10 wherein the pigment is derived from aqueous organic pigment.

18. A method of dyeing a yarn comprising the steps of applying a colourant organic resin dissolved in a first solvent which includes water, evaporating the solvent, applying a bonding resin in a second solvent which includes an isopropylalcohol and water and evaporating the second solvent.

19. A method according to claim 18 wherein the yarn has flame-resistant properties.

20. A method according to claim 19 wherein the yarn includes a blend of:
   (a) between 20% and 50% by mass of p-aramid fibres
   (b) between 0% and 40% by mass of fire-resistant rayon fibres
   (c) between 0% and 60% by mass of modacrylic fibres.