United States Patent

[11] 3,596,458

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[33] **Japan**
[31] **41/43692 and 41/43693**

[54] **SPUN YARN OF ELASTIC FIBER AND PREPARATION THEREOF**
18 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **57/156,** 57/140, 19/.46, 139/420
[51] **Int. Cl.** **D01g 1/08,** D02g 3/04
[50] **Field of Search** ..... 57/2, 3, 58.91, 140, 140 BL, 139, 152, 157, 160, 163, 156; 19/.30, .32, .35, .39, .43, .56; 139/420

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Primary Examiner—Donald E. Watkins
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ABSTRACT: A spun yarn of a 100 percent elastic fiber or of an elastic fiber blended with a hard fiber. The yarn is prepared by stretching and heat setting a multifilament yarn or tow of the elastic fiber, stretch breaking, drawing, if necessary, and twisting. The blended yarn is prepared by, after the stretch breaking of the basic elastic fibers and before the drawing, blending with hard fiber roving. The yarn is prepared by employing a modified direct spinning machine equipped with top and bottom aprons in a stretch breaking zone between the back roll and the intermediate roll; the aprons being driven by the revolution of the intermediate roll.

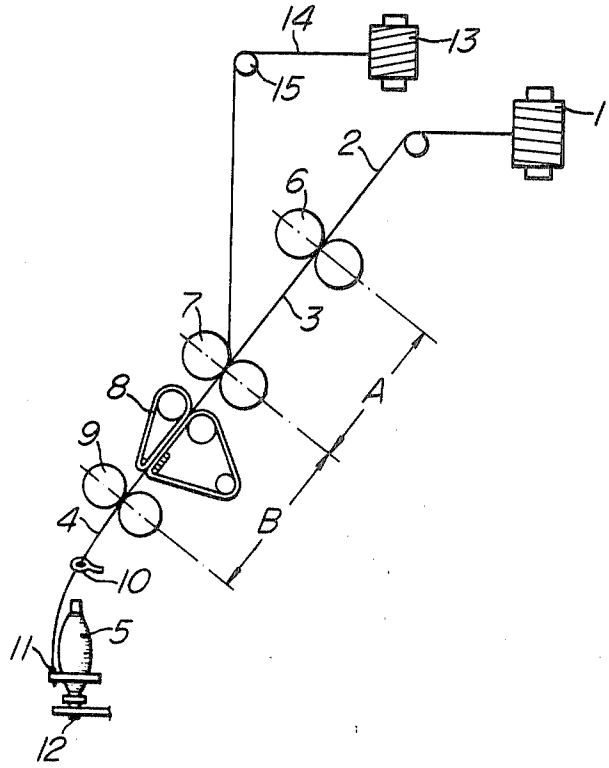


FIG. 1

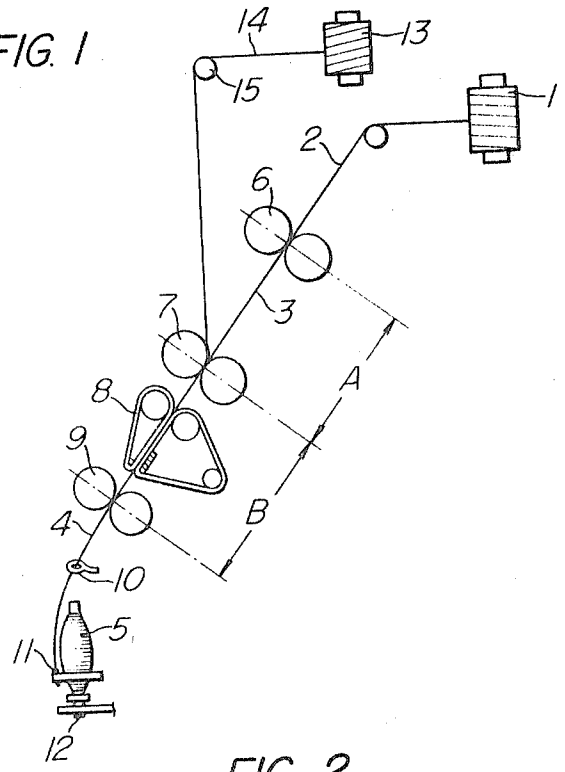

14
13
15
1
2
6
3
7
8
A
9
4
B
10
5
11
12

FIG. 2

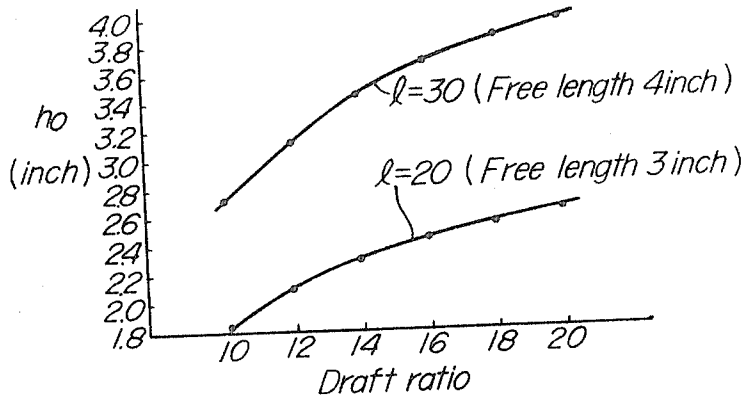

4.0
3.8
3.6
ho
3.4
3.2
(inch)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
ℓ=30 (Free length 4inch)
ℓ=20 (Free length 3inch)
10
12
14
16
18
20
Draft ratio

FIG. 3

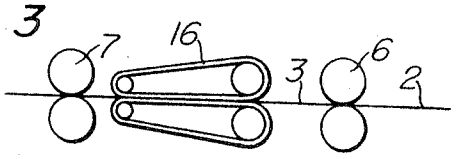

7
16
3
6
2

FIG. 4

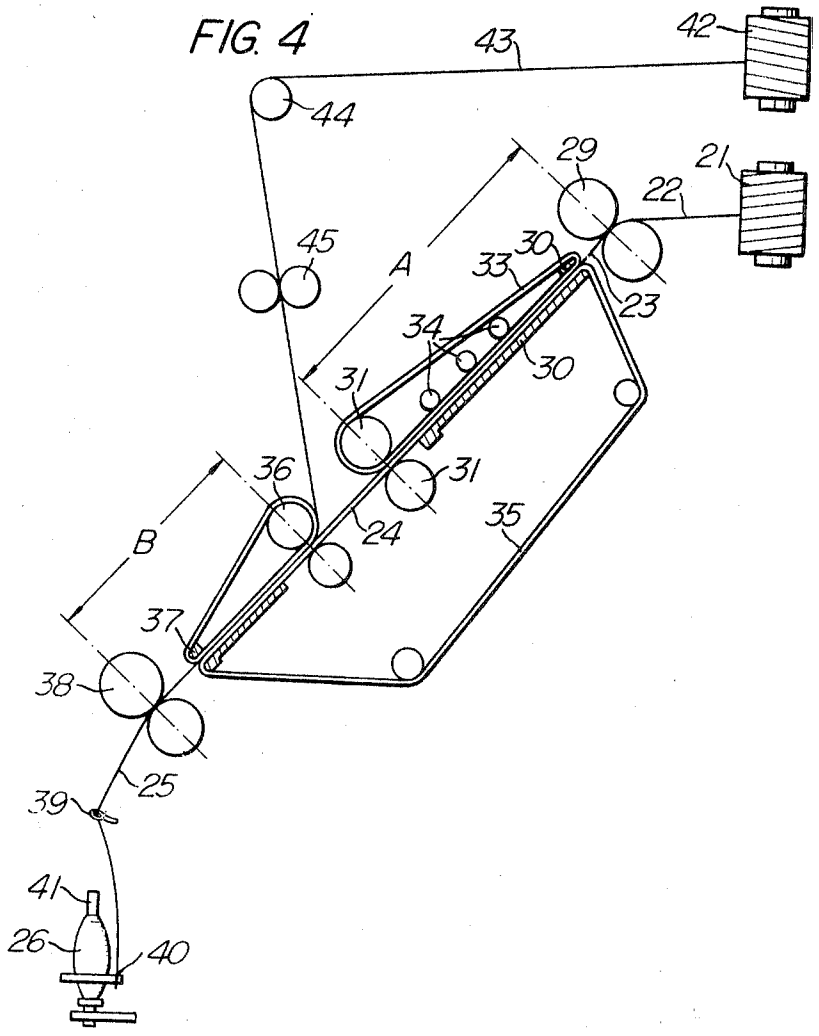

43
42
44
29
21
22
45
A
33
30
23
34
30
31
31
36
24
35
B
37
38
25
39
41
26
40

FIG. 5

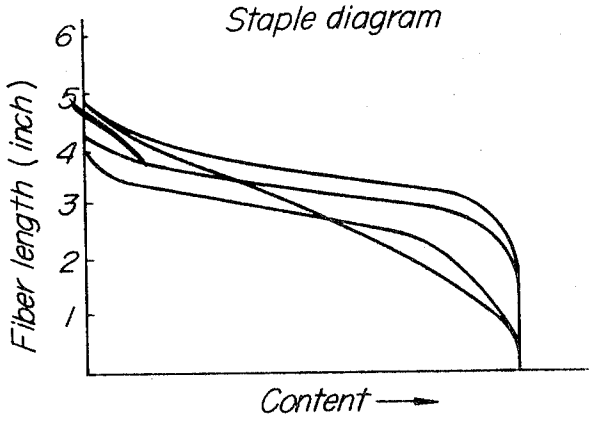
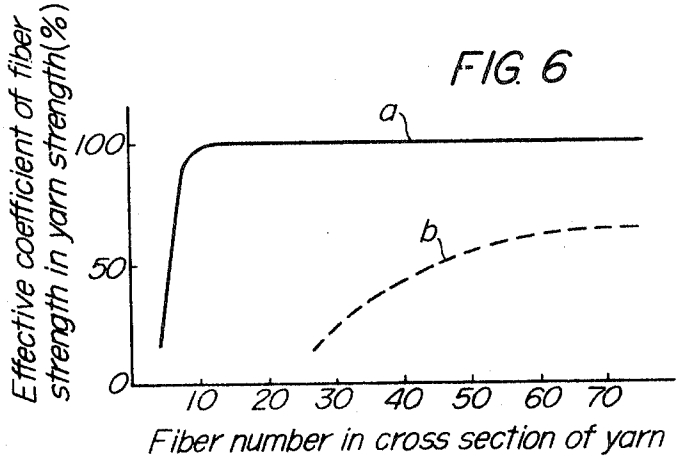

Staple diagram
Fiber length (inch)
6
5
4
3
2
1
Content

FIG. 6


Effective coefficient of fiber strength in yarn strength(%)
100
50
0
a
b
10
20
30
40
50
60
70
Fiber number in cross section of yarn

SPUN YARN OF ELASTIC FIBER AND PREPARATION THEREOF

The present invention relates to a spun yarn of an elastic fiber having excellent elastic elongation of more than 100 percent and a quick recovery from stretching to an elongation which is less than its breaking elongation, and a blended spun yarn of said elastic fiber with any of the known hard fibers.

Spandex is the first synthetic elastomeric fiber industrially utilized and is now used in the forms of bare yarn, covered yarn or core-spun yarn. However, the spandex fibers actually employed in these fields are all filament yarns, and no spandex spun yarn has been developed up to now. Furthermore, most of the spandex filament yarns used in these fields are of fine denier such as, for example, 140 d, 70 d and 40 d, and these fine-denier yarns are extremely expensive thereby preventing expansion of the market therefor.

Accordingly, a principal object of the present invention is to provide a cheap fine-denier spandex spun yarn. That is, the market price of the coarser yarn of, for example, 3,000 d or 5,000 d is less than about one third of the price of the above-mentioned finer yarn, and the price difference between the two was more than 5 dollars per pound as of Aug., 1966. Therefore, if it were possible to manufacture a finer yarn from this inexpensive coarser yarn with a reasonable spinning cost of, for example, less than 1 dollar per pound, it is beyond question that the market for spandex would be greatly expanded.

The second object of the present invention is to provide single covered spandex yarn or core-spun yarn having greatly reduced kinking properties. A highly twisted spandex yarn tends to produce kinking due to the high elasticity thereof. Therefore, in the covered yarn field, spandex is always supplied in the form of double covered yarn and no single covered yarn has been used. For the same reason, in preparing core-spun yarn, a steaming treatment has generally been used to prevent such kinking despite a lowering of the excellent elasticity. To the contrary, the present spandex spun yarn, used to cover yarn or core-spun yarn, is twisted in the spinning process in a direction opposite that of the twists thereafter given in the core-spinning or -covering process, so that this counter twist reduces or makes negligible the kinking properties of the core-spun yarn or single covered yarn under some conditions of twist multiplication.

The third object of the present invention is to provide a blended spun yarn of an elastic fiber and a hard fiber (natural or manmade fiber) with an optional blending ratio. Hitherto, the content of the elastic fiber in a blended spun yarn as far as has been reported to date is limited on the order of less than 30 percent as described in U.S. Pat. No. 3,007,227. Therefore, this novel blended spun yarn having no limitation in the blending ratio of elastic fiber affords a new kind of product and contributes towards rapid development of new markets for spandex fiber.

The aforesaid and other objects will become apparent to those skilled in the art from a consideration of the following specification and claims. The principle of the method is to employ a direct spinning system; i.e. a multifilament yarn or a tow of elastic fiber becomes spun yarn through the consecutive steps of breaking, drawing and twisting in one process.

In a conventional spinning system requiring a carding process such as the cotton-spinning system, worsted spinning system, modified system thereof, woolen spinning system etc., or in the conventional spinning system or the tow to top converter system requiring the drawing of thick slivers, it is impossible to make a pure spun yarn of elastic fiber or blended spun yarn of elastic fiber with an unlimited blending ratio for the following reasons. That is, in the first place, since very pliant elastic fibers are apt to adhere to the top end of the metallic wire, carding action is poor. In the second place, in the drawing process or roving process comprising drawing a sliver constructed of several thousands or several ten thousands of fibers, it is difficult to pick up a single fiber out of the sliver and to draw away each fiber relatively, because frictional resistance between the pliant fibers is large and it tends to cause stretching of fibers having an extremely small Young's modulus. Therefore, in these spinning systems, an elastic fiber can be carded or drawn only in the case when it is blended with a larger proportion of a hard fiber having a considerably high Young's modulus in order to make the elastic fiber move together with said hard fiber. In other words, the spinning of the elastic fiber is limited only to the case where the proportion of the elastic fiber is considerably low. In this connection, U.S. Pat. No. 3,007,227 describes as follows (In processing the fiber blends on conventional textile machinery, it has been found more practical to employ between 10 percent and 25 percent of the elastic fiber in the blend, although special equipment may be selected to more readily accommodate broader ranges of the elastic fibers. If the proportion of the elastic fiber in the blend is raised, sufficiently beyond 30 percent, fiber-processing operations into yarn become more difficult to control and the resulting yarn and fabric quality suffers: for example, when 50 percent elastic fiber is used.)

A direct spinning system employed for the manufacture of the present spun yarn of elastic fiber is described below while illustrating the accompanying drawings.

FIG. 1 is a cross-sectional view of the direct spinning machine which is conventional.

FIG. 2 is the correlation between the distance (*ho*) from back roll to intermediate roll and draft ratio of the spandex spun yarn prepared by using the apparatus as shown in FIG. 1.

FIG. 3 shows a part of a direct spinning machine equipped with a pair of endless aprons and employed in the practice of this invention.

FIG. 4 is a cross-sectional view of the direct spinning machine particularly useful in the practice of this invention.

FIG. 5 is a staple diagram representing the correlation between fiber length and content in the spun yarn of elastic fiber prepared by using the apparatus shown in FIG. 4.

FIG. 6 is the correlation between the effective coefficient of fiber strength in yarn strength and the fiber number in cross section of yarn prepared by using elastic fiber (*a*) or hard fiber (*b*).

In FIG. 1, multifilament yarn 2 released from bobbin 1 is fed, via back roll 6, to a breaking zone A, and is stretch broken between said back roll 6 and intermediate roll 7, the surface speed of the roll 7 being 10 to 20 times faster than the speed of roll 6. Thus a mass of broken and transformed fibers 3 is then sent to the subsequent draft zone B, in which it is drawn to a desired denier yarn between intermediate roll 7 and front roll 9 having a surface speed several times faster than that of roll 7. The yarn 4 come out of the front roll 9 and is passed through a pigtail 10, twisted to a desired twisting condition by means of revolving spindle 12, and wound up, via ring and traveller 11, on a cop as spun yarn 5. In case the elastic fiber is blended with a hard fiber, roving 14 of hard fiber is released from another bobbin 13, passed over a guide roll 15, and fed to the intermediate roll 7 and blended therein with the elastic fibers 3. In the other method, after passing over the guide roll 15, said roving 14 of hard fiber is fed to cradle 8 and blended with the elastic fiber therein. Some of the conventional direct spinning machines may possess a gear with edges in the breaking zone A, or a floating control roll and a single apron as a substitute for cradle 8 in the draft zone B. However, the principal action of these modified machines on the fiber is the same as that of the machine shown in FIG. 1. When the total denier of elastic fibers in the draft zone is too coarse and therefore a considerable high draft ratio is required to draw them to a desired yarn denier, the already described difficulty of sliver drawing also occurs here. Therefore, it is desirable to adjust the draft ratio in the breaking zone so that the draft ratio in the subsequent draft zone is less than 10, preferably less than 5.

Although spun yarn of elastic fiber can be prepared by using the conventional direct spinning machine illustrated in FIG. 1, it is difficult or impossible to obtain as good a quality yarn, as

will be obtained if the special pretreatment described hereinafter is applied to the elastic fiber. It is most preferable to employ the direct spinning machine equipped with a special apron apparatus concerning the present invention as shown in FIG. 4.

The first reason why it is difficult to obtain a good quality yarn with the machine shown in FIG. 1 is as follows: Compared with hard fiber having smaller breaking elongation and poor recovery from stretching, the elastic fiber used for the preparation of the present spun yarn possesses at least 100 percent breaking elongation and quick recovery from stretching to an elongation which is less than its breaking elongation. In order to obtain spun yarn having excellent elasticity using the elastic fiber and to prevent yarn breaking strength from being reduced by slipping between fibers in the yarn, it is necessary to employ a fiber of at least 0.5 inch minimum length, more than 1 inch average length and 3 inches as the preferable average length. When the average length of the fiber exceeds 4 inches and the total denier of the fiber is coarse, the drawing operation in the draft zone is quite difficult to carry out. Since the breaking elongation of spandex fiber, for example, is in general in a range of 400—800 percent, the broken length of the fiber will be about 20 inches (3 inches ×(5—9)), taking the fiber length under no load as 3 inches. In this connection, the distance (gauge length) between the back roll **6** and the intermediate roll **7** will be determined by using the following equation: $L / ho = D \log D - 1 / e\ D(1+\epsilon)$ wherein D is draft ratio; ho stands for distance between back roll and intermediate roll; ϵ means the breaking elongation of elastic fiber and L is the stretched fiber length which has been forwarded by the intermediate roll until it is broken. Taking the conditions of $\epsilon=6$ and $L=20$ inches, the correlation between ho and D is shown in FIG. 2. (Correctly speaking, L plus one-half of ho should be 20 inches, but for the sake of simple calculation L is taken as 20 inches.) According to this FIG. 2, even a large draft ratio of 20 gives only a narrow roll distance of about 2.6 inches in case of 3 inch fiber length. If the average free length of the fiber is less than 2 inches, this roll distance will be much smaller than that of the above case. Therefore, in the direct spinning system shown in FIG. 1, approximately 1,000 ends of fibers must be distributed in relatively a small zone. As already described, the elastic fiber possesses a large frictional resistance acting between fibers, so that an end of a fiber tends to be forwarded with the movement of the end of another fiber thereby causing a number of ends to be simultaneously caught by the intermediate roll, and stretched and broken in the breaking zone. That is, an evenly spun yarn can not be obtained in this method. Indeed, the above may be avoided by further widening the roll distance to give a considerably larger distribution of fiber ends, but it may also result in the necessity of employing a longer fiber length, (e.g. providing $ho=4$ and $D=20$, free fiber length should be 4 inches as shown in FIG. 2), which in turn causes a different problem in the draft zone as previously stated.

Therefore, one solution concerning the present invention for obtaining a better quality yarn with the direct spinning machine as shown in FIG. 1 is to subject the elastic fiber to a heat-setting treatment prior to feeding it into said machinery. That is, the elastic fiber is heat set in a stretched state to reduce its breaking elongation and increase its Young's modulus. For example, if the elastic fiber is previously modified to have 200 percent of breaking elongation, a fiber having a 3 inch free length should be broken at a stretched fiber length of 9 inches (3 inches ×3). In this case, from the above said equation, ho will be 4.1 inches when D is 20. This condition means a good distribution of fiber ends. Furthermore, a longer free fiber length such as 4 inches can be successfully employed, because the fiber is of high Young's modulus, so that little trouble is found in the drawing step in the draft zone. In this case, ho is 5.4 inches, so that it gives a quite favorable distribution of fiber ends. Spun yarn thus prepared from the pretreated fiber possesses a high Young's modulus and low breaking elongation. However, this spun yarn may conveniently be converted to the state in which it has the original properties as possessed by the unmodified elastic fiber, by subjecting the yarn to a relaxation treatment under free loading conditions (for example, in skein or in the form of woven fabric or knitted fabric) in boiling water or a steam box. This recovery may be somewhat influenced by the stretching ratio and heating temperature employed in the pretreatment, but almost complete recovery can be obtained. Some of the testing results in case of spandex fiber is shown in the following table 1.

TABLE 1

Material		After pre-treatment			After free relaxation		
Breaking elongation, percent	Young's modulus	Treating conditions	Breaking elongation, percent	Young's modulus	Treating condition	Breaking elongation, percent	Young's modulus
800	65	400% stretch, 80° C., 10 min., steam set	320	155	80° C., boil	515	50
					100° C., boil	680	43
					120° C., steam	790	40
		400% stretch, 100° C., 10 min., steam set	250	240	80° C., boil	390	100
					100° C., boil	510	60
					120° C., steam	690	45

Remark: Young 's modulus shows the value of tension gram in 250 percent extension of 530 *d* spandex multifilament yarn.

The second reason why a good quality spun yarn is hard to obtain by the direct spinning machine as shown in FIG. 1 is hereinunder described.

The elastic fiber employed in the present invention possesses a quick recovering property from various degrees of stretching, so that the fiber ends broken in the stretch-breaking zone spring back to form hook ends. This hook not only obstructs the even drawing of the fiber, but also often gets entangled with adjacent fibers to obstruct its movement as a single fiber, and cause many fibers to be stretched and broken simultaneously. In this case, as shown in FIG. 3, it is preferable to employ a pair of endless aprons placed between the back roll and the intermediate roll and driven with a speed which is faster than the surface speed of the back roll and slower that the surface speed of the intermediate roll, to prevent the spring back of broken fiber ends and, to reform the hook of fiber end therewith if such occurs.

In order to obtain the best quality spun yarn of elastic fiber, it is recommended to employ the direct spinning machine as shown in FIG. 4. In this figure, the area between back roll **29** and intermediate roll **31** is the stretch-breaking zone A, and the area between the intermediate roll **31** and front roll **38** is the draft zone B. Multifilament yarn **22** of elastic fiber is released from bobbin **21** passed through back roll **29**, and introduced via each tensor **30** into the clearance between top apron **33** and bottom apron **35**, these aprons being driven by intermediate roll **31** rotating with a surface speed several times faster than that of back roll **29**. The elastic fiber having a large breaking elongation is thus stretched by means of faster moving aprons **33** and **35**. The clearance between the tensors **30** (top and bottom) and the spring for the press roll **34** are adjusted so as to give slipping to the stretched fiber before breaking. The stretched elastic fiber is further advanced while slipping to the intermediate roll **31**, where it is nipped by the roll **31**, stretched in a desired draft ratio and broken. After

passing through the roll **31**, the stretch-broken elastic fiber immediately shrinks by its own elasticity to a predetermined free fiber length, and the thus obtained fiber **24** is, while being carried on the bottom apron **35**, sent to cradle roll **36** and drawn in a desired denier yarn **25** in the draft zone provided between the cradle roll **36** and front roll **38**. This yarn **25** is then passed through pigtail **39**, twisted by revolution of the spindle, and wound, via ring and traveller **40**, on cop **41** as a spun yarn **26**. As clearly known from the above, the elastic fiber in the stretch-breaking zone is stretched fully by a pair of faster moving apron means and fed to the intermediate roll **31** as it is. Therefore, the fiber length being forwarded by the intermediate roll before the fiber is brought to its breaking elongation, is considerably small and almost the same with that of hard fiber. Consequently, it is possible to select and fix the distance between the back roll and intermediate roll in a considerable size. Furthermore, by controlling the spring pressure of press roll **34** and the clearance between the top and the bottom tensors **30**, it is possible to change the extent of stretch and the position of slipping of the fiber placed between the aprons. Therefore, the breaking point can be concentrated in a desired position or distributed throughout the apron, and the fiber length can be controlled in any desired size desired. These are exemplified in FIG. **5**. When the elastic fiber is stretch broken in such a way, the spring back of the fiber end can be effectively controlled by the top and bottom aprons, so that no troubles are involved in this regard as compared with the case using the machinery as shown in FIG. **1**. Thus, a better quality yarn can be spun in accordance with this invention.

When it is required to prepare a blended spun yarn of elastic fiber and hard fiber, the same apparatus as shown in FIG. **4** is conveniently employed with a slight modification thereon. That is, another roving **43** consisting of hard fiber alone is released from another bobbin **42**, passed over guide roll **44** and blended with elastic fiber **24** at the cradle roll **36**. For convenience in varying the blend ratio or yarn count, it is possible to place roll **45** in a position between the guide roll **44** and the cradle roll **36** so that the hard fiber roving is drawn by the surface speed difference between the roll **45** and the cradle roll **36**. However, since it is difficult to place some apparatus for controlling floating short fibers in the roving in the position between the cradle roll **36** and the roll **45**, the draft ratio in this area must not exceed **5**, the preferable draft ratio being **1** to **3**.

In this type of blending system, mixing of each fiber is in general no so good. However, the spun yarn has an elasticity and these characteristic properties are brought by the elastic fiber employed. Therefore, the elastic fiber apt to be concentrated in the center of the yarn and the hard fiber will be distributed at the periphery, and thus complete mixing of the fibers is unnecessary in this case.

When it is required to give high elasticity to the blended spun yarn, this may be accomplished by adjusting the clearance between the top and the bottom tensors **37** of the cradle in the draft zone B, such that the elastic fiber can be nipped (however, slippable on the brink of breaking) and the hard fiber can be slipped therebetween. Thus, by adjusting the clearance between tensors, any elastic spun yarn having 0 to more than 100 percent of elasticity may be prepared at will.

As will be clearly understood, the present spun yarn of elastic fiber can be easily prepared by using the methods and the apparatus described hereinabove.

The present spun yarn of elastic fiber is a distinctive product and differs from any of the known spun yarns of hard fibers. The following are the reasons therefor.

Firstly, spun yarn containing 30 to 100 percent, by weight, of elastic fiber having more than 100 percent elastic elongation, extremely small Young's modulus and excellent quick recovery from various degrees of stretching to an elongation less than its breaking elongation, has never been prepared, though filament yarn of elastic fiber has been heretofore known. As mentioned above, the present spun yarn of elastic fiber is hardly prepared or cannot be prepared at all by merely using a conventional spinning system, and in order to obtain a better quality spun yarn it is necessary to modify the elastic fiber beforehand by giving a special heat-set treatment thereto or to employ a modified direct spinning system equipped with a certain device. That is, in case of hard fiber, its spun yarn is obtained as a matter of course by using any conventional spinning system or conventional direct spinning system, so far as its filament yarn exits. However, in the case of an elastic fiber, it is not the same as that in the case of hard fiber to obtain its spun yarn, even if its filament yarn exists.

Secondly, since elastic fiber possesses an extremely small Young's modulus, each fibers in the twisted spun yarn sticks to one another to cause a considerable frictional resistance between the fibers, and therefore when such a spun yarn is stretched, there hardly occurs any slipping between the fibers. To the contrary, in case of a hard fiber, in order to maintain a satisfactory yarn tensile breaking strength, spun yarn must be comprised of more than 50 ends of fibers. If the fiber number in cross section of the yarn is less than 50 ends, the said yarn strength abruptly decreases due to slippage between the fibers. Therefore, even thinking over fiber length, fiber denier, and twist multiplier, 30 ends are the minimum limit for practical use. Furthermore, even if the spun yarn of hard fiber possesses a satisfactory tensile strength under the best of conditions, it cannot be free from the slipping at the time of breaking the fiber. Therefore, it is impossible to bring the effective coefficient of fiber strength in yarn strength (i.e. yarn tensile strength/single fiber strength × fiber number in cross section of yarn) to 100 percent, the mean value being 50 to 60 percent and the maximum value being 70 percent. Contrary to the above, in the spun yarn of elastic fiber, no decrease in the yarn strength is detected for the above-said reasons even in a product having **15** fiber ends in cross section of spun yarn, and the effective coefficient of fiber strength in yarn strength is almost 100 percent. In this regard, the correlation between the effective coefficient and the fiber number in cross section of yarn is shown in FIG. **6**, wherein, (*a*) represents the curve for elastic fiber and the (*b*) the curve for hard fiber. From these curves, it will be seen that the minimum fiber number in cross section of the present spun yarn is to maintain the yarn strength is quite different from the corresponding value of the conventional hard spun yarn, and that the maximum effective coefficients are quite different from each other.

Thirdly, when fibers are stretch broken in a direct spinning system, there is a big difference between elastic fiber and hard fiber in their respective stretch-breaking phenomenon. That is, in case of hard fiber, though the maximum fiber length may be controlled by using a particular breaker, it is impossible to prevent the occurrence of short fibers, the minimum fiber length thereof being about several mm., for the following reasons. They are the facts that the breaking of the fiber occurs throughout the breaking zone, and since the breaking elongation (ϵ, in the aforesaid equation) of hard fiber is less than 0.4, in general 0.2—0.3, the L value becomes almost zero. On the contrary, in the case of elastic fibers, the breaking elongation of the fiber is in general 400—800 percent and therefore ϵ is in a range between 4 and 8 and L can be a considerably larger value. Thus, in the present spun yarn of elastic fiber, the minimum fiber length is quite long as compared with the case of hard fiber and the short fiber content is extremely small as a result.

The following examples will serve to illustrate the spun yarn of elastic fiber, preparation thereof and the useful effects obtained in this invention.

EXAMPLE 1

Employing multifilament yarn (5,000 d/500 fil.) of spandex elastic fiber having 300 percent breaking elongation, 0.2 *g/d* Young's modulus (stress in 100 percent extension), and 98 percent recovery from 100 percent extension, pure spandex spun yarn of 400 *d* having 40 ends of fiber in cross section was obtained by using the direct spinning machine as shown in

FIG. 4, under the following conditions.

Stretch-breaking zone
draft ratio 10
distance between back roll and intermediate roll 9 inch
Draft zone
draft ratio 1.2
Twist '26 T/inch Employing the same conditions as stated above, except that the draft ratio in the draft zone is increased to 3.4, another pure spandex spun yarn of 150 d having 15 ends of fiber, and 31 T/inch was prepared. Mechanical properties of these spun yarns are shown in table 2.

TABLE 2

	Material—Multifilament yarn	Pure spun yarn (400 d.) After spinning	Pure spun yarn (400 d.) After boiling in order to relax strain imposed during spinning process	Pure spun yarn (150 d.)—after spinning
Yarn denier (d.)	5,000	400	420	150
Breaking strength (g.)	2,300	210	260	68
Breaking strength (g./d.)	0.45	0.53	0.65	0.45
Breaking elongation (percent)	300	160	295	130
Young's modulus:				0.08
g./d. 50% extension		0.09		
g./d. 100% extension	0.20	0.30	0.15	
Kg./mm.²	2.8	2.7	0.7	

As clearly seen from the above table 2, the breaking elongation of spun yarn after spinning decreased and the Young's modulus slightly increased compared with that of multifilament yarn, because the elastic fiber is subjected to the stretch-breaking treatment. However, by the after boiling treatment, such as dyeing, the inner structural strain of the fiber was removed and the said breaking elongation and Young's modulus were restored to the normal conditions. However, the Young's modulus of the thus after-treated yarn was slightly lowered compared to that of the original material filament yarn. It might be due to the twists in the finished spun yarn. Even in the spun yarn constructed with 15 ends of fibers, the breaking strength (*g/ d*) was almost identical with that of material filament yarn. Thus, the effective coefficient of fiber length in yarn strength was 100 percent.

EXAMPLE 2

Pure spandex spun yarn (400 *d*, 26 T/inch S twist) prepared by the method of example 1, was employed as a core yarn and acrylic fiber roving (fiber denier 2 d , fiber length 2 inches) was used as a sheath fiber. Stretching the core yarn with a draft ratio of 2, core-spinning was carried out. Thus obtained core-spun yarn possessed 49 percent of elastic fiber content, 22 *Nm* (metric count) of yarn count (i.e. corresponding to 410 d) , and 12.2 T/inch of Z twist. Since the twist direction of pure spandex spun yarn was S while the twist direction of core spinning was Z, twisting torques of the yarn disappeared. The kink number of the thus prepared core-spun yarn was 26 and this product was found to be useful for the following knitting or weaving process. For the sake of comparison, similar core spinning was carried out with nontwist filament yarn (210 d) of elastic fiber and acrylic fiber roving, and consequently the kink number of core-spun yarn obtained was 52. This core-spun yarn had to be steam set to decrease the kink number to 20 for the subsequent process.

EXAMPLE 3

Employing the direct spinning machine shown in FIG. 4, multifilament yarn (5,000 d / 500 fil.) of spandex elastic fiber having 300 percent breaking elongation, 0.2 *g/ d* (stress in 100 percent extension) Young's modulus, and 98 percent recovery from 100 percent extension, was stretch broken in the stretch-breaking zone with the conditions of 7.45 draft ratio and 9 inches distance between the back roll and intermediate roll. Another roving consisting of 2 d fiber denier, 2 inches fiber length acrylic fiber and having 0.1 g/m sliver weight, was continuously fed to cradle roll in the draft zone, and blended with the elastic fiber come out from the stretch-breaking zone. Then the blended yarn is drawn with a draft ratio of 2.24 to give a desired yarn count of one thirteenth *Nm* (metric count), twisted (23 twist/inch) by revolution of spindle and wound up on a cop. The breaking strength and the breaking elongation of this product were 683 g and 107 percent, respectively. After subjecting to free relaxation in boiling water, these values changed to 558 g and 277 percent. The spun yarn obtained by this example comprised 43 percent spandex fiber and the remaining percent hard fiber. Excellent elasticity and good recovery from stretching were found on the spun yarn (after spinning) within the limit of 50 percent extension and on the relaxed spun yarn (after relaxation in boiling water) within the limit of 150 percent extension, respectively.

The term "elastic fiber" used herein refers to the synthetic fiber having elasticity due to construction with soft segment and hard segment such as spandex fiber having urethan group as a bonding group or the fiber having urea group or acid amide group as a bonding group, and includes fibers formed by extruding or cutting natural rubber synthetic rubber. Therefore, this elastic fiber has the following characteristic mechanical properties.

breaking elongation more than 100 percent (generally 400—800 percent) elastic recovery from high stretching more than 90 percent (generally more than 95 percent)

Young's modulus less than 0.5 g/d (generally 0.03—0.1 g/d wherein the elastic recovery from high stretching is indicated by the percentage of recovered stretch to the net stretched length of the fiber just after being stretched to one-half of breaking elongation thereof, kept it for one minute, and then released from stretching and the Young's modulus represents the stress when the fiber is 100 percent extended.

The term "hard fiber" used herein refers to fibers having less than 50 percent breaking elongation, and including natural fiber such as cotton, wool, linen, jute and silk, regenerated cellulosic fiber such as viscose, cuprammonium, and acetate, and synthetic fiber consisting of homopolymers such as polyamide, polyacrylonitril, polyester, polyvinylchloride, and polyvinylalcohol or consisting of copolymers thereof.

The present invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described hereinabove and as defined in the appended claims.

We claim:

1. A method of producing a spun yarn consisting of 100 percent of an elastic staple fiber, said method comprising preliminarily stretching and heat setting a tow of 100 percent elastic filaments, stretch breaking the stretched and heat-set tow, drawing the resulting elastic staple fiber, directly spinning the elastic staple fiber to a spun yarn, mixing said spun yarn with additional textile materials to convert same to a mixed

state and then subjecting the said spun yarn in a low-tensioned state to free relaxation by treatment with a member selected from the group consisting of steam and boiling water to thereby impart to the blended yarn excellent elasticity and high bulkiness resulting from the shrinking of the elastic fiber during the relaxation.

2. A method according to claim 1 wherein the mixed state to which the spun yarn is converted is in the form of a core spun yarn.

3. A method according to claim 1 wherein the mixed state to which the spun yarn is converted is in the form of a covered yarn.

4. A method according to claim 1 wherein the mixed state to which the spun yarn is converted is in the form of a fabric.

5. A method of producing an elastic, bulky blended spun yarn of elastic staple fiber and hard fiber, said method comprising stretching and heat setting a tow of 100 percent elastic filaments, stretch breaking the stretched and heat-set tow, blending same with a hard fiber roving, drawing the thus blended materials, directly spinning same to a spun yarn, mixing said spun yarn with other with additional textile materials to convert same to a mixed state, and then subjecting the said spun yarn in a low-tensioned state to free relaxation by treatment with a member selected from the group consisting of steam and boiling water to thereby impart to the said blended spun yarn excellent elasticity and high bulkiness resulting from the shrinking of the elastic fiber during the relaxation.

6. A method according to claim 5 wherein the mixed state to which the spun yarn is converted is in the form of a core spun yarn.

7. A method according to claim 5 wherein the mixed state to which the spun yarn is converted is in the form of a covered yarn.

8. A method according to claim 5 wherein the mixed state to which the spun yarn is converted is in the form of a fabric.

9. A method of producing a spun yarn consisting of 100 percent of an elastic staple fiber, said method comprising preliminarily stretching and temporarily heat setting a tow of 100 percent elastic filaments, stretch breaking the stretched and heat-set tow, drawing the resulting elastic staple fiber, directly spinning the elastic staple fiber to a spun yarn and subjecting said spun yarn to a post treatment.

10. A method according to claim 9 wherein said post treatment comprises subjecting the said spun yarn in a low-tensioned state to free relaxation by treatment with a member selected from the group consisting of steam and boiling water to thereby impart to the said spun yarn excellent elasticity and high bulkiness resulting from the shrinking of the elastic fiber during the relaxation.

11. A method according to claim 10 and further comprising mixing said spun yarn with additional textile materials to convert same to a mixed state in the form of a core spun yarn before subjecting same to said free relaxation.

12. A method according to claim 10 and further comprising mixing said spun yarn with additional textile materials to convert same to a mixed state in the form of a covered yarn before subjecting same to said free relaxation.

13. A method according to claim 10 and further comprising mixing said spun yarn with additional textile materials to convert same to a mixed state in the form of a fabric before subjecting same to said free relaxation.

14. A method of producing an elastic, bulky blended spun yarn of elastic staple fiber and hard fiber, said method comprising stretching and heat setting a tow of 100 percent elastic filaments, stretch breaking the stretched and heat -set tow, blending same with a hard fiber roving, drawing the thus blended materials and directly spinning same to a spun yarn.

15. A method according to claim 14 further comprising subjecting the said spun yarn in a low-tensioned state to free relaxation by treatment with a member selected from the group consisting of steam and boiling water to thereby impart to the said blended spun yarn excellent elasticity and high bulkiness resulting from the shrinking of the elastic fiber during the relaxation.

16 A method according to claim 15 and further comprising mixing said spun yarn with additional textile materials to convert same to a mixed state in the form of a core spun yarn before subjecting same to said free relaxation.

17. A method according to claim 15 and further comprising mixing said spun yarn with additional textile materials to convert same to a mixed state in the form of a covered yarn before subjecting same to said free relaxation.

18. A method according to claim 15 and further comprising mixing said spun yarn with additional textile materials to convert same to a mixed state in the form of a fabric before subjecting same to said free relaxation.