United States Patent

Gray

[15] 3,701,248

[45] *Oct. 31, 1972

[54] INTERLACED MULTIFILAMENT YARN

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[73] Assignee: E. I. du Pont de Nemours and Company, Wilmington, Del.

[*] Notice: The portion of the term of this patent subsequent to Feb. 16, 1988, has been disclaimed.

[22] Filed: April 28, 1971

[21] Appl. No.: 138,181

Related U.S. Application Data

[60] Continuation-in-part of Ser. No. 115,770, Feb. 16, 1971, which is a division of Ser. No. 883,536, Dec. 9, 1969, Pat. No. 3,563,021, which is a continuation-in-part of Ser. No. 801,596, Feb. 24, 1969, abandoned.

[52] U.S. Cl. 57/153, 28/1.4, 161/175

[51] Int. Cl. D02g 3/22

[58] Field of Search.....161/173, 175, 176; 57/157 R, 57/140 R, 140 C, 157 F, 153; 260/28.5 R; 28/1.4

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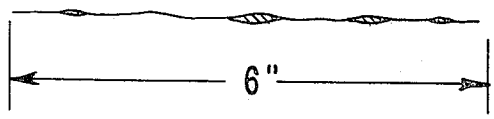
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[57] ABSTRACT

Interlaced multifilament yarn for weaving as warp in automatic power looms without size or twist is compact and uniform with unusually high bundle cohesion. Interlacing processes and finishes for retaining interlace are illustrated. Suitable intensity and permanence of interlace for weaving are defined by simple measurements.

9 Claims, 12 Drawing Figures



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SHEET 1 OF 4

FIG. 1

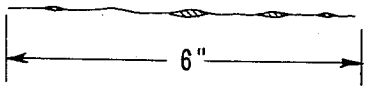


FIG. 3

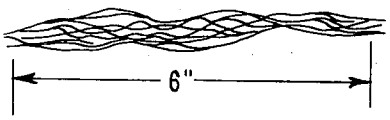


FIG. 2

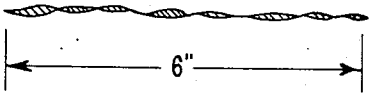


FIG. 4

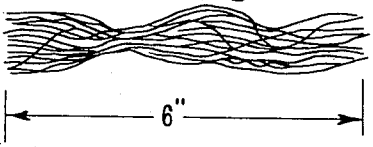
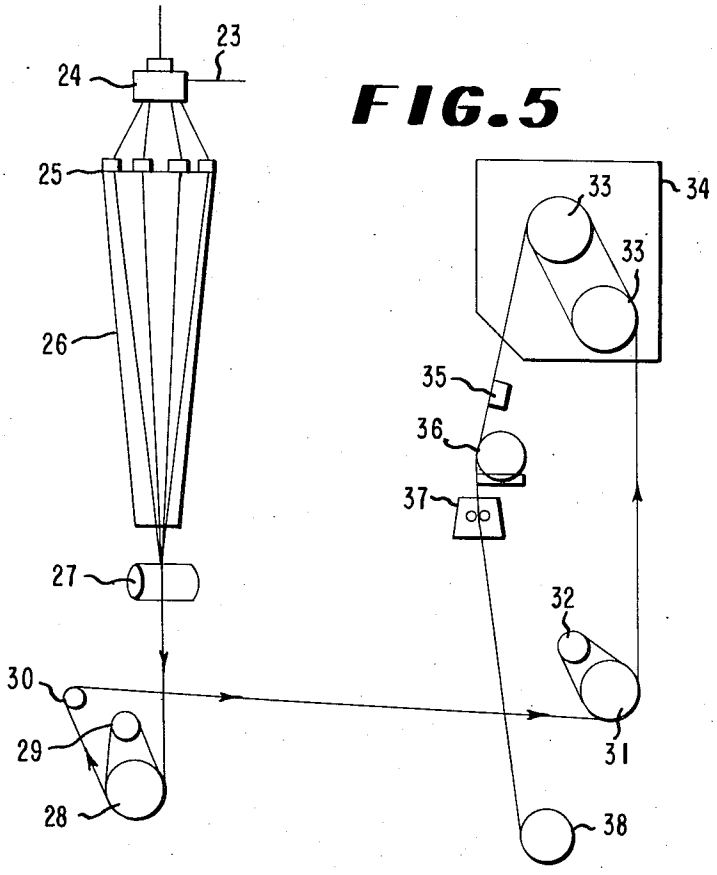


FIG. 5



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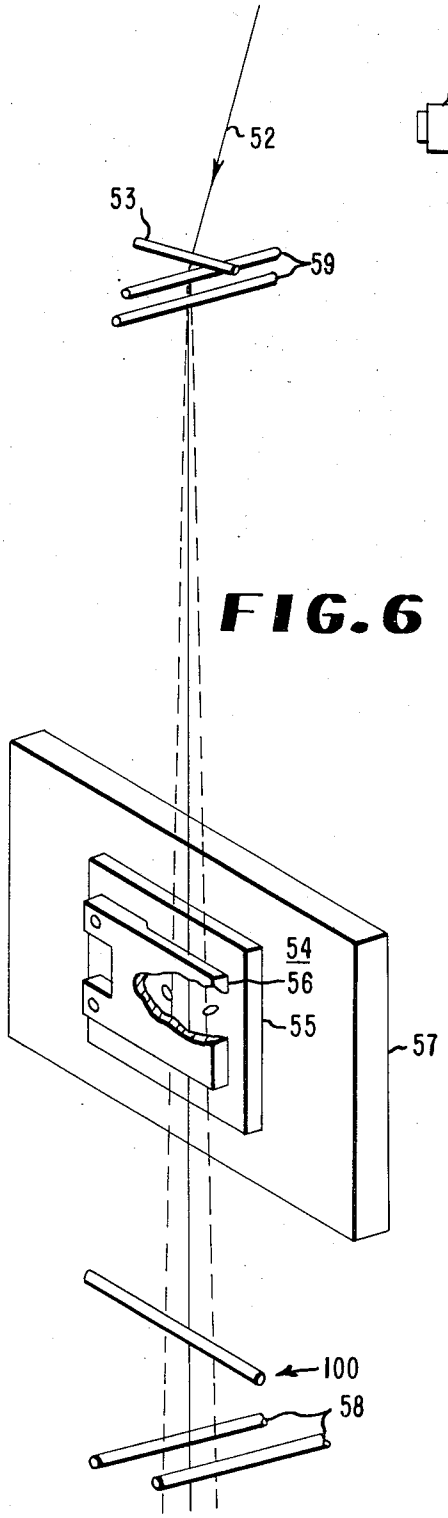


FIG. 6

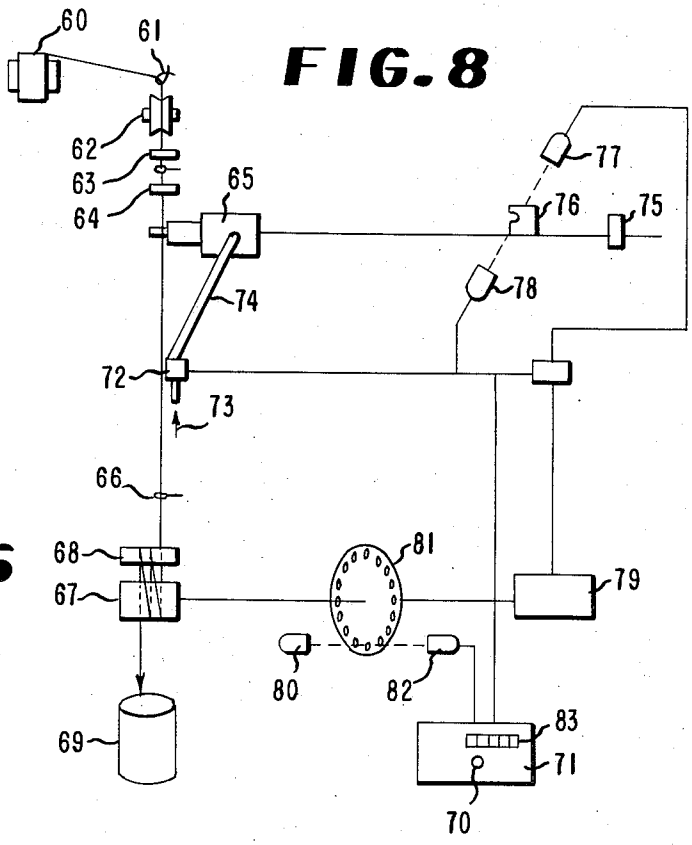


FIG. 8

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FIG. 7

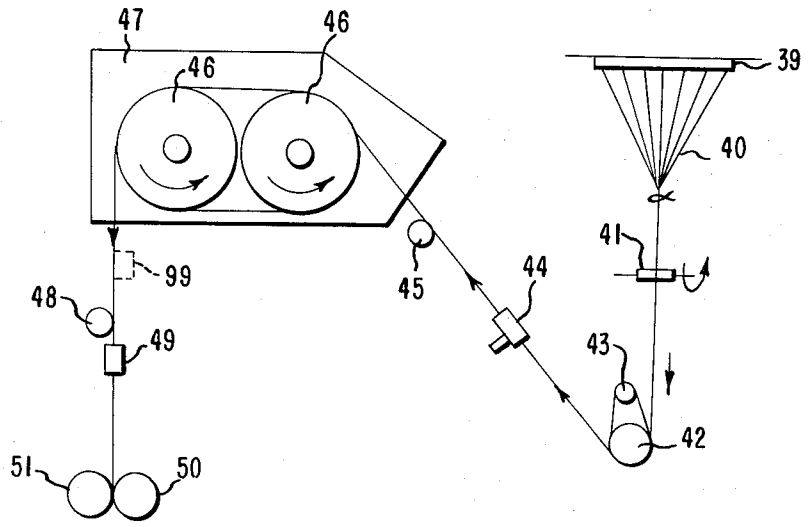
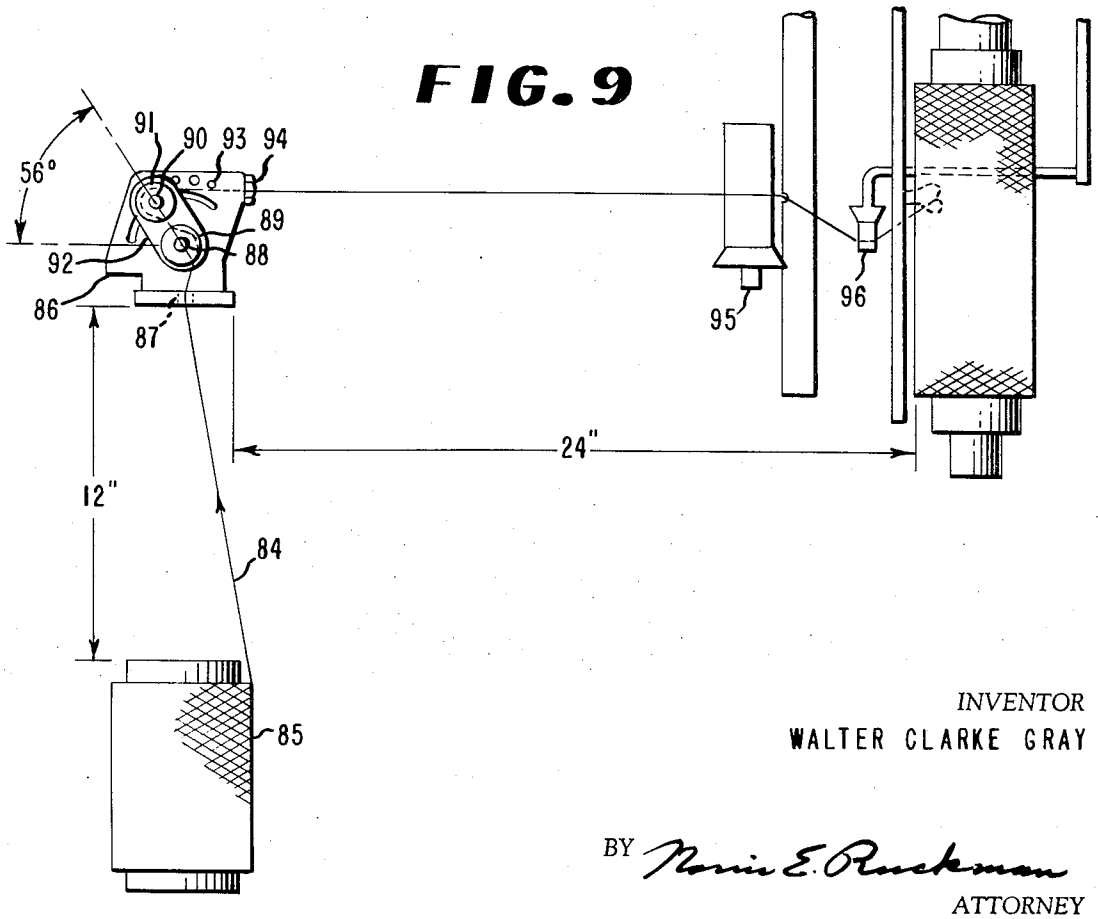


FIG. 9



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FIG. 10

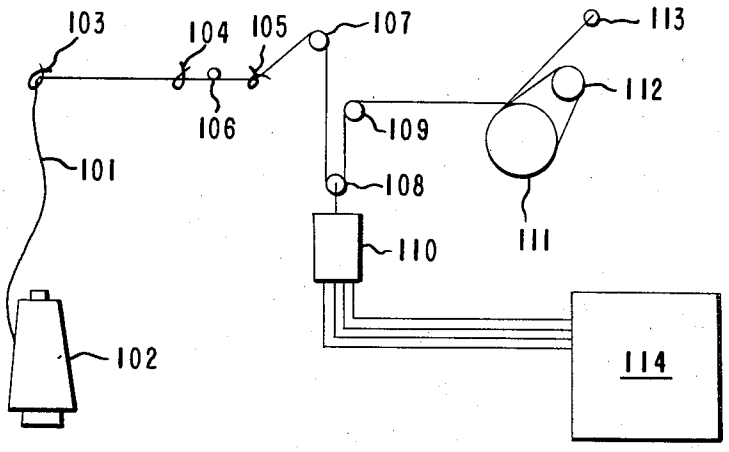


FIG. 11

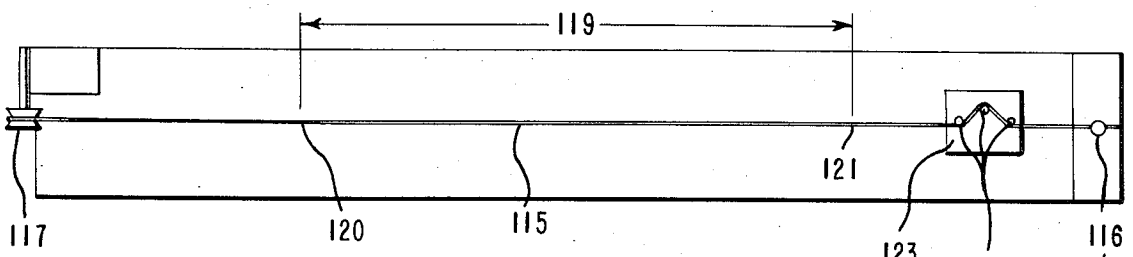
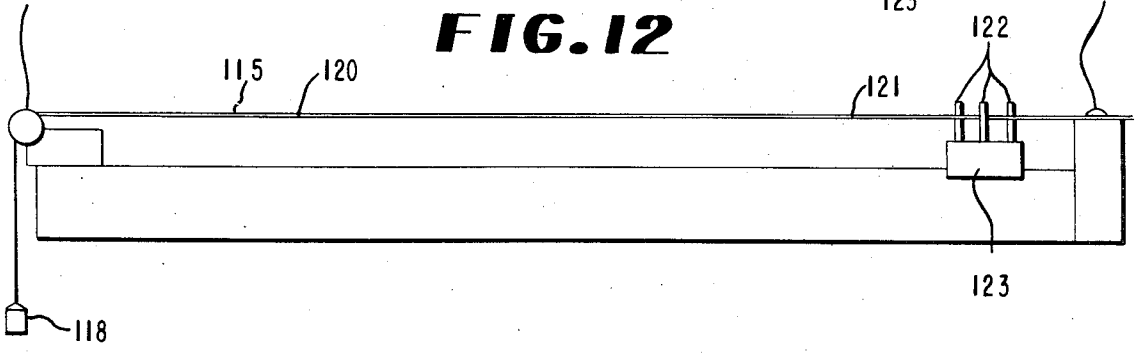


FIG. 12



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INTERLACED MULTIFILAMENT YARN

REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of my copending application Ser. No. 115,770 filed Feb. 16, 1971, as a division of my application Ser. No. 883,536, now U. S. Pat. No. 3,563,021, which was in turn a continuation-in-part of my application Ser. No. 801,596 filed Feb. 24, 1969, and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to compact multifilament yarn for use as the warp in automatic power looms, the yarn being of a type referred to as interlaced yarn wherein individual filaments and groups of filaments are entangled with adjacent filaments and groups of filaments along the length of the yarn to form a coherent unitary strand. The invention relates more specifically to continuous filament warp yarns which have been interlaced to have a combination of properties which make them suitable for use as the warp in shuttle looms without the need for the conventional sizing operation.

Yarns to be used for warp at present are twisted or interlaced sufficiently to prevent the yarns from becoming damaged as they are handled in the operations of forming a beam and feeding the beamed yarn into the sizing operation. Sizing, or slashing (slasher-sizing), is the process of immersing warp yarns in an adhesive solution, squeezing (quetching) the yarns to distribute the solution through the filament bundle and remove excess, and drying the yarns. The yarns are dried after application of size as a sheet of parallel ends (strands). Some filaments of neighboring ends adhere to each other and are often broken when the ends are separated at the split rod known as the "buster bar". From 0.5 to 1.5 percent of molten wax by weight may be added to the yarn to improve the running properties of the yarn, and then the yarn is wound on a flanged roller known as a loom beam, which supplies warp to the loom. To withstand this slashing procedure and weave well without interlace, warp yarns usually require 5–7 turns per inch (196–275 turns per meter) twist plus normal amounts of size.

Alternatively, sized warp ends are separated while wet, are partially or completely dried while separated and are recombined onto a beam after drying. This so-called "wet split" process will reduce the number of broken filaments.

After sized yarn has been woven, the fabric must be scoured to remove the size as one of the first operations in fabric finishing before dyeing and other treatments can take place. Since the amount of size on warp yarn is conventionally from 1.5–7.0 percent by weight of the warp yarn used, and since much of the size has been distributed within the filament bundles and dried, this scouring operation requires considerable time, detergent, and caustic solution. The size, detergent and other materials leave the plants in waste water and eventually are discharged into streams, where detergents kill or inhibit the activities of microorganisms which break down waste and which are food for fish life. When the size materials are attacked by microorganisms, the process depletes the dissolved oxygen content of the water which is needed for a healthy stream ecology. Thus, it would be desirable to eliminate the sizing operation or at least reduce the amount of size required.

Unsized yarns have not heretofore been successful for use as the warp of a woven fabric for several reasons. During weaving, warp yarn is subjected to severe abrasion from at least three major sources. First, the shuttle which inserts the filling yarns into the fabric slides across the warp end, tending to loosen filaments from the bundle and to snag and break filaments which become loose. Second, after the filling end has been inserted, the reed, which consists of thin metal strips between one or more warp ends, pushes the freshly inserted filling yarn closely parallel to the previous filling pass and, in so doing, the reed abrades the warp yarn longitudinally. Third, the harnesses (heald frames) with their heddles (healds) move warp ends or groups of warp ends alternately above or below the shuttle path.

In most fabric constructions, the warp ends are spaced close enough together so that they rub transversely against one another each time that the harnesses reverse the warp end positions. This transverse abrasion again tends to break down the bundle coherence and to separate individual filaments from the bundle so that they can be snagged and broken by either the shuttle or the reed. The presence of broken filaments in a fabric can lower the quality to second grade. When a warp end loses coherence and filaments begin to break, damage usually accelerates rapidly with each motion of the loom, resulting in a break of the complete warp end. This stops the loom, interrupts production until the damage can be repaired, and degrades this portion of the fabric to seconds or waste. Even if filaments do not break but are merely spread apart in one end, or if slack filaments are pulled out into loops, they can tangle with those of an adjacent end so that the defective end passes on the wrong side of the filling. This gives a fabric defect known as a "float" and second-grade fabric rating if severe enough.

True twist yarns which are sized are usually somewhat flattened because of the action of squeeze (quetch) rolls which remove excess size and because of the flattening effect of other rolls during sizing and drying in the "dry-split" process. The degree of flattening is usually quite variable. As these yarns are woven, the narrow dimensions of the warp ends can change their position randomly with respect to the plane of the fabric, creating varying gaps between ends and varying bending modulus depending upon the orientation of the narrow dimension with respect to the bending moment. The "wet-split" process can reduce this nonuniformity but does not eliminate it.

When the above conventional sizing treatment is used for interlaced yarn having highly-interlaced regions which absorb a different amount of size than less tightly interlaced regions, the warp yarn will be variable with respect to both filament bundle dimensions and stiffness, and highly-interlaced regions which are not as free to flatten during sizing and drying as are the regions between may also cause variations in filament bundle dimensions.

During weaving, varying filament bundle dimensions of sized warp ends may crowd neighboring warp ends or leave gaps between them, and the varying stiffness may force the filling out of its usual position. The resulting fabrics may have a non-uniform appearance characterized by streaks which can be ⅛ to 15 inches (0.31 to 38.1 cm.) long scattered through the surface.

In wet-split processes, sized warp ends can be partially dried under tension while out of contact with deforming surfaces. This keeps the filament bundles rounder than the dry-split process, but inevitable bundle shape variations are set into the yarn when the size drying is completed in contact with heated rolls (cans).

SUMMARY OF THE INVENTION

The present invention provides a compact interlaced yarn which is suitable for use, without size and/or twist, as warp yarn in automatic power shuttle looms with satisfactory loom operability to produce high quality fabric. The yarn consists of interlaced continuous filaments treated with cohesive finish for retaining interlace during processing of the yarn on textile machinery, the interlace permanence being at least 40 percent in the flexure test for interlace permanence described subsequently. The filaments are interlaced in a compact coherent structure characterized, when evaluated by the APDC test described subsequently, by a value for $\overline{X}' + \sigma'$ in centimeters of less than 0.17 (B/N) + 4.0, where $\overline{X}'$ is the average of 100 APDC readings on a representative sample after backwinding as described, σ' is the standard deviation of the APDC readings, B is the breaking strength of the yarn in grams and N is the number of filaments. The yarn must have a breaking strength of at least 4.0 N, with at least 50 percent of the yarn filaments having strengths of at least 2.0 grams per denier, for the yarn to weave satisfactorily as warp yarn without size or twist. These products will have less than 10 defects per million end yards of yarn when tested for projecting filaments with a defect analyzer as described subsequently.

The requirements of suitable cohesive finishes are discussed hereinafter and a variety of cohesive finish formulations are illustrated. Cohesive finishes may be applied at one or more locations, and a cohesive finish may be used after a conventional finish to provide the specified interlace permanence. The finish should be applied as uniformly as is practicable along the lengths of the filaments. A more dilute finish composition may be used to facilitate uniform treatment provided that enough cohesive finish is applied for interlace retention. The weight of finish nonvolatiles on the interlaced yarn should be between 0.3 and 3.0 percent of the weight of the yarn filaments.

The yarn will generally consist of at least seven filaments of 1–10 denier per filament, and is preferably of 20–250 total denier, but yarns of up to 520 denier are suitable. Preferably, the filaments are composed of synthetic linear condensation polymer such as polyethylene terephthalate or polyhexamethyleneadipamide. Preferably the yarn has an interlace retention of at least 70 percent after the abrasion-backwinding, as determined by the Interlace Retention Test described subsequently.

The interlaced yarn of this invention is compact. When tested as described subsequently in the compactness test, the diameter when measured at a tension of 0.1 gpd. is at least 90 percent of the diameter when measured at 0.01 gpd. Finishes may be used in amounts of up to about 3.0 percent by weight of finish nonvolatiles based on the weight of yarn, but satisfactory loom operation is obtained without size. Substances providing improved ranges of running friction between the yarn and guide surfaces, but increased static friction between filaments, may be applied to yarn either as finishes during the production step or may be applied instead of size at a slashing operation.

Most surprisingly, the appearance of fabrics made with the above yarn can be equal to or better than that of fabrics made with expensive highly-twisted sized warp yarns. Yarns prepared in accordance with this invention can be woven without size or with substantially reduced size at high efficiency to produce quality fabrics with uniform visual appearance equal or superior to the best sized yarns at similar luster levels. The slashing step is eliminated or greatly increased in speed, less wash water and detergent are used, the scouring operation can proceed more rapidly because there is little or no dried size to remove from the yarn bundle, and a single scour-dye operation becomes practical.

The compact interlaced yarn of this invention is provided by improvements in the process for spinning, drawing and interlacing synthetic polymer filaments to produce multifilament yarn for use without any twisting operation. In one process of the present invention, the filaments are interlaced by jetting gas under a pressure of 60–100 pounds per square inch gage pressure (4.2–7.0 kg./cm.^{2}) through a pair of adjacent orifices to form intersecting streams of jetted gas, feeding a group of at least seven filaments having an average filament strength of at least 4.0 grams per filament through the intersecting streams under a tension between 0.1 and 0.4 gram per denier to interlace the filaments into a yarn and then winding up the yarn to form a suitable package. The adjacent orifices are arranged side-by-side in an alignment perpendicular to the direction of yarn travel, e.g., as illustrated in FIG. 6 of the drawings. Yarn which weaves satisfactorily as warp in automatic power shuttle looms without twisting or sizing the yarn, and which has no more than 10 defects per million end yards of yarn in a conventional test for projecting filaments with a defect analyzer, is produced in the indicated process by applying finish to the filaments prior to interlacing to provide between 0.3 and 3.0 percent by weight of finish nonvolatiles on the filaments fed to the intersecting streams and rapidly traversing the yarn from side to side so that the filaments are oscillated in the intersecting streams to produce a compact interlaced yarn characterized by having a value for $\overline{X}' + \sigma'$ in centimeters of less than 0.17 (B/N) + 4.0, and an interlace permanence of at least 40 percent in the flexure test described subsequently, where X', σ', B, N are as defined above.

When preferred finishes are employed, yarns satisfying the above values for $\overline{X}' + \sigma'$ and interlace permanence may be produced without rapidly traversing the yarn from side to side.

The specified rapid traverse of the yarn from side to side, so that the filaments are oscillated in the intersecting streams, can be accomplished mechanically, or pneumatically by a tandem jet arrangement. The traversing guide used for producing a cross-wound yarn package on a windup roll provides a "fanning zone" in which the yarn is rapidly traversed from side to side. According to one embodiment of the invention, the intersecting streams are located so that the filaments are oscillated in the streams by this traversing action of the windup guide. Fixed guides to control the motion of the

yarn can be arranged adjacent to the intersecting streams. In accordance with another embodiment of the invention, two pairs of intersecting streams are arranged in tandem to cooperate in rapidly traversing the yarn so that the filaments are oscillated in intersecting streams.

The finish may be applied at one or more locations prior to interlacing to provide the specified 0.3–3.0 percent by weight of finish nonvolatiles on the filaments fed to the intersecting streams. The finish may be applied before or after drawing, or the finish may be applied both before and after drawing. If the full benefits of a preferred finish are to be obtained, the last finish applied should be a preferred type, although finish applied earlier may also be a preferred type.

As used herein, "compact interlaced yarn" refers to products essentially free from ring-like or other filament loops (being thereby distinguished from bulked, textured, "tousled" or loopy yarns), and which meets commercial standards for freedom from broken filaments or accidental loops in conventional nonbulked yarn. In addition, the interlaced yarn must be substantially free from slack filaments. The term "yarn" as used herein does not comprehend tows, which are large bundles of filaments brought together for processing treatment and subsequently drafted or cut into staple and spun into yarn for use in textile operations. The interlaced product of this invention consists of continuous filaments, which may be of the same polymer type or more than one polymer type, and the filaments may have been treated in different ways so that some filaments in the yarn bundle have different properties from others.

The lubricating finishes referred to herein are substances having the conventional functions of controlling the friction between yarn and guide surfaces or between adjacent yarns, and may reduce static electricity, but they do not appreciably adhere filaments together in the sense that sizes do, nor do they prevent yarn bundles from changing cross-sectional shape in normal textile processing operations. A convenient distinction between conventional size and finish is that a size dries to form a solid film which requires 2,500 g./cm.^{2} or more to elongate to 50 percent or less when tested as described subsequently, while a finish forms a film which requires less than 2,500 g/cm.^{2} to elongate up to 50 percent. Certain types of preferred finishes which aid in retaining interlace give conventional levels of running friction between yarn and guides or loom shuttle but give high static friction between filaments within the yarn bundle, inhibiting loss of interlace. Others inhibit loss of interlace by providing viscous deposits between filaments which resist sudden displacement of filaments during yarn processing but which permit the yarn bundle to conform to the weave when in a fabric.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings which illustrate the invention and apparatus discussed hereinafter:

FIG. 1 illustrates the appearance of a typical interlaced yarn product of the present invention when floated on water before backwinding.

FIG. 2 illustrates the change in appearance when floated on water after backwinding the same yarn.

FIG. 3 similarly illustrates the appearance before backwinding of interlaced yarn not suitable for the present purposes.

FIG. 4 illustrates the appearance of the yarn product of FIG. 3 when floated on water after backwinding.

FIG. 5 illustrates schematically a process and apparatus for making interlaced nylon yarns by this invention.

FIG. 6 is an enlarged perspective view of the interlacing jet apparatus 37 of FIG. 5, shown with plate 56 partially broken away.

FIG. 7 illustrates schematically a process and apparatus for making interlaced polyester yarns by this invention.

FIG. 8 is a schematic view of an instrument for measuring interlace.

FIG. 9 illustrates equipment for backwinding yarn to determine interlace retention.

FIG. 10 shows apparatus for measuring Package Delivery Tension.

FIG. 11 is a top view of equipment for performing the flexure test for interlace permanence.

FIG. 12 is a side view of the equipment of FIG. 11.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the appearance before backwinding of a typical interlaced 70 denier, 34 filament yarn of this invention, having a water-soluble (emulsifiable) finish, when laid carefully in a relaxed state on the surface of a quiescent water bath. Surface tension effects cause the filaments to separate where such separation is possible, thereby revealing the tight and loose sections of the interlaced structure. The scale is in inches. It can be seen that interlace holds the yarn bundle together almost continuously.

FIG. 2 shows the appearance after backwinding the above yarn and testing in the same way. The filaments are able to spread somewhat more, revealing the periodic nature of the interlace.

FIG. 3 similarly shows the appearance on water of an interlaced 70–34 nylon 66 yarn of the prior art. It can be seen that there are few tightly interlaced regions in this length of sample, but groups of filaments are entangled randomly.

FIG. 4 shows the appearance of the yarn of FIG. 3 after backwinding and floating on water. It is evident that filaments of this yarn have considerably more freedom to separate from the bundle when abraded transversely than those of FIGS. 1 and 2.

FIG. 5 shows a typical process for spinning, drawing and interlacing a polyamide product by this invention. Molten nylon 66 polymer is supplied through conduit 23 to pump 24 which divides the flow and supplies polymer to each of four spinnerets 25, each spinneret producing one or more groups of filaments. The filaments are cooled and solidified by air in chimney 26 and the groups of filaments are then gathered together into yarns at the bottom of the chimney before passing over the primary finish roll 27 where a first finish is applied.

A typical yarn then passes around powered feed roll 28 and freely rotating separator roll 29 in a series of wraps, the separator roll 29 being mounted at such an angle as to advance the wraps and to keep the yarns separated from each other.

The yarns then pass over freely rotating roll 30 to driven draw roll 31 which is rotating considerably faster than feed roll 28. The yarns are wrapped around draw roll 31 and associated freely rotating separator roll 32 in several wraps, and then proceed to a pair of positively driven angled draw rolls 33 rotating at a faster rate than draw roll 31 so that an additional amount of drawing takes place. Rolls 33, angled to provide wrap separation, are enclosed in hot chest 34 which is supplied with heated air to stabilize (heat-set) the yarn for reducing its shrinkage.

Each yarn then passes out of the hot chest and into and through an interlacing jet apparatus 35, the majority of the air flow leaving the jet in the same direction as the yarn motion. The yarn is under sufficient tension to prevent the formation of loops or slack filaments. The jet apparatus 35 consists of two jets of Type B (described hereinafter) in series for each threadline (yarn path) at a center-to center distance of 7/8 inch (2.22 cm.). Guide pins are provided before and after the jets to keep each yarn line properly centered in the jet. The yarn then passes over secondary finish roll 36 where an additional finish is applied.

In another embodiment of the process, no interlacing jets are used in position 35, but instead a single jet is used in position 37. This arrangement is shown in greater detail in FIG. 6. The yarn then passes to a multiple package windup where the yarn end is wound on package 38.

FIG. 6 shows a detail of the interlacing jet apparatus when it is mounted in position 37 of FIG. 5. Yarn 52 takes a sufficient change in direction over guide pins 53 and 59 to remain in firm contact with these pins and in accurate alignment with the jet at all times. Interlacing jet apparatus 54, which consists of air hole plate 55 and backing plate 56, spaced away from but parallel to plate 55, is mounted on adapter plate 57. Air is supplied through plate 57 to the jet apparatus by a conduit not shown. A pair of guide pins 58 is positioned below the jet in such a manner that straight lines drawn tangentially from guide pin 59 to each pin 58 will pass no further from the center line of the jet apparatus than the center line of the two air holes. In the case of the jet arrangement of FIG. 7, the major axes of the ellipses formed by the intersection of the air holes with the surface of air hole plate 55 will lie on a common line and guide pin 100 is used to guide the thread lines between plates 55 and 56.

FIG. 7 shows one yarn end of a multi-end process and apparatus for spinning, drawing and interlacing polyester yarn. The molten polymer is extruded through spinneret 39, is cooled in zone 40 and is converged into a filament bundle (a yarn) after which the yarn passes over finish roll 41, around feed roll 42 and associated separator roll 43 in a number of wraps. It then passes through steam draw jet apparatus 44 over finish roll 45 and to angled draw rolls 46 which are running considerably faster than feed roll 42. The draw rolls are mounted in hot chest 47. The yarn then passes to finish roll 48 and then through interlacing jet apparatus 49, after which it is wound on tube 50 which is driven by roll 51. The jet apparatus 49 is preferably that of FIG. 6, arranged as described in the preceding paragraph. Alternatively, jet apparatus 49 may be replaced with a jet apparatus 99 mounted ahead of finish roll 48. Driven rolls may be placed between jet apparatus 99 and roll 51 to provide more uniform yarn tension at the jet.

FIG. 8 shows a modification of the instrument which is described in Hitt U.S. Pat. No. 3,290,932, the instrument being modified to provide increased accuracy for measuring interlace in yarns of this invention. Yarn is taken over-end from supply package 60 through pigtail guide 61 to hysteresis brake 62 and then over guide pins 63 and 64, past needle holder assembly 65 and then through guide 66, around yarn drive roll 67 and freely rotating separator roll 68 to waste 69. In operation, a new yarn is tied to the end of the previous sample, and the instrument is actuated to move the new sample past the needle holder assembly 65, the needle being retracted during this time. The yarn then stops automatically. The operator then pushes button 70 on control panel 71 which starts the yarn moving and also actuates solenoid valve 72 allowing compressed air from supply 73 to flow through tube 74 into the (pivoted) needle holder assembly 65 and to push a needle (not shown) forward through the filament bundle. The yarn continues to move while the needle splits the yarn bundle until the density of interlace in the yarn is sufficient to tilt assembly 65 against the force exerted by weight 75. This movement causes flag 76 to interrupt the light beam from light 77 to photocell 78 which closes solenoid valve 72, allowing the needle to retract by means of a spring and at the same time stopping motor 79. During the time that the yarn was running and the needle was splitting the yarn, light from lamp 80 had been passing through holes in disc 81 to photocell 82, and these pulses were registered on Hewlett-Packard electronic counter 83. An operator then records the number and presses button 70 to repeat the cycle. The yarn travels 7.5 cm. between the point where the pin retracts from the bundle and the pin is inserted for the next splitting.

DETAILED DESCRIPTION OF THE INVENTION

Yarn Materials

The yarn filaments are preferably composed of synthetic linear condensation polymer, although filaments of other materials which meet the specified strength requirements may also be used. Examples of suitable materials are polyamides such as nylon 6, nylon 66, poly(hexamethylene terephthalamide), and poly(metaphenylene isophthalamide). Polyesters are also suitable. By "polyesters" is meant fiber-forming linear condensation polymers containing in the polymer chain the carbonyloxy linking radicals



Polymers containing oxy-carbonyloxy radicals are comprehended within this group. In the absence of an indication to the contrary, a reference to polyesters is meant to encompass copolyesters, terpolyesters and the like. Particular crystallizable, linear condensation polyesters are polyethylene terephthalate, polyethylene terephthalate/isophthalate (85/15), polyethylene terephthalate/5-(sodium sulfo)isophthalate usually in the range of 96/4 to 99/1 mol percent, but preferably 98/2, poly(p-hexahydroxylene terephthalate),

poly(diphenylolpropane isophthalate), poly(diphenylolpropane carbonate), the polyethylene naphthalene dicarboxylates (especially those derived from the 2,6- and 2,7-isomers) and poly(m-phenylene isophthalate).

Each filament may be composed of one material or of two or more different materials. However, weak filaments such as the usual textile counts of cellulose acetate and cellulose triacetate are not satisfactory materials for this invention.

Processing Equipment

Yarns may be spun (extruded) on one machine, then drawn and interlaced on another. The drawing and interlacing may be accomplished on draw twisters, draw winders or warp draw machines. The yarn may also be spun and drawn on one set of equipment, and then interlaced on a separate winder as an independent operation. However, a preferred method which reduces production costs is a continuous machine as described in FIGS. 5 and 7 for spinning, drawing, interlacing and winding yarn onto a package ready for shipment to the customer.

The preferred type of interlacing jet apparatus is one which has a self-centering action, as in the case of the jets of U.S. Pat. No. 3,115,691. Jets having dimensions listed in Table I were used in making the majority of the yarns of the present invention which are illustrated in the Examples.

TABLE I

(Figure Numbers and Reference Numbers Apply to U.S. Pat. No. 3,115,691)

Jet Type	A	B
Orifices		
Number per yarn	2	2
Diameter, inches	0.035 (0.89 mm)	0.035 (0.89 mm)
Air Impingement, Degrees (Angle β FIG. IV)	90	60
Distance between Hole Centers (measured at surface of Plate 12, FIG. III), inches	0.10 (2.54 mm)	0.10 (2.54 mm)
Hole Intersection, degrees (Angle α FIG. III projected on a plane perpendicular to the yarn)	90	90
Surface (12)	Aluminum Oxide	Uncoated Metal
Striker Plate Surface (5, FIG. IV)	Aluminum Oxide	Aluminum Oxide
Orifice to Striker Plate, (W) In.	0.030 (0.76 mm)	0.030 (0.76 mm)

Process Conditions

It has been found that a number of process conditions must be closely controlled in order that the yarn produced may be sufficiently cohesive, uniform and retentive of interlace. Yarn speed, air pressure, amount of finish on yarn and yarn tension at the interlacing jet must be optimized and maintained at a uniform level. Jets should be clean and preferably be of a type which do not collect deposits of finish or other material which may interfere with the interlacing operation. The yarn itself should be substantially free from monomer or other foreign matter at the time it is interlaced. The interlacing fluid must be free of dirt or oils which can deposit on the walls of the fluid passages and change their flow characteristics. The filaments approaching the interlacing zone should be uniform along their length in mechanical properties, denier and cross-sectional shape. Yarns must be guided uniformly through zones of equal interlacing effect. All yarn guiding surfaces must be kept clean and of uniform surface roughness, particularly those which follow the interlacing operation.

The threadline should be stabilized after leaving the jet to prevent shaking out interlace. A coanda may be used at the point where the yarn enters or leaves the jet to direct the exiting air flow away from the yarn line.

Air pressure must be between 50 and 150 pounds per square inch gage (psig.) (3.5 – 10.5 kg./cm.^{2} gage), and preferably between 60 and 100 psig. (4.2 – 7.0 kg./cm^2 gage) for the jet types described above in order to make the product of this invention. When operating within the preferred pressure range, the interlace level is relatively insensitive to tension fluctuations. Preferably the yarn tension in the jet is between 0.1 and 0.4 gm./den., finish on yarn at jet is between 0.3 and 3.0% nonvolatiles by weight, yarns are aligned accurately on center of the jet for the tandem arrangement, or are arranged so the yarn center line is midway between the two parallel plates in the fanning arrangement illustrated in FIG. 6. If a type of jet is employed wherein the zone of uniform interlacing action is not at the center, the yarn should be maintained in the zone of uniform action by suitable guides, high tension or other means. False twisting must be avoided so that there is no fluctuation in the freedom of filaments to separate and interlace at the jet.

The tension on the yarn is more than sufficient to prevent the yarn from escaping from the zone of uniform interlacing and prevent slackness and the development of loops, crimps or coils in the yarn due to the fluid action.

Because the jet apparatus of U.S. Pat. No. 3,115,691 has a self-centering action tending to force the yarn toward the center of the jet, the interlacing action appears to be intensified when the yarn is forcibly pulled toward one or the other of the intersecting air streams. Therefore, the arrangement shown in FIG. 6 was found to give yarn of tighter cohesion. It should be noted that the pair of pins 58 permit only a small amount of motion to the yarn line while the traversing action of the windup moves the yarn a much larger amount; therefore, the yarn in the interlacing zone runs a majority of its time toward one extremity or the other of its motion and crosses the center line during a relatively smaller portion of the total cycle time. However, as the yarn traverses on the package, the tension normally rises as the yarn approaches the ends of the package because it has to travel a greater distance. This higher tension would inhibit interlacing to some degree if the yarn remained in a zone of constant interlacing energy, but by moving the yarn into a zone of more intense interlacing action, the effect of the higher tension is largely or completely offset, thus giving interlace which is relatively unaffected by the traverse cycle.

On the other hand, uniform interlace may be produced if tension fluctuations are reduced or eliminated. In the case of the arrangement shown in FIG. 6, pins 58 tend to reduce the magnitude of the tension fluctuations as measured at the jet by snubbing the yarn. When the jets are located above the secondary finish roll in position 35 of FIG. 5 or position 99 of FIG. 7, the drag of the yarn on the finish roll dampens tension fluctuations. Tension may be made almost completely uniform if one or more driven rolls is interposed between the interlacing apparatus and the windup.

Two interlacing jets in tandem may be used in position 35 of FIG. 5 or position 99 of FIG. 7 where the yarn is not traversed by the windup. In this case, the yarn is guided constantly into the center of the jet apparatus where it is subjected to the dampened fluctuating tension described above. However, the two jets cooperate to produce interlace of degree and uniformity which can-not simply be obtained by using more air in a single jet. While the preferred type of jet keep the yarn generally centered between the two fluid streams, the turbulence is unstable and continuously moves the yarn back and forth between the two streams. Thus, the threadline oscillation produced by one jet acts to traverse the yarn between the orifices of the other jet in a somewhat similar manner to the action of the windup traverse but at a much higher frequency. Guides should not be placed between the two jets in a way which eliminates the traversing action. Tandem jets should not be located so close together that the air exhausting from one disrupts the interlacing or centering action of the other. Tandem jets may be used in position 37 of FIG. 5 or position 49 of FIG. 7.

Materials known as finishes are applied to yarns of this invention before and/or after interlacing at two or more locations. It has been found that the amount and uniformity of the finish applied to the yarn before it enters the interlacing jet has a distinct influence on the degree and uniformity of the interlace which the yarn displays immediately after interlacing and on the retention of interlace through processing. In view of this, the uniformity of application of the finish can be seen to have a large effect on the uniformity of the interlace produced. Either too much or too little finish, therefore, is to be avoided. Finish which is or may be applied after interlacing also has an affect on the interlace since the purposes of this additional finish are to lubricate the yarn surface and reduce abrasion and to improve the interlace retention. Varying application of this secondary finish can, therefore, cause nonuniform abrasion of the yarn in subsequent handling and nonuniform loss of interlace. Furthermore, the uniformity of the interlace can affect the uniformity of the secondary pick-up because yarn having different degrees of interlace will pick up varying amounts of secondary finish and such finish will be distributed on the yarn depending on the degree of interlace.

Among many methods which may be employed to improve the uniformity of finish application, a preferred one used to make most of the yarns of the examples is to dilute the finish solution and run the finish rolls faster than normal so that the finish will coat all areas of the strand more uniformly while applying the desired amount of or concentration of non-volatiles on the yarn. For example, prior art commercial yarns were made with finish concentrations of 12–20 percent whereas concentrations of 2–10 percent are used in the present examples. The term "nonvolatiles" is defined as materials which are not appreciably volatile at 105° C. and thus remain on the yarn after evaporation of the water or other medium in which they are applied.

Certain types of finishes are preferable for retaining interlace. Certain ones reduce the friction between the yarn and guides and between yarn and other yarn, thus reducing the force which tends to remove interlace and separate filaments from the yarn bundle. Other finishes increase the static coefficient of friction between filaments of a given yarn bundle so that they are less likely to slide over each other as they must do in losing interlace. Still other materials may bond the filaments lightly together but in such a way that the yarn bundle cross section may change shape and conform to the weave of the fabric and the yarns are not substantially stiffened by the finish. Materials which have a high viscosity when dry may be useful. Materials having a high degree of thixotropy may give a desirable combination of high static friction but low dynamic friction. Waxes have high viscosity between filaments but give low dynamic friction and good resistance to abrasion in the loom during weaving.

The composition of some types of finishes used in the examples are shown in Table II; volatile components of finish solutions are not included.

TABLE II

Finish Compositions

Type K	
Isocetyl Stearate	49.0%
Sodium bis 2 ethylhexyl sulfosuccinate	24.5
3 mole ethylene oxide condensate of stearyl alcohol	24.5
Triethanolamine	1.0
Oleic acid	1.0
Total:	100.0%
Type L	
Triethanolamine	3.4%
Oleic Acid	8.2
Sulfated peanut glycerides (80%)	20.5
Diethylene glycol	1.8
45% potassium hydroxide	1.8
Butyl stearate	62.6
Dowicide I (orthophenyl phenol)	1.7
Total:	100.0%
Type P	
Butyl stearate	74.7%
POE sorbitol hexaoleate	3.9
Fatty acid esters of higher polyglycols	8.1
Oleic Acid	2.3
Mono- and di-oleyl acid orthophosphates	7.4
45% KOH	3.6
Total:	100.0%
Type Q	
Polyethylene Glycol Diester	70.0%
Fatty acid esters of higher polyglycols 30.0	
Total:	100.0%
Type R	
Type P (on dry basis)	60%
Polyacrylic acid (on dry basis)	40%
Total:	100%
Type S	
Atlantic Wax 131 (a paraffin wax)	40.4%
Petrolite C-7500 (modified oxidized Fischer-Tropsch wax)	22.4
Alfonic 1618C-7 Nonionic (mixed 16–18 carbon primary alcohol ethoxylate)	22.4
18/15 (ethoxylate stearyl amine)	4.44
45% potassium hydroxide	0.36
Rhoplex V-336 (proprietary acrylic polymer dispersion	10.0
Total:	100.0%
Type T	
Yukon 75H9000 (copolymer of ethylene oxide and propylene oxide)	97.0%

Igepal C0630 (ethoxylated [9–10 mols] nonylphenol condensate)	3.0
Total:	100.0%
Type U	
45% potassium hydroxide	0.36%
Atlantic Wax 131 (a paraffin wax)	40.4
Petrolite C-7500 (modified oxidized Fisher-Tropsch wax)	22.4
Alfonic 1618C-7 Nonionic (mixed 16–18 carbon primary alcohol ethoxylate)	22.4
Ethomeen 18/15 (ethoxylate stearyl amine)	4.44
Rhoplex AC-201 (proprietary acrylic [100%] polymer dispersion)	10.0
Total:	100.0%
Type V	
45% potassium hydroxide	0.38%
Atlantic Wax 131 (a paraffin wax)	31.5
Petrolite C-7500 (modified oxidized Fischer-Tropsch wax)	15.71
Alfonic 1618C-7 Nonionic (mixed 16–18 carbon primary alcohol ethoxylate)	36.7
Ethomeen 18/15 (ethoxylate stearyl amine)	5.21
Rhoplex AC-201 (proprietary acrylic]100%] polymer dispersion)	10.5
Total:	100.0%
Type W	
Type L (20%)	60.0%
Polyfilm 321 (Proprietary acrylic polymer dispersion) (20%)	40.0
Total:	100.0%
Type X	
Type L (20%)	40.0%
Polyfilm 321 (Proprietary acrylic polymer dispersion) (20%) 40.0	
TLF-3045 antistat (ethoxylated Tallow amine quaternary)	20.0
Total:	100.0%

After-treatment

When weaving is completed, the fabric is scoured to remove normal yarn finish, size, afterwax, etc., and accumulated handling dirt. It is at this stage that the fabric finisher obtains his saving from the use of non-sized interlaced warp yarns. The fabrics may be dyed and scoured simultaneously.

Some yarns of the present invention may be sufficiently uniform to weave satisfactorily and yet may have a nonuniform or flashy appearance in certain fabric constructions. Several techniques used by commercial dyers may be used to minimize flashes and improve fabric uniformity. These include employing leveling type dyes, specially serrated "log rolls" in the dye bath which "work" the filaments in the fabric to remove interlace nodes, and caustic presoaks and caustic scouring procedures which also "work" the filaments in the fabric

Yarn Product

The product of this invention is a continuous filament yarn in which the filaments are interlaced to form a coherent structure, the filaments making some small angle with the filament bundle axis. A tightly-interlaced region may be analogous to a hair braid except that the number of filaments in the participating groups will vary. Individual filaments and groups of filaments may be randomly entangled with adjacent filaments and groups of filaments almost continuously along the length of the yarn, but more frequently the interlace is of a "periodic" type in which a region of tight entanglement is followed by a region of little or no entanglement in which the filaments are substantially parallel to the yarn axis and are not held together in this region. For either the continuous or periodic type of interlace to be satisfactory for weaving without size, the coherency must be such that when a pin is inserted in the yarn as described hereinafter the yarn line will not split for any substantial distance before encountering a region of tight entanglement. If entangled regions are not uniformly present at sufficient frequency, long sections of filaments can easily be pulled out of the bundle by the transverse motion of the shuttle. Furthermore, the interlace must be sufficiently permanent to prevent the yarn from losing substantial coherency during weaving so that filaments do not become free to be snagged and broken by the loom.

More uniform coherence is required for weaker filaments, and filaments of some materials are so weak that interlacing for satisfactory weaving without size is impractical. For example, cellulose acetate yarns having interlace measurements and freedom from loops or broken filaments within the apparently acceptable range for products of this invention produced so many broken filaments during weaving attempts as to be rated inoperable. It has been found that at least 50 percent of the filaments in a strand must have a tenacity of 2.0 grams per denier or more to be suitable for this invention.

Yarns which develop loops during processing and weaving, for instance, under alternate stretching and relaxing, are not suitable. A mixed yarn of cellulose triacetate filaments and nylon filaments is one such material.

An interlaced yarn of this invention has lower running friction than interlaced yarns of the prior art because of less guide-to-yarn contact due to the tighter, rounder bundle shape and the rougher bundle surface configuration contributed by the interlace. The more entangled the yarn is, and the closer together such entanglements become, the lower the friction. Yarns with preferred finishes have particularly low and uniform friction as shown by the Package Delivery Tension Test to be described subsequently. On the other hand, if a yarn had a substantial section without any interlace, the friction of this section would be higher and this would contribute to pulling and snagging of filaments. A low denier yarn of few filaments, where frequent entanglements are more difficult to produce, is likely to have worse performance than a large denier yarn with many filaments, where the statistical probability of entanglements is much higher. On the other hand, more filaments do not necessarily insure good weaving performance if the denier per filament and, therefore, the filament strength is reduced. It has been found that yarns which contain slack or loopy filaments are much more likely to have such filaments pulled and broken than yarns which do not. This invention is limited to yarns normally used for textile weaving. Denier per filament may range from 1–10 and filament bundle denier preferably ranges from 20–250, but may be as high as 520.

The filaments must be continuous; staple yarns are excluded. The feed yarns must have zero-twist or degrees of "producer twist" less than 1 t.p.i. (39.4 turns per meter) at the time they are interlaced. Filaments of more than one material may be combined either by spinning the different materials simultaneously and combining them into one yarn, or by combining filaments of two or more different materials by taking previously prepared yarns off packages. Filaments of one or more materials may be separated into groups so that a portion of the bundle has a different treatment from the rest and the components may then be intermingled and interlaced into a single bundle. In the case of mixed or combination yarns, the minor com-

ponent may be a single monofilament. Such yarns must be produced so that all filaments are at approximately equal tension, because a low tension component would tend to protrude from the filament bundle as loops when tension is released. In addition, the elasticity of the components must be such that one component is not stretched beyond its elastic limits by normal processing tensions, since that would cause the yarn to become loopy during weaving.

The filament cross section may be round or non-round. Certain filament cross sections may be particularly suitable for this invention in that they reduce friction between the yarn and loom, or in that they permit filaments of a given bundle to lock together so that interlace is retained well.

Products of this invention provide woven fabric of high quality. The warp ends maintain a relatively uniform spacing from each other because the filament bundle is not stiffened by size and the filaments are free to rearrange themselves as the fabric construction requires, which is not true of slasher sized yarns. In addition, the bending behavior of the warp yarn is relatively uniform along the ends, which is not true of highly interlaced yarns which have been sized at conventional size levels. As a result of this greater compliance, the interlaced warp yarns disclosed herein produce fabrics whose uniformity to the eye is equal to or better than that of the finest quality fabrics made with sized yarns at similar luster levels, particularly expensive yarns having high twist in an attempt to produce round, uniform filament bundles.

Since freedom of the filament bundle to bend and deform is a key to the improved fabric appearance obtainable by means of this invention, it follows that many of the benefits can be obtained by particular combinations of important factors. For example, the performance of yarns having interlace properties which are not quite satisfactory for use in shuttle looms without size can be made acceptable by adding a very small amount of conventional size or other adhesive which is deposited mostly on the bundle surface and thus does not stiffen the yarn appreciably, but which helps to improve the cohesion (sticking together) between the surface filaments. Elastic size or cohesive finish can have the same effect, whether concentrated near the bundle surface or impregnated through the bundle. Materials which form gels instead of solid or liquid films are also useful. Treatments which generally reduce friction between the yarn and the loom parts improve weavability. When yarn is to be treated by the addition of only small amounts of size or wax which may be dried rapidly, the yarn producer can apply such materials during the spinning, drawing and interlacing process, thus eliminating the need for any twisting or slashing operation by the customer. Alternatively, the customer can apply small amounts of such materials at greatly increased slashing speeds.

In addition to the effects which various finish types may have on the yarn performance in the loom, ingredients which increase the static friction between filaments but still have low dynamic friction with textile machinery can improve the interlace which a yarn obtains at the interlacing operation and retains during subsequent processing operations, if the finish is applied either before or immediately after the interlacing jet. Any treatment which reduces friction between yarn and loom parts or other yarn can reduce loom damage to yarns, and such treatments may include modifications of the filament compositions or surface configuration as well as topical applications.

Finishes which form brittle films are unsatisfactory because the flexing which they receive in the loom destroys the cohesion prematurely. Certain preferred finishes which are satisfactory in weaving at preferred mill conditions of at least 72° F. and 65 percent relative humidity may be unsatisfactory when woven at lower humidity. Finishes containing waxes have been found to be less sensitive to varying humidity and are, therefore, preferred for use at mills lacking humidity control. The yarn tests described hereinafter should preferably be performed at 72° F. and 65 percent relative humidity reduce errors.

Although this invention is primarily concerned with providing that combination of properties which is necessary for making a yarn suitable for direct weaving without size in shuttle looms, the interlaced yarn product is also particularly suitable for use as the warp of water jet looms. Such looms are rapidly coming into use because of their higher operating speeds and greater simplicity of operations than shuttle looms. However, when sized warps are used in these looms, the water used to propel the filling yarn softens the size and then, if the looms stop for any appreciable length of time, the size can dry again, fixing the warp yarns in their configurations at time of stoppage. When the loom starts again, the ends are found to be distorted at the point of stoppage, and adhesions between ends must be broken. An undesirable difference can be seen between the fabric woven before and after a stoppage which persists until the warp ends have become uniformly soft again. Stopping a loom using unsized interlaced warps creates no adhesion or variations in the yarn stiffness.

Since a water jet loom, having no shuttle, abrades the warp yarn less than does a shuttle loom, yarns with somewhat lesser degrees of interlace coherency uniformity and interlace retention can be used without size with the water jet loom than with the shuttle loom for equivalent performance. On the other hand, the same degree of interlace as that suitable for shuttle-loom warps can be used for obtaining maximum water jet loom performance and fabric quality.

Water jet looms may provide flash-free fabric without special scouring and dyeing procedures. It is believed that when the warp yarn is wet by the water jet, the interlace nodes are reduced in intensity due to the working of the heddles (healds) as the shed reverses.

A highly interlaced yarn of this invention can be used to replace 5-tpi true-twist yarn in the filling of a fabric where twisted warp and filling are normally needed to prevent raveling of the edges of the fabric when it is cut into complex shapes for shoe linings. The interlace gives satisfactory resistance to raveling. Where filling flashes are unacceptable, they may be masked by using spun staple warp yarns, or by constructing warp face satins.

Products of this invention also improve warp knitting performance, more than doubling the quantity of fabric made between yarn breaks. They may also replace

highly twisted yarn in Raschel knitting and Leavers lace. Products of this invention further reduce costs of mill processes by permitting higher running speeds during beaming and rebeaming, because of reduced damage provided by the greater coherency and uniformity.

YARN TESTING PROCEDURES

Filament Strength and Tenacity

Tensile properties are determined in conventional manner, using an Instron Tester or equivalent equipment. Average filament strength is defined as equal to the measured bundle breaking strength (B) divided by the number of filaments (N). The average filament strength determined in this manner is usually lower than that derived from breaking individual filaments because the weakest filaments in a bundle determine the bundle failure point. It is these same weakest filaments which initiate weaving defects.

Compactness

For the purpose of this invention a compact yarn is defined as one whose diameter when measured at a tension of 0.1 gpd is no less than 90 percent of its bundle diameter when measured at 0.01 gpd tension. After first removing and discarding the outer wraps of a yarn package, approximately 1 yard of yarn is cut from the package and attached to the yarn clamp at the digital counter end of a Suter Twist Counter. The movable yarn clamp assembly is removed and the other end of the yarn is then strung under and over the two pulleys and a weight is attached sufficient to provide a load of 0.01 gpd tension in the yarn sample between the clamp and the first pulley. If the yarn contains twist, the twist is reduced to zero. The diameter of the yarn bundle is then measured at 10 consecutive 1-inch points beginning 5 inches away from the Twist Counter clamp, using a microscope with 3.5× objective lens and calibrated eye piece (e.g., 12.5× Filar Micrometer). The yarn is then loaded sufficiently to produce 0.1 gpd tension and the diameter measurement is repeated. Compactness (in percent) is then computed from the ratio of average diameter at 0.1 gpd divided by the average diameter at 0.01 gpd multiplied by 100. If this value is less than 90 percent the sample is outside the scope of this invention.

Backwinding Test for Interlace Retention

Experience with handling interlaced yarns has shown that a disc tensioner has a fairly severe effect on properties of the yarns, tending to comb out interlace, and that interlace measurements measurements after backwinding through a disc tensioner can provide a highly significant indication of the behavior of yarns in warp weaving. Disc tensioners are normally used when yarn is taken off the package in a creel to form a beam for warping. The reed in the loom has a somewhat similar effect. Therefore, the equipment shown in FIG. 9 (a disc tensioner made by the Cocker Manufacturing Co., U.S. Pat No. 2,581,142) is used to work the yarn as the test of interlace retention. Yarn **84** is taken over-end from package **85**, mounted horizontally back of disc tensioner assembly **86** which is made by the Cocker Manufacturing Company. The yarn passes through guide hole **87**, around matte surfaced pin **88**, and between matte surfaced discs **89**. It then passes around matte surfaced pin **90** and between matte surfaced discs **91**. Disc mounting assembly **92** is positioned in the fourth stop away from and including hole **93**. Weights are added to discs **89** and **91** equally to attain a yarn tension of 0.3 gm./den. in the yarn as it leaves the second disc **91**. The yarn passes through hole guide **94** and over freely rotating roll **95** to the tension control roller **96** of a Leesona Model 959 winder, which winds the yarn onto a paper tube 3⅛ inches outside diameter by 11½ inches long (7.93 × 29.2 cm.). The winder is set to run at a constant speed of 400 yards per minute (366 meters per minute).

The yarn interlace is evaluated by making APDC measurements (described below) before and after backwinding the yarn. Percent interlace retention is defined as $(\overline{X}/\overline{X}')$ (100), where $\overline{X}$ and $\overline{X}'$ are the average APDC readings before and after backwinding.

APDC Evaluation of Yarn Structure

The Automatic Pin Drop Counter (APDC), disclosed in FIG. **8** and the description thereof, is used to evaluate the interlaced structure of the yarn. Several modifications of the basic instrument of Hitt U.S. Pat. No. 3,290,932 were made to provide the precision of measurement required. Hysteresis brake **62** is adjusted to give a tension of 10 ±1 gram between the needle holder assembly **65** and the drive roll **67**. Weight **75** on the pivoted needle is set to give 8 ±0.5 gram interlace entanglement force required to tilt the needle holder assembly. Disc **81** has 100 holes and drive roll **67** has a circumference of 100 mm. so that photocell **82** receives 1 pulse for every millimeter travel of the yarn, which travels at the rate of 250 centimeters per minute. The amount of movement of the needle required to interrupt the light from light 77 is 0.5 to 1.0 mm. The yarn travels 7.5 cm. between the point where the needle retracts from the filament bundle and the needle inserts to start the next measurement. The operator records 100 readings (X) for each yarn sample and averages them to obtain $\overline{X}$ expressed in centimeters. The standard deviation (σ) of the readings is calculated by the formula,

$$\sigma = \sqrt{\frac{\Sigma X^2}{N} - \left[\frac{\Sigma X}{N}\right]^2}$$

where N is the number of readings. The per cent coefficient of variation (CV) is calculated as $(\sigma\overline{X})$ **100**). Values for yarn which has been backwound are designated $\overline{X}'$, σ' and CV'.

As a result of extensive weaving experiments, conducted as illustrated in the examples, it has been found that yarns which weave well without size have interlaced structures characterized by low values for the sum of $\overline{X}'$ and σ' after backwinding, as described in the test for interlace retention, and that lower values are required with decreasing filament strength, i.e., for such yarns $\overline{X}' + \sigma'$ is less than 0.17 (B/N) + 4.0, where B is the breaking strength of the yarn in grams and N is the number of filaments.

Defect Analyzer Test

the quality of yarns is usually monitored during beaming operations to detect defective yarn ends that would cause unsatisfactory weaving performance. A widely used instrument is the Lindly defect analyzer, which projects a light beam across all of the warp yarns in the plane of the warp sheet and receives the light

beam on the opposite side of the warp in a photoelectric cell. Broken filaments or other defects projecting from the warp will reduce the intensity of light reaching the photoelectric cell. The instrument can be arranged either to register such defects on a counter or to stop the warper so that defects can be removed. For the present test a Lindly defect analyzer (1000 series) is set so that a 6 percent change in light intensity, caused by yarn defects, is registered on a counter. The number of defects per million end yards (MEY) is calculated by dividing the number of defects by the number of end yards monitored (expressed in millions). "End Yards" is the product of the number of yarns (ends) being monitored multiplied by the number of yards.

Yarn Inspection

Visual inspection methods are used by yarn producers to reject yarns having defects which would later be caught by the above defect analyzer. Packages of yarn ready for shipment to a customer are inspected visually under a bright light against a dark background. The entire outer circumference and ends of the package are inspected for protruding filaments. The package is rejected if more than three such defects per **10**-pound package can be seen with unaided eyes by an operator having average eyesight.

The presence of inherent loopiness or slack filaments which could result in defects when the yarn is subjected to alternate tensioning and relaxing, during processing by the customer, may be detected by the following inspection: After the outer wraps have been stripped from a yarn package to eliminate handling defects, a section of yarn approximately 1 yard long is cut and one end is attached to the yarn clamp at the digital counter end of a Suter twist counter. The movable yarn clamp assembly is removed and the other end of the yarn is then placed under and over the two pulleys at its opposite end and sufficient weight is attached to the free end hanging vertically to provide a load of 0.01 gpd. Caution should be exercised to overcome pulley friction to insure that the yarn load is distributed to the zone to be examined. The yarn is examined at 5 to 10× magnification for filaments or groups of filaments projecting from the bundle surface more than one bundle diameter. The diameter measurement to be used is the diameter determined at 0.01 gpd tension as in the compactness test. If more than one projecting filament is detected within a 20-inch region of the section between the clamp and the first pulley, the yarn is rejected for inherent loops. If only one loop is observed, additional lengths of yarn should be inspected and tested for compactness. A microphotographic montage of the sample is helpful for comparative studies.

Package Delivery Tension Measurement

Yarn **101** (FIG. **10**) is advanced vertically from package **102** to matte finished, chrome plated pigtail guide **103** where it takes a 90° turn, passes through matte finished chrome plated pigtail guide **104**, takes a 360° wrap on alsimag pin **106** which is 0.3243 inch in diameter with an AA roughness of 36 micro-inches and a coefficient of friction of 0.23 and is skewed just sufficiently so that the yarn as it exits the pin does not run against the yarn entering onto the pin. Coefficient of friction is determined on a "Shirley" General Purpose Yarn Friction Tester with 150—34—R02–56 Dacron yarn at 225 ypm yarn speed and 10 grams feed tension. The yarn then passes through matte finish, chrome plated pigtail guide **105** where it takes a break angle approximately 65° to go to rolling nylon guide **107** which has a friction bearing. The yarn as it leaves rolling guide **107** takes a vertical path downward and passes around rolling nylon guide **108** equipped with a low friction bearing and attached to strain gauge **110**. The yarn leaving guide **108** takes a vertical path up to rolling nylon guide **109** also equipped with a low friction bearing where it turns 90° and advances to polished chrome puller roll **111** (2.3 inch diameter) and its attendant separator roll **112** where five wraps are taken. The yarn then goes to waste through aspirating jet **113**. The output of the strain gauge **110**, which measures the yarn tension, is fed to an amplifier and strip-chart recorder **114**. (The instrument is calibrated by attaching a thread to pigtail guide **105** passing it over guide **107** under guide **108** up over guide **109** and hanging an appropriate weight on the thread.) Puller roll **111** is driven to give a surface speed of 400 ypm. The instrument is housed in a room where the temperature is controlled at 72° F. and the relative humidity is controlled at 65 percent. Yarn must be kept at these conditions for at least 16 hours before testing.

Testing is accomplished by running yarn through the instrument at 400 ypm and recording the yarn tension for 10 minutes after the tension trace levels out. In most cases, the tension will drop during the first 5 to 10 minutes as the pin is coming to temperature equilibrium and this first part of the trace is ignored in making the package delivery tension measurement. A transparent straight edge is used to mark the average tension of the last 10 inch flat portion of the trace and this is taken as the package delivery tension.

Flexure Test for Interlace Permanence

Yarn interlace permanence (resistance to loss of interlace caused by flexing and abrasion) is measured on an apparatus as shown in FIGS. **11** and **12**. The initial level of interlace is determined in the following manner. Yarn **115** is attached to clamp **116**, passed over low friction pulley **117** and attached to a free hanging weight **118** of 5.6 grams. The number of interlace nodes in a 15-inch length of yarn (yarn length **119** in the drawing) are counted by inserting a pin in the yarn at point **120** and moving it toward point **121** until an interlace node causes the weight **118** to move upward. The pin is then removed, moved one-fourth inch towards point **121**, reinserted in the yarn and moved towards point **121** until another interlace node is encountered. The total number of nodes encountered between points **120** and **121** is recorded. This operation is repeated on four additional pieces of yarn to get an average number of interlace nodes per 15 inch section. The final level of interlace after flexing and abrading is determined in the following manner. A new piece of yarn **115** is attached to clamp **116**, threaded through steel pins **122** which have a diameter of 0.0540 to 0.0545 inch and a coefficient of friction of 0.18 to 0.19 when tested on a "Shirley" General Purpose Yarn Friction Tester using 150–34—R02–56 Dacron yarn with a feed tension of 10 grams and a yarn speed of 225 ypm. The pins are centered on the vertices of an isoceles triangle having sides of 13/16 inch, and a base of 1-9/16 inches, arranged so that the yarn takes a path around pins **122** as shown in FIGS. **11** and **12**. The yarn then

passes over the low friction pulley **117** and is attached to weight **118**. The sliding member **123** to which the pins **122** are attached is then driven in a reciprocating motion with a stroke of approximately 23 inches so that it passes completely through points **120** and **121** during each traverse at a speed of 40 complete cycles (80 traverses) per minute. After the sliding member has made 20 complete cycles (40 traverses) it is stopped and the number of interlace nodes per 15 inches after flexing is determined with a pin as described above. This measurement is repeated an additional nine times to give an average number of interlace nodes after flexing. The Interlace Permanence is expressed as:

$$\text{Interlace permanence (\%)} = \frac{\text{Avg. nodes/15'' after flexing}}{\text{Avg. nodes/15'' before flexing}} \times 100$$

Test of Size or Finish Film Strength

Finishes may be distinguished from sizes by the following test. A sample of the material is poured onto polyethylene film, levelled to give a dry film approximately 0.015 cm. thick, and dried. The dry sample is removed from the polyethylene, a strip approximately 1 cm. wide and several centimeters long is cut from the sample, the exact film thickness is measured, and the strip is mounted between the jaws of a tensile testing machine with 1.26 cm. distance between the jaws at no load. A force-elongation determination is made at an extension rate of 2.54 cm. per minute. The results are converted into force (grams) per square cm. of sample cross-section vs. percent elongation. For the purposes of this invention, the force in gms./sq. cm. at 50 percent elongation is selected as a convenient single number to characterize a sample. Brittle sizes may break at 100 percent elongation or less at a high load. Certain finishes may not form a film which can be lifted off the polyethylene or may have such low tensile strength that the film breaks at low load and low elongation.

SPECIFIC ILLUSTRATIONS

The following Examples illustrate specific embodiments of this invention:

EXAMPLES

Apparatus for spin-drawing and interlacing yarn in a continuous process is set up as shown in FIG. 7. Polyethylene terephthalate having a relative viscosity of 26–28 and containing 0.3 percent titanium dioxide as a delustrant is melt spun into 34 round cross section filaments per yarn. Process conditions and yarn properties are shown in Table III. The interlace jet or jets are mounted inside an enclosure equipped with suitable guides to position the yarn in the jets for optimum interlacing.

Yarns of these Examples give Package Delivery Tension measurements of 10 grams or less and Interlace Permanence measurements of 45 percent or more, whereas yarns having conventional lubricating finishes give Package Delivery Tension measurements above 10 grams and Interlace Permanence measurements of 32 percent or less.

Yarns having Type W finish are found to be more susceptible to ambient humidity conditions than those having Types U, V, or X.

Yarns are beamed into warp without twist or size and are mounted on a Crompton-Knowles shuttle loom. Dacron yarn (70–34—R02—56) is used for filling. A 96 × 86 taffeta fabric sample **26** inches wide by 8 yards long is woven and the weaving performance of each yarn is evaluated.

TABLE III

Example	1	2	3	4	5
Yarn Denier (Final)	70.3	70	70	71	150
Finish applied at Roll (41)					
Type	K	K	K	K	K
Conc. (%)	9.0	3.9	3.9	3.9	8.0
Non-volatiles on yarn (%)	0.55	0.27	0.30	0.30	0.34
Feed Roll (42) speed (ypm)	874	857	857	891	768
draw jet (44) steam temp. (°C.)	200	185	185	185	220
Pressure (psig)	70	60	60	60	85
Draw Roll (46) speed (ypm	3200	3200	3200	3200	3000
Temperature (°C.)	116	113	112	113	120
Interlacing Jet – Type	B	B	B	B	A
	sin-gle	tan-dem	tan-dem	tan-dem	sin-gle
Location	99	99	99	99	49
Air pressure (psig)	91	~75	83	65	93
Tension at Interlacing (gms)	22	10	15	15	40 ± 2
Finish Applied at Roll (48)					
Type	S	V	W	X	U
Conc. (%)	10	10	10	10	10
Non-Volatiles on yarn (%)	0.41	0.77	0.95	0.94	0.46
Drive Roll (51)) speed (ypm)	~3150	3050	3145	3145	2904
Windup Traverse Cycles/min.	920	838	838	838	542
Yarn Tenacity (gpd)	4.1	4.4	4.1	3.9	4.1
Interlace Properties					
$\bar{X}$ (cm.) before backwinding	2.3	2.1	1.5	1.6	3.5
σ (cm.) before backwinding	0.91	1.05	0.65	0.70	2.02
CV before backwinding	0.40	0.49	0.43	0.42	0.59
$\bar{X}'$ (cm.) after backwinding	2.2	2.1	1.6	1.8	4.0
σ' (cm.) after backwinding	0.75	1.12	0.69	0.74	2.18
CV' after backwinding	0.34	0.53	0.45	0.43	0.54
Interlace Retention (%)	104	100	93	95	88
package delivery tension (gms)	6.0	6.7	~3.8	7.2	10.0
Interlace Permanence (%)	45	82	70	63	71
Weaving Performance	Ex-cel-lent	Ex-cel-lent	Ex-cel-lent	Ex-cel-lent	—

Polyhexamethylene adipamide yarns having a relative viscosity of about **40** and containing a nominal level of 0.5 percent titanium dioxide as delustrant are spun-drawn and interlaced on equipment shown schematically in FIG. **5** to form yarns of this invention. The tandem jets are in Position **35**. Processing conditions and yarn properties are shown in Table IV. The yarns are rebeamed onto 300 yard loom beams and woven into 96 × 86 taffeta fabric on two different types of commercial shuttle looms. Warp-caused stops with sized interlaced commercial warp yarn of the prior art are normally three stops per 100 yards of the Draper XD loom and seven stops per 100 yards on the Draper X–3 loom. The percentage following the finish type indicates the amount of finish non-volatiles in a water dispersion.

The interlace values tabulated represent determinations on 24 packages.

TABLE IV

Examples	6	7
Yarn denier	70	70
No. of filaments	34	34
Interlacing jets	B	B
Jet arrangement	Tandem	Tandem
Air pressure (psig.)	80	80
Primary finish		
Type	Q	T
Conc. (%)	8	2
Secondary Finish		
Type	Q	R
Conc. (%)	8	10
Yarn speed (ypm)	3500	3500

Yarn tension (after roll 36),g.	18		18	
Yarn tenacity (gpd)	5.2		5.2	
Yarn interlace				
$\overline{X}$ (cm.) before backwinding	2.12		2.06	
σ (cm.) before backwinding	.73		.62	
$\overline{X}'$ (cm.) after backwinding	2.19		2.15	
σ' (cm.) after backwinding	.75		.69	
$CV' = \sigma'/\overline{X}'$	0.34		0.32	
Interlace retention, %	97		96	
Package Delivery Tension	9.5		5.5	
Interlace Permanence (%)	47		85	
Weaving performance				
Loom type (Draper)	XD	X-3	XD	X-3
Weaving speed (picks/min.)	172	200	172	200
Warp-caused stops/100 yds.	1	4.5	4.5	5.5
Over-all weave rating	Excellent		Good	

I claim:

1. Compact interlaced yarn which weaves satisfactorily as warp in automatic shuttle looms without size or twist, the yarn consisting of interlaced continuous filaments treated with cohesive finish for retaining interlace during processing of the yarn on textile machinery, the interlace permanence being at least 40 percent in the flexure test for interlace permanence; the filaments being interlaced in a compact coherent structure characterized, when evaluated by the APDC test, by a value for $\overline{X}' + \sigma'$ in centimeters of less than 0.17 (B/N) + 4.0, where $\overline{X}'$ is the average of 100 APDC readings on a representative sample after backwinding, σ' is the standard deviation of the APDC readings, B is the breaking strength of the yarn in grams and N is the number of filaments; the yarn having a breaking strength of at least 4.0 N and at least 50 percent of the yarn filaments having strengths of at least 2.0 grams per denier.

2. Compact interlaced yarn as defined in claim 1 wherein the yarn is 20 – 250 denier and consists of at least seven filaments of 1 – 10 denier per filament.

3. Compact interlaced yarn as defined in claim 2 wherein the filaments are composed of polyethylene terephthalate.

4. Compact interlaced yarn as defined in claim 3 wherein the cohesive finish comprises paraffin wax, oxidized Fischer-Tropsch wax, 16 – 18 carbon primary alcohol ethoxylate, acrylic polymer, ethoxylate stearyl amine and potassium hydroxide.

5. Compact interlaced yarn as defined in claim 3 wherein the cohesive finish comprises acrylic polymer, butyl stearate, sulfated peanut glycerides, oleic acid, triethanol amine, diethylene glycol, orthophenyl phenol and potassium hydroxide.

6. Compact interlaced yarn as defined in claim 3 wherein the cohesive finish comprises acrylic polymer, butyl stearate, ethoxylated tallow amine quaternary, sulfated peanut glycerides, oleic acid, triethanolamine, diethylene glycol, orthophenyl phenol and potassium hydroxide.

7. Compact interlaced yarn as defined in claim 2 wherein the filaments are composed of polyhexamethyladipamide.

8. Compact interlaced yarn as defined in claim 7 wherein the cohesive finish comprises polyethylene glycol diester and fatty acid esters of higher polyglycols.

9. Compact interlaced yarn as defined in claim 7 wherein the cohesive finish comprises polyacrylic acid, butyl stearate, fatty acid esters of higher polyglycols, oleyl acid orthophosphates, polyoxyethylene sorbitol hexaoleate, oleic acid and potassium hydroxide.

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