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Lloyd

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[54] **METHODS AND APPARATUS FOR INTERLACING YARN**

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[52] **U.S. Cl.** **28/1.4;** 28/1.3; 28/72.12

[51] **Int. Cl.** **D02g 1/16**

[58] **Field of Search** ..... 28/1.3, 1.4, 72.12; 57/34 B, 157 F; 302/25, 63

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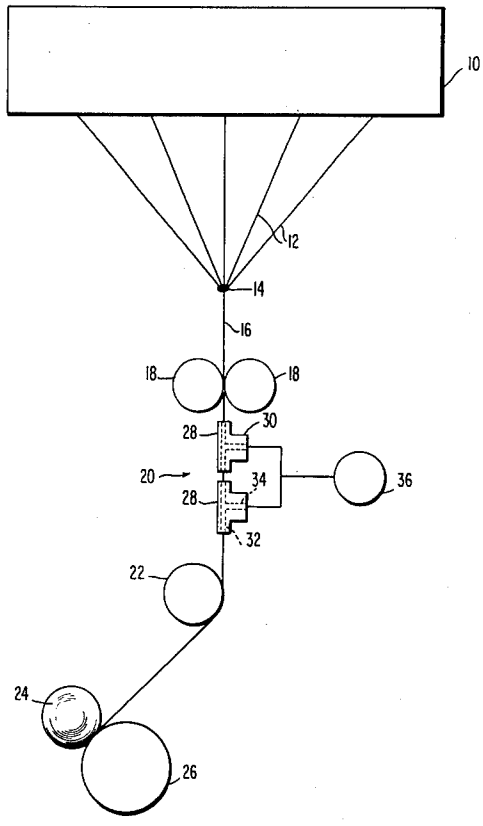
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[57] **ABSTRACT**

A multi-filament yarn bundle is compacted and interlaced by passing the bundle through a plurality of serially arranged processing bores. Each bore conducts oppositely directed flows of fluid which produce twin shock wave formations that are developed longitudinally relative to the bore axis. The shock waves extend completely across the path of travel of the yarn filaments such that the filaments pass through and continuously contact the shock wave formations and become substantially uniformly compacted and interlaced thereby. The fluid may shock out within the bore, beyond the bore, or within and beyond the bore. Yarn so produced exhibits minimal tie point frequency, e.g., as little as from one to two tie points per one hundred centimeters, while exhibiting requisite strength characteristics.

23 Claims, 5 Drawing Figures



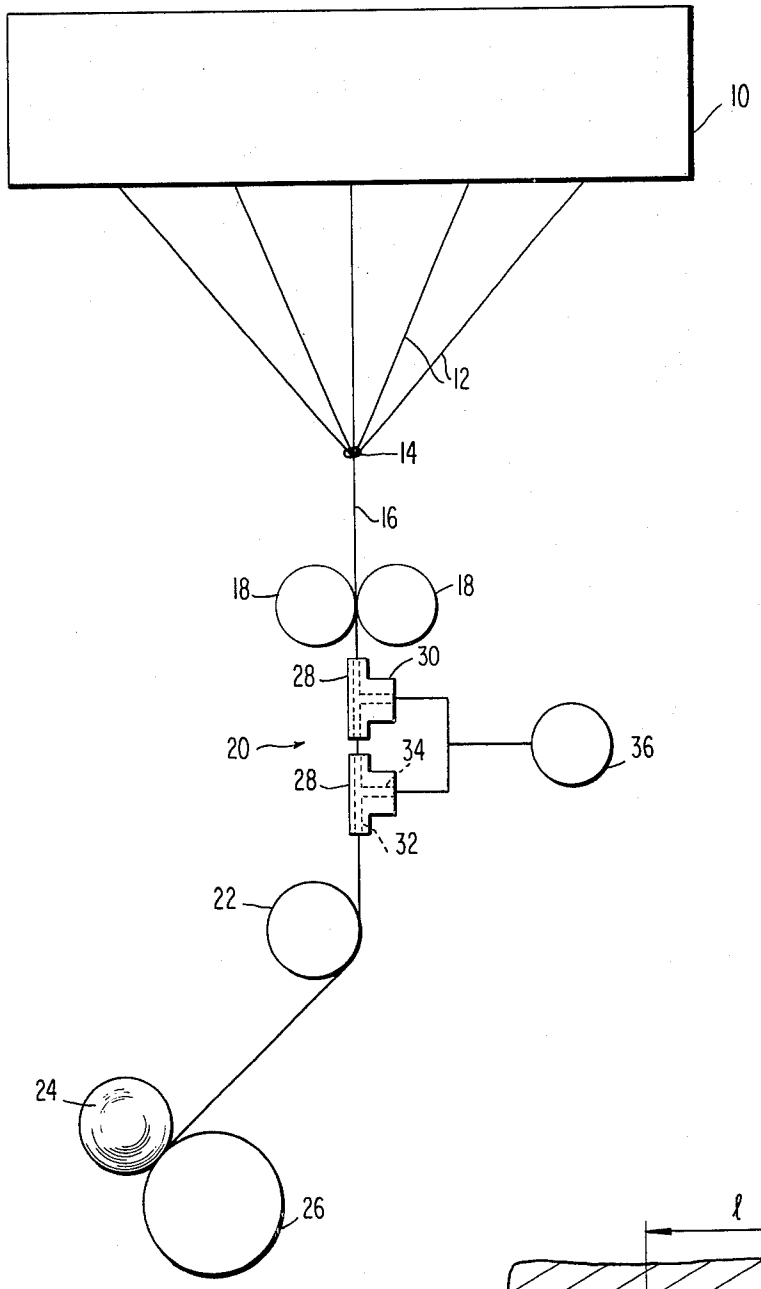


FIG. 1

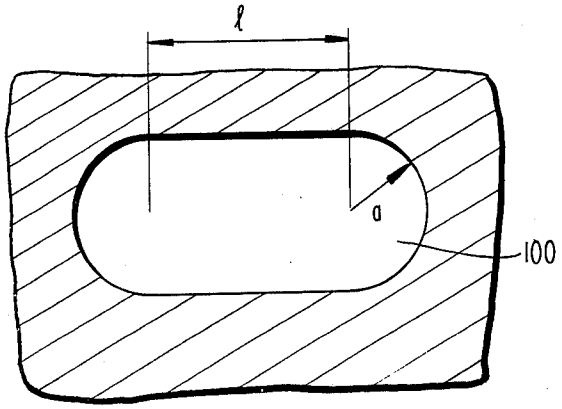


FIG. 5

FIG. 2

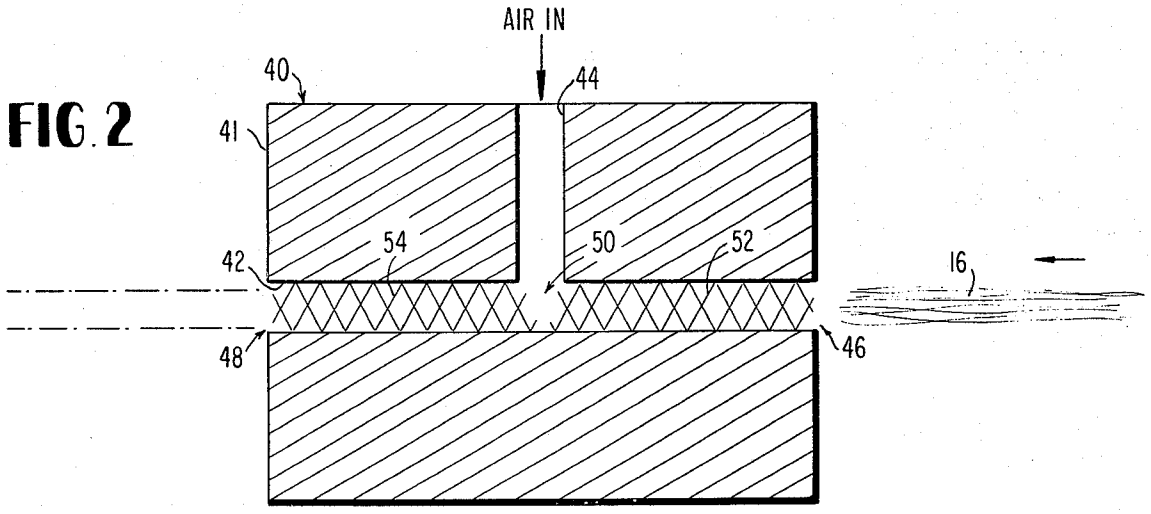


FIG. 3

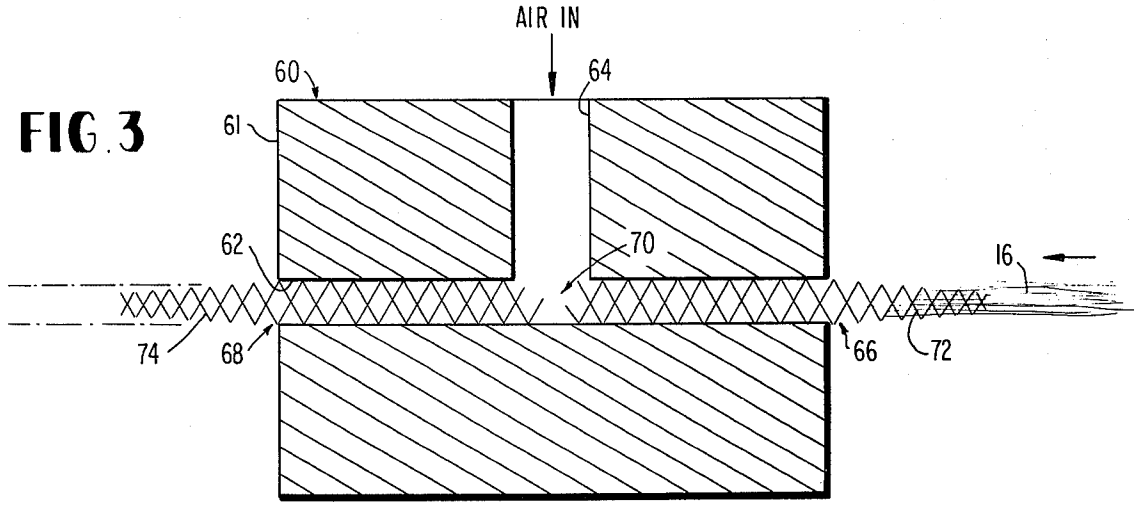
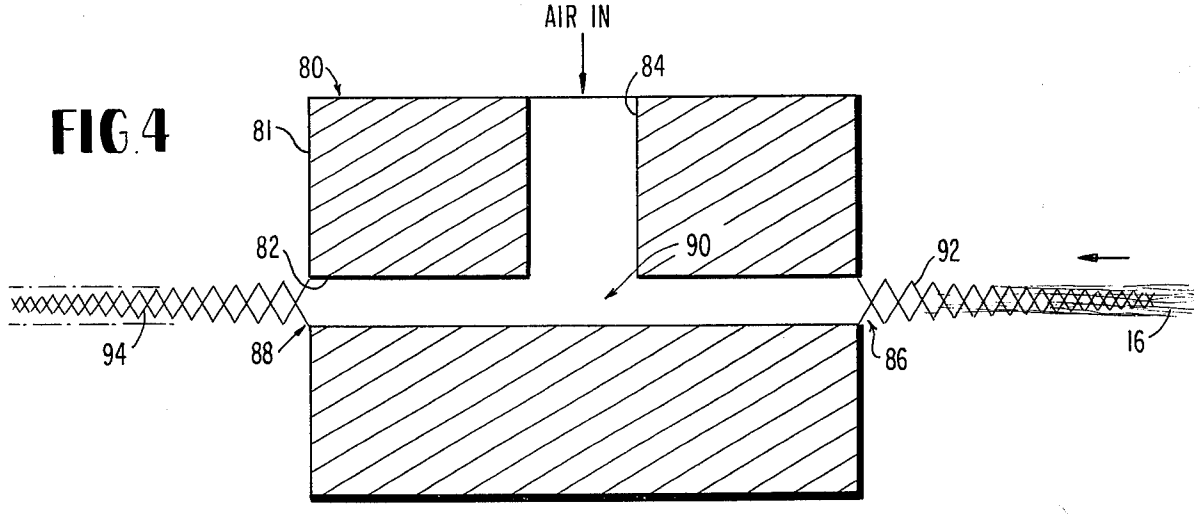


FIG. 4



METHODS AND APPARATUS FOR INTERLACING YARN

BACKGROUND AND OBJECTS OF THE INVENTION

This invention relates to fluid intermingling jets for multi-filament yarn and, more specifically, to fluid intermingling jets employing sonic velocities.

The production of multi-filament yarn by compacting and uniting a bundle of as-spun or zero twist filaments has long been practiced. It has heretofore been known to compact and unify the yarn filaments by a mechanical twisting and/or crimping operation which results in a more cohesive yarn structure that resists the pulling-out of individual yarn filaments. These twisting and crimping operations are expensive and time-consuming, however, and may often result in an overall reduction in yarn quality.

In order to obviate the necessity of twisting or crimping the filaments, fluid-interlacing operations have been proposed in which yarn filaments are compacted and united during passage through a turbulent flow of gas. Fluid interlacing operations of this type are disclosed in U.S. Pat. Nos. 2,985,995; 3,079,745; 3,110,151; 3,115,691; 3,220,082; 3,389,444; 3,364,537; 3,426,406; and 3,525,134. Basically, these patents discuss the production of fluid-interlaced continuous filament textile yarns by passing a continuous multi-filament yarn through a zone of very turbulent gas to cause the individual filaments to whip about rapidly and violently until the filaments become entangled.

The cohesiveness of the yarn is maintained by frictional forces between filaments that have become interlaced, entwined, and compacted together as a result of exposure to the turbulent fluid streams. This causes the yarn to retain its integrity as a compact bundle of filaments during subsequent processing operations such as beaming, coning, etc., followed by conventional slashing and weaving operations.

It is noted that yarn which has been tightly compacted by conventional fluid interlacing techniques may be characterized by the relatively frequent formation of "tie points" or "compaction nodes". These tie points may be described as of finite or definable limits which occur intermittently and randomly along the linear length of the yarn where the filaments are tightly interlaced, tightly compacted, and densely intermingled. While such tie points indicate a strong mechanical interlacing of the filaments, the relative high density of filaments at each tie point causes incident light to be reflected thereby in a manner different from those spans of the multifilament yarn that are not so tightly interlaced. It is such diverse reflective characteristics of the yarns which produce the phenomenon of "flashes" or "speckles" in fabric woven from such yarns.

Fluid interlacing techniques which make use of shock wave formations interacting with multi-filament yarn are proposed in U.S. Pat. No. 3,750,242, the disclosure of which being hereby incorporated by reference. As disclosed therein, a fluid stream traveling at sonic and/or supersonic velocities in fluid entry ducts expands and "shocks out" upon exhausting into a region of filament travel which is at lesser pressure than the exit plane pressure of the exhausting fluid. In this connection, highly pressurized compressible fluid, such as air, steam, nitrogen, or carbon dioxide may be introduced into a yarn processing bore through a lateral entry port.

Pressure conditions are such that the fluid, traveling at sonic or supersonic velocity at the entry port, shocks out to subsonic speeds in the yarn processing bore through a progressive series of alternating compression-rarefaction, oblique standing shock waves. This shock wave formation occurs at the junction of the fluid entry port and the yarn processing bore and is directed transversely across the yarn processing bore, i.e., the formation of standing shock waves is developed in a radial or tangential direction, relative to the axis of the bore. This shock wave formation assumes the general configuration of a miniature bayonet, as shown in the Schlieren photographs in FIGS. 4 through 7 of U.S. Pat. No. 3,750,242. Continuous filaments in the yarn bundle passing longitudinally through the yarn processing bore are displaced forwardly, backwardly and laterally relative to each other of the action of the shock waves. When the yarn emerges from the bore, it is highly compacted and interlaced.

While contributing significantly to the state of the art, the yarn interlacing techniques disclosed in U.S. Pat. No. 3,750,242, form tie points in the yarn, apparently through an interaction between the yarn and the shock waves as the yarn oscillates in and out of contact with the shock wave formation. Such intermittent contact is made possible because, as viewed in cross-section, the transversely developed shock wave formation in assuming the shape of a small bayonet, leaves space therearound into which the yarn may be intermittently urged. It is believed that the nonuniform application of fluid forces to the yarn filaments in the bore contributes to the relatively frequent formation of tie points at closely spaced intervals along the length of the yarn.

It is an object of the present invention to minimize or obviate problems of the type previously discussed.

It is another object of the invention to provide a non-twisted multifilament textile yarn, characterized by tightly compacted and interlaced filaments, which presents a substantially uniform density and appearance density throughout its length.

It is another object of the invention to provide such a yarn which is essentially free of intermittent, finite tie points.

It is still another object of the invention to provide novel fluid-interlacing methods and apparatus for the production of such yarn.

SUMMARY OF THE INVENTION

In accomplishing at least some of these objects, a continuous multifilament yarn is conducted through a yarn processing bore having a yarn inlet end and a yarn outlet end. Established within the bore are oppositely traveling fluid flows generating a plurality of shock wave formations. The development of the shock wave formations is such that shock waves extend completely across the path of travel of the yarn filaments so that filaments passing through the bore are in continuous contact with the shock wave formations. In this fashion, the filaments become substantially uniformly compacted and interlaced.

In one preferred aspect of this invention the shock wave formations, each in the form of a progressive series of alternating compression-rarefaction, oblique standing shock waves developed opposite, longitudinal directions relative to the bore axis, originate and terminate within the bore.

In another preferred aspect of the invention, the shock waves originate within the bore and extend beyond the yarn inlet and outlet ends thereof.

In a further preferred embodiment of the invention, the shock waves originate at the yarn inlet and outlet ends and extend outwardly therefrom.

THE DRAWING

The preferred embodiments of the apparatus of this invention are illustrated in the accompanying drawing in which:

FIG. 1 is a schematic view of an apparatus for producing interlaced yarn in accordance with the present invention,

FIG. 2 is a schematic view in longitudinal section, of one embodiment of a yarn interlacer unit in accordance with the present invention,

FIG. 3 is a schematic view in longitudinal section of another embodiment of a yarn interlacer unit in accordance with the present invention,

FIG. 4 is a schematic view in longitudinal section of yet another embodiment of the yarn interlacer unit in accordance with the present invention, and

FIG. 5 is a cross-sectional view of a fluid entry port which may be employed in the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

A conventional form of yarn spinning assembly, depicted schematically in FIG. 1 includes a spinneret housing 10 from which continuous yarn filaments 12 emanate. These filaments may be of cellulose acetate or triacetate, for example. The filaments pass through a guide 14 and are fed, in the form of a bundle 16, by a pair of nip rolls 18 to a fluid interlacer station 20. The interlacer station 20 may comprise a single interlacer unit 28 or a plurality of serially arranged interlacer units 28, the latter arrangement being preferred and depicted in FIG. 1. Each interlacer unit 28 functions to fluidly compact and interlace the yarn filaments as they pass therethrough. The yarn filaments subsequently travel over a feed roll 22 and are wound in a package 24 driven by a drive roll 26 in a conventional manner. Finishing agents may, if desired, be applied to the yarn at selected stages of the spinning operation.

The fluid interlacer unit 28 comprises a housing 30 which is provided with yarn process bore 32 extending therethrough. The bore 32 is aligned with the feed path of the continuous yarn filament bundle 16 and is preferably of constant cross-section. The continuous yarn bundle 16 is adapted to be fed through the bore 32 at a controlled rate by the nip rolls 18 and the feed roll 22.

A fluid entry passage or duct 34 in the member 30 communicates the yarn processing bore 32 with a source of pressurized compressible fluid, such as air for example. In this connection, a suitable pressurizing mechanism, such as an air compressor 36, for example may be fluidly connected with the duct 34.

The compressor 36 places the processing air under high pressure and this pressurized air flows at sonic speeds within the fluid entry passage 34 or the yarn processing bore 32, as will be subsequently explained in greater detail. The sonically traveling air is caused to "shock out" to subsonic speeds in a manner generating twin shock wave formations developed longitudinally relative to the yarn processing bore axis.

A first preferred embodiment of the yarn interlacer unit is illustrated in FIG. 2, and is designated by the numeral 40. This interlacer unit 40 comprises a housing 41 having therein a processing bore 42 and a fluid entry duct 44. The processing bore 42 includes a yarn inlet end 46 and a yarn outlet end 48. The fluid entry duct 44 extends substantially perpendicular to the processing bore 42 and communicates fluidly therewith at a junction 50 located midway between the yarn inlet and outlet ends 46 and 48. The duct 44 communicates with the fluid pressurizing compressor 36 which supplies highly pressurized processing air.

In this fashion, air supplied from the compressor 36 travels through the entry duct 44 and divides at the junction 50 into equal and separate longitudinal air flows within the yarn processing bore 42. One air flow travels toward the yarn inlet end 46 counter to the direction of yarn travel, and the other air flow travels in the opposite direction toward the air outlet end 48 in the direction of yarn travel.

In this first embodiment, the relative magnitudes and dimensions of the air entry duct 44 and the processing bore 42, and the intensity of air flow from the compressor 36, are such that the processing air is caused to flow at sonic speed within the air entry duct 44 and shock out within the processing bore 42. It has been found that, ideally, the cross-sectional areas of the air inlet duct 44 and the processing bore 42 should be approximately equal in order to achieve optimum results.

As will be apparent to one skilled in the art, the sonically-traveling air flow from the air entry duct 44 divides into separate flows at the junction 50. The separate air flows expand within the processing bore 42 and shock out to subsonic speeds. Each air flow shocks out in a shock wave formation comprising a progressive series of alternating compression-rarefraction, oblique standing shock waves.

These twin shock wave formations, shown schematically at 52, 54 in FIG. 2, are developed longitudinally relative to the longitudinal axis of the processing bore 42, in mutually opposite directions the terminate short of the yarn inlet and outlet ends. By virtue of such longitudinal development, the individual standing shock waves extend virtually completely across the processing bore to produce a condition wherein shock waves extend completely across the path of travel of the yarn filaments. This assures continual, uninterrupted contact between yarn filaments and shock waves during the interlacing treatment. Consequently, continuous yarn filaments passing through the inlet side of the processing bore 42 will continually contact the first shock wave formation 52 that is developed toward the yarn inlet end 46, i.e., counter to the direction of yarn travel. As the yarn filaments pass through the outlet side of the bore 42 they will continually contact the shock wave formation 54 that is developed toward the yarn outlet end 48, i.e., in the same direction as yarn travel.

In an instance, then, where continuous yarn bundles are passed through a pair of serially arranged interlacer units 40, the yarn filaments will contact four shock wave treatment zones, i.e., at the inlet and outlet sections of each interlacer unit. Continual contact of the yarn filaments with shock wave formations during the interlacing treatment assures that the filaments will be interlaced absent the frequent formation of tie points

characteristic of yarns interlaced by the techniques disclosed in U.S. Pat. No. 3,750,242.

As previously noted with regard to that patent, the yarn filaments oscillate into and out of contact with a single shock wave formation developed transversely of the processing bore axis and thus interact periodically, rather than continually, with shock waves. The resulting period interaction between the yarn and the shock wave formation apparently produces the tie points. These points of relatively intense filament compaction along the yarn length reflect light non-uniformly and thus create speckles or flashes in garments woven from such yarn.

A second preferred fluid interlacer unit in accordance with the invention is depicted in FIG. 3 and is designated by the numeral **60.** The interlacer unit **60** comprises a housing **51** having therein a processing bore **62** and a fluid entry duct **64.** The processing bore **62** includes a yarn inlet end **66** and a yarn outlet end **68.** The fluid entry duct **64** extends substantially perpendicular to the processing bore **62** and communicates fluidly therewith at a junction **70** located midway between the yarn inlet and outlet ends **66** and **68.** The duct **64** communicates with the fluid pressurizing compressor **36** to supply highly pressurized processing air through the processing bore **62**

The relative magnitudes and dimensions of the air entry duct **64** and the processing bore **62,** and the intensity of air flow from the compressor **36,** are such that the processing air is caused to flow at sonic speed within the air entry duct **64** and shock out within and beyond the confines of the processing bore **62.** Preferably, in order to achieve such results, it is desirable that the cross-sectional area of the air inlet duct **64** be greater than, but not more than one and one-half times, that of the processing bore **62.** Thus, sonically traveling air flow from the air entry duct **44** generates twin shock wave formations **72** and **74** which originate within the bore **62** and are of sufficient strength to extend outwardly beyond the yarn inlet and outlet ends **66** and **68.**

Each shock wave formation **72** and **74** comprises a progressive series of alternating compression-rarefaction, oblique standing shock waves. These shock wave formations are developed longitudinally relative to the longitudinal axis of the processing bore **62** in mutually opposite directions. By virtue of such longitudinal development, the individual standing shock waves extend virtually completely across the processing bore to produce a condition wherein shock waves extend completely across the path of travel of the yarn filaments. The continual, uninterrupted contact between yarn filaments and shock waves during the interlacing treatment resists the creation of frequently occurring tie points along the length of the interlaced yarn.

In a third embodiment of the invention, illustrated in FIG. **4,** still another preferred form of fluid interlacer unit is shown, designated by the numeral **80.** This interlacer unit **80** comprises a housing **81** having therein a processing bore **82** and a fluid entry duct **84.** The processing bore **82** includes a yarn inlet end **86** and a yarn outlet end **88.** The fluid entry duct **84** extends substantially perpendicular to the processing bore **82** and communicates fluidly therewith at a junction **90** located midway between the yarn inlet and outlet ends **86** and **88.** The duct **84** communicates with the fluid pressurizing compressor **36** to receive a highly pressurized flow of processing air.

The magnitudes and dimensions of the air entry duct **84** and the processing bore **82,** and the intensity of air flow from the compressor **36,** are such that the processing air is caused to flow at sonic speeds within the processing bore **82** and shock down to subsonic speed upon being discharged from the bore ends **86** and **88.** In other words, each end of the yarn processing bore functions as an underexpanded nozzle relative to air being discharged therefrom. In order to accomplish this, the cross-sectional area of the air entry duct **84** must be at least double, and preferably more than double, the cross-sectional area of the yarn processing bore **82.**

As will be apparent to one skilled in the art, as the sonically traveling dual air flows are discharged from the yarn inlet and outlet ends **86** and **88,** each air flow shocks out in a shock wave formation comprising a progressive series of alternating compression-rarefaction, oblique standing shock waves. These twin shock wave formations, shown schematically at **92, 94** in FIG. **4,** are developed longitudinally relative to the longitudinal axis of the processing bore **82,** in mutually opposite directions. By virtue of such longitudinal development, the individual oblique shock waves extend completely across the path of travel of the yarn filaments. This assures continual, uninterrupted contact between yarn filaments and shock waves during the interlacing treatment. Continual contact of the yarn filaments with shock waves during the interlacing treatment assures that the filaments will be tightly interlaced without the frequent formation of tie points in the same manner as disclosed in connection with FIGS. **2** and **3.**

EXAMPLES

A series of test runs A, B, and C were performed to interlace yarn bundles in accordance with the invention. These test runs, outlined in the description and chart following, are illustrative of advantages and possible uses of the present invention.

In Examples A, B, and C a continuous multi-filament yarn bundle was pulled through an interlacer mechanism consisting of two serially arranged fluid interlacers, each having a yarn processing bore of 9/16-inch length. Each of these bores was provided with an air entry duct intersecting the yarn processing bore at right angles to its axis at the midpoint of the bore length. The distance between the yarn outlet end of the first interlacer and the yarn inlet end of the second interlacer was one inch.

Additional data for Examples A, B, and C are given in the chart following:

Condition:	EXAMPLE A 75/20 Acetate Yarn	EXAMPLE B 150/40 Acetate Yarn	EXAMPLE C 150/40 Acetate Yarn
Process Air Pressure	88 psig	80 psig	88 psig
Yarn Tension Upstream of Nozzle Assembly	8–10 grams	15–18 grams	18–20 grams
Yarn Processing Speed	938 meters/minute	888 meters/minute	888 meters/minute
Diameter of Upstream Yarn Processing Bore	0.034 inch	0.033 inch	0.033 inch
Diameter of Downstream Yarn Processing Bore	0.034 inch	0.033 inch	0.033 inch

CONTINUED

Condition:	EXAMPLE A 75/20 Acetate Yarn	EXAMPLE B 150/40 Acetate Yarn	EXAMPLE C 150/40 Acetate Yarn
Diameter or Area of Upstream Air Entry Duct	0.032 inch Diam.	0.031 inch Diam.	0.002 square inches
Diameter or Area of Downstream Air Entry Duct	0.032 inch Diam.	0.031 inch Diam.	0.002 square inches
Material of Construction Upstream and Downstream Yarn Processing Bores	Hardened Steel	Hardened Steel	Hardened Steel
Surface Finish of Upstream and Downstream Yarn Processing bores	16 RMS microinch	16 RMS microinch	16 RMS microinch

EXAMPLE A

In Example A a 75 denier, 20 filament bright acetate yarn bundle was pulled through a pair of serially arranged 0.034-inch diameter yarn processing bores at 938 meters per minute. At each of the multi-filament yarn interlacers the yarn was continuously subjected to shock wave formations along those portions of the filaments disposed within the processing bores. The shock wave formations comprised twin formations, developed in longitudinal directions from the fluid entry port to the yarn entrance end and the yarn outlet end, respectively, The shock wave formations in each yarn processing bore were generated by compressed air applied to each interlacer at **88** psig and traveling at sonic speeds in the 0.032-inch constant diameter fluid entry duct.

Yarns which were interlaced by this process and apparatus exhibited a tie point frequency of no more than 1 to 2 relatively loosely entwined tie points per 100 centimeters length of yarn. In comparison, yarns compacted by conventional fluid processes, such as described in U.S. Pat. No. 3,750,242 can exhibit a tie point frequency of as much as from 20 to 100 tie points per 100 centimeters length of yarn.

The tie point frequency may be detected by employing the "water bath" test, described in U.S. Pat. No. 3,603,043. In this test, 4-feet lengths of sample compacted yarns are laid quickly and evenly upon the surface of a water bath, the yarns having previously been uniformly treated with finishing oils and/or other agents. Some of these finishing oils and agents have an organic base and transfer immediately to the surface of the water table and tend to form a mono-molecular film of finish material on the water surface between each of the filaments making up the multi-filament yarn bundle. This action generates a surface tension that tends to mutually separate the individual filaments making up the yarn bundle. Points of strong mechanical interlacing of the filaments constitute a tie point. Such a tie point shows itself graphically in a two dimensional plane on the water bath as a result of surface tension forces separating or spreading the individual filaments at either side of the tie point. At the tie point regions, however, the filaments tend to remain much closer together.

The continuously interlaced filaments constituting the substantially uniformly compacted multifilament yarn bundle produced under the operating conditions of Example A spread to a width on the order of 0.2 to 0.3 centimeters, as compared with highly frequent, randomly located tie points of conventionally compacted filament bundles which spread to widths of 0.05 to 0.15 centimeters.

The spread of non-tied, but nevertheless highly interlaced filaments, between the infrequent tie points of yarn produced under the operating conditions of Example A ranges from 0.5 to 0.2 centimeters in height as compared with 0.8 to 1.4 centimeters height in conventionally compacted yarns.

The loosely entwined tie points of Example A yarn may vary from 0.2 to 0.3 centimeters in length, as compared with 0.2 to 1.2 centimeters length in conventionally compacted filament bundles.

In order to test the degree of coherency of the processed yarn, the "hook drop" test, disclosed in U.S. Pat. No. 3,110,151, may be utilized. In this test a sample of yarn is clamped in a vertical position under the tension provided by a weight in grams which is 0.20 times the yarn denier (but not greater than 100 grams). A weighted hook, having a total weight in grams numerically equal to the mean denier per filament of the yarn (but weighing not more than 10 grams) is inserted through the yarn bundle and lowered at a rate of 1 to 2 centimeters per second until the weight of the hook is supported by the yarn. The distance which the hook has traveled through the yarn is a measure of the average frequency of conventional tie points inserted in the yarn and characterizes the extent of filament entanglement. The result is expressed as a "coherency factor" which is defined as 100 divided by the above distance in centimeters. Since filament intermingling is random in interlaced yarn, a large number of samples should be tested to define a representative value for the whole yarn.

When yarns compacted in accordance with Example A are tested by the hook drop test described in U.S. Pat. No. 3,110,151, the mean centimeter pulls normally average about 9.5 centimeters (coherency factor of 10.5), with a corresponding standard deviation of 6.75 centimeters and a coefficient of variation of 73, based on 450 needle pulls. This compares with conventionally compacted yarns displaying average mean centimeter pulls ranging from 1.31 (coherency factor of 76.34) to 2.2 (coherency factor of 45.45) with corresponding standard deviations of 1.24 and 4.18 centimeters and coefficients of variation of 95 and 191, based on 600 needle pulls.

EXAMPLE B

In Example B, 150 denier, 40 filament acetate yarns were pulled through a pair of serially arranged 0.033-inch diameter yarn processing bores at a speed of 888 meters per minute. At each one of the pair of pneumatically energized multi-filament yarn interlacers, the yarn was continuously subjected to twin shock wave formations generated within the confines of the yarn processing bore. The shock wave formations in each

yarn processing bore were generated by compressed air applied to each interlacer at 80 psig and traveling at sonic speeds in the 0.31-inch constant diameter fluid entry duct. The water bath test performed on the continuously interlaced yarn produced in this example indicated the tie point frequency to be no more than 1 to 2 loosely entwined tie points per 100 centimeters length of yarn, similar to the results obtained for 75 denier yarn discussed previously.

EXAMPLE C

In Example C, 150 denier, 40 filament acetate yarns were pulled through a pair of serially arranged 0.033-inch diameter yarn processing bores at a speed of 888 meters per minute. At each of the pneumatically energized yarn interlacers the yarn was continuously subjected to twin shock wave formations generated immediately beyond the yarn entrance end of the yarn processing bore, and also immediately beyond the yarn exit end of the yarn processing bore in the manner of FIG. 4. These shock wave formations were generated by compressed air applied to each interlacer at 88 psig and shocking down upon being discharged at sonic velocity from the 0.033-inch diameter yarn processing bore.

The fluid entry duct **100** in this example, shown in FIG. 5, comprised an orifice having an oblong cross-section. The longitudinal axis thereof was oriented perpendicular to the longitudinal axis of the yarn processing bore and intersected the latter at its mid-point. In cross-section, the oblong fluid entry duct was rounded on each end to radius *a* of 0.031-inches and a length *l* of .040 -inches measured between radius centers at each cross-sectional end. Such an oblong duct could be employed in other yarn interlacing operations in accordance with the invention.

A water bath test was performed on the interlaced yarn produced in Example C and indicated the tie point frequency thereof to be no more than 1 to 2 loosely entwined tie points per 100 centimeters length of yarn similar to the results obtained for 75 and 150 denier yarns discussed previously with reference to Examples A and B.

The hook drop test produced mean centimeter pulls averaging about 15.7 centimeters (coherency factor of 6.37) with a corresponding standard deviation of 10.4 centimeters and a coefficient of variation of 66, based on 420 needle pulls.

OVERALL RESULTS

The compacted yarns produced by the techniques utilized in Examples A, B, and C exhibited ample degrees of compaction, and only one to two tie points per one hundred centimeters of yarn length. The yarns were found to reflect incident light in a very uniform manner continuously along the yarn length. The reflection characteristics were, in fact, comparable to twisted yarns having 0.18 turns per inch of twist. When the fluidly compacted yarns were incorporated as warp ends in high sley satin fabrics, or as filling ends in taffeta fabrics, the phenomena of "speckling" (in satins) and "flashing" (in taffetas) were virtually absent due to the high uniformity of light reflectivity.

In summary, as a result of the disclosed embodiment of the present invention, wherein a bundle of yarn filaments is passed through serially arranged, longitudinally developed twin shock wave formations, a more uniformly compacted yarn is produced. This yarn exhibits requisite strength characteristics without a high-frequency occurrence of tie points. Garments produced from woven fabrics made from such yarn are essentially free of speckles and flashes which have heretofore been characteristic of fluid-compacted yarns.

It will be appreciated that any numer of fluid interlacer units may be serially arranged in accordance with the teachings of the present invention to establish a series of longitudinally developed twin shock wave formations contacting the continuous yarn filaments.

Moreover, the fluid interlacing methods and apparatus of the present invention may be used in any known yarn treating operation, such as spinning and drawing operations, for examle.

It is noted that the processing air which is delivered under pressure to the yarn processing bore should preferably be near the moisture saturation point. The use of highly humid processing air tends to avoid the generation of excessive static electricity during the violent interlacing and enmeshing action of the filaments which rub mutually against one another as they pass through the shock wave formations. Thus, the tendency for some of the filaments to separate and spread apart from the main body of the yarn bundle as they leave the yarn processing bores, is significantly reduced.

Although the invention has been described in connection with a preferred embodiment thereof, it will be appreciated by those skilled in the art that additions, modifications, substitutions and deletions not specifically described may be made without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. Yarn interlacer apparatus for subjecting a bundle of yarn filaments to turbulent fluid movement such that the filaments become compacted and interlaced, the interlacer apparatus comprising:

means defining a yarn processing bore having yarn inlet and outlet ends;

means for passing a continuous bundle of yarn filaments through said yarn processing bore; and

means for establishing, in said bore, separately traveling fluid flows generating a plurality of shock wave formations which extend completely across the path of travel of said yarn filaments such that said filaments pass through and continuously contact said shock wave formations and become compacted and interlaced thereby.

2. Yarn interlacer apparatus according to claim **1** including a second yarn processing bore and shock wave generating means arranged serially with said first-mentioned yarn processing bore relative to yarn travel.

3. Yarn interlacer apparatus according to claim **1** wherein said fluid flow establishing means comprises means for establishing a first fluid flow generating a first shock wave formation in the form of a first series of compression-rarefaction oblique standing shock waves developed longitudinally relative to the axis of said bore in a first longitudinal direction, and a second fluid flow generating a second shock wave formation in the form of a second series of compression-rarefaction oblique standing shock waves developed longitudinally relative to the axis of said bore in a second direction longitudinally opposed to said first direction.

4. Yarn interlacer apparatus according to claim **3** wherein said flow establishing means is arranged to es-

tablish first and second shock wave formations which originate and terminate within said yarn processing bore.

5. Yarn interlacer apparatus according to claim 4 wherein said fluid flow establishing means includes a fluid entry duct communicating with said processing bore generally at the midpoint thereof, the cross-sectional area of said fluid inlet duct being substantially equal to the cross-sectional area of said yarn processing bore.

6. Yarn interlacer apparatus according to claim 3 wherein said flow establishing means is arranged to establish first and second shock wave formations which originate within said bore and extend outwardly beyond the yarn inlet and outlet ends thereof.

7. Yarn interlacer apparatus according to claim 6 wherein said fluid flow establishing means includes a fluid entry duct communicating with said processing bore generally at the midpoint thereof, the cross-sectional area of said fluid inlet duct being greater than but not more than one and one-half times the cross-sectional area of said yarn processing bore.

8. Yarn interlacer apparatus according to claim 3 wherein said flow establishing means is arranged to establish first and second shock wave formations which originate at the yarn inlet and outlet ends and extend outwardly therebeyond.

9. Yarn interlacer apparatus according to claim 8 wherein said fluid flow establishing means includes a fluid entry duct communicating with said processing bore generally at the midpoint thereof, the cross-sectional area of said fluid inlet duct being at least double the cross-sectional area of said yarn processing bore.

10. Yarn interlacer apparatus in which a bundle of yarn filaments is subjected to highly turbulent fluid movement such that the filaments are substantially uniformly compacted and mutually interlaced, the apparatus comprising:

at least one fluid interlacer unit, said unit having a housing and a yarn processing bore of substantially constant cross-section extending therethrough and said bore having yarn inlet and outlet ends;

said housing including fluid entry passage means communicating with said bore intermediate said yarn inlet and outlet ends;

means for continuously passing a bundle of yarn filaments through said processing bore;

fluid pressurizing means communicating with said fluid entry passage means for pressurizing compressible fluid and establishing fluid flow through said fluid entry passage means at least at sonic velocity; said fluid exhausting into said bore intermediate the yarn inlet and outlet ends to produce fluid flows in said bore flowing toward said yarn inlet and outlet ends;

said fluid entry passage means and said yarn processing bore being configured such that said fluid flows generate twin shock wave formations originating and terminating within said bore, said shock wave formations being developed longitudinally relative to the axis of said bore in opposite directions and extending completely across the path of travel of said yarn filaments such that the filaments continuously contact said shock wave formations and become fluidly compacted and interlaced thereby.

11. Yarn interlacer apparatus according to claim 10 wherein the cross-section of said fluid entry passage means is of oblong configuration.

12. Apparatus according to claim 10 wherein said fluid entry passage means comprises a single passage of substantially constant cross-section oriented substantially perpendicularly to said constant cross-section yarn processing bore; the cross-sectional area of said fluid entry passage means being approximately equal to the cross-sectional area of said yarn processing bore such that the flow of sonically traveling pressurized fluid from said fluid entry passage divides into first and second subsonic fluid flows which produce said shock wave formations.

13. Yarn processing apparatus in which a bundle of yarn filaments is subjected to highly turbulent fluid movement such that the filaments are substantially uniformly compacted and mutually interlaced, the apparatus comprising:

at least one fluid interlacer unit, said unit having a housing and a yarn processing bore of substantially constant cross-section extending therethrough; said bore having yarn inlet and outlet ends;

said housing including fluid entry passage means communicating with said bore intermediate said yarn inlet and outlet ends;

means for continuously passing a bundle of yarn filaments through said yarn processing bore;

fluid pressurizing means communicating with said fluid entry passage means for pressurizing compressible fluid and establishing fluid flow through said fluid entry passage means at least at sonic velocity; said fluid exhausting into said bore intermediate said yarn inlet and outlet ends to produce fluid flows in said bore flowing toward said yarn inlet and outlet ends;

said fluid entry passage means and said yarn processing bore being configured such that said fluid flows generate twin shock wave formations originating within said bore and extending beyond the yarn inlet and outlet ends thereof, said shock wave formations being developed longitudinally relative to the axis of said bore in opposite directions and extending completely across the path of travel of said yarn filaments such that the filaments continuously contact said shock wave formations and become fluidly compacted and interlaced thereby.

14. Apparatus according to claim 13 wherein said fluid entry passage means comprises a single passage of substantially constant cross-section oriented substantially perpendicularly to said constant cross-section yarn processing bore; the cross-sectional area of said fluid entry passage means being more than, but not greater than one and one-half times the cross-sectional area of said yarn processing bore such that the flow of sonically traveling pressurized fluid from said fluid entry passage divides into first and second subsonic fluid flows which produce said shock wave formations.

15. Yarn processing apparatus in which a bundle of yarn filaments is subjected to highly turbulent fluid movement such that the filaments are substantially uniformly compacted and mutually interlaced, the apparatus comprising:

at least one fluid interlacer unit, said unit having a housing and a yarn processing bore of substantially constant cross-section extending therethrough and said bore having yarn inlet and outlet ends;

said housing including fluid entry passage means communicating with said bore intermediate said yarn inlet and outlet ends;

means for continuously passing a bundle of yarn filaments through said processing bore;

fluid pressurizing means communicating with said fluid entry passage means for pressurizing compressible fluid and establishing fluid flow through said fluid entry passage means and into said bore intermediate the yarn inlet and outlet ends to produce fluid flows in said bore flowing at least at sonic speed toward said yarn inlet and outlet ends;

said fluid entry passage means and said yarn processing bore being configured to produce twin shock wave formations originating at the yarn inlet and outlet ends of said bore and extending outwardly therebeyond, said shock wave formations being developed longitudinally relative to the axis of said bore in opposite directions and extending completely across the path of travel of said yarn filaments such that the filaments continuously contact said shock wave formations and become fluidly compacted and interlaced thereby.

16. Apparatus according to claim **15** wherein said fluid entry passage means comprises a single passage of substantially constant cross-section oriented substantially perpendicularly to said constant cross-section yarn processing bore; the cross-sectional area of said fluid entry passage means being at least double the cross-sectional area of said yarn processing bore such that the flow of pressurized fluid from said fluid entry passage divides into first and second sonic fluid flows which produce said shock wave formations at the ends of said processing bore.

17. A method of compacting and interlacing yarn filaments comprising the steps of:

passing a continuous bundle of yarn filaments through a yarn processing bore having yarn inlet and outlet ends; and

establishing, in said bore, separately traveling fluid flows generating a plurality of shock wave formations which extend completely across the path of travel of said yarn filaments such that said filaments pass through and continuously contact said shock wave formations and become compacted and interlaced thereby.

18. A method according to claim **17** wherein said step of establishing fluid flows comprises establishing, in said bore, separately traveling fluid flows generating twin shock wave formations developed longitudinally relative to the axis of said processing bore in opposite directions, said shock wave formations originating and terminating within said bore.

19. A method according to claim **17** wherein said step of establishing fluid flows comprises establishing, in said bore, separately traveling fluid flows generating twin shock wave formations developed longitudinally relative to the axis of said processing bore in opposite directions, said shock wave formations originating within said bore and extending outwardly beyond the yarn inlet and outlet ends thereof.

20. A method according to claim **17** wherein said step of establishing fluid flows comprises establishing, in said bore, separately traveling fluid flows generating twin shock wave formations developed longitudinally relative to the axis of said processing bore in opposite directions, said shock wave formations originating at the yarn inlet and outlet ends of said processing bore and extending outwardly therebeyond.

21. A method of substantially uniformly compacting and interlacing an endless bundle of yarn filaments comprising the steps of:

continuously passing said filaments through a yarn processing bore of a yarn interlacer housing such that the yarn enters an inlet end of said bore and exits through an outlet end thereof, said bore being of substantially constant cross-section;

pressurizing compressible fluid and establishing fluid flow within fluid entry passage means at least at sonic velocity, said fluid entry passage means communicating with said processing bore intermediate said yarn inlet and outlet ends such that said fluid exhausts into said bore intermediate said yarn inlet and outlet ends to produce fluid flows in said bore flowing toward said yarn inlet and outlet ends; and

causing said fluid flows to generate twin shock wave formations originating and terminating within said yarn processing bore, said shock wave formations being developed longitudinally relative to the axis of said bore in opposite directions and extending completely across the path of travel of said filaments such that the filaments continuously contact said shock wave formations and become fluidly compacted and interlaced thereby.

22. A method of substantially uniformly compacting and interlacing an endless bundle of yarn filaments comprising the steps of:

continuously passing said filaments through a yarn processing bore of a yarn interlacer housing such that the yarn enters an inlet end of said bore and exits through an outlet end thereof, said bore being of substantially constant cross-section;

pressurizing compressible fluid and establishing fluid flow within fluid entry passage means at least at sonic velocity, said fluid entry passage means communicating with said processing bore intermediate said yarn inlet and outlet ends such that said fluid exhausts into said bore intermediate said yarn inlet and outlet ends to produce fluid flows in said bore flowing toward said yarn inlet and outlet ends; and

causing said fluid flows to generate twin shock wave formations originating within said yarn processing bore and extending outwardly beyond the yarn inlet and outlet ends thereof, said shock wave formations being developed longitudinally relative to the axis of said bore in opposite directions and extending completely across the path of travel of said filaments such that the filaments continuously contact said shock wave formations and become fluidly compacted and interlaced thereby.

23. A method of substantially uniformly compacting and interlacing an endless bundle of yarn filaments comprising the steps of:

continuously passing said filaments through a yarn processing bore of a yarn interlacer housing such that the yarn enters an inlet end of said bore and exits through an outlet end thereof, said bore being of substantially constant cross-section;

pressurizing compressible fluid and establishing fluid flow within fluid entry passage means communicating with said processing bore intermediate said yarn inlet and outlet ends to produce fluid flows in

said bore flowing toward said yarn inlet and outlet ends at least at sonic speed; and

causing said fluid flows to generate twin shock wave formations originating at the yarn inlet and outlet ends of said yarn processing bore and extending outwardly therebeyond, said shock wave formations being developed longitudinally relative to the axis of said bore in opposite directions and extending completely across the path of travel of said filaments such that the filaments continuously contact said shock wave formations and become fluidly compacted and interlaced thereby.

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